2nd excurtion day. August 22
TRIP TO GIRVAS

Shelekhova, T.S., Svetov, S.A., Medvedev, P.V.
FIC KarRC RAS Institute of Geology, Karelian Research Centre, RAS, Petrozavodsk, Pushkinskaya str., 11, RUSSIA
E-mail: shelekh@krc.karelia.ru

Stop 1. Sulazhgora (Sulazh Hill) glaciofluvial delta

The delta is located in the northern environs of Petrozavodsk. Standing on the top of the hill, a visitor will enjoy a spectacular view of the Shuya Lowland (40-75 m.a.s.l.) and the Solomennoye denudation ridge (122m.a.s.l.).

The delta consists dominantly of ca.40 m thick sandy, occasionally gravel sediments. In the southern part of the delta, deltaic sediments are covered by ablation till. The laminae dip at 15 to 40 degrees. The material was transported from west to east. This big delta evolved in Middle Dryas (Neva cold stage) - early Allerod time, when the ice front rimmed the northern and eastern slopes of the so-called Olonets denudation uplift at an altitude of 120-313 m.a.s.l. The Shuya Lowland was already ice-free at this time and was covered by meltwater from Shuya Ice Lake. The lake had an outlet to the east into Onega Ice Lake located in the southern part of modern Lake Onega and adjacent lowlands. Delta was formed between the ice front on the north and bedrock uplift on the south. It looks like a glaciofluvial terrace, 3 km in length and up to 2 km in width. The maximum altitude of the delta is 117 m.a.s.l. It shows the maximal level of Onega Ice Lake at this time. The northern slope of the delta is very sharp because it was formed at the contact with the ice front. Paleomagnetic measurements of a varved clay sequence north of the Sulazhgora delta (Bakhmutov et al, 1986), and new data on the age of a western declination peak in Onega Ice Lake sediments (Saarnisto&Saarinen, 2002) have led us to conclude that the ice front retreated from the delta and varved clay deposition began about 11800 C14 years ago.

At about 11200, the ice front retreated from the Lake Onega - White Sea water divide and Onega Ice Lake acquired a lower threshold to the north into the White Sea basin. The Ice Lake level dropped to ~ 20-30 m over a short time and stabilized at ~ 95 -85m a.s.l. Offshore formations on these levels are well known both in the Petrozavodsk area (~85m) and on the northern shore of Lake Onega between Povenets and Medvezhyegorsk (~95m).

The rapid decline of the lake level and changes in drainage direction (previously, Onega Ice Lake had discharged to the south-west along the ancient Svir River) provoked an intensive mixture of oxygen-enriched surface water and oxygen-poor bottom water in Onega Ice Lake. Rapid changes of hydrochemical conditions, followed by oxidation of sediment (Fe 2+ → Fe 3+) at the water-sediment contact triggered the formation of a so-called pinkish-brown varved clay horizon slightly enriched in iron. The layer is 15-20 cm thick, displays a sharp, erosion-free lower contact and a gradual upper contact. The layer is in the upper part of a varved clay unit in Lake Onega. It is a reliable stratigraphic marker reported from 15 boreholes in Onega Ice Lake deposits. Radiocarbon measurements (AMS method) have shown that it formed about 11 200 C14 years ago (Saarnisto &Saarinen, 2002; Wohlfarth et al, 1999).

The trip continues at the western flank of the Onega Structure (OS).

The Onega Structure is dominated by Paleoproterozoic (2.5-1.7 Ga) sedimentary, volcanic and intrusive rock sequences.

The Onega Structure is dominated by Paleoproterozoic (2.5-1.7 Ga) sedimentary, volcanic and intrusive rock sequences.

Stratiform rock associations make up six suprahorizons (Sumian, Sariolian, Jatulian, Ludicovian, Kalevian and Vepsian) preserved to a varying extent (from old to young). The age boundaries of the suprahorizons (see Table 1) and their geochronological equivalents are shown on a regional chronostratigraphic scale [General stratigraphic…, 2002].

Table 1. Subdivision of the Lower Proterozoic in Karelia on the General Precambrian Stratigraphic Scale of Russia.

Age of lower boundary, Ma	Type stratigraphic units (suprahorizons) of the regional stratigraphic scale of the Lower Proterozoic:	Local units:
1800	Vepsian	Shoksha suite
		Petrozavodsk suite
1920	Kalevian	Ladoga series
2100	Ludicovian	Suisari suite
		Trans-Onega suite
2300	Jatulian	Tulomozero suite
		Medvezhyegorsk suite
		Yangozero suite
2400	Sariolian	Seletsk suite
		Vermas suite
2500	Sumian	Ozhijarvi suite
		Tunguda suite
		Okunevo suite

During this field trip participants will see the Paleoproterozoic rock associations of the Ludicovian and Jatulian complexes in the Onega structure. The bus will drive down Highway R-21 Kola (M-18) and R-15.

It should be noted that these are Russia's and Karelia's classical geological localities, where Academician Grigory Helmersen, the first Director of the Geological Committee of Russia, took his first trip to the Olonets Province in June-July 1856. The aim of his trip was to examine the most important old mines, to assess their possible use and to compile a geognostic map of the Olonets Mining District with Petrozavodsk in its centre.

Stop 2. Shuiskaya Station

The hill at Shuiskaya Station and Mount Bolshaya Vaara, seen from the hill and located on the opposite shore of Petrozavodsk Bay of Lake Onega, consist of ca. 1.95 Ga agglomerate tuffs of plagioclase and pyroxene-plagioclase basalt of the Suisari volcanic complex. These rocks are also known as Solomennnoye breccia, which has been used since the early 18th century in architecture to decorate many buildings, e.g. the interior of the Isaac Cathedral in St.Petersburg.

