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THE KARST OF PINEGA REGION (RUSSIA)

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This book is an overview of studies on sulphate karst within the Pinega River basin, Arkhangelsk area. It has been prepared for print by the organizing committee of the International Conference «Northern karst ecosystems in our changing environment» and serves as a guide for participants. This book is designed for a wide range of readers – geologists, biologists, speleologists, explorers and tourists.

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Cover photo: *Gypsum exposure at the left bank of the Northern Dvina River near its junction with the Pinega River. Photo by E.V. Shavrina*

CONTENT

INTRODUCTION

The taiga zone of the Russian European North lies upon undulating plains formed during several ice ages, with the latest (Upper Valdai glaciation) finishing about ten thousand years ago. The cold humid climate, loamy glacial deposits and poor natural drainage account for the development of coniferous forests and bogs. However, locally occurring rock strata and their geological history, particularly, the processes of rock dissolution by surface and ground waters cause significant changes in the topography and vegetation within some areas, such as the Belomor-Kuloy Plateau, which is located between the White Sea and the rivers Kuloy and Pinega in the Arkhangelsk region (Fig 1.1). Its unique landscapes result from the presence of gypsum, calcareous rocks and red-coloured siltstone, increased tectonic activity and a complex geological history. At the end of the ice age a vast volume of thaw water percolated the soluble rocks and shaped the most extraordinary karst relief ever found on plains. The karst topography ‘refracted’ the action of biological and climatic factors: the typical spruce forests changed to larch forests, natural meadows, open woodlands and rock outcrops colonised by plant species atypical for the northern taiga; the bogs practically disappeared and gave place to karst streams, lakes, caves and other karst features. The local soil cover, flora and fauna acquired both taiga and alpine characteristics that bring this region close to mountainous forest countries.

In 1974 the State Nature Reserve «Pinezhsky» was created in the south-eastern part of the plateau with the aim of conservation and research of its unique natural complexes.

LOCATION AND PHYSIOGRAPHY

GEOGRAPHIC LOCATION

The Pinega Region is a picturesque northern province in the north-west of Russia (c. 64^o North lat., 43^o East long.) by the Pinega River in the Arkhangelsk area. The Region's central settlement is a small town of Pinega that is going to celebrate its 875th anniversary in 2012. Pinega has first been mentioned in 1137 among the lands that belonged to Svyatoslav the Prince of Novgorod. An earlier human colonization of this region has been proved by archaeological finds. There was also a legend about the ancient tribe of Pin – after which the River was named. The central settlement of that tribe was at the same place as the modern Pinega. During the Middle Ages Pinega used to be a river and sea port – from here boats were carried to the Kuloy River and then sailed to the Mezen’ River estuary and, past the White Sea inlet, to the Barents Sea to several main destinations: Svalbard, Novaya Zemlya, Mezen’, Pechora and Siberia. Pinega was given the status of town during the reign of Katherine the Great (the second half of the 18th century). Currently it has a population of five thousand people employed mainly in timber industry. A 200-km-long road connects Pinega to the town of Archangelsk.

Karst landscapes are found within the areas of gypsum outcrops by the lower and middle reaches of the Pinega River and the upper reaches of the Kuloy River, within the two major topographic structures - Belomor-Kuloy Plateau and Pinega-Kuloy Plain (Fig 1.2).

CLIMATE

The Pinega Region is situated within the Arctic-Atlantic climatic region of the temperate zone and has a cold humid moderately-continental climate. It is characterized by long and cold winter, relatively short moderately warm and cloudy summer, rather long spring and autumn with frequent temperature fluctuations.

A dramatic difference between the winter and summer solar energy balances is related to the influence of the Arctic Ocean seas, especially, the Barents Sea that never freezes. The climate continentality increases from the north-west to the south-east. The mean annual temperature decreases from the south-west to the north-east.

The mean values of temperature and other parameters recorded at the Pinega Meteorological Station within a period from 1978 to 2008 are given below (by Komponenti ecosystem…, 2008):

- Mean annual temperature +0.4 °C,
- Mean January temperature -14.7 °C,
- Mean July temperature +15.6°C,
- The sum of temperatures higher than ten degrees 1177°,
- The period with mean daily temperature below zero 160-200 days,
- Mean soil freezing depth is 75 cm (ranges between 33 and 134 cm).

The 'climatic spring' (i.e., when the maximal day temperature rises above 0°C) begins on average on March 26. The thaw begins in the middle of April and ends on average on the 19-22 of May, but patches of snow can persist within topographic depressions, karst sinkholes, northern slopes and karst canions till the beginning and, sometimes, the middle of July. Breaking up and drifting of ice on rivers usually starts between the 3 and 7 of May.

The 'climatic summer' (i.e., when minimal temperature rises above 10°C) begins on the 22 of June. 'Phenological summer', i.e. the growth season, is 50 days long. The frost-free period lasts about 70 days.

Autumn is usually long, with a large amount of precipitation. The 8th of August is the mean annual date of beginning of the autumn season (i.e., when the minimal temperature drops below 10ºC). Snow cover begins to establish between October 25 and November 10.

The 'climatic winter' (with maximal day temperature below 0ºC) begins on the 8th of November. The winter lasts about 140 days. The Pinega River starts to freeze on average on the 12th of November.

Mean annual precipitation of 569 mm is distributed evenly over the year, the 55% of it falls within the warm season. The P/ET ratio is 1.33. The mean depth of snow is 60 cm. The air humidity is high: 85-95% in autumn and winter due to the warm air influxes and 70-90% in summer and spring due to the cool cloudy weather conditions.

The Pinega Region is exposed to frequent influxes of arctic air masses. Northerly winds prevail in summer, while southerly and westerly winds prevail during the autumn and winter.

Observations at the Pinega Meteorological Station within a period from 1978 to 2008 revealed a trend of increase in the mean air temperatures and precipitation (Fig 1.3).

GENERAL GEOLOGICAL CHARACTERISTICS AND TOPOGRAPHY

The Pinega Region is situated within the western wing of the Mezen' Syncline of the Russian Platform, in the south-eastern part of the Belomor-Kuloy Plateau and on the Upper Kuloy Plain. The depth of erosional dissection is 20-40 meters (Struktura I dinamyka., 2000).

The main stratigraphic feature of this region is the soluble rocks that lie close to the surface and account for the local topography and geomorphological setting. The region is characterized by wide-spread Paleozoic sulphate-carbonate and terrigenous sediments, particularly, the Lower Permian (Sotka Sequence, Sakmar Stage) evaporites – gypsum and anhydrites strata 40-70 m thick. They can occur at the surface or sometimes under a cover of the Upper Permian red-coloured siltstone and limestone (Fig 1.4).

The mantle of Quaternary deposits, i.e., sandy and loamy moraines varies from very thin (0-5 m) to thick (15-20 m) and very thick – more than 30 m within erosional insisions (Karst I pechery…, 2001). The moraines were formed by glacial deposition of weathering products of Fennoscandian rocks and sediments of the Vendian and Riphean ages. Usually such moraines are chemically and mineralogically poor, which is the case for all European North. During the ice age the products of glacial deposition were occasionally mixed with the bedrock, therefore the present moraines can contain the local bedrock fragments. The lower layer of moraine is loamy and the upper layer (usually 10-100 cm thick) is sandy loam. Quaternary lacustrine and glacio-fluvial deposits are, essentially, the sorted moraine products. The glacio-fluvial deposits are sandy and the lacustrine deposits vary from clay to sandy loam and sand.

The areas where the Quaternary deposits are underlain by calcareous bedrock are characterized by a low degree of surface karstification (karst landforms occupy about 10% of such areas) and by the absence of caves (Malkov, Gurkalo, Monakhova et. al., 2001). The low degree of karstification allows for preservation of loose glacial deposits.

The degree of karstification is much higher over sulphate bedrock formations – karst landforms occupy about 75% of such areas and often become more frequent than 100 karst forms per 1 km^2 (Fig 1.5). The sulphate karst is represented by a wide diversity of surface forms: sinkholes, dolines, gorges, canyons, residual blocks, towers (Fig 1.6) and *'shelopnyaks'* – karst fields with output and residual landforms. The sulphate rocks also have extensive subterranean karst systems: there are 436 caves with a total length of cave passages of more than 128 km registered within the Pinega River basin by the beginning of 2011. That is one of the highest cave network densities in the world.

There are two major topographic structures - Belomor-Kuloy Plateau and Pinega-Kuloy Plain.

The Belomor-Kuloy Plateau is about 70-80 m above sea level and undergoes a modern tectonic uplift. It is dissected by river valleys and has well-developed karst topography: karst valleys, canyons, shelopnyaks, karst lakes and subterranean streams. One side of the Belomor-Kuloy Plateau forms a high (about 30 m) bank by the Pinega River (Fig 1.2, 1.7).

The Pinega-Kuloy Plain is about 30-50 m a.s.l. There is a combination of boggy land and karst landforms – dolines and depressions.

LANDSCAPES

The first landscape survey of the Pinega Region was carried out in 1972 by D.N.Saburov. Later, during the study in the State Nature Reserve «Pinezhsky» in 1992 the classification by V.N. Andreichuk was adopted for karst landscape description (Struktura I dinamyka., 2000) (Fig 1.8).

In the nature reserve there are three genetic types of landscapes that differ by the degree of karst processes development – 'karstogenic', 'karsto-glasiated' and 'glaciated with karst elements' – which correspond to the concepts of '*open*', '*covered*' and *deep-seated karst*, respectively. Regarding our definitions of 'open' and 'covered' karst, the former includes also exhumed and denuded karst and the latter – entranched and subjaced karst according to international terminology. The explanations of these three landscape types are given below.

The karstogenic landscapes are distinguished by the development of *open gypsum karst* within certain parts of fissured gypsum massifs adjacent to large karst canyons (Fig 1.9). In these areas the Quaternary deposits are very thin (less than 0.5 m) and fragmentary (cover less than 50% of the surface) and the karst topography is most prominent and diverse. The best examples of such landscapes include: a) polije with residual blocks and towers by the Eras'kino Lakes, b) the karst canyon of the Sotka River and c) shelopnyaks in the Chuga Reserve and by the village of Kulogory. Shelopnyaks are the karst fields with an extremely dense network of output and residual landforms (Fig 1.10). There are more than 3000 landforms per km^2, which is the highest karst landform density within the European part of Russia.

The karsto-glaciated landscapes are characterized by the development of *covered (entranched and subjacent) karst* in gypsum rocks. The thickness of Quaternary deposits is such landscapes reaches 5 meters and gypsum outcrops are rare. The relief includes all typical karst landforms – sinkholes, dolines, etc (Fig 1.11).

The glaciated landscapes with karst elements (*deep-seated karst*) where gypsum strata are present under a thick layer of Quaternary deposits may have occasional subsidence forms at the surface, but generally look similar to the glaciated landscapes.

Carbonate karst landscapes are not developed within the Pinega Region, however, limestone and dolomites sometimes occur at the surface as the parent rocks for soils and induce certain changes in the vegetation cover.

SOILS

The northern taiga glaciated and karsto-glaciated landscapes, i.e., terrains with various types of interstratal (deep-seated and covered) karst are characterised by a wide occurrence of Luvi-Albic Podzols Ruptic (WRB, 2006). These soils develop on bisequal moraine deposits under bilberry-bryophyte spruce forests at the well-drained topographic positions – the top parts of moraine hills and moderately steep slopes.

Luvi-Stagni-Histic Podzols Ruptic and Luvi-Stagnic Podzols Ruptic (WRB, 2006) are formed on bisequal deposits on gentle slopes of meso-depressions in the area of watersheds (drainage divides) usually within glaciated landscapes, but not over karst.

Stagni-Histi-Ortsteinic Podzols (WRB, 2006) are formed at the geochemical barriers in conditions of regular water stagnation and active lateral migration of iron compounds within the soil profile.

Haplic Regosols and Cutanic Luvisols (WRB, 2006) are commonly formed under meadow vegetation.

Rendzic Leptosols (WRB, 2006) with a dark humus horizon develop over limestone or dolomite bedrock capped by a thin (<10-15 cm) loamy moraine. Folic Leptosols HyperCalcaric (WRB, 2006) with a black organic horizon are formed directly over limestone and dolomite rocks.

The *open karst* landscapes are characterized by an outstanding soil diversity and a highly complex soil cover. Unique soils with pure-gypsum horizons and raw organic matter occur over gypsum outcrops. They are called 'Sulphorendzinas' (Goryachkin, 1993), Gypso-Petrozems and Lithozems (Russian Soil Classification) or Folic Leptosols Hypergypsiric (WRB, 2006). These soils are morphologically similar to Folic Leptosols HyperCalcaric, but have different chemical properties. Soils of 'gypsum rain' can be formed close to gypsum karst towers from continuously falling gypsum stones gradually covered by moss.

The karst processes and topography predetermine the distribution of soil moisture and temperature, the parent rock composition and, therefore, the soil functioning. There is a significant soil temperature variation related to the topographic position within karst landscapes: the 'warmest' soils are found on elevations and the 'coldest' soils – at the bottom of karst sinkholes. In the latter, the summer temperature is lower than in soils of the southern tundra of the European part of Russia. Due to the low temperature during a whole growing season the biological processes in karst sinkholes and caves are slow. The bottoms of karst sinkholes are occupied by Histosols and Gleysols (WRB, 2006).

FLORA AND PLANT COMMUNITIES

The most interesting feature of the plant world within the Pinega karst landscapes is the presence of post-glacial relic (arctic, arctic-alpine, hypoarctic, southern taiga and nemoral) species surviving among the typical spruce forests and raised bogs of the northern taiga. Such relic species constitute about one quarter of the vascular flora within these karst landscapes. The survival of these species has been possible due to a wide variety of habitats associated with the karst topography and the presence of gypsum outcrops, calcareous rocks and specific soils. The flora of karst landscapes comprises more than a third of the vascular plant species protected in the Arkhangelsk area and two thirds (7 of 11) of nationally-protected species (Red Data Book of Russia) found within the Pinega Region.

The landscapes of *open karst* are occupied by *low-productive open woodlands* – pine-larch, birch-spruce and mixed (of the 4 tree species) (Fig 1.10). Due to a number of features (low canopy density, poor tree growth, complexity of lower tires and predominance of hypoarctic species) these open-wood communities resemble those of the forest-tundra belt. Over pure gypsum rocks the ground cover of such oligotrophic communities consists of common hypoarctic species, e.g., northern bilberry (*Vaccinium uliginosum*), bog rosemary (*Ledum palustre*) and crowberry (*Empetrum nigrum*) and oligotrophic lichens (*Cladonia rangiferina, Cladonia arbuscula, Cladonia stellaris*). Here the only rare species is *Gypsophila uralensis* ssp. *pinegensis*. Gypsum karst fields ('shelopnyak') overlain with dolomite stones and also gypsum slope exposures by rivers and karst canions are occupied by relic arctic and arctic-alpine species, e.g., net-leaved and mountain willows (*Salix reticulata, S. arbuscula)*, mountain avens (*Dryas octopetala), Dryas punctata*, alpine bitterwort (*Pinguicula alpina*), yellow saxifrage (*Saxifraga aizoides*) and black bearberry (*Arctous alpina*) (Fig 1.12), hypoarctic species, e.g., *Poa lapponica*, *Cotoneaster uniflora* and pallid milk vetch (*Astragalus frigidus*) and endemic species of the North European flora – *Gypsophila uralensis* ssp. *pinegensis* and *Thymus talijevii* that form the lower tires of the open-wood communities.

The landscapes of *covered karst* are occupied by relatively *highly productive (i.e. tall) woodlands – pine* forests, locally rare *mixed-herb larch* forests and floristically rich *grass spruce* forests – which by their productivity and species composition are comparable to the southern-taiga woods. The lower tires of grass spruce forests include southern-taiga species and also nemoral species: wood stitchwort (*Stellaria nemorum*), baneberry (*Actaea spicata*) and eastern dog violet (*Viola mirabilis).* Slopes and bottoms of karst dolines are covered by unique *species-rich meadows* (Fig 1.13) with representatives of nemoral (e.g., *Corydalis solida*) and South Siberian flora: *Paeonia anomala*, *Hedysarum alpinum*, *Crepis sibirica* and *Pleurospermum uralense.* Landscapes of covered karst are outstandingly rich in orchid species: dark red helleborine (*Epipactis atrorubens*), fragrant orchid (*Gymnadenia conopsea*), common spotted orchid (*Dactylorhiza fuchsii*), lesser butterfly orchid (*Platanthera bifolia*), European common twayblade (*Listera ovata*) and many other, including such rare species as lady’s slipper orchid (*Cypripedium calceolus*) (Fig 1.14) and Calypso orchid (*Calypso bulbosa*).

The plant communities within the weakly karstified landscapes of *deep-seated karst* are practically the same as those of the glaciated landscapes, their vegetation is typical for the northern taiga (Fig 1.15). The Siberian spruce (*Picea obovata*) forest communities are dominant. The *bryophyte-dwarf shrub spruce* forests predominate in naturally drained topographic positions (i.e., on elevations), while *sphagnum and polytrichum spruce* forests, *sphagnum pine* forests and *sphagnum-eriophorum* bogs are occupying poorly-drained closed depressions and *mire-grass spruce* forests and *sphagnum-sedge bogs* occupying better-drained open depressions. All forest phytocenoses have a low growth class. All the plant communities of deep-seated karst, except for *mire-grass spruce* forests, are species-poor (composed of 10-15 species).

FAUNA AND ANIMAL COMMUNITIES

Studies have shown that the fauna of the State Nature Reserve «Pinezhsky» provides a good representation of vertebrate fauna within the Pinega Region as a whole. There are 207 species of vertebrates: 37 mammal species, 149 bird species, 15 fish species, 5 amphibian and 1 reptile species. The invertebrate fauna of the reserve has been comprehensively studied within the last decade with the new data particularly improving our knowledge on the local fauna of springtails (*Collembola* – 132 species) and macrochelidae (*Acari*: *Mesostigmata*) – 116 species**.**

The mammalian fauna of the reserve includes 37 species belonging to 6 different orders and 13 families. The moose or Eurasian elk (*Alces alces*) is the only representative of the ungulates. There are two species of bat – the northern bat (*Eptesicus nilssoni*) and the Brandt's bat (*Myotis brandtii*). Rodents are represented by 11 species. Eurasian beavers (*Castor fiber*) having a long-established colony in the Sotka River valley are currently colonizing a wider territory. Chipmunk (*Tamias sibiricus*) can be encountered in mixed forests with thick undergrowth over the slopes of karst dolines. There is a diverse group of predatory animals, the largest being the brown bear (*Ursus arctos*) with about 30 individuals living within the reserve (Fig 1.16). Many other predatory mammals such as Eurasian lynx (*Lynx lynx*), European Pine Marten (*Martes martes*), wolf (*Canis lupus*) and wolverine (*Gulo gulo*) are dispersed throughout the reserve area, but the European otter (*Lutra lutra*) is living only by the Sotka River.

Regarding the bird fauna, there are 149 species from 12 orders recorded within the reserve including 102 nesting and 29 wintering species. There are 60 other species encountered within close proximity of the reserve, mostly within the Pinega River valley. Several invasive species of crossbill (*Loxia curvirostra*, *L. pytyopsittacus* and *L. leucoptera*) visit the reserve once in every 4-7 years when conifers, especially spruce, produce a high yield of seeds.

There is only one representative of reptile in the reserve and surrounding areas – the common lizard (*Lacerta vivipara*). There are five amphibian species including the Siberian salamander (*Salamandrella keyserlingii*) (Fig 1.17), the reserve being at the boundary of its western distribution.

There are 15 species of fish living in the reserve's lakes and water courses. The lakes are inhabited by 4 species – European perch (*Perca fluviatilis*), northern pike (*Esox lucius*), common roach (*Rutilus rutilus*) and burbot (*Lota lota*). These species also inhabit the Sotka River together with grayling (*Thymallus thymallus*), lavaret or common whitefish (*Coregonus lavaretus*) and occasional Atlantic salmon (*Salmo salar*) with the latter coming to Sotka to spawn.

Regarding protected animal species, there are osprey (*Pandion haliaetus*), peregrine falcon (*Falco peregrinus*), Eurasian eagle-owl (*Bubo bubo*) and grey shrike (*Lanius excubitor*) nesting within the reserve. These four bird species and one butterfly species (*Driopa mnemosyne*) are all protected at the national level (i.e., listed in the Red Data Book of the Russian Federation, 2001). The locally protected species (Red Data Book of the Arkhangelsk Area, 2008) include 2 mammals (Brandt's bat *Myotis brandtii* and Siberian flying squirrel *Pteromys volans*) and several bird species, of which 5 are nesting – whooper swan (*Cygnus cygnus*), Eurasian hobby (*Falco subbuteo*), boreal owl (*Aegolius funereus*), Eurasian pygmy owl (*Glaucidium passerinum*) and Ural owl (*Strix uralensis*) and the other two are presumably also nesting – honey buzzard (Pernis apivorus) and great grey owl (*Strix nebulosa*).

The rich fauna of the State Nature Reserve «Pinezhsky» results from the reserve's location at the interface of several animal assemblages and its landscape and biotope diversity. As compared to more southern localities on the Russian Plain, the reserve's fauna is enriched with representatives of the Siberian and Arctic animal assemblages. A significant proportion of vertebrate animal species of the reserve comes from the Siberian taiga assemblage: 6 species (17%) of mammals, 36 species of birds (35% of all nesting species) and 1 species of amphibians. Examples of these species include Siberian chipmunk (*Tamias sibiricus*), northern red-backed vole (*Clethrionomys rutilus*), wood lemming (*Myopus schisticolor*), western capercaillie (*Tetrao urogallus*), hazel grouse (*Tetrastes bonasia*), three-toed woodpecker (*Picoides tridactylus*), Himalayan Cuckoo (*Cuculus saturatus*), Siberian jay (*Perisoreus infaustus*), grey wagtail (*Motacilla cinerea*), red-flanked bluetail (*Tarsiger cyanurus*), Siberian salamander (*Salamandrella keyserlingii*), etc. Many vertebrates – 9 species (25%) of mammals and 31 species (30%) of birds – belong to the South-European animal assemblage: European mole (*Talpa europaea*), northern birch mouse (*Sicista betulina*), bank vole (*Clethrionomys glareolus*), common wood pigeon (*Columba palumbus*), chaffinch (*Fringilla coelebs*), spotted flycatcher (*Muscicapa striata*), European robin (*Erithacus rubecula*), common toad (*Bufo bufo*), common frog (*Rana temporaria*), smooth newt (*Triturus vulgaris*), etc. The Arctic fauna in the reserve is represented by a lesser number of vertebrate animal species: one fish, one mammal and four bird species (4%): burbot (*Lota lota*), Arctic fox (*Alopex lagopus*), willow grouse (*Lagopus lagopus*), merlin (*Falco columbarius*), etc. The animal assemblage of mountain woodlands is represented by several fish species (Atlantic salmon *Salmo salar*, grayling *Thymallus thymallus*, swamp minnow *Phoxinus percnurus* and bullhead *Cottus gobio*) that live in the Sotka River and three bird species that inhabit the canyon-like valley of this river – goosander (*Mergus merganser*), grey wagtail (*Motacilla cinerea*) and white-throated dipper (*Cinclus cinclus*).

THE INFLUENCE OF KARST ON LANDSCAPES AND BIODIVERSITY

The surface karst forms are most developed within areas where the Permian soluble rocks lie under moraine layer less than 5 m thick, i.e., in the landscapes of open and covered karst.

The karst processes influence all components of such landscapes. The formation of karst relief results in specific distribution of ecological niches, which is comparable to that in mountainous landscapes. A high rate of water infiltration through gypsum strata accounts for the absence of common taiga bogs. The surface and ground waters become slightly saline, with the salt concentration from 1 to 2 g/l.