Standing on the hilltop, participants will enjoy a beautiful view of the plain (Fig.1), which hitherto was the old floor of Lake Onega (together with the periglacial Shuya Lake basin) between 11000 and 6000 years ago, when the shoreline was 35-44 m higher than the present one. Seen far away are the outlines of Petrozavodsk Bay of Lake Onega and part of Lake Logmozero. When the glacier retreated from Petrozavodsk ca. 11 700 y.a., two large periglacial lakes, namely Lake Shuiskoye located in the Shuya River valley, and Lake Onega located at that time in the southern part of what is now Lake Onega, the Vodla River valley and the southern Lake Onega area, joined. The water level of this periglacial basin in the Petrozavodsk area was at an absolute altitude of 85 m (the present Lake Onega level is at an altitude of 33 m). Thus, most of the area discussed was covered by its cold water. It is important to point out that the road leading to Stop 1 extends along an abraded morainic ridge, about 450 m in width and 2 km in length. Facing old Lake Onega are boulders washed out from moraine and scattered on the eastern slope of the ridge. Most boulders are 40-50 cm in diameter, but some are up to 1-1.5 m across. 10- to 15-cm thick washed-out sand lenses occur under a soil-plant layer. These are underlain by ca.60 cm thick greyish-yellow sandy, unconsolidated moraine, which, in turn, is underlain by highly consolidated grey sandy loam. The strand (wavecut platform) passes eastwards into a paludified lacustrine-glacial plain composed of varved clay. The edge of the strand is at an absolute altitude of 44 m and the rear suture (water edge) is at an altitude of 35 m. The absolute altitudes indicate that the strand was forming from about the mid-Atlantic to the early Sub-Atlantic Period of the Holocene (6.5 – 2.7 thousand years ago). The Onega Lake level varied considerably but generally declined: the Atlantic regression of the lake was followed by short-term transgression in the Subboreal Period. The formation of glacial deposits was largely responsible for the modern topography of the area and the discrete exposure of Precambrian rock complexes.

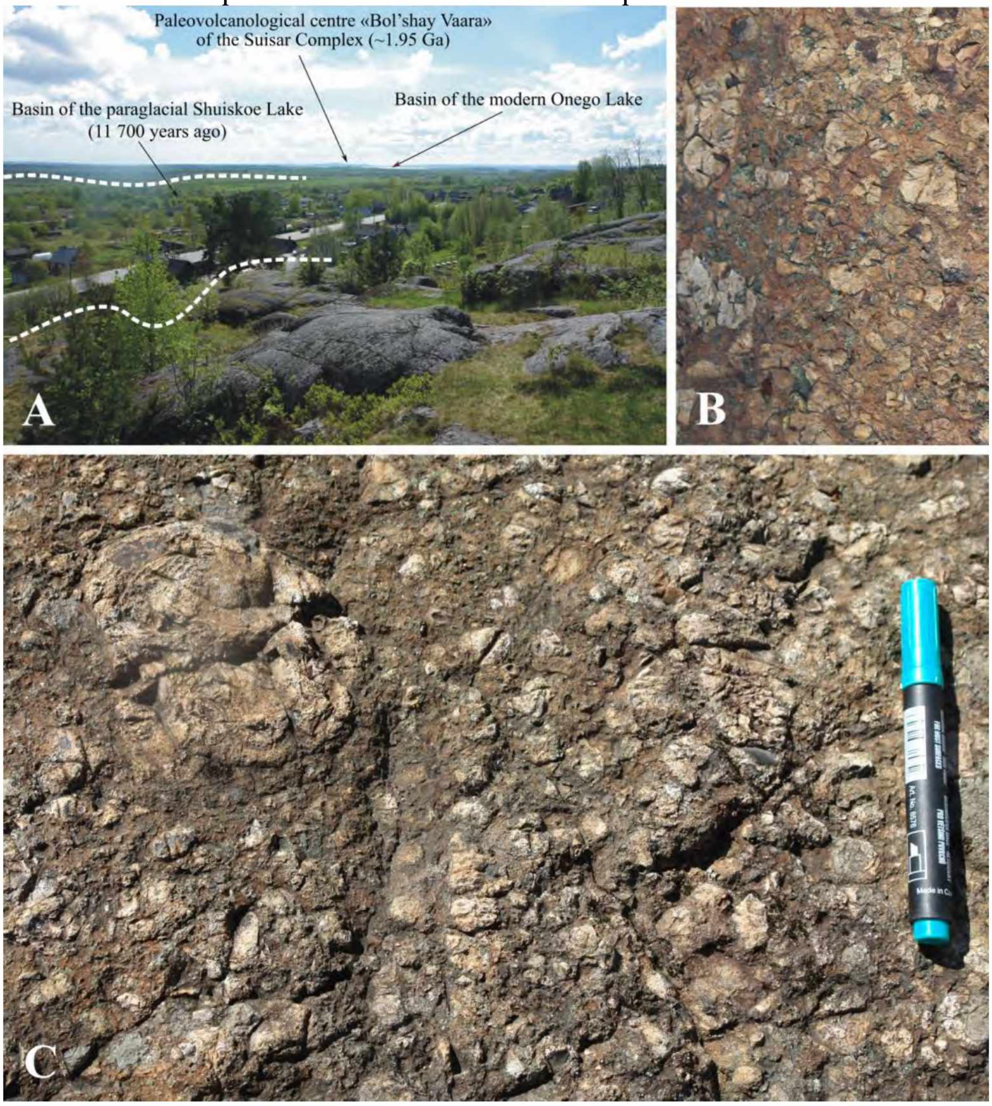

Fig. 1. View from the hilltop at Shuiskaya Station (A) and rock lithotypes of Suisari volcanogenic rocks (B-agglomerate tuffs, C-scarce bombs in agglomerate tuffs).

Agglomerate tuffs that make up the hill at Shuiskaya Station (Stop 2) consist of plagioclase and pyroxene-plagioclase basalt, which contains numerous sharply angular fragments and less common rounded clasts supported by the finely divided matrix. The tuff sequence at this locality is about 30 m thick.

Suisari rocks will also be seen in road cuts at the intersection of Highway R-21 Kola and R-15 (turn-off to Girvas Town). The pyroclastic sequence at this locality (Stop 2) is formed as alternation of fine-grained tuffs with agglomerates and coarse bomb tuff horizons (Fig.2).