The taiga trees within the landscapes of open karst become shorter and sparser due to a lack of nutrients in pure gypsum rocks. There are oligotrophic open-wood communities with lichen-dominated ground cover. The lower tiers include arctic, arctic-alpine and hypoarctic species occupying cooler positions, i.e., northern slopes, closed depressions and cave entrance areas. Frequent landslides and colluvial processes continuously provide new substrates for pioneer vegetation and hamper the development of advanced succession stages.

The larch, which is atypical tree for glaciated landscapes of the European north taiga, becomes more competitive than spruce within karst landscapes. The roots of larch are deeper anchored into rock cracks and fissures and, therefore, have a firmer grip on the slopes in conditions of continuous denudation and better access to nutrient solutions. The thick bark of larch is more resistant to forest fires that frequently happen in dry karst landscapes.

A high diversity of habitats and their mosaic distribution pattern within karst landscapes provide for a high biological diversity and the presence of more northern and more southern species within the taiga forest communities. An increase in the vegetation diversity always leads to an increase in the animal diversity due to a better food supply and wider range of habitats.

There are several invertebrate species (12 springtail and 6 mite species) that commonly occur in more northern i.e. tundra regions and also occupy the coldest habitats within the reserve – karst sinkholes and northern slopes. The representative of more southern i.e. nemoral flora *Corydalis solida* grows on species-rich meadows on the slopes and bottoms of karst dolines within the reserve and serves as the fodder species for the endangered butterfly *Driopa mnemosyne*

The presence of alpine species is generally typical for karst landscapes. There are several alpine bird species nesting by the Sotka River (goosander, dipper, grey wagtail, etc.) and fish species from the mountain woodland assemblage living in the Sotka River (Atlantic salmon, grayling, swamp minnow and bullhead). There is one alpine species of copepods *Acanthodiaptomus denticornis* found among zooplankton within the reserve and one alpine species of mite *Syskenozercon gaieri*.

An increase in the brown bear population density within karst landscapes is connected with better food supply from karst doline meadows and grass-rich forests. The moose is more common in karst landscapes also due to the better food supply. Moreover, the moose is attracted by cooler karst depressions during hot summer days.

The bats hibernate in caves over winter. The brown bear makes 44% of dens in karst cavities within the reserve.

The processes of bacterial sulphate reduction are developed in stagnant water pools with high sulphate concentration. The water salinity in karst lakes favours the reproduction of zooplankton and benthos and consequently an increase in numbers of many invertebrate, fish and bird species.

The landscapes of covered karst with good natural drainage and relatively abundant soil nutrients including calcium are characterized by taller woodlands with a high proportion of south-taiga species.

In the tundra zone to the north of Arkhangelsk trees can be found only within karst sinkholes, probably, because of the better water regime and accumulation of snow that protects young trees from cold and wind (Fig 1.18, 1.19).

KARST DEVELOPMENT

STRATIGRAPHY (Fig. 1.4)

The territory is situated in the west part of Mezenskaya syncline of Russian platform (Geology of the USSR, 1963). Uplifting tectonic activity is noticed in this region compared to many other platform regions in European part of Russia. This territory has positive index of latest earth's crust movement. There are also many north-west spreading breaks and cracks in the crystalline basis, owing to the influence of the Baltic shield located not far to the north-west.

Thick strata of Vendian, Carboniferous and Permian sediments lies with stratigraphical breaks on crystalline base that consists of granites, amphiboles and Archaean plagiogneisses. Sedimentary mantle is 1000-1500m in thickness and consists of Proterozoic and Paleozoic sediments overlying predominantly by Quaternary glacial sediments. Sedimentary mantle (Carbon – Perm) spreading is longitudinal or sublongitudinal (see geology map on Fig. 1.4) (Malkov, Gurkalo, 1995; Malkov et al., 2001). Stratification is monoclinal with incline up to 1-2° to the east and south-east.

This sedimentary mantle can be divided into following several formations in respect of formation conditions and lithological composition: carbonate (C_{2-3}, P_1a-s, P_2kz_2), sulfate-carbonate (P_1s), sulfate-terrigenous (P_2u), carbonate-terrigenous (P_2kz_2). Most ancient sediments are represented by a carbonate rock layer with total thickness of 75-150m. This layer is divided into 2 formations: lowest – Middle and Late Carbon, upper – Early Perm. Sulfate stratum is completely overlaying these sediments in the region.

Sulfate subformation (P_1sot) consists of lagoon deposits of Sotkinskaya sequence, Sakmar stage of Low Perm - gypsum and anhydrite strata with rare (with thickness up to 0,5m) dolomite, siltstone, clay and sandstone intercalations on carbonate-gypsum cement. Gypsum predominates in the upper part of the subformation, gypsum and anhydrite interstratification – in the lower part. Anhydrite layers and lenses thickness is from 0.1 to 6m and more. The units of transitional character – gypsum-anhydrite – can also occur here. Total thickness of this sulfate layer is 40-70m. The upper part of sulfate subformation has the most homogeneous constitution: the rock consists of gypsum of different crystal sizes almost without intercalations of other sediments.

Usually gypsum is white, light-gray, but sometimes has pink, light-yellowish, brownish, green-grayish hue. Gypsum rocks are practically monomineral ($CaSO_4xH_2O$ concentration is up to 95-98%), but fine anhydrite, rare fluorite crystals could be found in thin sections of gypsum monocrystals. Often there are fine grain carbonate units in gypsum mass. Occasionally there are dolomite lens-like stratum and nodules in gypsum strata with thickness from 1mm to 2-3cm.

There are many rivers, creek valleys, karst canyons and ditches deeply entrenched into the sulfate subformation, and sometimes they are up to 30-40m deep.

Sulfate-carbonate (P_2kl) subformation overlies sulfate subformation deposits with transgressive disconformities (P_2sot). Sulfate-carbonate (P_2kl) subformation includes lagoon-marine deposits of Kulogor sequence, Sakmar stage of Low Perm with dolomites, gypsum, rare marls, limestone interstratifications. Subformation thickness is 3-12m. Subformation sediments are situated on watershed of Rivers Kyelda, Sotka and Pinega, also on Pinega left bank and on east bank of Kuloy. Frequently, sequence deposits lie in the form of “caps”, which protect gypsum strata, but entrenched by creek valleys and karst canyons.

Terrigenous-sulfate (P_2u_1) subformation appears in the form of residual “caps” on the watershed of Rivers Sotka and Pinega, and also on the right bank of Kuloy. The thickness of subformation varies from 3-10 m near village Golubino to 20-25 m in Sotka river valley. Red-colored gypsiferous sand-siltstones or sandstones are deposited in the lower part of subformation. There are gypsum lenses and units. Recent karst features and newest collapse forms are related to this subformation deposits.

Sulfate-terrigenious (P_2u_2) subformation is presented fragmentary on the watershed of Rivers Sotka and Pinega, and also on the right side of River Pinega. Its thickness is 45-60 meters. Deposits consist of red-colored sandstones, siltstone with sand, siltstone, gypsum, marl layers. There are no karst processes inside this subformation, but karstification of lower deposits layers could be the reason of karst features near borders of this subformation.

Carbonate-terrigenious formation of Low Kazan substage of Upper Perm (P_2kz_2) occur fragmentary on the watershed of Rivers Sotka and Pinega, and also to the south-east from this region. Thickness is up to 16 meters. Deposits consist of interstratified grayish marls, clays, sandstones, limestone, formed under littoral-marine conditions.

Quaternary deposits. Early and Middle Pleistocene deposits are usually covered by sediments of Valday glaciation or denuded. Sandy moraine loams and boulder-free loams of problematic genesis are outcropping only at elevated parts of denudation plains. These areas are considered to be nunataks during the glaciation of Late Pleistocene. (Stankovskiy et al., 1980; Malkov et al., 1986). Quaternary deposits have various thicknesses in the region: from 0 to 50 meters (Malkov, Gurkalo, Monakhova and others, 2001). Glacial and lacustrine-glacial loams, also clays and sands (gQIIIos, lgQIII-IV) predominate. Glacial moraine loams contain gravel and pebble with their content up to 10-15%. Fluvio-glacial sandy sediments (outwash) with gravel and pebble content up to 20% (fQIIIos) and thickness 4-6 (up to 10-15) meters are found on watersheds.

Topography depressions filled with lacustrine and lacustrine-glacial clays, loams, sands (lgQIIms-lgQIIIvd) up to 34 meters thick occurs on Belomor-Kuloy plateau. Sites with Quaternary deposits thickness less than 2 meters can be found frequently. Alluvial sands, loamy sands and pebbles which are 2-7 meters in thickness are deposited in river valleys. Recent loams, sands, loamy sands, silts, rarely loose carbonate accumulations and sapropel occur in lake depressions. Bog massifs consist of peat formation that are 2-5 meters thick. Gravitational collapse and colluvial deposits in form of blocks and gravel from 5-10 to 20 meters in thickness occur in karst canyons and depressions.

STAGES OF KARST DEVELOPMENT

For wide development of surface and subterranean karst following conditions are favorable:

- close to surface layering of karstolites
- small thickness of loose topsoil (up to 10 meters)
- penetrability of loose topsoil
- openness of karstolite top layer
- surface entrenched by erosion-denudation channels
- stable upward or weak inversional downward new tectonic movement
- availability of circulation of karst currents
- concentrated subterranean drainage.

The development of karst in Pinega Region was prefaced by a long period of common denudation, the development process was active during the whole period of formation of modern relief. The period of common denudation lasted from Mesozoic Era to middle of Neogene Period.

In the history of karst development of Pinega Region four stages can be distinguished.

First stage started in the second part of Neogene, when the territory resembled a peneplain with heights up to 100 m (Spiridonov, 1978). In the Late Pliocene, a rising of territory followed with simultaneous regression of Polar Basin and drainage of relief. These changes helped the formation of a continuous net of narrow gullies and valley canyons with depths of more than 100 m. (Zarhidze et al., 1984). For Pinega Region this stage of continental development, most probably, was most favorable for common large-scale karstification of the territory. The first stage lasted about 1,5 million years and ended in the middle of early Pleistocene.

The second stage of karstogenesis was active in the Middle Pleistocene age in conditions of constant changing of warm and cold periods. The stage began with Lower Pleistocene lowering of territory and filling of valley canyons with lake-alluvial depositions (Lastochkin, Safonov, 1984). Due to influence of three continental glaciations periods and overall flattened character of relief, karst processes were going on, on the whole, in unfavorable conditions. Still, by degradation of glaciers and activity of isostatic rising, separate groups of large landforms and subterranean karst voids may have been intensively formed. The second stage lasted around 300 thousand years, 170 thousand years were glacier-free and relief developed in the regime of increasing erosion-denudation dissection.

The third stage of karstogenesis comprised with Late Pleistocene and lasted for 110 thousand years. It included the Mikulin transgression - 30 thousand years, cold Early and Middle Valdai – 69 thousand years, Late Valdai continental glaciations – 11 thousand years. The beginning of the stage collided with climatic optimum and penetration of the boreal sea basin (Devjatova et al., 1983). The orographic face of relief was similar to modern. The river net was also formed and corresponded with modern valleys of large and small rivers. Mikulin Sea was shallow, its waters covered Nijnepinskaya and Verhnekuloiskaya lowlands. In the south-east part of Belomor-Kuloi plateau on the left bank of Pinega River an island of dry-land existed. The Sea cut inside it with narrow coves upward river valleys.

The land was under comparatively active development of erosion dissection, of surface and subterranean karst. Most favorable for karstification was the higher part of Belomor-Kuloi plateau. Here, apart from typical dolines and sinkholes, a net of large depressions formed, that stayed preserved also in the modern relief.

During Mikulin time the washing-out of caves with several levels, situated on high gypsometric level, was ongoing.

After regression of the Mikulin Sea (in Valdai period) most part of Pinega Region became dry-land (Devjatova, 1982). Climatic conditions became worse, resulting in slowing down of erosional and and karst processes. Still due to long period of karstification and low-amplitude rising of western part of territory overall karstification level of Pinega Region was wider, than in modern relief.

During Early and Middle Valdai a net of valley formations was formed and karstified, a widely spread relief rich with dolines and depressions was formed. In depths of massifs speleological water-transporting systems were formed.

During age of Late Valdai glaciations the surface kartification stopped until the glacier melted and fell apart into separate tongues and massifs of dead ice. Partly the continental ice stepped back 13 thousand years ago, fully it disappeared 9,8 thousand years ago (Malkov, 1983). By melting of rests of glacier cover, valley drainage of melt water, formation and shaping of dammed pools, conditions for intensive surface and subterranean karstification existed and were active. In all karst areas of Pinega Region surface karst has clear traces of inherited development from late-glaciation time. Parallel to new formations the existing ones were also widened, deepened and re-formed. In that time some of old depressions were opened, filled by sediments, but preserved a dissected karstified bed. Other part of these formations was opened and taken over by the valley relief. Many small karst voids were saccumulated and turned into a covered or semi-covered state.

In this connection three morphogenetic specific features of Pinega karst can be marked. First feature has to do with outer dynamics of glaciations, availability of Severodvinsky-Pinejsky and Kuloi glacier tongues, the maximum reaches of which were parted by period of 10 thousand years. In the middle part of River Sotka a nunatak rising existed, not covered by continental ice. In its reaches weak karst and erosion-denudation processes did not stop even in the progressive phase of glaciations (Malkov et al., 1983, Structure and dynamics of natural components…, 2000).

Second specific feature of karstogenesis was conditioned by inner dynamics of glacier. In its peripheral zone with exarational relief subglacial grooves and valleys were detected, cut into the roof of karstolites. Valleys and adjacent stripe of relief have clear signs of kartification before collapse of glacier cover (Structure and dynamics of natural…, 2000).

Third feature of karstogenesis is displayed in presence of exarational segments of relief, consisting of gypsum rock and covered by crust of dead ice. By their melting and karstification of crack-rich basement the formation of unique shelopnyak fields progressed.

Due to rich underglacial and melt output the Late Valdai glaciation had a strong effect on the subterranean karstification. This output, flowing through existing and newly made net of karst denudation valleys, ensured concentrated feeding with water and intensive growth of existing caves (Malkov et al., 1983, Structure and dynamics…, 2000).

Some caves under glacial forces and side cutting were exhumed and destroyed to different level. Other caves after melting of ice stopped their growth. A number of large caves developed with maximum output and connection of several gypsometric levels. Formation of most caves went on under pressure conditions (pointed phreatic). This was conditioned both by underglacial positioning of hollows, as well as by reaction of earth crust on the spreading of continental glaciation.

The activity of glacier pressure caused an uneven lowering of massifs, opening of tectonic cracks of carbonate complex into sulfate layer and opening of cracks inside the sulphate mass. Under influence of isostatic forces karst waters rose from carbonates into sulfate masses, together with dislocation of levels of flow upwards inside borders of cave blocks.

Thus, caves existed, where sculptural relief was created out of tectonic cracks together with their tectonic opening. Elements of model of uprising speleogenesis first were scientifically proved and thorough studied on the example of cave labyrinths of Podolje (Klimchuk, 1990). The fast development of Late Valdai caves lasted until zonal degradation of glaciation and isostatic rising of territory, that caused a reformation of water feeding system and growing drying out of voids.

Thus, the third stage was most important for understanding the principles of development of surface and subterranean karst of Pinega Region.

Forth period of karstogenesis belongs to Holocene. During this period following changes took place: degradation of zone of long-period glaciations, formation of river output, entrenching of erosion network, destruction of after-glaciation watershed lakes and their most complete mooring, development of woods, rhythmic change of warm and cold periods. Modern landscape and climatic conditions took over two thousand years ago.

Pinega Region in the beginning of Holocene (10,3 thousand years ago) was a place of different natural conditions. The western part of territory was totally free from continental ice. Here preserved the zone of island permafrost with large lake reservoirs in the watershed areas. In the eastern part the melting of remaining segments of Kuloi ice shell (Malkov et al., 1983). In gypsometric relation the territory had a lower position, than it has today. In the valleys of Kuloi River and Pinega River existed the remaining lake-glacier basin, that in the north went over into freshwater bay of Early Holocene Sea (Stankovsky et al., 1980). Soon the basin degraded and the sea bay widened to the south and occupied the same territory, as earlier existing basin. The time of existing of early basin and late reservoir is about 1,0-1,3 thousand years. In this time, due to ingression of sea the lower parts of valleys of Rivers Polta, Kelda, Sotka, Soyana, Siya, Belaya, and also karst-denuded valleys in areas of Kulogora, Vonga, Golubino widened. Situated in the coastal stripe caves went over a stage of development in the flooded regime with changing of water-level.

Most favorable for karstification were Boreal and Atlantic periods of Holocene, during a rising of air temperature and dampening of territory (Hotinsky, 1977). Because of rising of territory and cutting of river valleys up to level of modern floodplains, the basis of erosion lowered and simultaneously karst and erosion processes activated in all elements of surface and subterranean output. Parallel to this, lakes lost a part of their water in depressions and then began to form swamps.

An interesting fact is the process of sedimentation of freshwater carbonate silts (sheetrock) in karst lakes, adjacent to stripe of regional Belomor-Kuloi step. The absolute age of sheetrock in Lake Rodnichnoje (between Rivers Sotka and Kelda) was dated as from 8,7± 0,12 thousand years to 6,95±0,13 thousand years (Gataullin, Kokarovzev, 1986).

In Late Holocene (4500 years ago) climatic conditions became worse, landscape zones have moved to the south (Problems of geology and history, 1982). Than short-time warm and cold periods followed by overall aridisation of climate. Most significant colds were detected 2100-2000 and 700-600 years ago. A noticeable warming can be spoken of 1500 years ago. Due to lowering of regime of humidization and output and periodic strengthening of seasonal-freezing processes, the relative tempos of karsitfication should have slowed down, too.

HYDROLOGY AND HYDROCHEMISTRY

The character of water supplies of territory is quite uneven, that has to do with differences in geological structure and relief (Structure and dynamics…, 2000). Territories, untouched by active processes of gypsum karst, are characterized by high level of mooring (over 15 %). As waterproof horizons quaternary loams and clays are met. Due to this surface waters are low mineralized (fresh) and hold higher quantities of organic acids and iron.

At the same time on territories, with close positioning of sulfate rocks, karst relief defines the drainage level of landscapes, the mooring level there is much lower and sometimes is practically absent. The effect of karst is visible also in lowering of flood: the surface output is taken in by ponors in dolines and depressions and water flow dives into subterranean passages (Fig 2.1.). Due to absence of steady waterproof layer complexes of quaternary and pre-quaternary sediments are hydraulically connected one with another. Subterranean and most part of surface waters have a higher mineralization (weak salted) and sulfate-calcium salt composition (Table 2.2).

Groups of lakes with surface and subterranean flow or with periodic consummation of water in karst channels (ponors) in bed are also typical for the territory (Fig. 2.2). From 1974 to 2000 on the territory of "Pinejsky" Reserve the mean quantity of lowering of level of lakes was about 1 meter (Shavrina, 2000). Streams, swallowed by vertical pits or discharging into sides of karst canyons, often form waterfalls (Fig. 2.3).

Table.2.1. The comparison of hydrochemical data for surface waters of gypsum-karst and moraine landscapes.

Place of probe	pH	Mineralization, g/L	$HCO3^-$	Cl^-	$SO4^{2-}$	Ca^{2+}	Mg^{2+}	Na^+	K^+
		g/L							
Moraine landscape, surface of moor	4.92	0.030	5.86	4.55	1.39	11.46	2.43	2.11	2.51

Karst landscape, water flow in gypsum cave	6,98	1,456	34,16	1,42	1209,6	501,6	6,08	1,61	0,39

KARST REGIONS

By region index of Pinega Region, we use the scheme of main karstologic region index of Arkhangelsk oblast (Malkov, Gurkalo, 1994). The territory is a part of Soyano-Pinezsky and Koido-Kuloisky kast areas.

The south-east of Bolomor-Kuloi plateau belongs to Sotka-Kelda karst region, that is separated into four sub-regions: Nijnesotkinsky, Srednesotkinsky, Verhnesotkinsky and Sotko-Kachevsky (Shavrina, Malkov, 2000).On higher level this karst region belongs to Soyano-Niznepinsky karst area of the Mezen karst region (Malkov et al., 2001). (Fig. 3.1.)

Upon results of region analysis taxa are taken as units of region division. Regions and sub-regions (higher class of region system) are set by ancient geological history and are formed upon geologic-tectonical factors. Areas and sub-areas (middle class) are defined upon analysis of morphological structure and neotectonic movements inside boundaries of large areas of relief. Districts and sub-districts (lower class) are defined upon individual differences of influence on the territory by last period of relief development. For Pinega Region it is late Pleistocene-Holocene, when under development of last continental glaciation the relief undergone some serious changes and a layer of different thickness of loose young sediments formed.

SURFACE KARST FORMS

Modern face of karst relief was formed to time of degradation of Verhnevaldai glacial shell (9 thousand years ago). Development of karst is still active in our time. Maximal density, rich variety of surface karst forms and all known caves of the region are connected with presence of sulphate rocks – gypsums and anhydrites.

Pinega Region is rich with forms of surface karst usual for all karst regions of the world: alvars, ditches, dolines, poljes, depressions, canyons, dry canyons, blind valleys. Rare and unique forms, typical only for northern karst are found, such as: gutters, furrows, polygenetic (karst-glacier) canyons, "shelopnyak" fields, towers, polije- shaped depressions (Fig.1.5, 1.6).

Depending on size and evolution connections karst forms are divided into three groups: micro-, meso- and macroforms. First two groups were formed directly by the karstification process (the map on Fig. 2.4). Third group includes karst-denudation formations that developed for a long time in changing physical and geographical surrounding. Types of karst in landscape relation are divided into nidal, linear and areal. This was defined by the character of glacier melting.

Micro-forms include alvars, niches, subsidience dolines, that intersect the open surface of karst rocks. By areal development micro-forms form 'shelopnyak" fields, where the density of karst forms may exceed 2800 per km^2. "Shelopnyak" fields were formed by melting of caps of dead ice on areas of open rich with cracks gypsum rocks (Fig 1.6, 1.10). The size of "shelopnyak" fields reach up to several hundreds of meters, the depth of dissection can be up to 1,5-2,5 m.

Most common mesoforms of karst in Pinega Region are dolines and small depressions – corrosional, suffusion and subsidience hollows. Their diameter varies from 2 to 150 m., depth – from 1 up to 25 meters. In open and half-open karst dolines (of surface leaching, corrosion-erosional, leaking) form due to widening and depthening of ponor. Collapse dolines form by collapse of roof over a significant subterranean hollow. In conditions of covered karst prior to forming of doline comes the development of subterranean void, followed by collapse of roof.

Among forms of sulphate karst quite rare are kast-erosion residual towers. They form picturesque groups in banks of rivers and lakes, in sides of canyons (Fig. 2.5, 2.6). Residual towers may belong to micro- and macroforms.

The largest and most specific forms of karst of Pinega Region are canyons (karst-glacial valleys). By length from 1-3 to 12 km., these canyons are from 0,2 to 1,0 km. wide and from 20-30 to 40 m. deep. In beds of canyons terraces, depressions, cols and gullies are usual.

Polije-shaped depressions are developed in crossing points of ancient valleys. Their size reaches 2,0 × 1,2 km. with depth reaching up to 20 m.

Periodically disappearing small rivers and streams are also related to hydrological features of surface karst of Pinega Region. They are characterized by full or periodical consuming of water by subterranean hollows in banks and beds of karst canyons.

Karst lakes develop in dolines or in groups of connected dolines. Most lakes are medium in size (from 3 to 50 hectares), but their depth may reach tens of meters (Fig.2.7).

MODERN DYNAMICS OF EXOGENOUS GEOLOGICAL PROCESSES

Structural monitoring of exogene processes is active in “Pinezsky” Reserve from beginning of 90-ties of XX century. Research of exogene processes is carried out on constant routes in canyons, river valleys, lake depressions, and in certain caves, that are being monitored. The overall length of these caves is close to 50 km. The position of processes is being registered and parameters of change are surveyed and measured – size of disruption (by inaccessible objects – visual survey), lithology of deformed rocks is surveyed. Reasons and character of process is researched, as well as time of finding and/or development, possible influence and negative outcome for nature complex.