Fig. 2. Rock lithotypes of the agglomerate sequence of the Suisari complex (road cut, turn-off to Girvas). A – flat lenticular bombs in agglomerate matrix; B- chill zone of a large volcanic bomb; C- local stratification pattern of a pyroclastic sequence (succession of fine agglomerate and bomb tuff layers)

The agglomerate sequence, which contains tuff interlayers of various sizes, is exposed in road cuts. Pancake-like bomb tuffs, often “flattened”, are common here. The bombs vary in size from 10-15 to 150 cm along the long axis. The bombs have thin to thick (up to 3 cm thick) chill zones, which reflect changes in eruption conditions and a difference between the temperatures of the matrix and volcanic explosive bomb material. Some of the bombs display internal cavities that contain recrystallized quartz-carbonate material.

Stop 3. Shuiskaya Chupa

The rocks that underlie the Suisari suite are exposed at Shuiskaya Chupa (Konchozero Lake shore). They make up the upper unit of the Trans-Onega suite, where several andesite-basalt, trachyandesite-basalt, and lesser basalt lava flows, up to 10 m thick, are interbedded with tuffaceous-sedimentary rocks that contain carbonaceous rock lenses.

Three more lava sheets of the Trans-Onega suite, interbedded with tuffaceous-sedimentary rocks, were revealed at Shiuskaya Chupa, above the sheet described above.

The key sequence of the overlying 389 m thick Suisari suite in the Konchezero-Ukshezero area (Konchezero volcanic zone) was revealed, based on cores from borehole 5 drilled by the Karelian Geological Survey 420 m south-east of Lake Angozero. V.S.Kulikov and B.S.Lavrov (1999) identified five volcanogenic rock members in this sequence varying in chemical composition. Participants in the field trip will see the rocks that constitute the first (Shuiskaya Chupa) and second (Tsarevichi) members.

Occurring near the south-western roadside of the Highway Petrozavodsk-Girvas in the first member is a so-called transitional unit composed of tuffaceous-sedimentary rocks, in which a 0.5-1.5 m thick horizon with coarse-clastic rock beds (2-3) (conglomerates and gravel stones) was encountered. The clasts consist dominantly of Trans-Onega volcanics and sediments (plagiobasalt, andesite-basalt, shungite, etc.). V.S.Kulikov described this horizon as the basal bed of the Suisari suite. Compositionally similar psephites were revealed at the base of the Suisari suite and in other parts of the first member of the suite (Solomennoye Town, Peski Airport, Lake Karelskoye, Lake Surgubskoye, Ternavolok Village, Suisar Island, etc.).

The sequence of the first member of the Suisari suite displays areal facies variability. At Shuiskaya Chupa, this member consists of mafic tuffites (0.5-15 m thick) and tuffs (breccia) of aphyric basalt (over 20 m thick) occurring above Suisari basal conglomerates on the ridge, which extends north-west along the Highway Petrozavodsk-Girvas. The rocks dip SW at 45-80°.

Stop 4-5. Tsarevichi Village

The second member of the Suisari suite is most complete at Tsarevichi, where it is over 100 m thick and actually constitutes the entire isthmus between Lakes Konchezero and Ukshezero. The village was called Tsarevichi in honour of the Emperor Peter the Great, who used to stop over here on his way from St.Petersburg to Martian Waters health resort. To commemorate his visits, a chapel was built on the northern side of the highway (Fig.3).

The lower portions of the member consist of three augite melabasalt flows (9-13% MgO) interbedded with similar tuffs exposed on the Konchezero side of the isthmus.

Stop 4. (Tsarevichi village, Konchezero Lake shore). Before entering Tsarevichi village, the bus will stop to let participants look at agglomerate tuffs exposed at the contact with pillow basalt lava with thin (up to 1m) tuff-tuffite horizons (lenses) (Fig.3).

Stop 5. (Tsarevichi village, Ukshezero Lake shore). The Ukshezero side of the isthmus is made up of several tuff and picrobasalt beds and thin (up to 3-5 m) massive picrobasalt flows. The rocks dip SW at 40-60°.

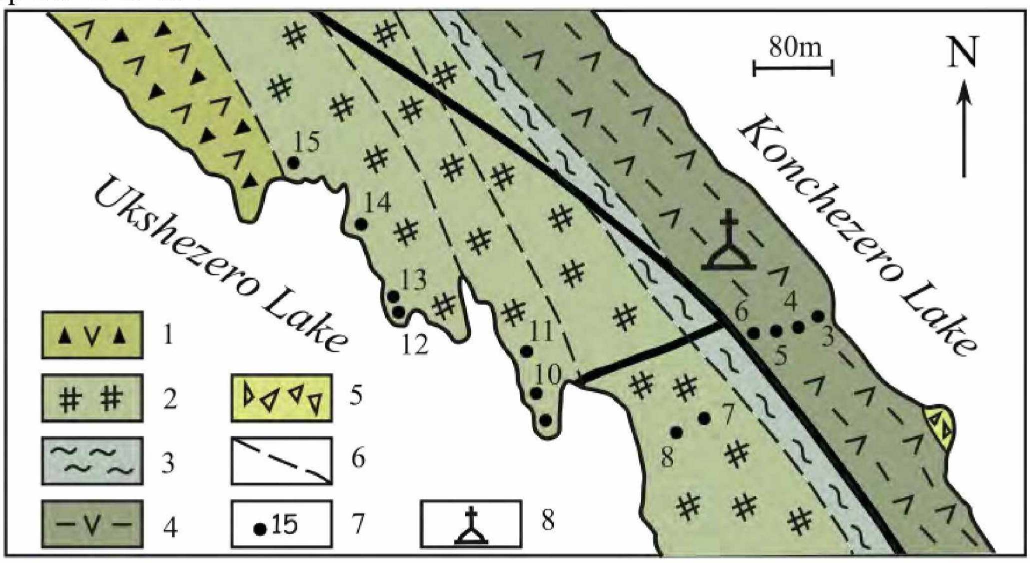

Fig. 3. Scheme showing the geological structure of Tsarevichi locality (2nd member of the Suisari suite). Legend: 1 – plagiopyroxene basalt and its breccia; 2 – picrobasalt and its breccia; 3 – tuffites; 4 – melabasalt and its breccia; 5 – basalt tuffs; 6 – geologicl boundaries; 7 – sample numbers (Table1); 8 – chapel.

The trip continues along the western limb of the Onega trough made up of sedimentary, sedimentary-volcanic, volcanogenic and intrusive (diabase, gabbro-diabase and ultrabasic) rocks of Lower Proterozoic age. The rocks are thrown into various folds and are broken into a series of axial faults. Both folds and faults generally strike north-east. The area along the route offers a complete idea of the denudation-tectonic and structural-denudation relief so common to Karelia. The relief is composed of alternating ridges normally confined to volcanogenic and intrusive rock exposures. The relief generally displays a linear orientation and the strike of the ridges and depressions are fully consistent with the strike of the structures. The accumulative relief, confined to erosion-denudation topographic lows, consists dominantly of lacustrine, glacio-lacustrine accumulation and abrasion-accumulation planes, isolated moraine and esker ridges and fluvio-glacial deltas.

Stop 6. Mount Sampo. (Svetov at all., Field Guide, 2015). The mountain was called Sampo because a feature film, based on the Karelian-Finnish epos "Kalevala", was being shot here in the 1960s. Sampo is a magic mill, a source of happiness, well-being, and profusion.

Occurring along the Petrozavodsk-Girvas Highway, near Kosalma (north of the village outskirts) and on Mount Sampo, are mafic rocks (Suisari suite) formed as a series of alternating lava flows and agglomerate tuffs with thin sedimentary intercalations.

The top of the ridge on the isthmus between lakes Ukshozero and Konchezero provides a good view which gives a good idea of how the ancient structural elements of the crystalline basement are reflected in the relief. Direct and indirect correlations between the relief and the structure can be seen here.

The Ukshezero basin is situated in the central Ukshezero syncline. The core of the structure is made up of arkose and quartz sandstone, siltstone and shale, and the flanks are composed of picrite-porphiryte, tuffite and tuff breccia. In this case, a direct reflection of structure and landforms can be observed (Fig.4). The Lake Konchezero basin displays a linear shape (22 km in length and 3 km in width) and is rather deep (10 to 19m). The basin is confined to the axial part of a linear anticline, whose crown is broken into a system of axial faults. This fault system contains diabase and gabbro-diabase bodies traceable along the axial part of the basin as a chain of islands and underwater bottom swells. In this case, the reflection of structure and relief is indirect.

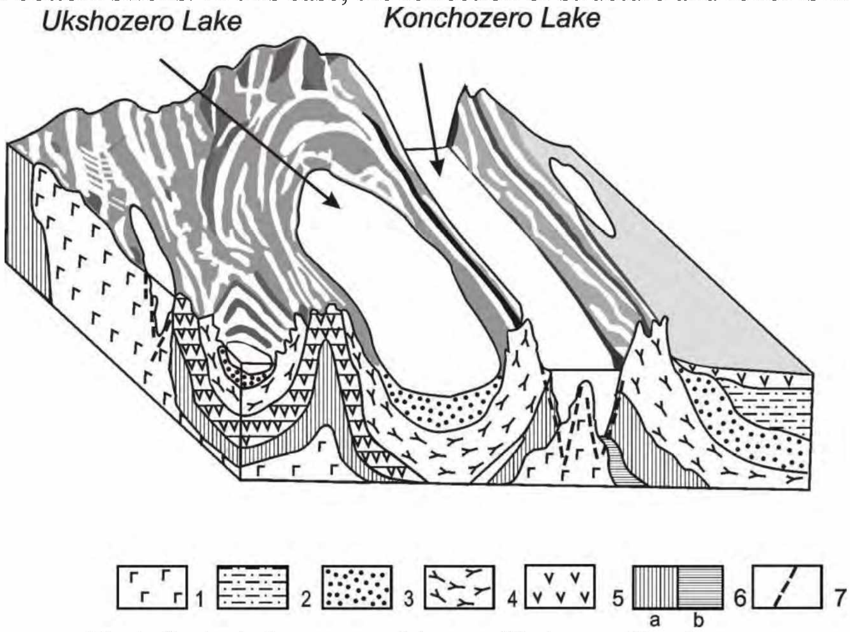

Fig.4. Geological structure of the area Ukchozero-Konchozero
1 – intrusive sheets and dykes of diabase and gabbro-diabase; 2 – schist-sandy rocks; 3 – siltstone, schist, sandstone, conglomerates; 4 - tuffaceous lava rocks; 5 – amygdaloidal diabase and diabase porphyrite; 6 a – shungite shale, limestone, tuffaceous rocks; 6 б - shale; 7 - faults.

Stop 7. Martian Waters Town

Martian Waters, Russia's first health resort, which became famous for its mineral springs, was founded on 20 March, 1719. The springs were discovered in 1714 by Ivan Ryaboev, a peasant, who worked at a copper smelter. He informed Mr.Genin, Director of Olonets metal-producing plants, about his discovery. Genin sent a letter to the Emperor Peter the Great. In 1717, the czar asked the court physician L.L.Blumentritt to analyze the spring water. A church and a wooden palace were built near the springs for Peter I, who came here with his family in 1719, 1720, 1722 and 1724.

In 1724, while at the resort, the czar signed a decree on the establishment of St.Petersburg Academy of Sciences and Art (now the Russian Academy of Sciences).

After a preliminary study, mineralized water from the springs, rich in active bivalent iron, was called Martian in honour of Mars, God of War and Iron.