The largest collapses are registered in banks of River Sotka (Fig.2.8, 2.9), where the total volume of rock blocks may reach several hundreds of cubic meters, by weight of some blocks up to 100-150 tons. During the time the reserve existed a number of large collapses was registered, that caused a full blocking of stream channel (in 1980, 1981, 1990, 1994, 1997, 2001 and 2008). As a rule, these processes become active in the end of July and in August. Blocks that fall into water dissolve in 5 – 10 years, in points of collapse the freshet usually tends to erode the opposite stream bank.

Judging by the volume and size of collapses, gravitational (collapse – landslide and block) collapses prevail (Fig.2.10). Washing away of bed rocks and secondary sediments by far overlap their re-sedimentation in the area of karst landscapes. Roof collapse activity is registered more seldom, due to few cases on the territory and their uncertain localization in the massif, that makes their finding more complicated.

It was proved that modern development of karst develops in paragenesis with a number of exogene processes, which is connected both with geologic structure of territory, specifics of natural-historic development as well as with outer energetic influences on the karst massifs. The termin “paragenesis” means not only combined setting, but also genetic common features of development of exogene processes – common field of conditions and factors of development , complex linear and backdraft connenctions in different groups of processes. Leading exogene processes of the territory are slope-related, erosion, mooring, karst and suffusion. Their common activity may result in common strengthening, weakening or even activity of processes. Zones of development of activation may be dotted or linear, depending on the level of readiness of karst surrounding.

Natural rules of development of exogene processes in time are caused by outer triggering processes: temperature of air and water, incoming into the massif, speed and amplitude of snow freshet and yearly distribution of precipitations.

Depending on frequency zones of single, periodic and constantly active occurrences of exogene activity are taken into respect, they are connected with repeating activity of outer factors or with inner tensions, present inside the massifs of karst rocks.

Collapse of rock in respect of volume and number of cases happens most often, it counts over a half of known activations (Fig. 2.10, 2.11). Landslides are common and often are a form of long-lasting or periodic development. Specific for karst massifs are landslides with consumption of carried material into the doline in the side of canyon or hollow. Subsidence and settling, as traditional indicators of active karst, are taken as separate type of processes, although the gravitational component in the moment of catastrophic development is dominating. Washing out of sediments overlap over accumulation processes, involving both loose sediments as well as bed rock.

Over the monitoring period over 5000 cases of exogene activity were registered, their sum volume makes around 170 thousand m^3. Volume of 200 activation cases exceeds 100 m^3, and in 7 cases it is to speak of 1000 m^3. Over 55 % cases belong to small and medium activations (with total volume of lower then 10 m^3). Stable trends of growth of activations and their volume is registered (Fig.2.12). Due to rhythmus of climate change, melting of subterranean icing , better penetration and cracking of karst rocks, karst processes become more active, as well as paragenetically connected exogene processes. In modern period common tendencies of growth of exogene activity keep growing, although in some cases of monitoring this activity has changeable character.

CAVES

GENERAL

The Arkhangelsk region in the early 2011 counted 468 caves (according to information from O.V. Butakov), 436 of them are in the Pinega Region. The longest in the Russian North and the European part of Russia cave Kulogorskaya-Troya is also located here, it was explored up to length of 17 kilometers. The distribution of caves according to different speleological massifs is shown in pic. 3.1., the characteristics are given in table 3.1 and 3.2.

All caves are of karst origin. Most caves are laid in a layer of gypsums and anhydrites of sulphate subformation of Sakmarian age of Lower Permian (pic.1.4.). Sometimes caves are born in red gypsum sandstone of Ufimian age of Upper Permian. Such are four smaller caves, two are located on the banks of Pinega River nearby villages Shel'ye and Vijevo, one on River Sija (Orange sky cave) and one on River Sotka. Carbonate rock in Pinega Region is known to have smaller voids (Karst and caves, 2001).

During last 20 years the exploration of new caves is done only by amateur speleologists.

Table 3.1.. Exploration data on speleological massifs up to early 2011 (by O.V.Butakov)

Name of speleological massif	Number of caves	Cave length	Number of large caves	Names of large caves
Nijnesotkinsky	35	22576	7	Olympijskaja-Lomonosovskaya, Zolotoj Kluchik, Simfonija
Srednesotkinsky	39	9967	4	Leningradskaya,Yubilejnaya, Medeja
Verhnesotkinsky	28	14471	2	Kumichevka-Vizborovskaya, Konstituzionnaya
Kulogorsky	16	22896	4	Kulogorskaya Troya,Vodnaja, Kulogorskaya-5,Kulogorsksaya-8
Svetlo-Olminsky	Undefined			
Nijneolminsky	2			
Poltinsky	3	58		
Keldinsky	Undefined			
Megrinsky	8	290		
Soyansky	1	30		
Golubinsky	73	26394	16	Severniy Sifon,Bolchaya Pechorovskaya,Pechorovsky Proval

Bereznikovsky	50	9174	4	Imeni Tereshenko, Severjanka,Severnaya Veneziya,Kupel Istiny
Severo-Gbachsky	4	286		
Piljegorsky	2	60		
Vongsky	13	846		
Utopelksky	6	40		
Sijsky	8	451		
Portjugsky	18	2152	1	Gbach-7
Chugsky	119	16788	11	Pogranichnaya,Lunniye Gory,Aprelsky Uzel
Ugzengsky	10	1778	2	Mobil,Molodeznaya
Verhnepozersky	10	235		
Total:	436	128172	51	

Table. Largest caves of Pinega Region (by O.V.Butakov)

№	Search number	Name	Lenght m	Area m^2	Volume m^3	Amplitude	Speleological massif
1	108	Kulogorskaya-Troya	17000	-	-	18	Kulogorskiy
2	244	Olimpijskaya-Lomonosovskaya	9110	78335	158845	32	Nijnesotkinskiy
3	242	Kumichevka-Vizborovskaya	7260	-	-	24	Verhnesotkinskiy
4	202	Konstituzionaya	6130	25900	32880	32	Verhnesotkinskiy
5	62	Severniy Sifon	4617			25	Golubinsky
6	331	Zolotoy Kluchik	4380	5618	14157	10	Nijnesotkinsky
7	274	Simfoniya	3240	6120	9660	10	Nijnesotkinsky
8	151	Bolshaya pechorovskaya	3205	19258	27923	18	Golubinsky
9	286	Leningradskaya	2970	22430	56480	27	Srednesotkinsky
10	9	Tereshenko	2599	9335	12560	12	Bereznikovskiy
11	112	Vodnaya (K-4)	2650			8	Kulogorsky
12	285	Yubilejnaya (C -26)	2555	16400	29459	30	Srednesotkinskiy
13	153	Pechorovsky Proval	2262	16730	23260	22	Golubinskiy
14	105	Kulogorskaya-5	2035	5555	4250	10	Kulogorsky
15	334	Pogranichnaya-Zvezdochka	1910			10	Chugsky
16	165	Severjanka	1830	4500	6300		Bereznikovsky
17	72	Golubinsky Proval	1622	5267	8255	17	Golubinsky
18	297	Geograficheskogo Obshestva	1600	-	-	18	Golubinsky
19	253	Muzeynaya (ZV-53)	1480	10880	13190	10	Niznesotkinsky
20	248	ZV-12	1380	5300	2630	10	Niznesotkinsky
21	328	Lunniye Gory	1233	4823	6481	11	Chugsky
22	419	Saburovskaya	1104	-	-	7	Golubinsky
23	482	Niznaja Saburovskaya	1084	-	-		Golubinsky
24	337	Aprelsky Uzel	1069	-	-	10	Chugsky

The formation of caves is connected to neotectonic displacements and concentrated strong glacial waterflow during the time of development and degradation of last glaciation period. Some geomorphological and paleological signs indicate, that the time of cave birth in the region could be during Pleistocene and Holocene. Most positive for cave evolution were the conditions of concentrated waterflow absorption into karstified bed, consisting of underglacial channels, side-trenches, valleys and depressions. In modern period (last 8 thousand years) most caves develop inheritedly, under influence of alternate vadose waterflows, infiltration and condensation waters (see chapter 2 for more info).

Cave entrances are situated in sides of river valleys, in slopes and beds of karst canyons and dolines, in rare cases – in the watershed areas. Most entrances are down-sloping (pic. 3.2.), more rarely – horizontal (Fig. 3.3.) or vertical . A number of caves have a collapse sink-hole entrance (pic. 2.2.) – as, for instance, caves Pechorovsky proval and Balunovsky proval.

Most caves in the Region belong to corrosion-erosion class, resembling cave-ponors, open karst caves or cave-springs (Dublyansky, 1977). Cave systems , sub-parallel to side of canyon or river valley develop by edge (board) cracking. during migration of water flow. Sub-perpendicular caves, cutting watershed areas, develop by concentrated underground tributaries through cracks, determining the main displacing disruption. The character of flow through crack structure of blocks and hydrogeological conditions define the structural type of cave – linear, branch-like, labyrinth or aerial. (Karst and caves.., 2001, fig. 3.4.).

Usually caves resemble horizontal and sub-horizontal systems of passages consisting of different levels. This indicates their origin and development in the hydrodynamic zones of horizontal and siphon circulation. A number of smaller caves are born in the zone of vertical downward circulation. Whatever the length of an underground cavity, as a rule, it combines different morphological elements: tunnels (pic. 3.5), galleries, collapse chambers, and vertical forms: organ tubes (pic. 3.6) and chimneys. Sometimes a cave may combine up to 3 levels with amplitude reaching 32 meters.

As a rule, lower levels of karst caves are rich with water and are on the stage of modern development . Caves concentrate more than half of drainage of karst waters in the Region. Most underwater caves have constant streams and rivers, or during flood they serve as pathways for discharge of large temporary flows. A number of caves have waterfalls and active springs that discharge hanging waters, underground lakes are also present but less common. The low water and flood levels of underground flows vary between 1,5-3,5 m.; the discharge changes between 10 and 5000 liters per second; mineralization varies from 2,5 (low water) to 0,4 gram per liter (flood); water temperature changes from 0 to 5°C (a maximum is registered during flash floods). By amplitude of flood and low water levels of underground waters from 2-4 meters and flood speed of flow of 0,5-1,0 m. p. s. an intensive output or re-sedimentation of secondary filling of cave is registered, as well as washing out of collapsed rock and rubble sediments.

MODERN DYNAMICS OF CAVE MICROCLIMATE

In modern conditions caves of European North of Russia resemble unchained systems with high level of self-regulation of active exchange processes. Caves are, as a rule, up to 10-25 meters deep, any change of underground conditions is connected, to a considerable extent, with outer influence. They are determined by seasonal and unseasonal influence of air and water temperature, growth and lowering of water output entering from the surface.

Last decade was characterized by a warmer and contrast unstable weather, with cold periods in spring with heavy snowfalls, hot weather in July, accompanied by drought, heavy rains, that caused flooding on rivers and late freezing-over on rivers and lakes. In the yearly microclimatic cycle of caves the main importance is the dependence on abnormal climatic factors: heavy rains, out of season snowfalls, sudden cold days in the time of flood.

The microclimate of caves on the territory is characterized by low mean air temperatures, high humidity and low speed of air movement. Most temperature observations were conducted with maximal and minimal thermometers, that by 1 monthly measurements gave a temperature amplitude for that period. The use of temperature loggers with measurements interval of 3 hours made the possibilities if data analysis much wider.

Analysis of data collected in a number of years showed a common tendency of lowering of air temperature in caves due to their lowering in summer period (pic. 3.7.). Values of winter temperatures stay without change, according to observations from most of caves being monitored. The difference to mean air temperatures on the surface rises to 0,3-2°C in different caves. Mean short-term temperatures in zones of constant ice formation sunk by 0,3-2,3°C, and for zones of seasonal icing grew by 0,2°C.

The relative cave air humidity varies from 85 to 100 % in winter period, whereas in spring and summer these values are close to 100%. The speed of air currents, as a rule, is small, up to 10- 20 centimeters per second. Though, by small cave entrance or in constricted passages air speed can increase to 1-3 meters per second.

As a rule, in caves with one entrance and length of more than 150-200 meters several microclimatic zones are present. They are: zone of seasonal fluctuation, transition zone and zone of stable temperatures (pic. 3.8.). In winter period cold air enters from the entrance and through cracks. In summer in caves with high entrance cold air prevents warm air from flowing inside, forming a temperature barrier (“cold bag”). Another case of summer air circulation is the escaping of cold air through a low laid entrance. A stable downward flow of air in winter is registered in Pinega caves also earlier by V.M. Golod (1974).

In caves with large waterflow (cave-rivers) decrease of air temperature was registered by drop of water temperature by spring flood and rise of air temperature by summer flood caused by rain. A simultaneous rising of water and air temperatures is registered on the day of first summer heavy rains that indicates high speed of heat exchange. A stable connection of dynamics of air temperature and its humidity in winter period, a clear drop of humidity by decrease of air temperature.

Seasonal and long-term tendencies of basic parameters change of underground environment are described. Yearly changes of environment are divided into seasons that resemble the earthly ones, but come with delay due to slower transition of active flows.

Winter in caves comes in the end of October – beginning of November (it’s begin is marked by growth of ice formations).

Spring comes in the end of April – beginning of May, it is marked by begin of underground freshet, which usually outruns flood on rivers by 5-7 days. The length of this season depends on snow quantity on the surface and period of its melting (depending on air temperature it can last from 2 to 6 weeks). A change of spring snow-fed flood with rain-fed flood is also possible.

Summer in caves, due to low temperatures during whole season, can be marked only literary. It’s begin is marked by end of flow of snow-fed flood. It is characteristic with rise of air temperature in the zone of seasonal fluctuation to positive values and change of air current direction.

Autumn begins in the end of August – beginning of September, it is marked by begin of a rain-fed flood. During this period a rise of air temperature is also possible due to warming effect from incoming rain water (so-called Indian summer).

The forecast possibilities of environmental change in caves at the time are shortened by less than 20 years of observations, which gives precise data for only short-time forecasts. They allow to form following logical series:

Rash melting of snow-mass ⇒ high speed flood ⇒ erosion of base of slopes ⇒ growth of slides and collapses in caves (2-3 years after a high speed flood).

High rising of underground level of water during flood ⇒ melting of cemented ice and icing in caves, caverns, cracks ⇒ activation of sliding, collapse and subsidence processes.

High speed flood in caves ⇒ washing-out of secondary sediments ⇒secondary re-sedimentation in the zone of flood backwater or carrying into main drainage channels.

Strong rain showers (daily quantity of water can reach monthly norm) ⇒ activation of flash floods in caves, increase of air temperature, decrease of mineralization.

Monitoring in caves of “Pinezhsky” Reserve, apart from microclimatic parameters, includes also hydrological observations (levels, discharge, temperature and mineralization of karst waters). Dynamics of ice formations and activity of exogenous processes is registered. The monitoring activity is carried out by speleologists of “Labyrinth” caving club (Archangelsk) in Kulogorskaya cave. The information collected allows to research and evaluate climatic change during last decade that led to change in the microclimatic characteristics in a number of caves.

MECHANIC AND CHEMOGENIC SEDIMENTS IN CAVES

Secondary deposits in Pinega caves are represented by all main genetic types of cave deposits, by ranking of G.A. Maksimovich (1963): gravitational, hydro-mechanical, hydro-chemogenic, kriogene (ice) (Malkov, Shavrina, 1991). Active development of secondary deposits is also active at present, changing the face of underground landscapes.

Gravitational sediments are widely presented by collapse and subsidence subtypes, more rare are thermo-gravitational sediments that tend to be found at the entrance zone, formed by multiple freezing and melting.

Hydro-mechanical sediments are widespread in all cavities, considerable thickness are typical only for large caves (pic. 3.9.). By facial composition of sediments following types are marked: alluvial, delluvial, lacustraine and a number of other subtypes. The age of sediment development begins with beginning of Holocene, late Pleistocene sediments are also present, as well as paleokarst filling of undefined age.

Hydro-chemogenic sediments are much less common. Crystals, crusts, stalactites and stalagmites prevail, developed by overlying carbonate layers. Sediments of different age of calcite, aragonite and carbonate-clay composition are also found. Carbonate sediments are formed in caves with close layering of carbonate sediments of Kulogorskaya suite. Most often they are found in chimneys and pits of first layer. Apart from that, gypsum crystals, more often ephemeral, concretions (gypsum hedgehogs), gypsum crystal crusts (Malkov, Shavrina, 1989), with addition of clay material are present. Their development is connected with high mineralization of pore solution of secondary filling of caves and criogene accumulation of gypsum powder in the winter cycle of evaporation of mineralized ice (Korshunov, Shavrina, 1998).

Subsidence-gravitational sediments form by collapse of ceiling of hollows. They are usually triggered by earthquakes. By this screes of large blocks are formed, often with addition of surface quaternary sediments. This type of sediments is common for side zones of caves, layered along the side of karst canyons and structural basins.

Delluvial – prolluvial (allochton) sediments resemble material of surface quaternary formations , that was brought into cave through cracks, organ pipes, pits and voids. These can be seen in most caves, mostly composed of moraine loam with pebbles and gravel, moved from the surface by fluvioglacial sands and red sand-alevrite particle size material. Boulders, tree-trunks and vegetation rests, deposited as output cones and screes under cracks, pits and along side zones, are also present.

CAVE ICE

Practically in all caves of Archangelsk region seasonal ice is registered, many enclose long term ice. Cave ice formations are quite different in morphology and are presented by all genetic classes. All types of ice formations, described in various caves of plain and mountain karst, are found here, as well as a number of special forms of ice, found only in the conditions of the North (pic. 3.10.).

Most common is congelation ice (formed by freezing of liquid and drop-liquid water), which is formed by water, coming from the zone of vertical downward and horizontal circulation. Metamorphic and sublimation ice is less common.

Typical forms for northern caves are ice blisters and cavern- lode ice bodies, cement ice, covering ice of water reservoirs, stalactites, stalagmites and columns (pic. 3.11.), ice crystals (pic.3.12., 3.13). Another specific form of underground ice is ice siphons (blocks) and ice screens. Ice siphons can be formed on constant underground streams or on downward sloping cave entrances, ice screens develop in the zone of frontal splashing of waterfalls and dripping springs.

The reason of ice formation is, mainly, water of zones of vertical downward and horizontal circulation, the role of ice of metamorphic and sublimational genesis is secondary. Ice is a mineral, its morphological features, to a considerable degree, depend on the character and speed of incoming water. Important factor, that defines the development of cave ice, is undercooling of rock that holds a cave. Main volumes of ice are deposited in the cave entrance areas where the seasonal melting of ice comes together with warmth absorbtion, which also helps to keep low temperatures in hollows.

Three seasonal cycles of cave ice development can be described. The pre-winter cycle is characterized by development of ice crystals, stalactites, stalagmites and columns, ice blisters, icing, and also ice crust on lakes and streams. The pre-spring cycle is characterized by formation of ice blisters in the downward sloping entrances of caves and close to side areas, by growth of crystals. The summer (after freshet) cycle comes with development of constitutional ice by freezing of overhydrated loose deposits and ice crystals.

Mineralization and facial composition of ice depends on the primary mineralization of water and its composition. For ice blisters and cavern-lode ice, ice-cement, crust and icing, stalactites, stalagmites and columns it is 1,5-2,5 gram per liter, facies SO_4 Ca. For ice crystals and sublimation icing - 0,2-0,5 gram per liter, HCO_3 Ca (pic. 3.14.).

The presumable maximum age of underground ice, dated by radiocarbon dating method using a fragment of wood from a icing from the cave C-26 (Yubileynaya), gave a result of no less than 200 years. Most possible the age of ice is much greater, but precise data to prove this is absent. Never the less, for region with relics of long term permafrost, there are reasons to suppose a longer existence of underground ice in caves.

Process of shrinking of long-year ice volumes in caves is ongoing, the period of seasonal icing comparing to previous ice conditions until mid-90-ties of the XX century also decreased. By long-lasting autumn freshets subterranean flows tend to cover up with ice 1 or 2 months later. In winter of 2008-2009 for the first time the lake in cave Bolshaya Golubinskaya did not froze over. In 2010-2011 the frames of seasonal ice development returned into normal.

Expeditionary exploration in 2005 in cave Yubileynaya (C-26) showed, that the volume of long-term icing reduced by half. A stable growth of ice from beginning of XXI century was found only in cave Ledyanaya Volna, which is due to positioning of ice and water current in different cave levels. The growth of icing here prevailed in summer and autumn period, by penetration of water from melted snow and rainwater into the undercooled massif. By growth of ice volume the speed of air circulation and its temperature decreased. In 2004 the entrance into this cave was covered by a landslide.

VERTEBRATE CAVE FAUNA

Caves of the region are not inhabited by vertebrates constantly, they use hollows as shelter, source of water or they get in by accident. Often in caves traces of small predators are found: such as otter, stoat and water shrew (*Neomys fodiens*). On the territory of “Pinezhsky” Reserve A.M. Rykov found a number of bear lairs in small caves, where it is probably warmer in wintertime due to inflow of warm air from the underground hollows.

Fish is often seen in cave rivers and lakes. In winter period burbots are seen in lakes, most probably they rise to sprawn upstream and come into caves (Semikolennyh, 1999). In summertime grayling is common for caves, which is choosing the cold karst waters during warm days.

In Pinega Region during 30 years of observations two species of cave cheiroptera were found – Northern bat (*Eptesicus nilssoni*) and Brandts bat (*Myotis brandti*). Bats use caves for winter stay. In cave Golubinskiy Proval the calculation of bats in winter were carried out from 1986 until 1999 (until begin of exploitation of cave for excursion needs).The average number of wintering bats during these years was 5,7 species. The total numbers of bats registered in this period is 52, 50 of them proved to be Northern bats and 2 species were Brandts bats (Structure…, 2000, Components…, 2008).

INVERTEBRATE CAVE FAUNA

The fauna of invertebrates in Pinega caves is weakly researched, the data is not numerous and fragmented.

N.G.Bayanov (Bayanov, 2003)basing on hydrobiological research of karst lakes of Pinega reserve names following species as inhabitants of cave waters: rotifer *Notholca caudate* (Rotatoria, Brachionidae), that was earlier registered in the plankton of Sweden and Canada (Kutikova, 1994), and also crustaceans *Mysis relicta* (Mysidacea, Misidae) and *Pallasea quadrispinosa* (Amphipoda, Gammaridae). *M. relicta* is the inhabitant of water reservoirs of basin of the Arctic Ocean and the Baltic Sea (Filchakov, 1995). *P. quadrispinosa* inhabits the oligotrophic lakes of Europe (Starobogatov, 1995). Amphipoda (Amphipoda) are also registered in caves Kulogorskaya, Kitez, Golubinskiy proval, Vodnaya (Semikolennih, 1992, Franz, 1992, 2003a, 2003b, Bikulov, 2003). Probably, the species mentioned are the relicts of ice age (Bayanov, 2003).

O.L. Makarova (2006, 2007, 2009) and A.L. Babenko (2008) have carried out research of mesofauna of karst landscapes – Moseev, Severniy and Tarakaniy karst canyons were explored, rock outcrops and isolated karst dolines. Also organic material (dust of rotten wood, rotten leafs) from caves Golubinskiy proval and Ledyanaya volna was studied. Cave material was not inhabited by microarthropods, temperature in caves was negative (Makarova, 2006). On the contrary the fauna of landscapes above possessed of a complex of specific species, registered only in cold karstogene areas of the reserve.

Research showed presence of Acari (Parasitiformes, Mesostigmata) - arctic *Dynychus micropunctatus* (Uropodidae), *Arctoseius* sp. (Ascidae), northeuropean-siberian *Trachytes edleri* (Polyaspididae) and *Pachylaelaps kievati* (Pachylaelapidae), arctomontan *Veigaia belovae* (Veigaiidae), *Trachytes hirschmanni* (Polyasididae), *Iphidinychus gaieri* (Uropodidae), *Cheiroseius* cf. *sayanicus* (Ascidae), *Zercon* sp. (Zerconidae), species with motional connections *Gamasellus* sp. (Rhodacaridae), *Arctoseius* sp. (Ascidae), *Syskenozercon kosiri* (Zerconidae) (Makarova, 2009).

Among springtails (Collembola) also siberian species are present, that demonstrate the eastern-palearctic influence on the fauna of the Reserve (*Protaphorura jacutica* (Onychiuridae), *Desoria alaskensis, Pachyotoma* sp., *Isotomodella psammophila* (Isotomidae)), as well as various in type of habitat arcoalpine (*Chaetophorura simplex*, *Ch. Bella* (Onychiuridae)) and arctic, typical for zones of tundra and polar deserts (*Desoria tshernovi*, *D. inupikella*, *Isotoma* sp. aff. *variodentata*, *Pseudisotoma sensibilis*, *Folsomia ciliata*, *F. cryptophila*, *F. bisetosa*, *Tetracanthella wahlgreni* (Isotomidae), *Oligaphorura* cf. *ursi* (Onychiuridae), *Hypogastrura tullbergi* (Hypogastruridae)) (Babenko, 2008). Also a psychrophilic european species *Appendisotoma abiskoensis* (Isotomidae) and *Willemia trisphaerae* (Hypogastruridae) are registered, known from habitat spots both in northern Europe and mountains of south Siberia. *Desoria tschernovi* and *D. inupikella* are the most common of all arctic species in karst dolines. That, together with large numbers of *Folsomia rossica*, leads to high specificity of their communities (Babenko, 2008). *D. tschernovi, I.* sp. Aff. *variodentata*, *A. abiskoensis* and *W. trisphaerae* were earlier registered in caves of Central Ural (Potapov, 2003, cit. according to Babenko, 2008).

Judging upon observations, cold karst habitat areas helped to preserve the cryophile species, that settled here during the ice age (Makarova, 2007). That, combined with possible settling or introduction of northern species, lead to formation of modern communities of microarthropods (Babenko, 2008).

Data on insects in caves is fragmentary. In the paddles of cave K-1 some larva of mayflies (Ephemeroptera) was found (Franz, 2003c, 2003d). Mosquitoes (Diptera,Culicidae) are found in the far part of cave K-2 (Franz, 1992), probably they use the cave as a wintering refuge. Unidentified mosquitoes were also seen in cave K-5 (Franz, 1992). *Helomyza serrata (Diptera*, Helomyzidae) was registered in caves Golubinskiy proval, Kitez, imeni Vysotskogo, imeni Tereshenko (Semikolennih, 1992). This species has a holarctic prevalence, it is common in underground hollows of Central Russian Plain and South Ural (Kapralov, 2010).

Low temperature in caves and its considerable change (Shavrina, 2010) on the whole produces a negative effect on the variety of underground fauna, at the same time due to these conditions various and specific biocoenosis of surface karst forms is present.

MICROORGANISMS IN CAVES

The structure of microbe complexes of caves has specific features similar to surface soils with dominating bacteria of the order Myxococcales, genera *Cellulomonas*, *Aquaspirillum* and *Arthrobacter* (Semikolennih et al., 2004).

Number of bacteria in soils and cave biotope areas was also comparable, it gave a result from 10^7 to 10^9 CFU/gram for soil litter and its fragments in the cave, and from 10^5 to 10^7 CFU/gram for mineral horizons and cave sediments (according to data from inoculations on the glucose-peptone-yeast agar). At the same time a test with decay of cotton cloth proved, that speed of decay of cellulose in a cave is 1-2 times lower, then on the surface (Semikolennih et al., 2004).

Number of bacteria, capable to grow at low temperatures in soil and cave biotopes differs. In cave biotopes the share of psychrotolerant pool of bacteria (able to grow at +5°C from those able to grow at +25°C) made 0,6 % for organic substrate and 20 % for cave clay . Whereas for soil the relative amount for duff is 0,4 % and 6,31 % for mineral horizons on the average. The best ability to adapt to cold was registered by oligotrophs (Semikolennih et al., 2004).

The variety of species of microfungal community in cave sediments has an inherited similarity to communities of surface soil horizons. In microfungial complexes of surface soil litters *Trichoderma viride* is always present, a large variety and richness of specimen of genus *Penicillium*. But cave communities of micromicets differ from soil ones with high homogeneity (index of similarity E=0,95-0,99). They are presented by rare met species, that have at the same time rich in numbers (often over 30%), by total absence of species, small in numbers. The prevalence of rare met, but rich in numbers species of fungi by their spotted and casual character is due by poorness and discreteness of organic substrate that is present in cave clays, which is a specific feature of cave biotope. A mass occupation on such discrete spread substrate of predominantly one population, one species is possible by lack of competition between species (pic.3.15.) (Semikolennih et al., 2004).

In the conditions of spreading of sulfate mineralization of waters bacterial processes connected with transformation of sulphur compounds are often in water systems and over-moistened soils. We respect *Desulfotomaculum acetoxidans* as the dominating species of sulphatreducing bacteria for Pinega Region, it was taken from black silts of lake Eras'kino and bogs in G-1Cave. Temperature plays one of key factors for the development of sulphatreducing bacteria. The temperature border of near to +8°C serves as limiting factor that stops processes of bacterial sulphatreduction in caves. By lower temperature of karst waters this process stops (Semikolennih, 2001).

Sulphur redox bacteria are presented with several species, found in specific biotops. In large karst lakes (for instance, Eras'kino lake) the oxidation of sulphurdioxide happens in turbid suspension and film on water surface, that consist of small singular bacteria. Most probably, here bacteria of genus *Thiobacillus* are present. In smaller, well warmed and lightened narrow gullies, filled by sulphate waters, we have found colorless filiform bacteria *Beggiatoa*, often met in same biotope with iron-oxidating organisms. Another type of community was described in a deep karst sink-hole of Krasnaya Rada in Chugsky Reserve (64° 10' 51,9" North lat., 42° 44' 01,8" East long.) (pic.3.16.), where phototroph filiform mooving green sulphur bacteria were registered, probably of species *Chlorobium limicola*, in association with phototroph purpur sulphur bacteria *Thiocapsa roseopersicina* and cianobacteria of genus *Lyngbya.*

WILFLIFE CONSERVATION AND ENVIRONMENTAL EDUCATION

THE PINEGA STATE RESERVE

The State Nature Reserve "Pinezhsky" was created by the efforts of the Komarov Botanical Institute of the Russian Academy of Sciences and particularly Prof. Dmitry Sabourov – geobotanist and geographer that studied the Pinega Region in the 1960s. The State Nature Reserve "Pinezhsky" was officially opened on the 20th of August 1974 by the Russian Federation order no.474. Its buffer zone was established ten years later i.e. on 26 of July 1984 by the Archangelsk administration order no. 110 and then increased following the local government orders no. 8 in 31.01.1991 and no. 355 in 1997.

The reserve is located in the southeast of the Belomor-Kuloy Plateau at the right bank of the Pinega River (№1, Fig. 1.2.). The reserve area is 515,22 km^2, the buffer zone area is 305,45 km^2. The reserve is aimed at conservation and study of the north-taiga ecosystems, karst landscapes and rare species of plants and animals, ecological monitoring and ecological education.

The recent research within the reserve has revealed 118 caves, several unique soil varieties, 755 species of vascular plants and mosses, 453 species of fungi and lichens and 207 species of vertebrate animals, of which 50 species are included in regional, national and international Red Data Books.

The Red Data Book of Russia includes the following plants: lady's slipper orchid (*Cypripedium calceolus*), Calypso orchid (*Calypso bulbosa*), ghost orchid *(Epipogium aphyllum)*, narrow-leaved marsh orchid *(Dactylorhiza traunsteineri),* the Pinega Region endemic *Gypsophila uralensis* ssp. *Pinegensis* of the carnation family and two species of lichens - *Lobaria pulmonaria* and *Bryoria fremontii*. The Red Data Book of Russia also includes the following species of animals: osprey *(Pandion haliaetus)*, white-tailed eagle (*Haliaeetus albicilla)*, golden eagle (Aquila chrysaetos), peregrine falcon *(Falco peregrinus)*, eagle awl (*Bubo bubo*), northern grey shrike *(Lanius excubitor)*, *Driopa Mnemosyne* butterfly and bullhead fish *(Cottus gobio)*.

The major part (87%) of the reserve area is occupied by forests. More than 70% of them are spruce forests and about 20% are pine forests. Birch forests grow in places where the conifers were destroyed by fire of cutting. Larch forests are confined to most karstified locations. About 10% of the reserve area is covered by oligotrophic and mesotrophic sphagnum bogs. There are very small areas of meadows and open woodlands.

Three groups of relief can be distinguished. The central strip of land running from the northwest to the southeast of the reserve has small- and medium-hill relief with patches of undulating plain, the southwest of the reserve has slightly undulating and flat relief with hilly patches; the more hilly relief is found in the northeast. The relief was sculptured by glacial processes during the Late Valdai ice age. The amplitude of heights is 15-20 m, the height above sea level varies from 145 to 173 m (Shavrina and Malkov, 2000).

The surface water courses include permanent and temporary rivers and streams and numerous karst lakes. The main rivers of the reserve are Sotka and Pinega.

The Pinega River – one of the Northern Dvina tributaries – is not included within the reserve, but drains its eastern and southeast parts.

The Sotka River drains the northern and central parts of the territory. Before entering the open gypsum karst area, just after the Belomor-Kuloy Plateau, this river looks like a typical taiga river with low banks, slow current and drift wood accumulations. Then within the 38 km of karst area the river turns into a roaring mountain stream with fast current, canyon-like valley, rocky cliffs and occasional floodplain woodlands. The bank height reaches 40-60 m. The river bed has more than 120 steps 0.5-1 m high, hence its height above sea level decreases by 45 m within the gypsum karst area.

The most curious natural features of the territory are the karst caves, the Sotka River canyon (Fig.2.5, 2.8), the Eras'kino Lake polje with residual gypsum blocks and towers and the waterfall by the entrance to the Pekhorovsky Proval cave (Fig. 2.3). The unique plant communities of karst landscapes include open woodlands, pine-larch forests, grass spruce forests and meadows of karst dolines and the Sotka floodplain.

According to the Pinega Reserve records by the early 2011 there are 92 caves within the reserve and 27 caves within its buffer zone. That makes up about ¼ of all caves registered within the Archangel area. There are 54 caves more than 500 m long (Butakov, 2011) with 18 of them found within the Pinega Reserve (Table 4.1).

The Pinega Reserve territory is a natural laboratory with a unique capacity for monitoring the development of karst and exogenous geological processes on the surface and underground.

Table 4.1. The caves over 500 m long within the Pinega State Reserve and its buffer zone.

Cave name	Length, m	Area, m^2	Volume, m^3	Amplitude, m	Number of entrances	Speleo massif
Koumichevka-Vizbor System	7260	45298	102160	24	4	Upper Sotka
Konstitutsionnaya, (C-10)	6130	25900	32880	32	1	Upper Sotka
Northern Syphon	4617	-	-	25	1	Goloubino
Bol. Pekhorovskaya*	3205	19258	27923	18	1	Goloubino
Leningradskaya, C-7*	2970	22430	56480	27	2	Middle Sotka
Yubileinaya, C-26	2555	16400	29459	30	4	Middle Sotka
Pekhorovsky Proval	2262	16730	23260	22	1	Goloubino
Severyanka*	1830	4500	6300		1	Bereznik
im. Geographic Society	1600	-	-	18	3	Goloubino
Sabourvskaya	1104	-	-	8	2	Goloubino
Lower sabourovskaya	1091	-	-	8	1	Goloubino
Kitezh*	953	4450	6995	14	2	Goloubino
Bol'shoi holodilnik	815	7050	13395	20	1	Goloubino
Svyato-rucheinaya(Г2+П2+П3), Pobednaya*	771	3555	4100	20	3	Goloubino
im Zelenina	716	-	-	2	3	
Medea, C-21	712	4145	4940	14	1	Middle Sotka
Svyato-schelnitskaya-1, Svyataia*	652	2130	4230	10	3	Middle Sotka
Karielovsky Proval	510	1734	2947	30	1	Goloubino

*– buffer zone caves

THE GOLUBINO /GOLOUBINO KARST MASSIF

The 'Goloubino karst massif' is located at the right bank of the Pinega River, 17 km southwest of the Pinega town (Fig. 1.2., fig. 4.1). This karst massif is bordered by the Pinega State Reserve in the west and the Pinega River in the east.

The Goloubino karst massif has a total area of 210 ha and characterized by an active development of modern karst relief. The surface karst forms are varied by their types, morphological and morphometric parameters and spread throughout the area of the massif.

The macro-forms of surface relief are represented by karst canyons having the most complex morphology and genesis. They were created by the simultaneous action of karst and other exogenous geological processes: karst-erosion, karst-glaciation and karst-denudation. A 2km stretch of the Pinega River bank, which formed by the side of the Belomor-Kuloy Plateau, includes three karst canyons – Pekhorovsky, Tsygansky and Tarakania Shelia (Fig. 1.9).

The typical meso-forms of surface karst are medium-sized sinkholes (from 15 to 25 m in diameter), small depressions, gullies and residual forms. Most sinkholes are found within a close proximity of karst canyons and by the river bank.

The karst micro-forms are represented by ancient and recent karren, collapse/subsidence forms and ponors. Closely spaced output and residual forms (shelopnyaks) are also found by the Tarakania schelia canyon.

The area of the Goloubinsky karst massif includes 9 caves, the 4 of which are over 500 m long (Table 4.2). The total length of all these caves is 4277 m. The entrances to Goloubinsky Proval, Kolybel'ka, Vysotskogo and some smaller caves open at the sides of the Tarakania Schelia canyon.

Permanent surface water courses are absent within this karst massif. At the time of spring thaw an underground stream of the Tarakania Schelia canyon sometimes rises to the surface but soon disappears into the caves at the canyon banks and ponors at the bottom. There is a small 150 m long stream starting from the right bank by the Tarakania-2 cave and disappearing in the middle of the canyon. The number of temporary water courses at the Pinega River bank between the Tarakania Schelia (Fig. 2.1) and Pekhorovsky canions varies from year to year from 15 to 20. The karst waters change their level, speed, temperature and salinity from season to season.

Table 4.2. Large caves of the Goloubino karst massif

Cave's name and search number	Location	Length, m	Area, m^2	Volume, m^3	Entrance altitude a.s.l./ amplitude, m	Number of entrances/levels	Additional information
Goloubinsky Proval * (Г-72)	"Tarakania schelia" karst canyon	1622	5267	8255	29/17	1/2	Vertical entrance, perennial ice, carbonate crusts, gypsum concretions, permanent stream, siphon, organ pipes
Malaya Goloubinskaya (Г-149)	"Belomor-kuloy" Plateau	880	3320	3520	13/11	2/3	Labyrinth, permanent water course and perennial ice
Malaya Pekhorovskaya (Г-73)	"Pekhorovsky" karst canyon	820	2345	2420	33,1/15	1/1	Glacier at the entrance, permanent stream, waterfall, carbonate crusts
Vysotskogo (Г-156)	"Tarakania schelia" karst canyon	591	2620	2595	42 /9	1/2	Seasonal and perennial ice, carbonate stalactites and crusts, stream and waterfall

CHOUGSKY WILDLIFE RESERVE

The Chougsky National Wildlife Reserve of the regional value was created by an act of Arkhangelsk Region Administration of 11 November in 1996. The preserve is located on the left bank of the Pinega river, 40 km to the south-east of Pinega village (object 2 on Fig 1.2, fig. 4.2, 4.2).

At the beginning of 2008, on the territory of Chougsky speleomassif, 119 caves were registered, which is about 25% of all known caves in the Arkhangelsk region. The entire length of the caves is 16.7 km, 11 of them exceed a length of 500 m (Table 4.3). The density of caves in Chougsky area is the highest in/within the Russian North.

The uniqueness of Chougsky karst topography is due to the large area of opening of the gypsum base under the action of glacial exaration, to the large formations of extended pre-glacial topography, to the small and low Quaternary cover thickness, to ingressive valley network and to karst strata gypsum outcrops development. Such unique forms of karst as karst fields with output and residual landforms, canyons, dolines, sinkholes, disappearing lakes and rivers, outliers, residual blocks, towers (Fig. 2.5) and caves are widely represented here.

Chouga karst is unique and original, even against the background of a vast karstification of the Arkhangelsk region. The reason for such diversity is a geological structure and features of the geological history of the area. The thickness of Quaternary cover within and nearby the Chougsky reserve is 2 -10 meters, but sometimes less than 1 meter. Deposits are represented by glacial boulder loams and water-glacial sandy formations. Under cover/layer of Quaternary deposits on the entire territory of the reserve gypsum outcrops and anhydrites of Sotkinskaya Svita Sakmarian layer of the lower Perm are developed. Their thickness reaches 70-90 meters. The most impressive forms of surface karst are shelopnyak (karst fields with output and residual landform) polygonal fields (Fig. 1.10). They contain the association of superficial, transient and often subterranean forms developing according to the scheme of adjoint multifocal process. Karst fields with output and residual landform are associated with zones of increased fracturing of rocks reflecting the discontinuous zone in the sedimentary/ aqueous cover. The density of karst forms is more than 3,000 per 1 km². Karst fields with output and residual landform are developed throughout the sulfate rocks of the Arkhangelsk region, but area-development occurs only in the Chouga area.

The largest man-made threats to karst fields in the Arkhangelsk region are connected with the pit/open-cut mine approach of gypsum extraction. The territory near the border of the Chougsky reserve was taken over by the branch of the German company *Knauf-gypsum* for the open mining of gypsum (Fig. 4.4).

Mining operations, carried out very close to the boundary of the protected area, will inevitably lead to the destruction of a number of protected sites of a great value. For instance, the Aprelsky uzel- Sineglazka cave system (Fig. 3.6), which occupies the 77th place in the top biggest gypsum caves of the world, is potentially in danger. The entrances are located on the border of the reserve; at an extremely close distance from the influence zone of the open-cut mine. Further deepening of the mine and expansion of the development areas can result in a lowering of groundwater levels, the collapse of caves vaults in fractured and highly soluble sulfate rocks and adversely affect the conditions of rare species of flora (orchids), larch forests and unique soils on gypsum karst (sulforendzin) of the Chougsky reserve.

Table. Big caves of Chougsky speleomassif

Search number	Cave's name	Length, m	Area	Volume	Amplitude, m	Number of entrances
334	Pogranichnaya-Zvezdochka system	1910			10	7 (8?)
328	Moon Mountains/Lunnye Gory	1233	4823	6481	11	6
337	Aprelsky uzel	1069			10	3?
339	Shining/Siyaniye	902			9	1
194	Key/Klyuchevaya	794				2
445	Valentine/Valentinka	768				2
332	Amakhinskaya	732	1693	2609		8
434	Pozerka	648			10	?
329	Unique/Unikalnaya	630				6
193	Providence's/Provideniya	540	3775	8590		1
219	Bratynya	525	2110	2740		6

"IRON GATE" WILDLIFE RESERVE

The "Iron Gate" National Wildlife Reserve of the regional value is located on the border of the White Sea-Kuloyskogo plateaus and Verhnekuloyskoy lowlands (object number 3, Figure 1.2, Fig. 4.5). The reason for its creation was the executive committee solution of Arkhangelsk

Region Congress of People's Deputies of April 30, 1991 № 42 (as amended by an act of Arkhangelsk region Head of Administration of 20.12.2005 № 221). The preserve has a total area of 8.074 hectares. Here, as a result of favorable conditions for development was formed a unique complex of morphosculptural forms of underground and surface karst, the development of which occurred under the influence of continental glaciation, sea ingressions and zone denudation processes.

In the territory of “Iron Gate” Wildlife Preserve maximum elevation altitude is 110 m - in the watershed of the White river and the Birch river, minimum is 20.4 m to Hay lake. Gently undulating surface of the White Sea-Kuloyskogo plateau has a implicit slope to the north. It is dissected by karst canyons on isolated karst massifs. Karst canyons system with the collective name Iron Gate has a lattice structure in plan and consists of several smaller structures: sublatitude canyons the Chief/Glavnogo or Stanovogo, the Outsider/Postoronnego, Belorechensk submeridional canyons of Middle/Blijnego, East/Vostochnogo and Far/Dalnego. The total length of canyons in the territory of Wildlife Preserve is about 30 km.

Occurrence of surface karst forms include karst relief, as well as elements of karst hydrography. They are formed under the influence of karst, or its interfaced denudation processes. Aggregate origins have karst-glacial and karst denudation forms. Small and medium-sized forms are mainly karst or karst-glacial. As a rule, large forms have karst denudation origin. They manifest the elements of destruction and a significant accumulation.

Karst hydrography is characterized by the following occurences: disappearing streams, dry dolines, karst springs, lakes with a strong vibration levels, disappearing lakes, springs.

Most caves are fragments of ancient karst aquifer system, which has developed under the influence of glacier-derived melt water during the last continental glaciation. There are 32 caves of an information, recreational and aesthetic value within the preserve area. The entire length of the caves is more then 22 km, six of them included in the land inventory of the largest gypsum caves in the world. The length of the second largest cave system in the European North, Olympic Lomonosov (Table 4.4) is 9.1 km.

The vast majority of caves have horizontal and subhorizontal multilevel system. This indicates the initiation and development of caves in the hydrodynamic areas of horizontal and siphon circulation.

The territory of Wildlife Preserve may rightfully be considered the standard of karst process for the periglacial zone. The number of karst canyons reaches 8, caves - 32. The density of surface mesoform is 350 per 1 sq. km, the density of caves - 0.4 per 1 sq. km.

Table 4.4. The largest caves of “Iron Gate” Wildlife Preserve. Composed by Butakov O.V.

Search. №	Cave’s name	Length, m	Area, sq.m	Volume, cu.m	Amplitude
244	Olympic-Lomonosov System	9110	78335	158845	32
331	Gold Key/Zolotoi Klutchik	4380	5618	14157	10
274	Symphony/Simfoniya	3240	6120	9660	10
253	Musuem (JV-53)/Muzeinaya (ЖВ 53)	1480	10880	13190	10
248	JV/ЖВ-1.2	1380	5300	2630	10
273	Speleomorje (ЖВ-21)	830	3575	2100	10
256	Crystal(JV-54)/Hrustalnaya (ЖВ-54)	660	2292	2246	10

KULOGORSKY KARST MASSIF

Kulogorsky karst massif is located in the Pinega area, near the village Kulogory in 7 km to the northeast of the village Pinega in the area of its sublatitudinal bend r.Pinega at the eastern edge of the ancient river basin Pinega and Coulomb (object number 4, Figure 1.2). In an array of caves was found out 16 caves, length is 22.2 km (Gurkalo, Butakov, 2006). The caves K-1, K-2 and Troy are joined into one cave system Kulogorskaya-Troy, 17 km (Fig. 4.6).

Entrances of the caves located at the foot Kulogorskiy Uplift, covered with occasional rocky outcrops, slope erosion and ancient glacial valley on the site along Pinego-Kuloyskogo channel. The entrances to the caves are known for a long time, most likely, since the time of the edge settlement in the eleventh century. The first description was written by Russian academician Alexander Ivanovich Schrenk, who visited Pinezhye in 1837. The caves are protected from mass visiting only by a significant number of semi-submerged passageways, making them inaccessible without special equipment.