According to A.V.Ieshina, sulphate-type Martian water is formed in the lower hydrogeochemical subzone. Its mineralization varies from 0.27 to 0.67 g/l, and its composition ranges from hydrocarbonate-sulphate-magnesium-calcium-iron to sulphate-hydrocarbonate-magnesium-iron-calcium (Table 2). Its iron concentration is 16-87 mg/l. The presence of the water in the lower hydrogeochemical subzone is confirmed by elevated water mineralization and the composition of dissolved oxygen-free gases. The total gas concentration of 60-80 mg/l is higher than the background value. CO_2 (72-76 vol.%) and nitrogen (22-26 vol.%) are the dominant gases. Martian water is famous as one of Russia's major iron-rich water types with a high active iron concentration and spring flow. It is used in medicine for healing blood, stomach, liver, kidney and metabolic diseases. In addition to Martian water, muds from Lake Gabozero are used here for medical purposes. The muds display anti-inflammatory, spasmolytic, anesthetic and resolving effects and are used to heal diseases of the peripheral nervous system, motion organs and chronic inflammatory diseases.

Table 2. Chemical composition of mineral water from Martian Waters health resort

Constituents and indices	Unit of measure-ment	**Well 1**	**Well 2**	**Well 3**	**Well 4**
HCO_3	mg/l	96.3	122.6	108.6	134.2
SO_4	Same	80.7	224.8	261.1	343.7
CI	"	1.0	1.0	1.1	1.1
NO_3	"	-	-	-	-
F	"	0.2	0.2	0.2	0.2
Na	"	3.0	4.5	4.5	5.5
K	"	2.3	4.6	5.0	5.7
Ca	"	24.0	39.0	34.0	49.0
Mg	"	14.6	44.4	37.7	45.6
Fe^{2+}	"	16.0	31.0	56.0	76.9
Fe^{3+}	"	Traces			
Mn	"	0.4	0.8	1.0	1.0
H_4SiO_4	"	4.0	10.4	16.6	18.6
Mineraliza -	"	242.5	482	525.8	681.5
on H_2PO_4	µg/l	-	-	35	35
Al	Same	13	30	25	20
Cu	"	9	23	34	47
Zn	"	13	100	72	150
Co	"	2,5	3,7	4,8	10
Sr	"	43	46	72	100
Ni	"	6	46	72	15
Li	"	10	40	20	20

Note. Resources and geochemistry of Karelia's underground waters. Petrozavodsk, 1987, 151 p.

Stop 8, 9. Raiguba – Pyalozero. During the field trip the participants will be shown Paleoproterozoic sedimentary rock sequences containing organic remains.

The geological localities to be visited first represent the lower part of the Upper Jatulian unit (Onega Formation). The rocks exposed here from the base upwards are as follows

1) Beds with *Lukanoa* (on_1^a). Sandstone with argillaceous dolomite calcareous matrix, pink fine-grained dolomitic limestone, and brown clastic dolomite occurs at its base. These are followed upwards by sedimentary largely dolomitic breccia which contains problematic rounded bodies *Lukanoa* Medv. The total thickness of the beds is 140 m.

2) Beds with *Nuclephyton* (on_1^b) made up of various granular grey, pink and red dolostones with carbonate matrix in sandstone interbeds. At the base of this member the participants will see a nuclephytonic dolostone stratum. Pinkish colour rocks with a medium- grained structure contain lenses and biostromes made up of the stromatolite *Nuclephyton confertum* Mak. On the plane parallel to the bedding surface, the stromatolites show a characteristic pattern of rounded figures or smoother-angular polygons, 5-7 cm in diameter. In the section perpendicular to the bedding, polygonal cells can be seen to correspond to the outcrops of subparallel prisms and cylinders (columns) made up of fine-to medium grained, almost massive dolomite (thin relics of gently convex stromatolite laminations are hardly distinguished). Columnar buildups are either oriented perpendicular to the general bedding or are slightly oblique. The columns are separated from each other by relatively thin (fractions of centimetre) intracolumnar portions (interspace filling); normally recrystallized and silicified, hence they are well-defined on the weathering surface. The nuclephytonic dolostone stratum is 2.0-2.5 m thick. The total thickness of the Beds with *Nuclephyton* is 42 m.

3) Beds with *Sundosia* (on_1^c) are composed of pink-grey dolostones, dark-brown carbonate-bearing matrix and siltstone intercalations. The dolostone contains large elongated biostromes, indistinctly isolated dome-shaped bioherms or small lens-shaped bodies consisting of the rock-forming stromatolites *Carelozoon metzgerii* Mak., *Sundosia mira* (But.) and *Parallelophyton raigubicum* Mak. At point l, a dolomitie exposure with the rock-forming stromatolite *Carelozoon metzrerii* Mak. can be seen. Abundant Carelozoon structures, showing a cell relief, occur on the weathered bedding surface. Cells are formed where stromatolitic columns are exposed, as the intracolumnar portions (interspace filling); containing silica material and dividing the columns, appear to be more resistant to weathering. The stromatolites *C. metzgerii* make up lenses and gently undulating biostromes. Their fragments are occasionally presented as low-relief domal bioherms, up to 3 m in diameter.

In the upper part of the carelozonic dolostones, small lens-shaped portions with *Sundosia mira* (But.) stromatolites are encountered. These are subcylindrical branching columns, 1.5-2.0 cm in diameter. In one of the small outcrops horizontal sections of these structures, looking like concentric laminated circles, can be seen.

The appearance of biostrome-forming stromatolites *Parallelophyton raigubicum* Mak. is confined to the top of the dolostone bed described. These structures display either a planeprismatic or parallelepipedal shape. The long axes of the structures are parallel and are commonly oriented E-W, suggesting that the E-W direction of tidal currents predominated .The total thickness of the Beds with *Sundosia* is 60 m.

After examining the lower part of the Onega Formation, the trip continues in the Pyalozero area.

Beds with *Omachtenia kintsiensis* occur in the middle portion of the Jatulian carbonate sequence (on_1^d). The beds consist of various granular pink and red dolostones with silica intercalations and arenaceous dolostones (with abundant sandy and siltstone quartz impurity). The rocks contain the index species *Omachtenia kintsiensis* Mak., elongated biostromes with the complex columnar stromatolites *Carelozoon jatulicum* Metz., isolated buildups comprised of *Colleniella palica* Mak., *Colonnella carelica* Mak., *Parallelophyton strictum* Mak. and oncolites *Palia septentrionalis* But., *P. bicolor* G.Kon. and *Glebosites palosericus* G.Kon. The maximum thickness of the Beds with *Omachtenia kintsiensis* is 130 m.

Girvas Hamlet. Extramarginal glaciafluvial delta

To the east of Girvas Town, in the Palyeozero-Sundozero lake isthmus, there lies a large accumulation plain, which is the surface of an extramarginal delta formed at the mouth of big glacial meltwater discharge systems on the shore of Onega Ice Lake (Fig.5). The surface of the delta has dunes, rill channels, and is inclined to the east towards the lake. Therefore, its absolute altitudes decrease from 100 m in the west to 75 m in the east. The delta then passes into a glacio-lacustrine plain formed of varved clay and loam. Its surface has an altitude of 70-75 m., but varved clays are known at an altitude of up to 80 m.a.s.l. The delta covers an area of about 36 sq. km, and the total thickness of its sediments is 40 m. The catchment area of the ancient delta, which incorporates several powerful glacial meltwater discharge systems, about 90 km in length, was over 400 sq. km. Till or crystalline rocks occur at the base of the sequence. These are overlain by layered silt and loam lenses. Resting on them is a 35 m thick pile of fine-, medium-, and less common coarse-grained sand and silt (Biske, 1959). In the sand, which constitutes the delta, well-defined units of obliquely laminated series alternate with parallel-laminated series. The laminae are inclined at 20-40 cm in obliquely laminated series. It has been shown by measuring the direction of oblique laminae that the material was transported northeast, east, and southeast. Submarine landslide folds, characteristic of deltas, can be seen in the lower part of the sand unit. The pollen of birch, pine, alder, spruce, willow and plants of the grass, sedge, sheaf-leaf, cruciferae, and aster families, etc. was revealed in the pollen spectra of sand along with club-moss, fern, and moss spores. The pollen spectrum remains unchanged over the entire sequence (from a depth of 7.7 m to 13 m). The pollen of woody species is less abundant than that of grasses, and indicates sedimentation in poorly forested forest-tundra or forest-steppe terrains (Biske, 1959).

The Girvas delta began forming at the end of Allerod time, when Onega Ice Lake got a new outlet into the White Sea basin and its level has dropped from120 m.a.s.l to 100 m.a.s.l. A fluvioglacial delta, located south of the Girvas delta, was formed originally in the Lake Kudzyulampi area, near the ice margin. The delta consists dominantly of coarse-grained sand and semi-gravel. The Girvas delta began to form after the retreat of the ice margin northwest beyond the deep basin of lakes Sukhoye, Vikshozero, and Lavalampi. Gravel and coarse sand, carried by glacial meltwater, were deposited in the deep basins of these lakes. Fine- to medium-grained sand and silt were basically accumulated near the isthmus, between lakes Palyeozero and Sundozero. It took several hundred years for the delta to be formed. Meanwhile, the ice margin had retreated by about 90 km. At that time new discharge thresholds were opened in the Onega-White Sea Isthmus (~11 300 y.a. according to M. Saarnisto), and the Onega Lake level dropped by about 20 m. A terrace was formed on the delta slope at an absolute altitude of 75-80 m. The inflow of meltwater had markedly decreased because the delta was fed solely by the glacial meltwater discharge system down the River Suna controlled by lakes Gimoly and Lindozero, large periglacial water bodies. The Semch and Yangozero fluvio-glacial systems supplied the material into Lake Segozero. In Late Dryas-Early Holocene time, the Onega Lake shore retreated from the area discussed, so that river erosion, accumulation and dune formation dominated in the delta area.

After the Second World War the River Suna was diverted and began flowing along a new channel, Pionerny Canal, as the construction of the Girvas power station began. It took a few days for an alluvial+ delta, covering an area of about 3 sq. Km, to be formed at its mouth on the shore of Lake Palyeozero.

Therefore, the Girvas delta is a periglacial, rather than fluvio-glacial, delta which was forming far from the ice margin from mid-Allerod to late Young Dryas time. This conclusion is supported by the absence of coarse-grained sand and gravel in the delta, the geological and geomorphological structure of the area, its geological evolution, and pollen spectra characteristic of periglacial conditions.

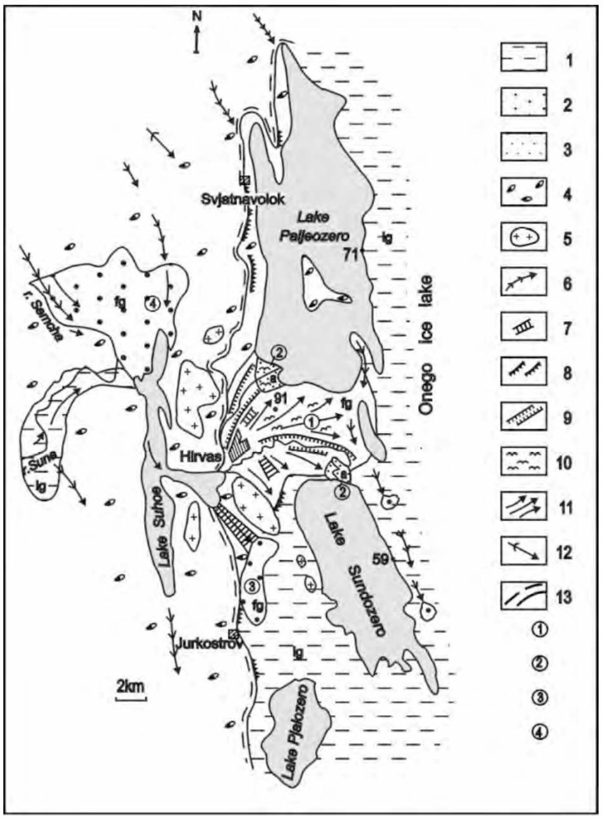

Fig. 5. Structural scheme of the Quaternary cover in the Yurkostrov-Hirvas-Svyatnavolok area
Key: 1 – limnoglacial silt and clay; 2- fluvio-glacial gravel-sand deposits, 3- sand, 4 – till, 5 – bedrock exposures, 6 – eskers, 7 – rills of glacial melt water discharge, 8 – shore scarps, 9- erosion scarps,10- dunes, 11- direction of transport of glacial meltwater material, 12- direction of ice movement, 13- shoreline of periglacial Lake Onega 1 – Girvas periglacial delta, 2- present alluvial deltas, 3 – Kudzyulampi fluvioglacial delta, 4 – outwash plan.