The Kulogorskaya-Troy cave has a complex morphological structure caused in plan by imposing of several types of elaboration: vector, areal and labyrinthic. The caves structure in the section (profile) is characterized by three stages. The youngest layer (of modern studies) - the bottom. More deeply laid underwater stage which virtually unexplored. The presence of dolomite substrata causes a small height of the arches on the average 0.7-1.2 m. On crossing cave passages developed landslide forms with the height up to 3-4 m. Sections of compressed character with considerable excess of width over height are characterized. There are sections of tunnels with traces of water pressure movement on the walls and arch. The cave is flooded periodically by flood waters of r. Pinega, as evidenced by the various items brought by water from the surface. Loading-out is carried out through the siphon circulation, opened in a cave with numerous hydrogeological windows – wrapped up in sections of cave watertanks.

At the organization of the caves - natural sites in 1987, (Table 4.5), protected areas have been identified within, slightly above the area of the caves themselves, without their water modular area and zones of potential anthropogenous influence on underground objects. For high-grade protection, Kulogorskij massif should be uniform into a single protected area, taking into account a reservoir structure. It is advisable to include in its boundaries the bedrock outcrop at the bend of r. Pinega, which was a reference cut of limestone with fauna at the allocation of carbonate deposits of Kulogorskoy Formation Lower Permian age. The most expedient for it the status of natural park, with preservation of the environmental management, traditional for area population. It is possible to construct a tourist complex under condition of the protection regime of the caves.

Table 4.5. Kulogorskie Caves-natural monument

Cave's name	Length, m	Area, sq.m	Volume, cu.m	Amplitude	Protection area territory, hectare
Kulogorskaya-Troya system	17000	-	-	18	50,8
Water/Vodnaya (K-4)	2598	6540	6960	8	6,6
Kulogorskaya-5	2035	5555	4250	10	17

BEREZNIKOVSKIY KARST MASSIF

Bereznikovskij karst massif is located on the right bank of r.Pinega in 40 kilometers below the village Pinega down the river, near the village Bereznik (object number 5, Figure 1.2).

The caves entrances were found in the bank cutting r.Pinega and canyon Settlement/Gorodische. Canyon with the width from 100 to 200 m represents a closed ring with the length about 1 km in the center of which located native gypsum massif- residual hill, broken by the system of cracks in the blocks along the boundaries of which are underground tunnels of d several cavities (Fig. 3.5) The bottom of the canyon is flooded with the water even in summer. At the daytime the surface of residual hill is dissected by shallow karst forms. The main area of discharge of karst waters located on the right bank r. Pinega between the village Bereznik and the mouth of White River. Offloading occurs downstream springs subaqually. There are 50 caves which were found, the total length is more than 8.2 km. Large caves: Tereshchenko - 2.6 km, Severyanka - 1.8 km (in the exclusive zone of the preserve), North Venice - 0.95 km.

Currently Bereznikovskiy karst massif has no conservation status, however, it’s reasonable to establish a complex landscape wildlife preserve or natural monument.

ENVIRONMENTAL EDUCATION

Teaching of taking care of fragile natural system Pinezhye is one of the main focuses of environmental education in Pinezhsky Wildlife Preserve and the primary goal of the Environmental Education Department created in 2000.

In the recent years, the growing interest of Russian people in natural sites of the North of Russia is obvious. The tourist flow to Pinezhye area is increasing from year to year. Unique as well as very vulnerable karst landscapes attract the attention of both the tourist groups and single tourists more and more.

The staff of the preserve both carries out diverse work on environmental education of various categories of the population and works with the tour guides of other travel agencies tending to form a careful attitude to the karst landscapes of the visitors. About 3,000 pupils, students and adults come to the visiting center and nature reserve protected area, learn about the unique natural system.

Since 1996, a preserve's ecological base/sight in Golubino has been open. The cabins for visitors staying (40 seats), a summer kitchen, an information center, a playground and other facilities are available. In the summer, in Golubino village an eco-camp is working, where groups of students of the Arkhangelsk region and other regions of Russia combine learning and recreation and the university students have field internship. The reserve staff organizes one- or more days tours, case studies, introducing the peculiarities of topography, flora and fauna of the territory.

The preserve area is closed to mass attendance, so ecological routes and tracks are laid in the buffer zone and around Golubino (Fig. 4.7, 4.8). On the territory of the reserve buffer/protection zone and surrounding areas of Golubino there is a nature trail and five tour routes.

The Museum of Karst, which represents unique karst landscapes, karst topography, features of its formation, karst system as a whole to pupils, students and adults was created thanks to the grant money of the National Parks Fund under the project "Karst is a Pearl of Pinezhye" awarded in 2003.

Scientific articles, booklets and calendars are annually published. Since 1997 "The unique wildlife land” newsletter has been issued. Besides, “Pinega Caves Ice Tale”, “Music of water and stones”, “Nature and People” documentaries were filmed.

In 2010, the own website was developed (http://www.pinega-zapovednik.ru/), where the information of the preserve, the Karst Museum, tour routes of the Pinega region can be found.

Special environmental protection exhibitions in the visiting center of the preserve, Pinezhsky high school, kindergarten № 77, in museums, libraries are annually held. These exhibitions are visited by about 2,000 people.

For the second time the regional competition on junior research studies "Natural Heritage of the North: conservation and study," dedicated to the birth anniversaries M.V. Lomonosov has been held. The best works are included into a special collection. The competition results are fed/ announced at a scientific conference which is a part of the regional environmental rally, in which students and teachers-scientific advisers, participate.

The Reserve is in contact with the Department of Natural Resources and Environment, the Ministry of Science and Culture, the Ministry of Youth, Sport and Tourism, the Administration of the Arkhangelsk Region, the Regional Museum and the Pinezhsky Cultural Center.

Currently, all environmental education and travel activities are carried out mainly in the protection zone of the preserve and other adjacent areas. However, both the regional administration and travel companies insist on that the protected areas to be open for all categories of tourists and sightseers/visitors. Under these circumstances, the importance of improving the forms of environmental education of the population as well as involving an increasing number of categories of people in active wildlife protecting activity is actually growing.

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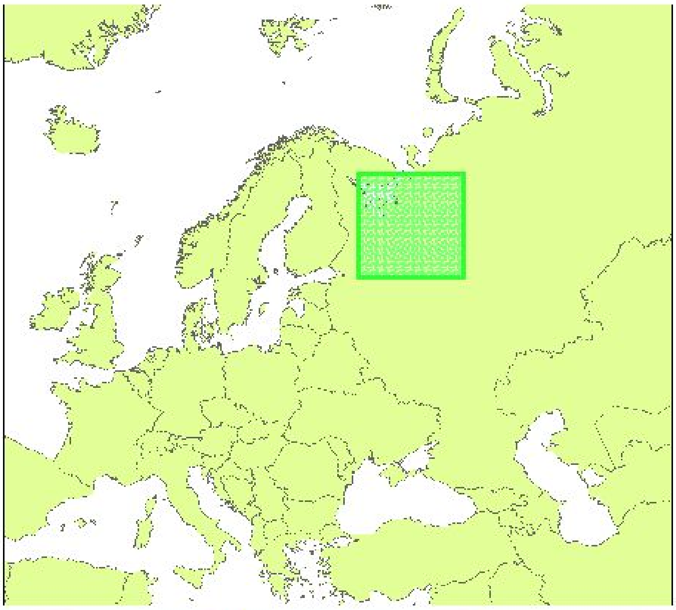
ГРАФИЧЕСКИЕ ПРИЛОЖЕНИЯ

PHOTOGRAPHS and CHARTS



Место проведения конференции "Карст 2011"

Karst 2011 conference location.

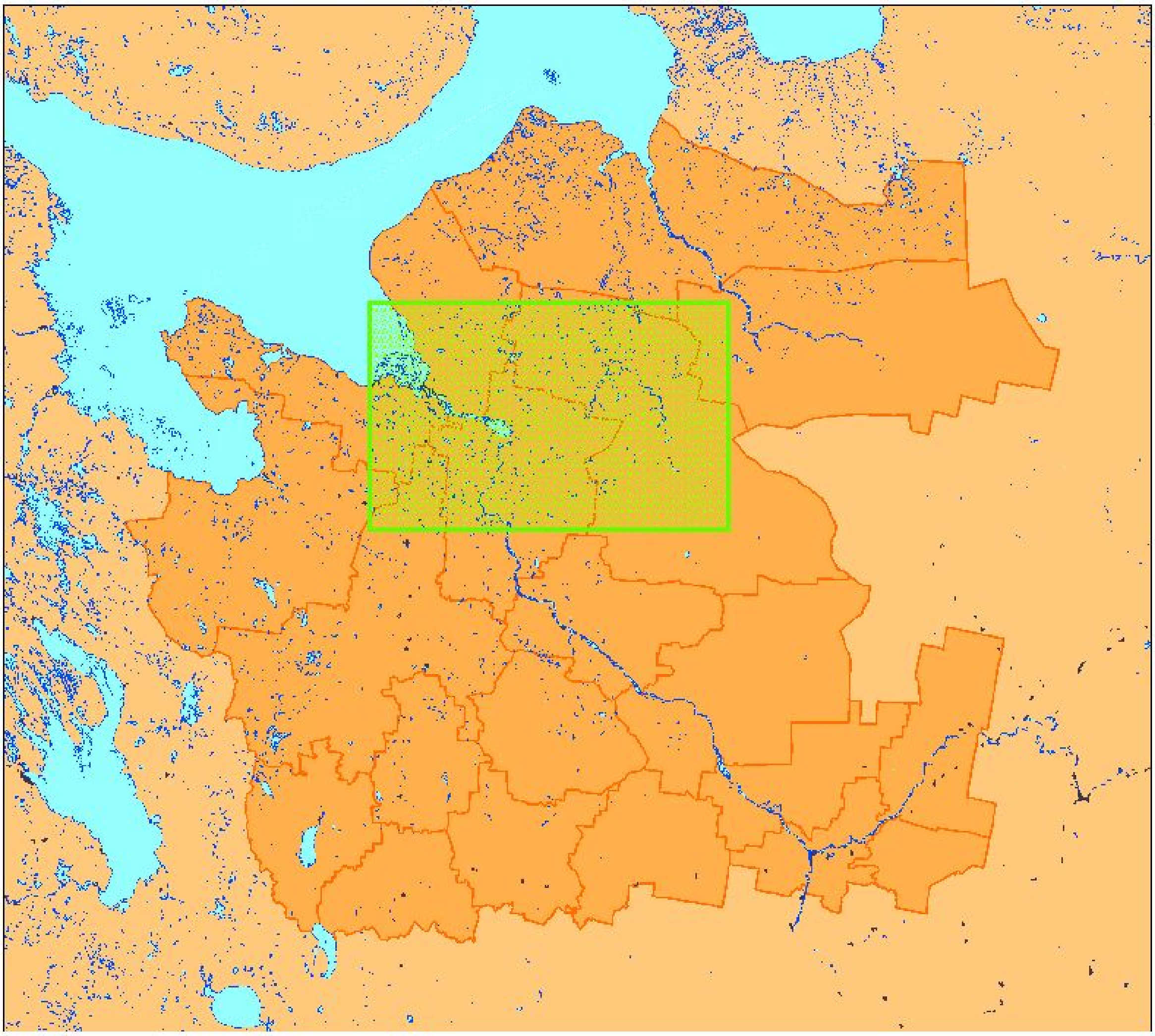


Fig 1.1. Karst conference location.

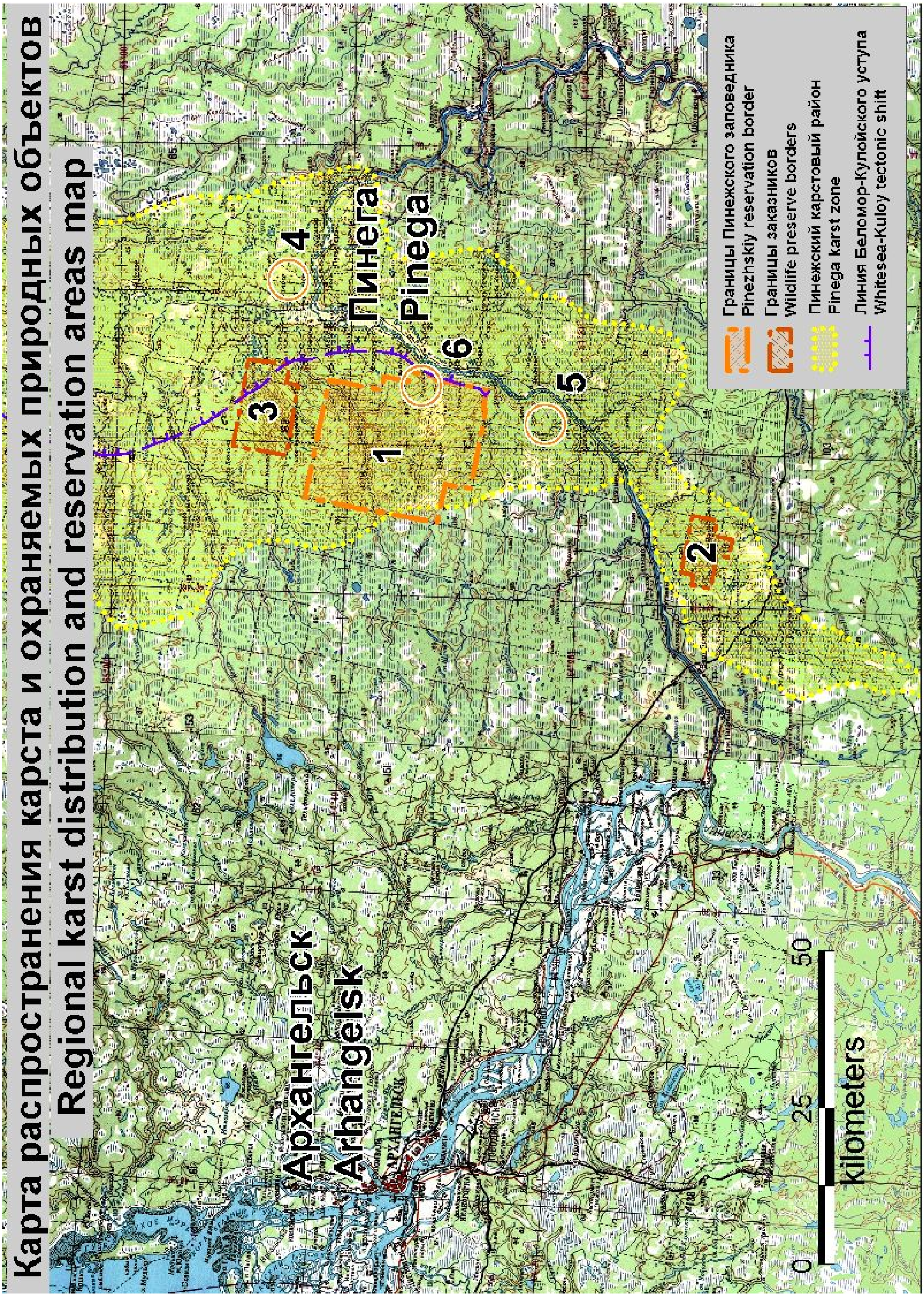


Fig. 1.2. Karst distribution map and protected natural objects. 1 - Pinezhsky State Reservation, 2- Chugsky local wildlife reserve, 3 – Zheleznie Vorota local wildlife reserve, 4 – Kulogory karst area, 5 – Bereznik karst area, 6 – Golubino karst area.

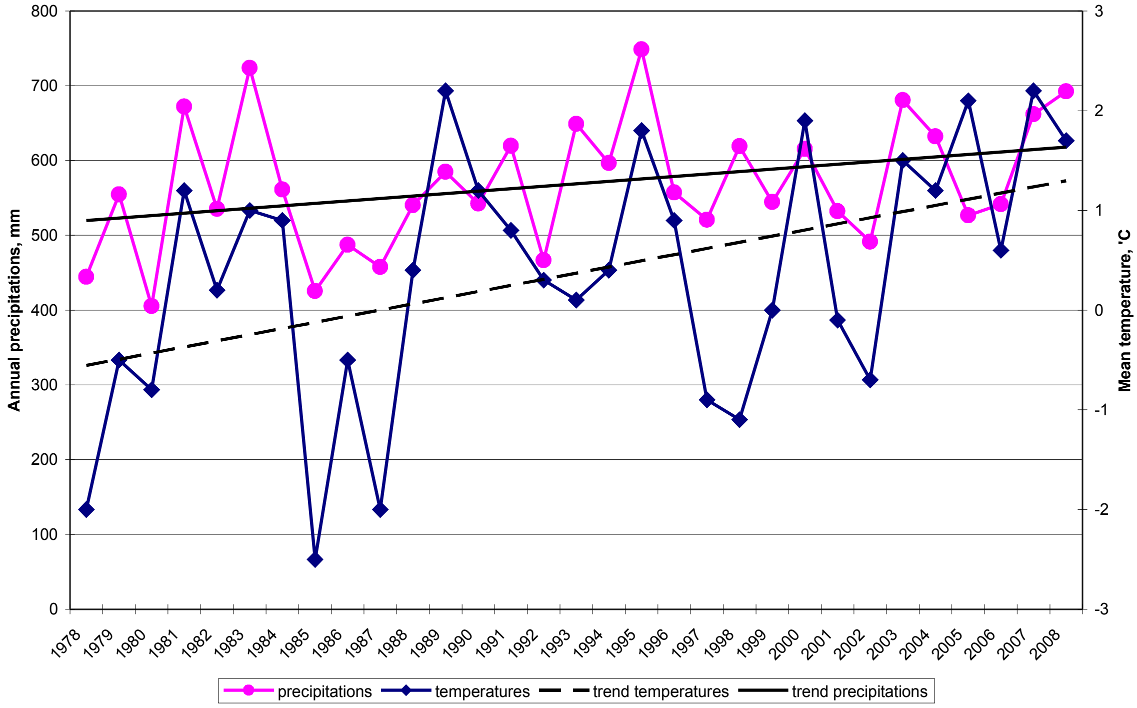


Fig 1.3. Dynamics of mean temperatures and annual precipitations at Pinega meteo-station (1978-2008).

Fig. 1.4a. Legend of geological map. Lithological formations: carbonate (C_{2-3}, P_1a-s, P_2kz_2), sulfate-carbonate (P_1s), sulfate-terrigenous (P_2u), carbonate-terrigenous (P_2kz_2). The detailed description is in the text of chapter 2.

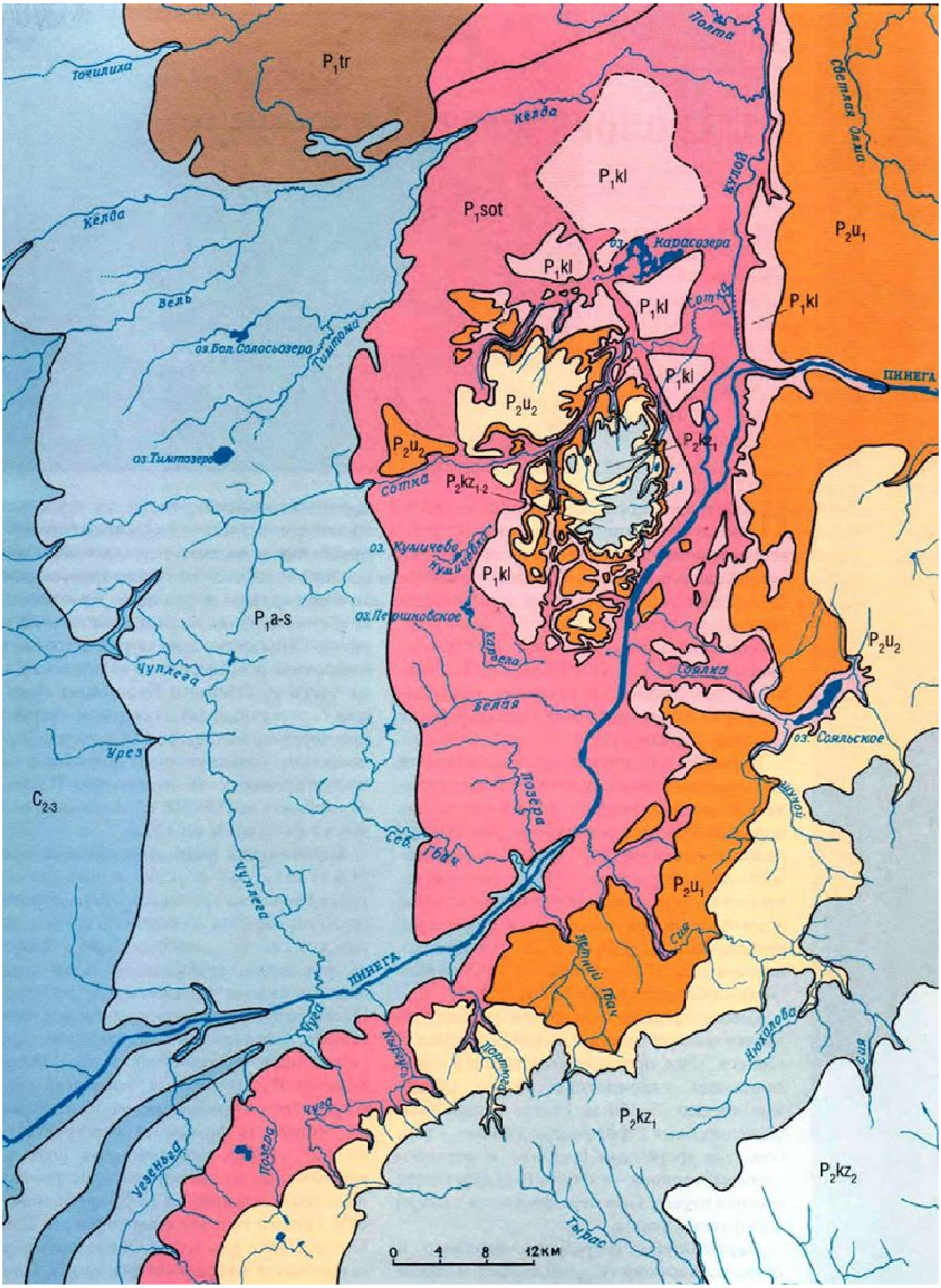


Fig. 1.4b. Geological map. Lithological formations: carbonate (C_{2-3}, P_1a-s, P_2kz_2), sulfate-carbonate (P_1s), sulfate-terrigenous (P_2u), carbonate-terrigenous (P_2kz_2). The detailed description is in the text of chapter 2.

Fig 1.5. Karst field at left bank of Pozera River.

Fig. 1.6. Karst residual hills in Svyatogo Ruchiya (Saint River) canyon.

Fig 1.7. Belomoro (White Sea)-Kuloy tectonic shift in Pinega River Valley.

Fig 1.9. Karst canyon Tarakaniya Shelia.