Suna River canyon

Stop 10. River Suna. Lower Jatulian tholeiitic basalts in the Suna River channel are overlain by ca. 10 m thick conglomerates and quartzitic sandstones that alternate from the base upwards.

1. Pinkish-grey, greenish-grey quartz conglomerates and gravelstones. Rock colour depends on the colour of the quartz pebble-supporting micaceous or quartzy sandstone matrix. The micaceous sandstones are rich in green chlorite responsible for the dark-green colour of the rock; sandstones with limonitized hematite, imparting a pinkish-grey colour, occasionally contain feldspar grains. The unit varies in thickness from 10 to 50 cm.

2. Fine- to medium-grained quartzitic sandstone with scarce quartz pebbles and coarse feldspathic sandstone. The rock is commonly dark-grey, while pinkish and cherry-grey colours are more scarce. Ten to forty centimetre thick cross-bedded series, wedging out along the strike, are characteristic of the quartzitic sandstones. Cross-bedded series, which are sometimes trough-shaped, truncate each other. The base is formed of coarser stuff. Laminated schist pebbles are occasionally encountered. The laminae are unidirectional, and sometimes pinch out towards the base.

The top of the bed is formed of horizontally-bedded quartzitic sandstone with ripple marks on the bedding planes. The ripples are asymmetric, and the waves are 3-6 cm long and up to 1 cm high. Bedding planes with crescent-shaped cellular-elongate ripple marks are observed upwards. The bed is 2 m thick.

3. Ca. 1.0 m thick pinkish-grey coarse-grained quartzitic sandstones with dirty-grey thick-and cross-bedded series. Straight and curved seams are flattened towards the base. 4. Quartz conglomerates and gravelstones with angular-rounded pebbles, up to 3-5 cm in size along the long axis, that rest on the rough scoured surface of quartzitic sandstones. The conglomerates are

supported by arkose matrix with poorly rounded feldspar clasts, up to 1 cm across. The quartz conglomerates vary in thickness along the strike, fill pockets and grade upwards into coarse-grained quartzitic sandstone. These, in turn, pass into medium-grained sandstone mixed with feldspar grains. The rock is pinkish-grey. The bedding is commonly coarse and horizontal. Poorly-defined oblique lamination is locally observed. The top is always formed of dark-grey, irregularly fine-grained quartzitic sandstone which occurs beneath an overlying mafic bed.

The mafic bed incorporates a series of lava sheets. The base of the lower bed is composed of pillow lava supported by a matrix, which has arenaceous stuff of underlying sediments. An undulating surface, formed by a lava flow, is visible at the top of the second lava sheet.

Lava sheets 2 and 3 are separated by a bed consisting of tuffaceous-carbonate rocks, tuffaceous sandstone, and tuff schist in which hydrothermal siliceous rocks are deposited.

Lava sheet 3 displays a columnar jointing which is uncommon to Precambrian units.

Stop 11. Paleovolcano Girvas

Relics of a volcanic conduit system, produced by Jatulian mafic volcanism, occur here. The visible portion of the conduit system consists of the following morphological elements: the south-eastern slope of the lava cone, part of the diatreme and a larger part of a subordinate (parasitic) vent occurring as a volcanic pipe.

The volcanic cone is composed of several 10-15 m thick basalt flows, which overlie one another. The flows consist of abundant lava breccia. The vent of the subordinate volcano is clearly seen. It has an oval shape and is 10x20 m in size. The diatreme is filled with small blocks of basaltic breccia. Intense tourmalinization has been revealed in the rocks near the western endocontact.

When conducting palaeovolcanological studies of volcanic rocks at the northern end of Girvas, geologists found bizarre volcanic rocks in the water discharge channel of the Palyeozero hydropower plant. The rocks make up a structurally complex volcanic conduit system associated with Jatulian mafic volcanism and known as Girvas Volcano (Svetov & Golubev, 1967).

In the present erosion section, one can see only a small portion of the volcano, which consists of the following morphological elements: part of the eruptive vent, the southeastern slope of the lava cone and presumably most of the subordinate (parasitic) crater (volcanic pipe). The rest of the volcano is buried under a thick pile of unconsolidated lacustrine-alluvial Quaternary rocks.

The eruptive vent of Girvas Volcano is located on the left slope of the water discharge channel. In the present erosion section it has a rounded shape and is slightly elogate in a northeastern direction. Its exposed portion is 20 x 50 m in size.

The eruptive vent acted as an excurrent channel through which lava was transported in Middle Jatulian time to form a lava plateau in the western Lake Onega region (Prionezhye). In the contact zone, the vent is filled with massive, locally highly fractured, basalt and basaltic porphyrite that occasionally pass into thinly-laminated, fine-clastic collapse breccia. Off the endocontact, the rocks attain some features increasingly characteristic of blocky vent breccia in medium-grained basalts. Sharp south-eastern and eastern contacts with rocks of the volcanic lava cone are emphasized by vertically dipping thinly-laminated breccia zones and by zones in which tourmalinization is intense and albite and albite-quartz veins are abundant. Gradual transition from eruptive vent rocks to a gabbro-dolerite type of rocks occurs chiefly as the degree of recrystallization of rocks rises and porphyraceous brecciated varieties of basalts are succeeded at first by fine-grained, massive varieties and then by medium- to coarse-grained (pegmatoid) gabbro-dolerites.