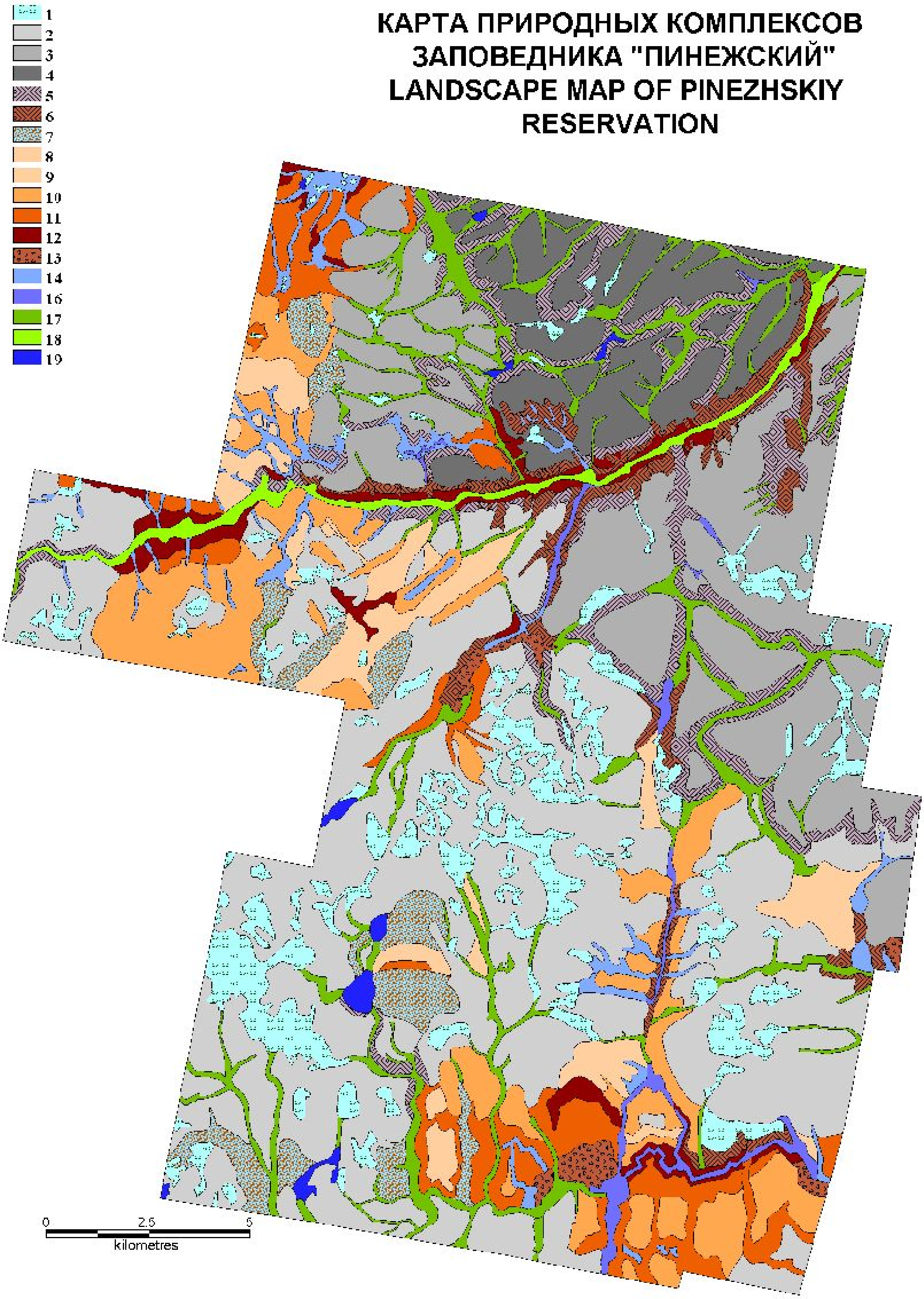


Fig. 1.8. Landscape complexes of Pinezhsky State Reserve. Contour basis is “Topography map” of Saburov, 1987. Digital processing by Pyukov M.A., Dobrynin D.V.

THE LEGEND OF LANDSCAPE COMPLEXES MAP
(by Semikolennykh A.A. according different reference)

№	Type	relief	sediments	Development of karst	drainage	soils	vegetation
1	Glacial with elements of karst	Flat and salient bog complexes	Upper and transitional peats	Separate elements, often burial by peats	bad	upper and transitional Histosols	Sphagnous and sedgely-sphagnous bogs
2		Corrugated-hilly accumulative-denudation glacial plain with plots of exaration	Thick and medium-thick moraine loams	Separate elements (sink-holes, blind valleys)	moderate	Luvi-Stagni-Histic Podzols	bilberry greenmoss firs. Wet and moist
8, 9		Sloping accumulative glacial ranges and ridges	Thick and medium-thick moraine loams	Separate elements (sink-holes, blind valleys)	moderate	Luvi-Stagni-Histic Podzols	bilberry and motley grass birch forests. moist
17		The bottoms of sloping modern and ancient water-glacial erosion valleys	Redeposit moraine and fluvioglacial sediments (slide-rocks) alluvium of small streams	Absent or weak	moderate	Luvi-Stagni-Folic Podzols Ruptic	horsetail, highgrass and spirean meadowsweat firs. wet
3	Beddedly-denudational with elements of karst	Ridgy and wavy hilly accumulatively-denudation plain, weak partitioned by gently sloping erosion walleyes	medium-thick moraine loams	Separate elements (sink-holes, blind valleys)	moderate	Luvi-Stagni-Histic Podzols	bilberry greenmoss firs. Wet and moist
4		Ridgy and wavy hilly accumulatively-denudation plain, medium partitioned by gently sloping erosion walleyes	medium-thick moraine loams	Separate elements (sink-holes, blind valleys)	moderate	Luvi-Stagni-Histic Podzols	bilberry greenmoss firs. Wet and moist
5		Gently-sloping modern and ancient water-glacial erosion walleyes	Redeposit moraine and fluvioglacial sediments (slide-rocks)	Absent or weak	moderate	Cutanic Luvisols and Haplic Regosols	birchly-fir and birch (second) motley grass forests. Moist
14		The bottoms of sloping modern and ancient water-glacial erosion valleys, complicated by separate presence of karst	Redeposit moraine and fluvioglacial sediments (slide-rocks)	Separate elements (sink-holes, blind depressions)	moderate	Folic and Haplic Regosols, folic and cutanic luvisols	horsetail, highgrass and spirean meadowsweat firs and birchly-firs (second). wet
7	Karsticly-glacial	Large gently sloping depressions	Redeposit moraine and fluvioglacial sediments (slide-rocks)	Moderate (sink-holes, blind valleys) exposed or burial by slide-rocks	moderate	Luvi-Albic-Podzols Ruptic and Stagni Podzols	firs, birches (second) and bilberry pineries. Moist
10		Accumulatively-denudation plain, medium partitioned by presence of karst	Medium-thick erosion moraine and fluvioglacial loams and sandy-loams, redcolour sediments	Moderate (mainly separate large sink-holes and valleys)	good	Luvi-Albic-Podzols Ruptic and Cutanic Luvisols	bilberry pineries, pinery-deciduous forests and birches (second). Moist
11		Preslope plots accumulatively-denudation plain, strongly partitioned by presence of karst	thick erosion moraine and fluvioglacial loams, redcolour sediments,dolomite, gypsum	Intensive (sink-holes, residual hills, karst ditches)	perfect	Luvi-Albic-Podzols Ruptic, Cutanic Luvisols, Regosols, Rendzic Leptosols	bilberry motley grass pineries and deciduous forests. moist
16		Partitioned bottoms of karsticly-denudation ravines, mainly dry	Redeposit moraine and fluvioglacial sediments (slide-rocks) outcrop of gypsum	Moderate (sink-holes, residual hills)	perfect	Cutanic Luvisols	low meadows
18		Erosion walley of Sotka river, complicated by presence of karst	Alluvial sediments, mainly sandy-pebble	Intensive by board repulse on the outcrops of gypsum)	perfect	Fluvisols and Umbrosols	flood plain complexes
6	carstiogenic	Slopes of large erosion cuttings (including the walleyes of Sotka and Kar'ela rivers) strongly partitioned by presence of karst	thick erosion moraine and fluvioglacial loams, redcolour sediments,dolomite, gypsum	Intensive (sink-holes, residual hills, karst ditches)	good	Luvi-Albic-Podzols Ruptic and Regosols оподзоленные дерновые	bilberry pineries. Moist and motley grass pinery-deciduous forests
12		Strongly partitioned by small forms of carsticly-denudation plots with full absorption of drainage ("Shelopnik")	Fragmentary erosion moraine loams and redcolour sediments, outcrop of gypsum	Intensive (sink-holes, residual hills, karst ditches)	perfect	Thin Luvi-Albic-Podzols Ruptic, Regosols, Rendzic Leptosols	pinery-deciduous forests and sparse growth bilberry lichen and motley grass deciduous forests
13		Strongly partitioned by small forms of carsticly-denudation plots with full absorption of drainage (residual karst)	Fragmentary erosion moraine loams and redcolour sediments, outcrop of gypsum	Intensive (large residual hills, karst ditches)	perfect	Luvi-Albic-Podzols Ruptic, Regosols, Rendzic Leptosols	pinery-deciduous forests and bilberry and motley grass deciduous forests
19	Water						

Fig. 1.10. Low-productive open woodlands on open karst fields ('shelopnyak').

Fig 1.11. New collapse sink-hole in karsto-glasiated (covered) landscape.

Fig. 1.12. Black bearberry (*Arctous alpina*) in autumn colors.

Fig. 1.13. Meadow vegetation. Butterfly orchid (*Platanthera bifolia*) is foreground.

Fig. 1.14. Lady’s slipper orchid (*Cypripedium calceolus*).

Fig 1.15. Typical boreal spruce forest. Without karst forms.

Fig. 1.16. Young brawn bear (*Ursus arctos*).

Fig. 1.17. Siberian salamander (*Salamandrella keyserlingii*).

Fig. 1.18. Typical south tundra in Koida area.

Fig 1.19. Forest appearing in karst sink-holes within tundra in Koida area.

Fig 2.1. Karst springs at the right bank of Pinega River

Fig. 2.2. Disappearing Lake. The image from Google Earth, 2008. Left bank of Pinega River. Palen'ga Lake.

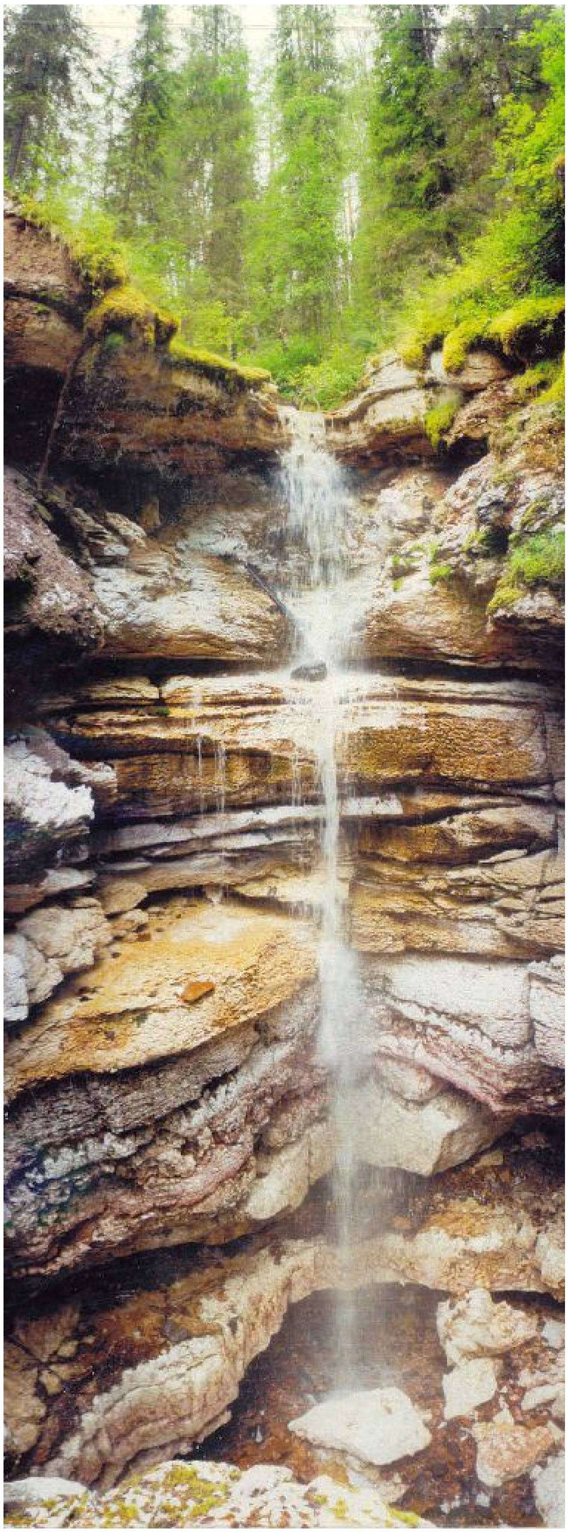


Fig. 2.3. Waterfall at the entrance of Pechorovsky Proval Cave

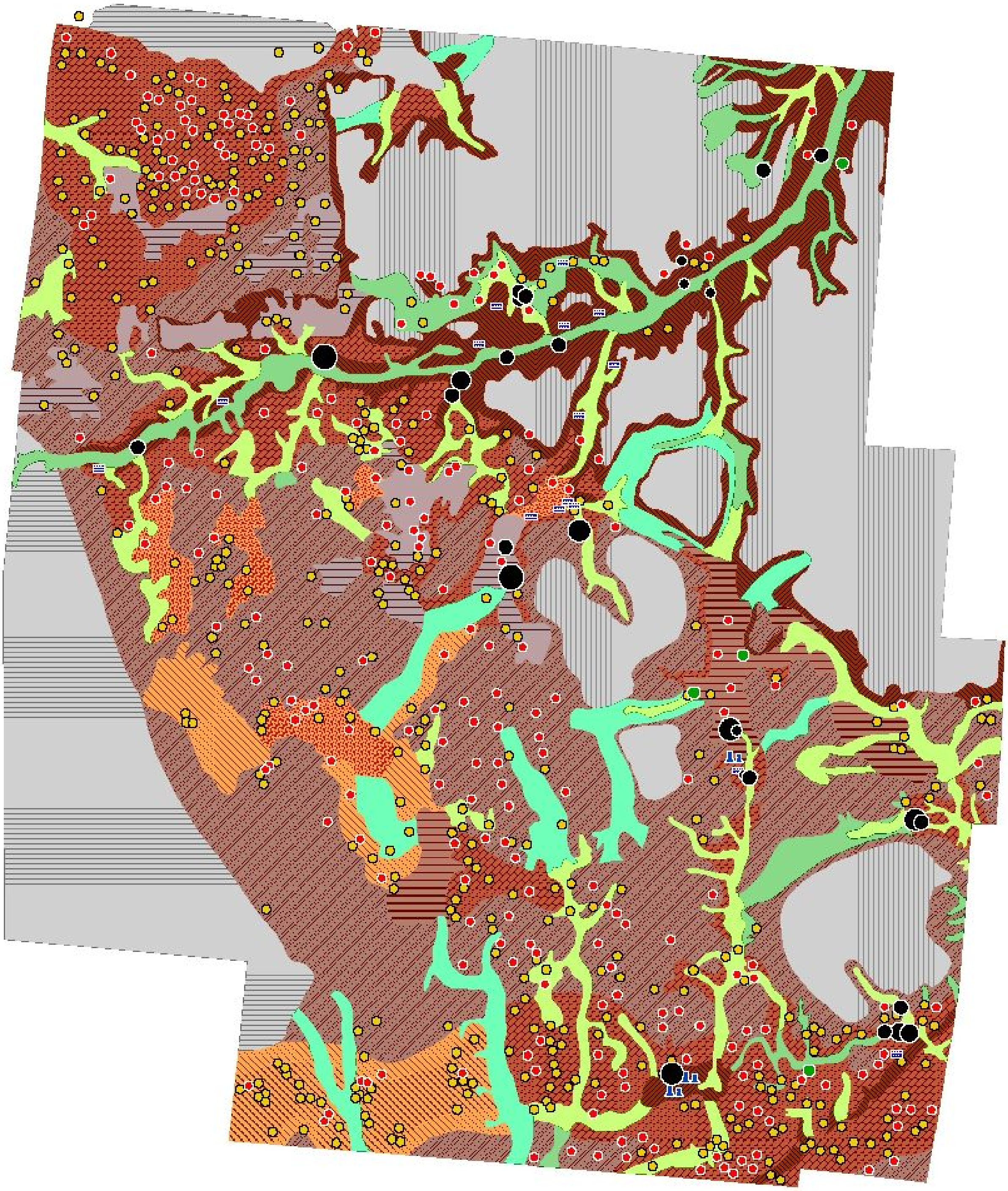


Fig. 2.4. Karst development and karst forms map. Contour basis by "Karst development map" (Malkov V.N., 1998) under digital processing and abbreviation by Dobrynin D.V. Legend translation by Semikolennykh A.A. Types:
1 – ложбинный карстово-ледниковый (*entranched karst* in small post glacial water erosion valleys), 2 – долинный карстово-эрозионный (entranched and denuded karst in the complex with valley fluvial erosion), 3 – покровной стадии денудации (*subjacent karst),* 4 – полуоткрытой стадии денудации (*semi-open karst*), 5 – котловинный (depression or semi-polije type), 6 – предельно-котловинный (полье-образный) (fully closed depression or polije type), 7 – аккумулятивный котловинный (accumulative depression type), 8 – закрыто-экранной стадии денудации (*deep-seated karst),* 9 – покровно-экранной стадии денудации (deep-seated/subjacent karst), 10 – раскрыто-покровной стадии денудации (*entranched karst),* 11 – ложбинно-долинный карстовый субледниковый (экзарация и сток талых вод) (entranched karst in post glacial valleys with elements og glacial exoration)

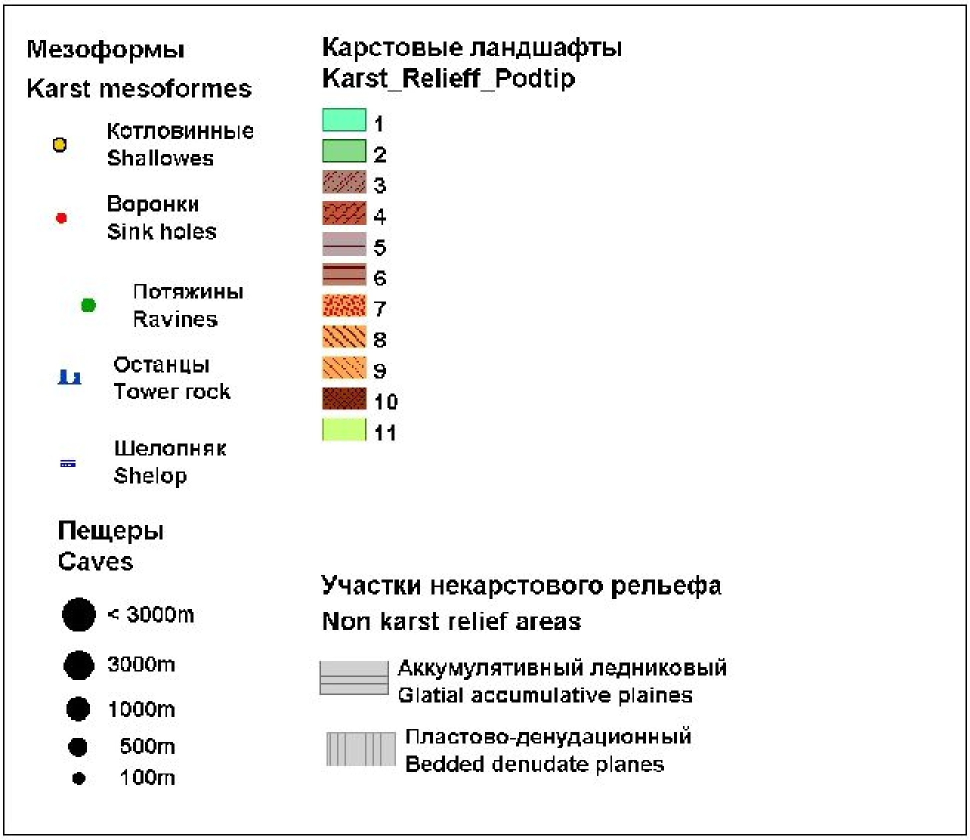


Fig. 2.5. Famous residual blok (tower) “The Sotka River Hostess”

Fig.2.6. Karst arch at the right bank of Chuga River (Chugsky Wildlife Reserve)

Fig. 2.7. Karst lake in “Severny Log” karst depression-canyon

Fig. 2.8. The collapses of bedrocks at the bank of Sotka River

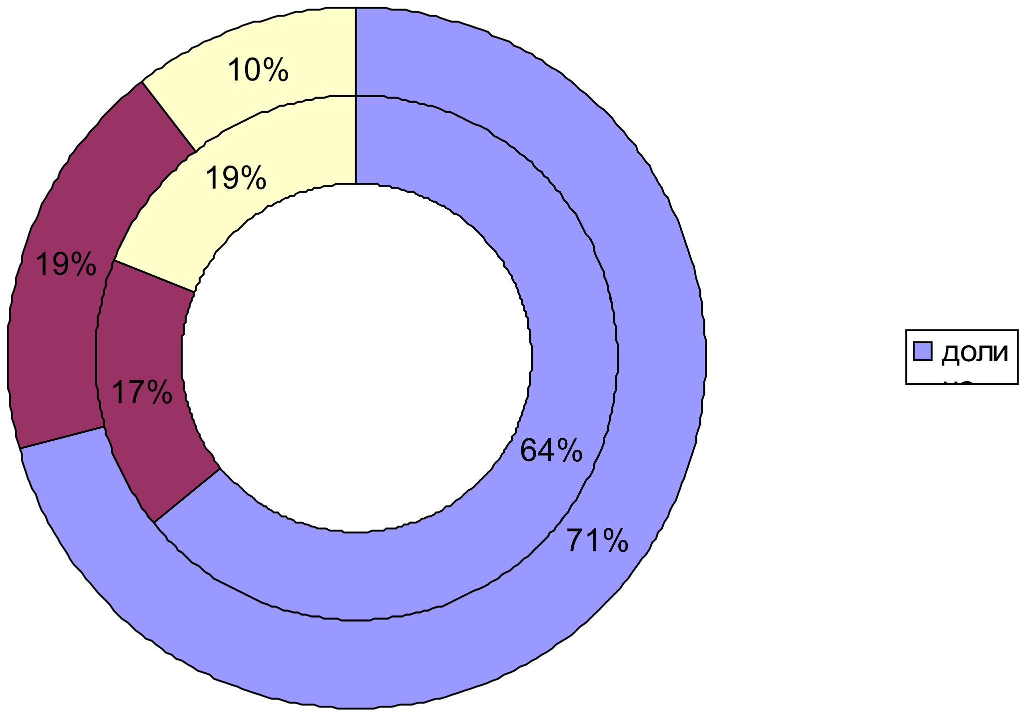


Fig 2.9. Distribution of exogenous processes activity by topography elements. External circumference – the quantity of actives; internal circumference – the volume of actives. Blue – Sotka River Valley, red – karst canyons and depressions, yellow – caves.

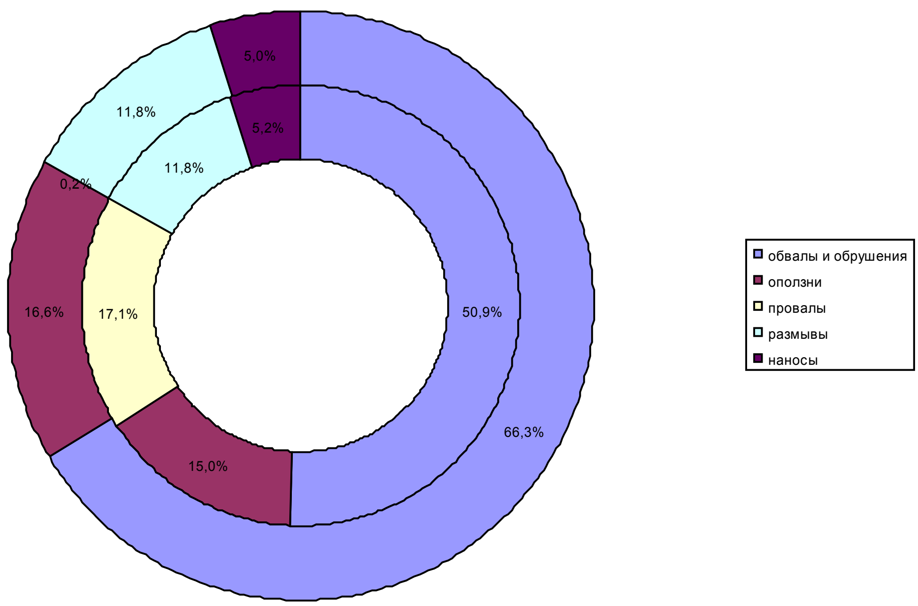


Fig. 2.10. Distribution of exogenous processes activity by topography elements. External circumference – the quantity of actives; internal circumference – the volume of actives. Blue – slope collapses, red – landslides, yellow – underground collapses, light blue – water erosions and suffusion, yellow – water accumulating sediments.

Fig. 2.11. Karst collape in “Karyulovsky Log” canyon.

Fig. 2.12. The trends of exogenous processes dynamics. Quads – quantity, triangles – volumes.

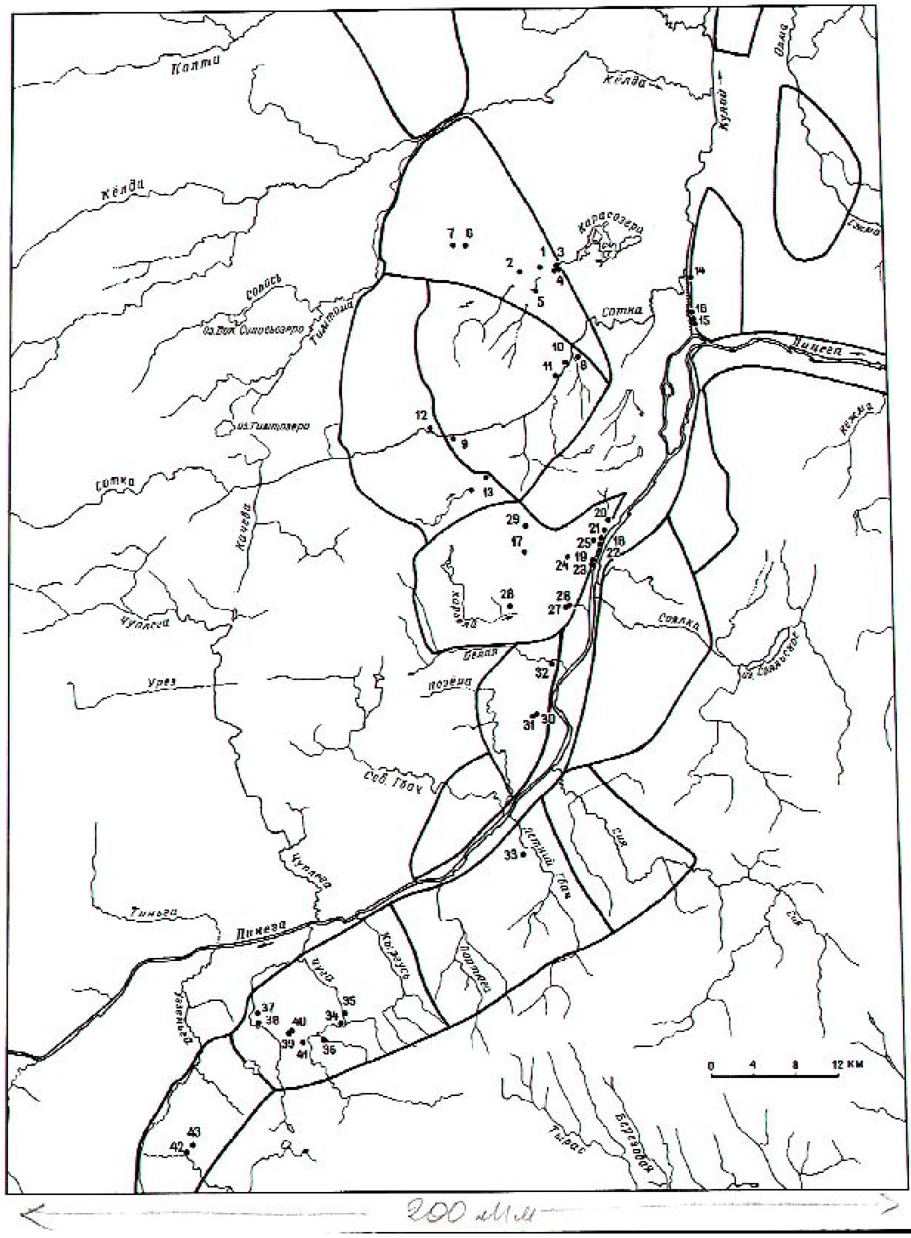


Fig. 3.1. **Speleological regions of Kuloi River Basin: K-1** - Nizhnesotkinskii. **K-2** - Srednesotkinskii, **K-3** - Verhnesotkinskii, **K-4** - Kulogorskii, **K-5** - Svetlo-Olminskii, **K-6** - Nizhneolminskii, **K-7** - Keldinskii.
Speleological regions of Pinega River Basin: P-1 - Golubinskii, **P-2** - Bereznikovskii, **P-3** - Severo-Gbachskii, **P-4** - Pil'egorskii, **P-5** - Vongskii, **P-6** - Utopelkskii, **P-7** - Siiskii, **P-8** - Portyugskii, **P-9** - Chugskii, **P-10** - Ugzen'skii.
Large Caves: 1 - sist. Olimpiiskaya - Lomonosovskaya, **2** - ZhV-1,2, **3** - Muzeinaya (ZhV-53), **4** - Hrustal'naya (ZhV-54), **5** - Speleomor'e, **6** - Simfoniya, **7** - Zolotoi Klyuchik, **8** - Svyato-Shel'nickaya, **9** - Medeya, **10** - Yubileinaya, **11** - Leningradskaya, **12** - Konstitucionnaya, **13** - sist. Kumichevka - Vizborovskaya, **14** - Kulogorskaya-5, **15** - sist. Kulogorskaya - Troya, **16** - Vodnaya, **17** - Severnyi Sifon, **18** - Golubinskii Proval, **19** - M. Pehorovskaya, **20** - Svyatorucheinaya, **21** - Kitezh, **22** - M. Golubinskaya, **23** - B. Pehorovskaya, **24** - Pehorovskii Proval, **25** - Vysockogo, **26** - B. Holodil'nik, **27** - Kar'yalovskii Proval, **28** - Geograficheskogo Obshestva, **29** - Saburovskaya, **30** - Tereshenko, **31** - Severnaya Veneciya, **32** - Severyanka, **33** - Gbach-7, **34** - Provideniya, **35** - Klyuchevaya, **36** - Bratynya, **37** - Lunnye Gory, **38** - Unikal'naya, **39** - Amahinskaya, **40** - Pogranichnaya, **41** - Siyanie, **42** - Molozhezhnaya, **43** - Mobil'.

Fig. 3.2. The down-sloping entrance in G-1 Cave

Fig. 3.3. Entrance in Kumichevskaya Cave

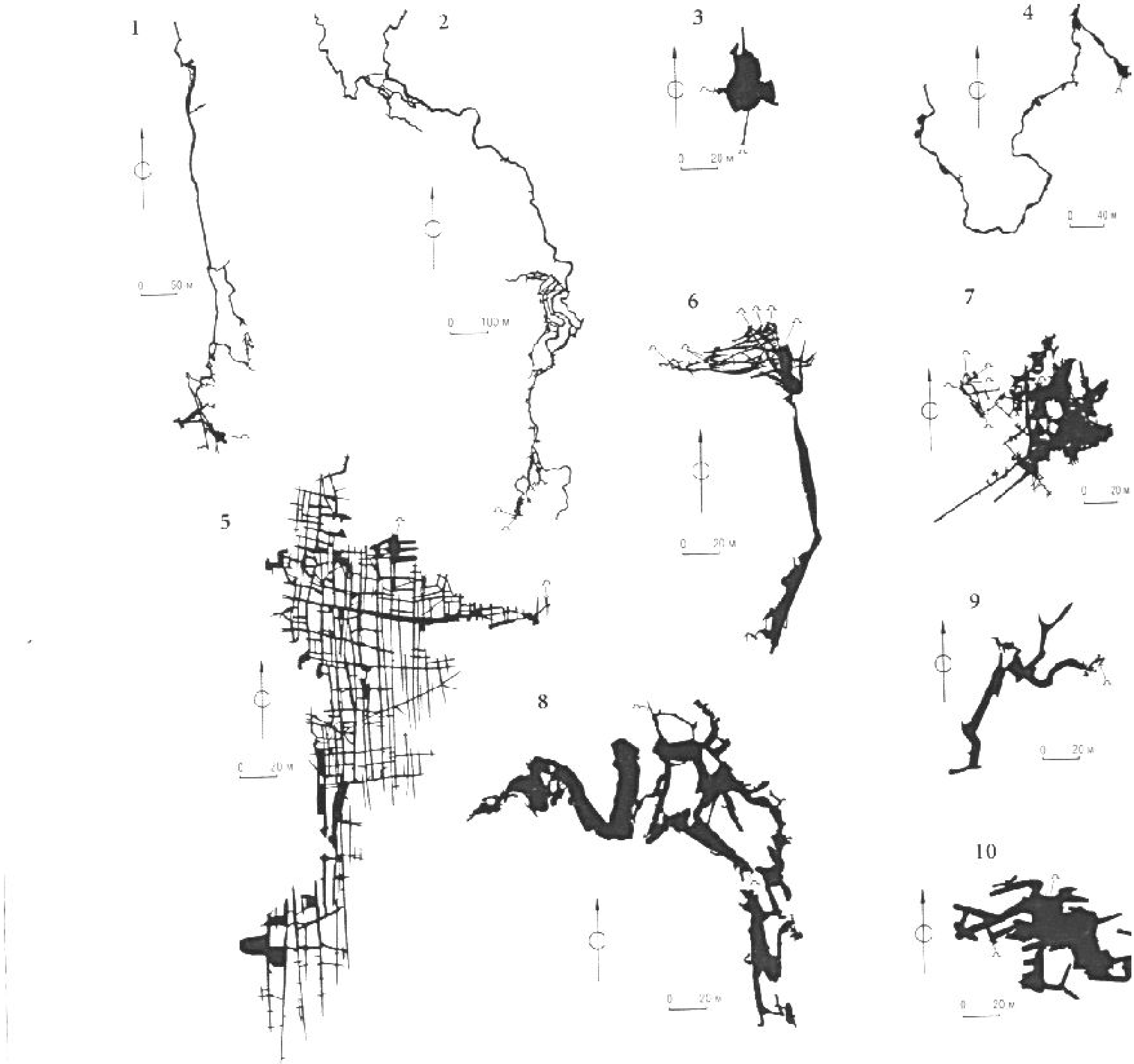


Fig. 3.4. Structural types of caves. 1. – line-branchy type (Golubinsky Proval Cave); 2. - line-branchy type with reticulate labyrinth elements (Konsituscionnaya Cave); 3. – areal type reticulate labyrinth elements (Kapitan Nemo Cave); 4. – lineal type (Malaya Pekhorovskaya Cave); 5. – classic reticulate type (Zolotoi Klyuchik Cave); 6. – the combination of lineal and reticulate types (Amakhinskaya Cave); 7. – the combination of areal labyrinth and reticulate types (Pogranichnaya Cave); 8. – reticulate labyrinth type (Kitezh Cave); 9. - branchy type (Margaret Cave); 10. - areal type with labyrinths frames (Zazerkalie Cave)

Fig 3.5. Tunnel passage in Tereshenko Cave (Bereznik Area)

Fig 3.6. Organ tube in Sineglazka Cave (Chuga Area)

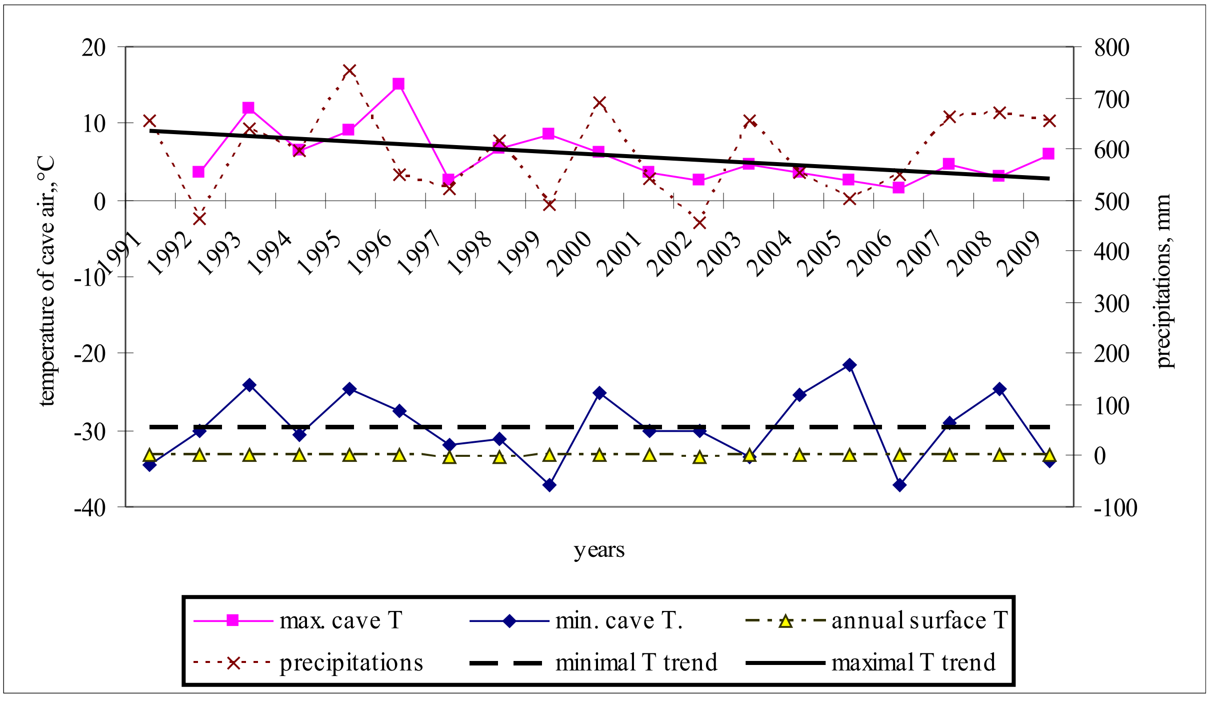


Fig. 3.7. Trends of temperature amplitudes in G-1 Cave.

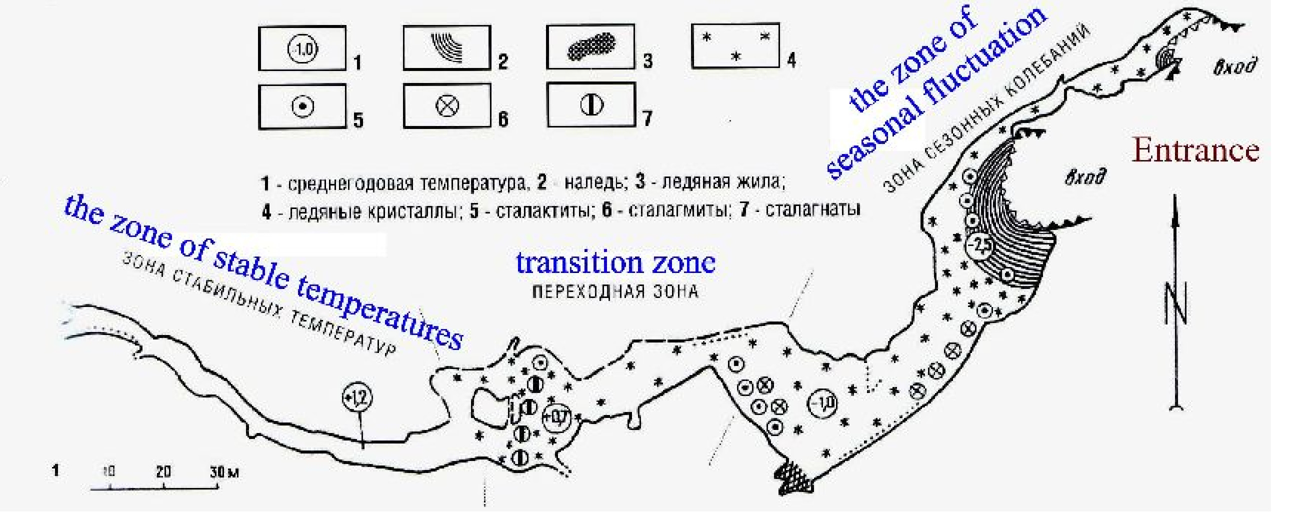


Fig. 3.8. Microclimatic zones in G-1 Cave. 1 – annual temperature, 2 – icing, 3 – ice vein, 4 – ice crystals, 5 – ice stalactites, 6 – ice stalagnates.

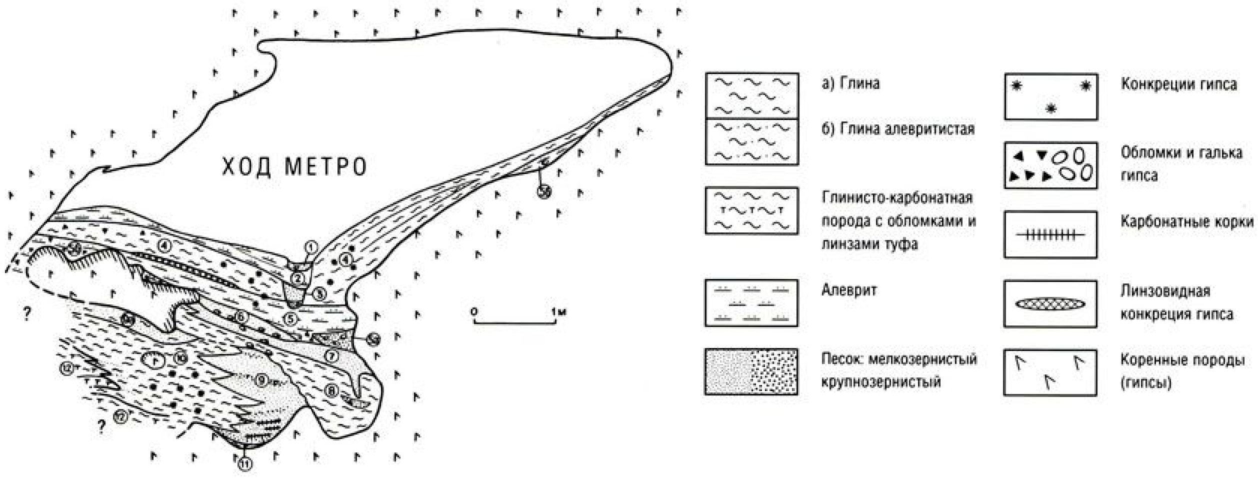


Fig. 3.9. The chart of deposits from "Metro" Passage in Golubinsky Proval Cave. Left column: clay, clay-carbonate deposits, alevrite, sand; right column: gypsum concretions, gypsum pebble, carbonate cores, lens-like gypsum, bedrock (gypsum)

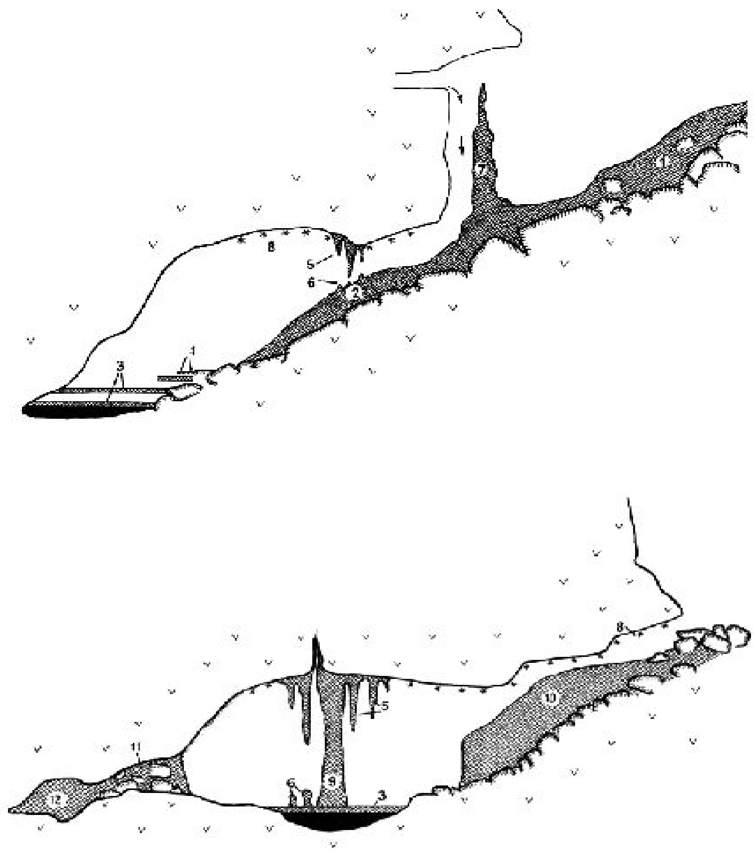


Fig. 3.10. The most typical ice formations in caves. 1 – icing (blister) at down-sloping entrance, 2 – mobile slope icing, 3 – ice of water pools, 4 – remain ice of former water table, 5 – ice stalactites, 6 – ice stalagmites, 7 – vertical icing of splashes, 8 – ice crystals, 9 – ice stalagnates (columns), 10 – remain ice, 11,12 - lode ice bodies, cement ice, ice syphones.

Fig. 3.11. Ice stalagmites in Kitezh Cave

Fig. 3.12. Ice crystals in Olympiskaya Cave (January)

Fig. 3.13. Ice crystals in Kitezh Cave (March)

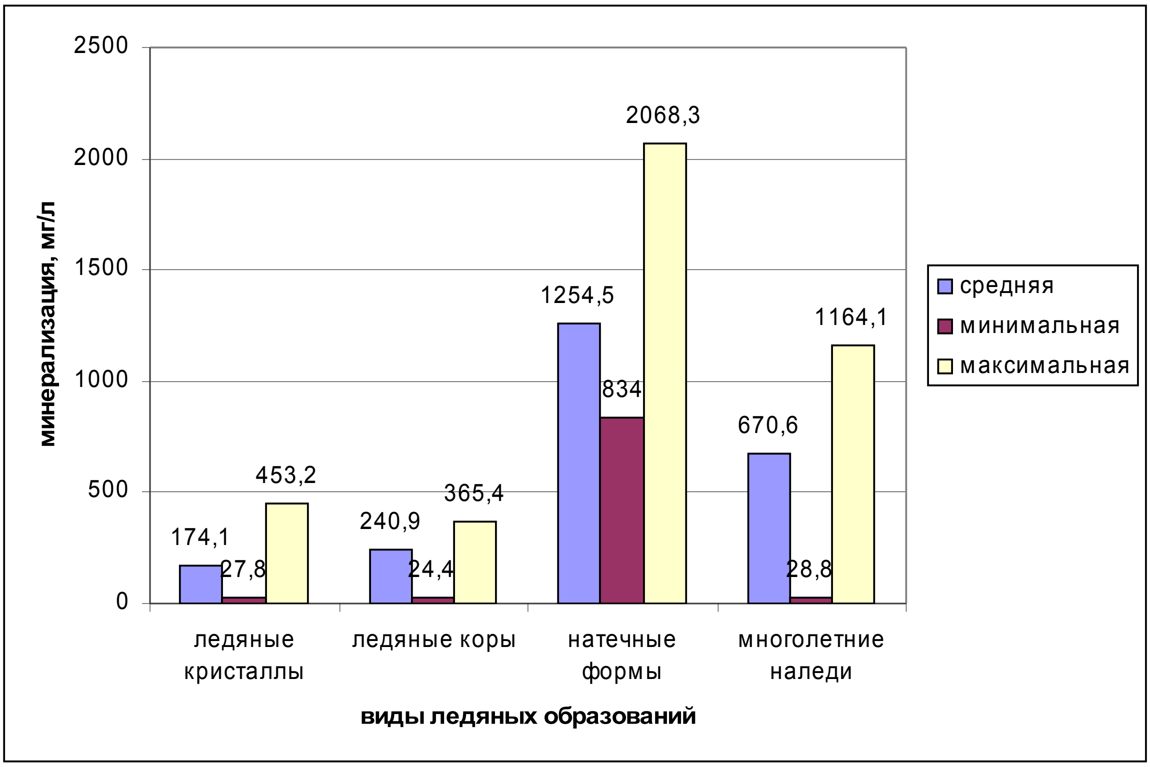


Fig. 3.14. Total mineralization of cave ices (left axis).
Lower axis: ice crystals, ice cores, stalactites, many-years icing. Blue – average, red – minimal, yellow – maximal.

Fig. 3.15. Macro-colony of fungi on organic matter. Kulogorskaya Cave (winter season).

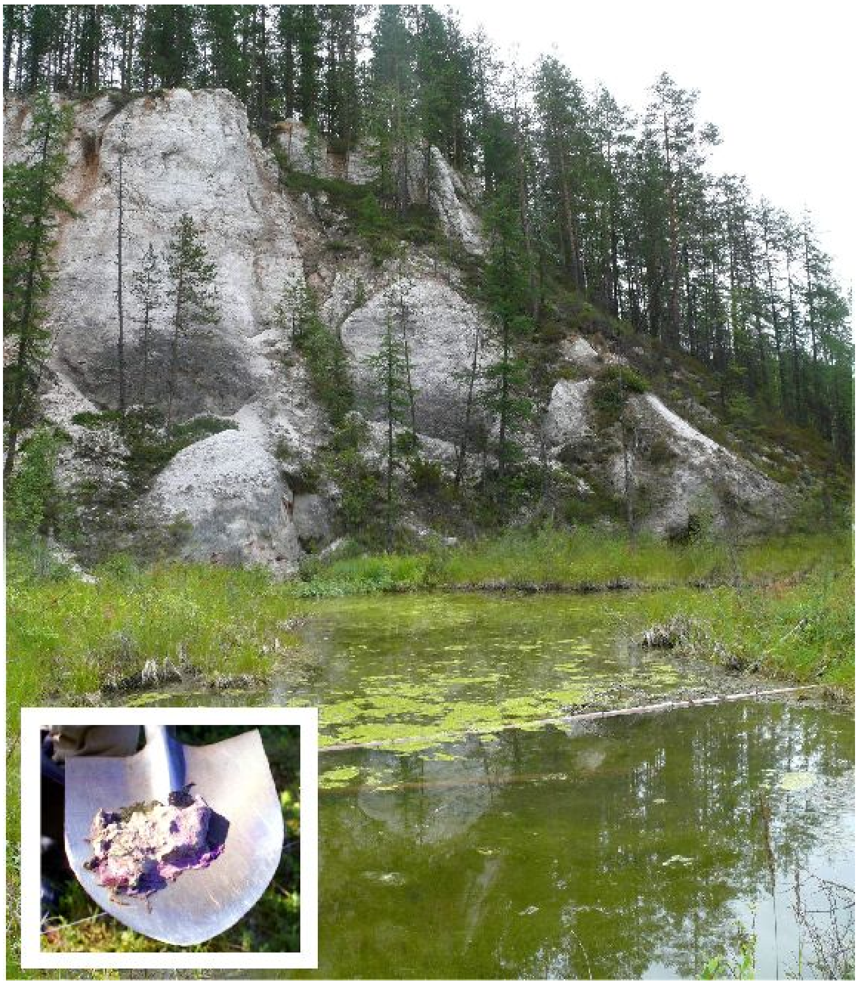


Fig. 3.16. Karst sink-hole in Krasnya Rade site (Chugsky Wildlife Reserve) – habitation of phototrophic purple and green sulfur bacteria (bacterial film (matt) on a spade).

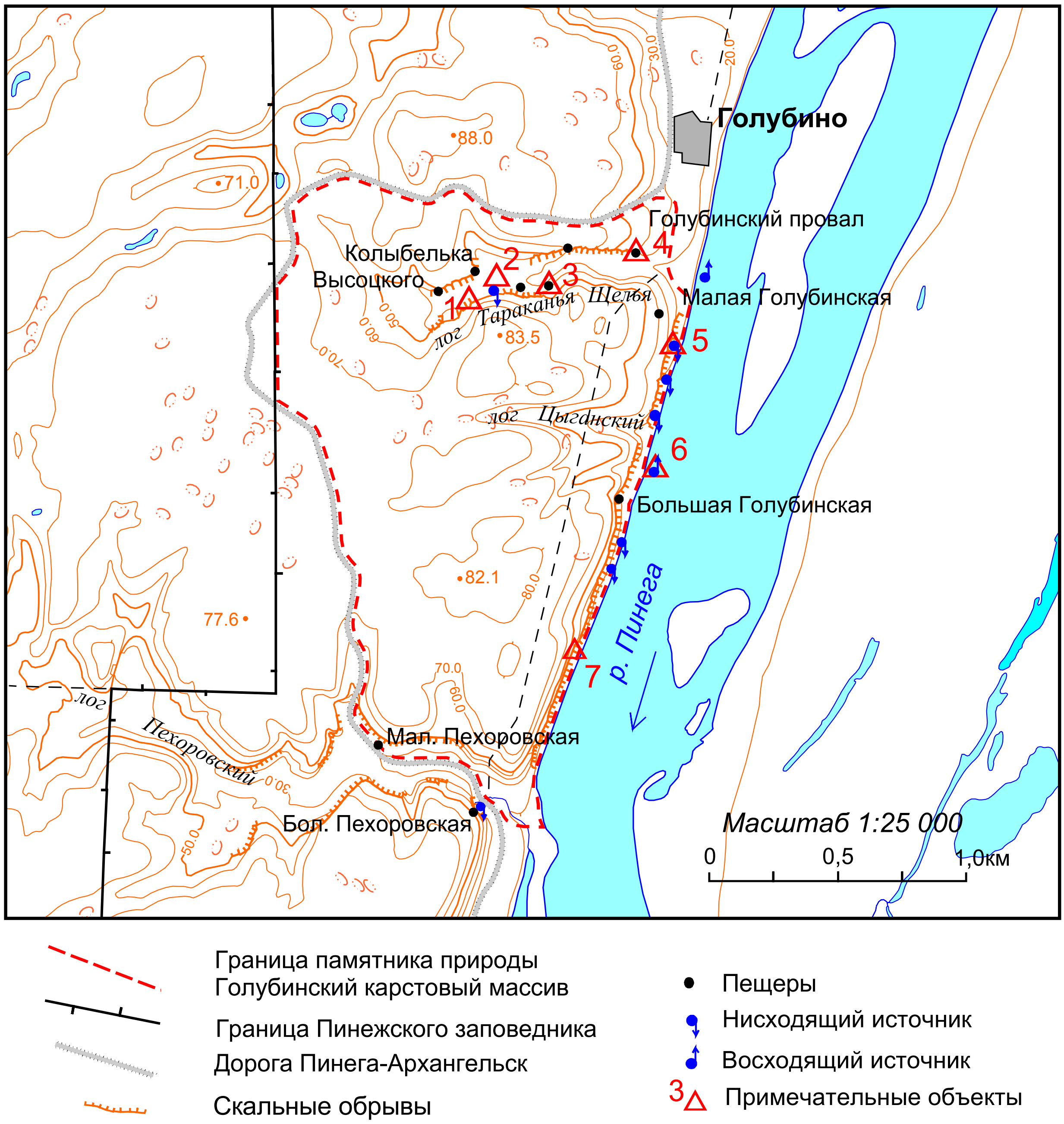


Fig. 4.1. The chart of the most interesting objects at Golubinsky Karst Massif

1 – red-colored ourcrops with karrs, 2 – disappeared stream, 3 - Tarakanya-1 cave (recently opened), 4 – Golubinsky Proval Cave, 5 – karst circus, 6 – pressure streams at the bank of Pinega River and Bolshaya Golubinskaya Cave, 7 – block of carbonate cements

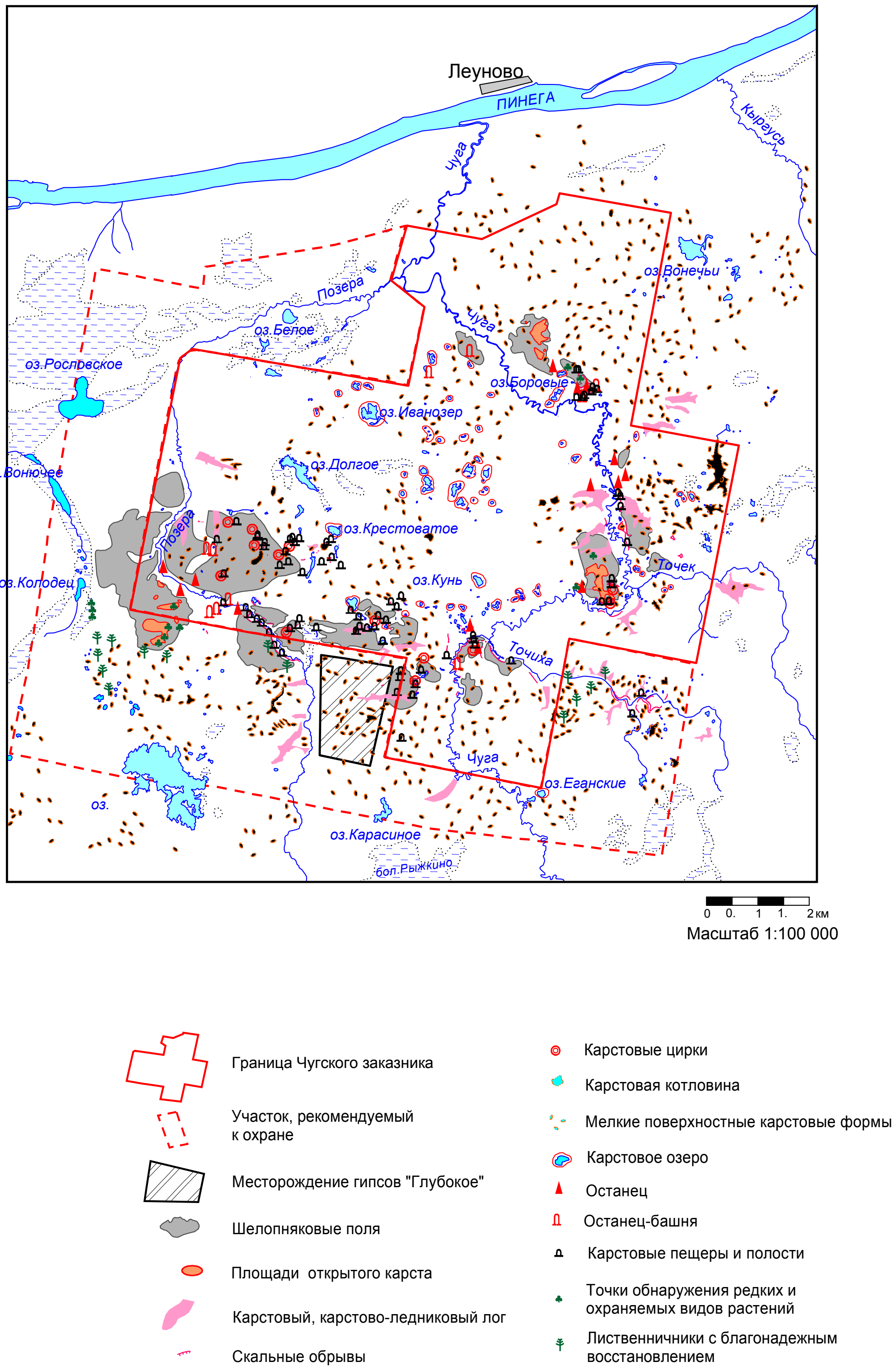


Fig. 4.2. The chart of the most interesting objects at Chougsky Wildlife Reserve

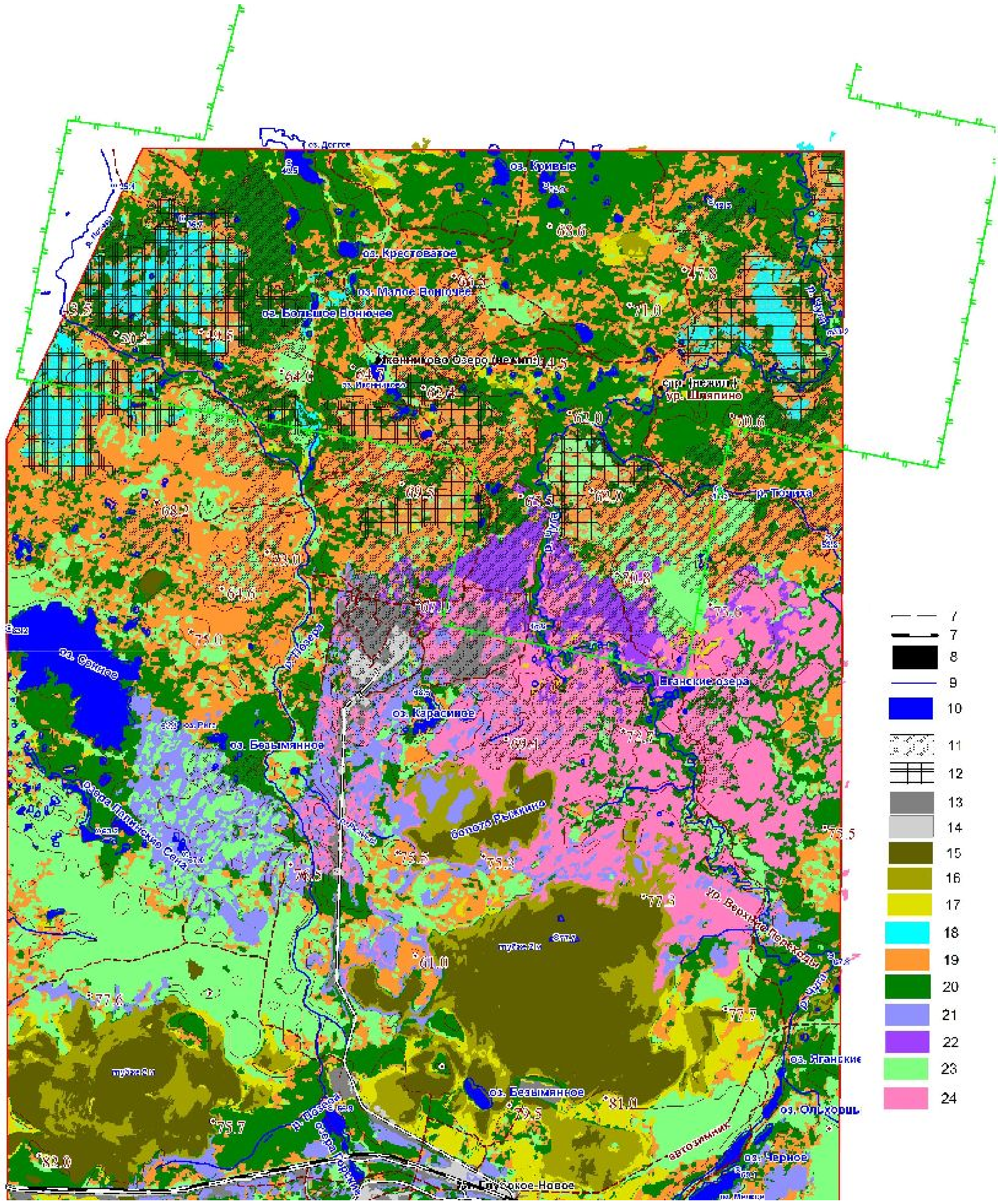


Fig. 4.3. Landscape complexes of Chougsky Wildlife Reserve (according Spot satellite censer, Semikolennykh A.A.). 12 – intensive karst development ares, 15, 16, 17 – bogs, 18 – open woodlans, 19 – mainly pine forsts, 20 – good spruce forests, 22, 23, 24 – bearch forests (including secondary on impacted areas), 14 – Knauf-gips quarry and roads


Fig. 4.4. Gypsum quarry at the southern boundary of Chougsky Wildlife Reserve

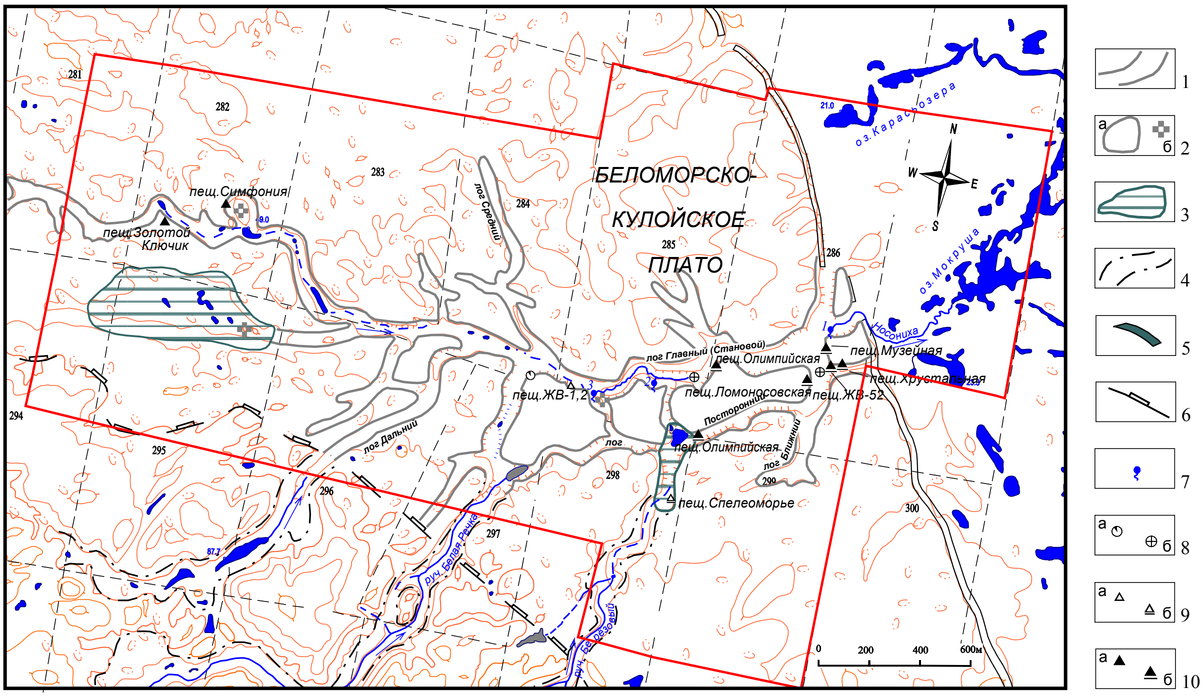


Fig. 4.5. The chart of the most interesting objects at "Iron Gate" Wildlife Reserve. 1 – karst dolines, 2 – residual forms, 3 – karst poljes, 4 – shallow valleys, 5 – Belomorsko-Kiloisky tectonic shift (uplift), 7 – springs, 8 – circuses, 9, 10 – caves

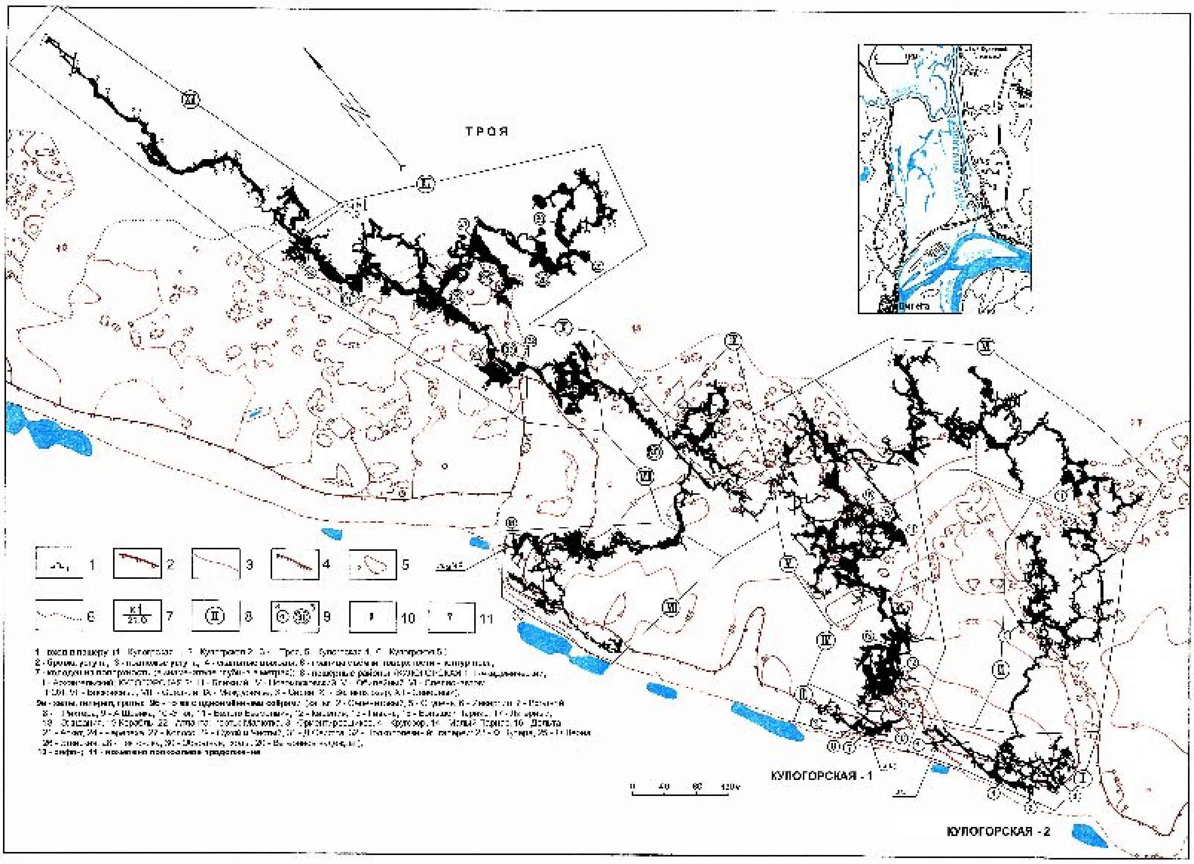


Fig.4.6. Kulogorskaya-Troya Cave System. The biggest horizontal cave of Russian European part

Fig. 4.7. Geomorphologist Shavrina Elena provide an excursion

Fig. 4.8. Schoolchildren excursion in winter caves

MEMORY

Наши коллеги и друзья рано ушедшие из жизни, исследования которых были тесно связаны с Пинежьем, являются участниками и соавторами многих идей изложенных в этой книге. Светлая им память!

Владимир Энгельсович Киселев

Vladimir Kiselev

Владимир Киселев – географ, спелеолог, подводник - внес огромный вклад в исследования и прохождение пещер, С именем Владимира связаны крупные открытия на Кавказе, в Крыму и в том числе на Пинеге. Погиб в пещере ЖВ-52 в районе Железные Ворота при погружении с аквалангом 8 марта 1995 года.

Виктор Викторович Коршунов

Viktor Korshunov

Виктор Коршунов исследователь геологического факультета МГУ им.Ломоносова множество экспедиций провел на Пинеге. Будучи неординарным человеком проводил оригинальные научные исследования по воздействия теплового потока Земли и силы кариолиса на морфологию пещер и другие. Особенно интересовался Виктор геохимией и минералогией, генезисом минералов и их агрегатов. Погиб при тренировочном погружении 8 мая 2000 года.

Евгений Иванович Гуркало

Eygeny Gurkalo

Евгений Иванович Гуркало закончил Ленинградский горный институт в 1978 году с средины 80-х годов XX века возглавлял Карстовый отряд "Архангельскгеолразведки". Исследование карстовых ландшафтов было неразрывно связано для Евгения Гуркало с идеей сохранения наиболее уникальных карстовых объектов. Он был инициатором организации Чугского ландшафтного заказника, отдавал много сил исследованиям этого уникального карстового массива пытался остановить разворачивающиеся там работы по добыче гипса. Евгений Иванович автор более 20 статей. Самой значительной печатной работой является соавторство и редактура монографии "Карст и пещеры Пинежья". Ушел из жизни в октябре 2006.