Stop 12. Kivach Falls. It is located in the centre of Federal Kivach Reserve. It was founded in 1931 to protect and restore a model site in the mid-taiga subzone of European Russia. Integrated studies and monitoring, conducted here for decades, are now in progress. The reserve covers an area of 10 870 hectares. Its mature coniferous forests are most valuable. Pine forests make up 42%, spruce forests 32% and secondary stands over 20%. Broad-leaved trees, such as mountain elm, lime and black alder, are less abundant. The average age of the forests is 120 years, but some of the pine-trees are 300-350 years old. The reserve's flora consists of over 580 vascular plant and 193 cormophyte moss species. 268 terrestrial vertebrate, 24 fish and 977 insect species have been reported. Some of these plant and bird species are listed in the Red Data Books of Russia and Karelia. The knowledge of Kivach Reserve's geological structure is scanty.

A scheme, showing the geological structure of the adjacent area, is in **Fig.6.** (V.S.Kulikov & V.V.Kulikova, 1998)

Kivach Reserve is located at the northwestern flank of the large Konchezero anticline composed of sediments and volcanics (Trans-Onega and Suisari suites), which are cross-cut by Paleoproterozoic gabbro-dolerite and dolerite. Their isotope age has not been estimated.

The rocks dip gently ENE at 10-15° and become steeper only in fault zones. Trans-Onega rocks are dominated by shungite shale, siliceous schist and pelite; basalt and andesite lava is less common. The Suisari suite is made up of basalt tuffs; clastic stuff is dominated by blocks and sharply angular fragments of Trans-Onega shungite shale and siliceous schist. A Suisari tuff unit has been traced along the Suna River for over 2.5 km.

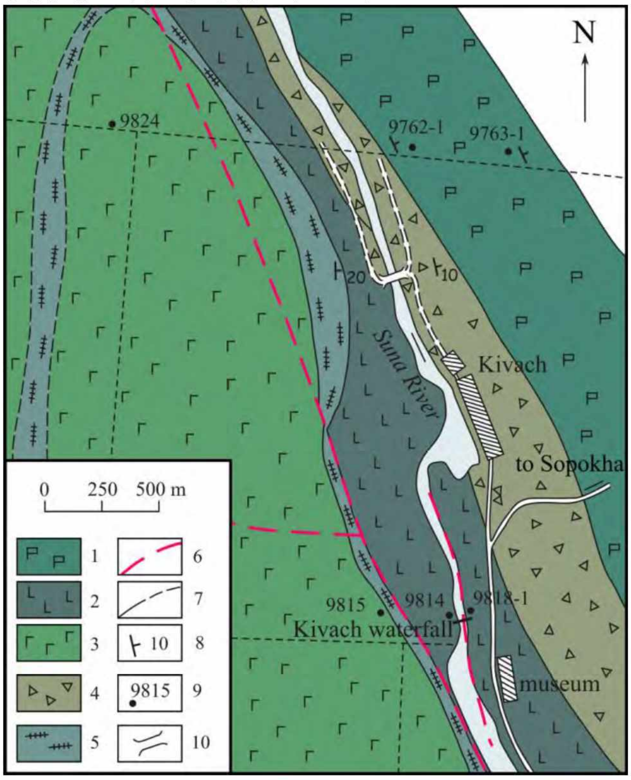

Fig.6. Scheme showing the geological structure of the Kivach area [V.S.Kulikov & V.V.Kulikova, 1998]
1 – gabbroic rocks in Levoberezhny Sill; 2 – gabbro, ferrogabbro, and dolerite in Vodopadny Sill; 3 – gabbroic rocks in Pravoberezhny Sill; 4 – Suisari tuffs and tuffaceous conglomerates; 5 – Trans-Onega shungite shale and schist; 6 – faults; 7 – boundaries of rock bodies and units; 8 – inclined mode of occurrence of rocks; 9 – sample numbers in Table 4; 10 – hanging bridge.

Gabbro-dolerite predominates. Three large bodies, named Levoberezhny, Pravoberezhny and Vodopadny, depending on their position relative to the Suna River, are distinguished (Fig. 6). Each of the sills is up to 100 m thick in the swells.

The sills differ in chemical composition, mainly in iron, calcium and titanium concentrations, and presumably in age.

Vodopadny Sill, on which Kivach Falls is located, is a major tourist attraction. The name Kivach seems to originate from the Finnish word "kivi" (stone). Prior to the construction of Girvas Hydropower Plant in pre-war time and the diversion of Suna River water into another water system (Lake Sandal), Kivach Falls was a magnificent sight. It is Europe's second plain fall with respect to water fall elevation (11 m).

You can see a shatter zone in a near-N-S-trending gabbro-dolerite body, which coincides with the Suna River channel and a small mylonitization zone within it. Occurring on the left-hand bank, 10-20 m from the river channel, is a spheroidal jointing in dolerite. Its genesis is the subject of debate: some scholars argue that it is a spheroidal jointing typical of basalt, which flowed into a water body; others assume that it is a distinctive jointing produced by massive rock weathering. If further studies prove that the former version is correct, then this body is a large lava sheet, rather than a sill. This igneous mafic body is differentiated, displays a more melanocratic composition at the base (right-hand bank) and a mesocratic composition on top (left-hand bank). Shatter zone rocks are brown and contain elevated iron oxide concentrations. While touring the Olonets Province, Academician G.P.Helmersen was impressed with “giant boilers” - rounded cavities of various sizes on the exposed rock surfaces in the river channels and in the near-bank portions of water bodies. Such cavities with an oval bottom and smooth walls are similar to iron boilers in bath-houses. They are up to several metres in diameter, suggesting that tremendous efforts were made to produce them. Hence, the name “giant boilers” [Sokolov & Erte, 1984]. Such boilers are common in Fennoscandia. Local tales say that the “boilers” were created by the Jatulians, mythic giants, who allegedly lived in this province.

G.P.Helmersen saw such “boilers” near Helsinki, on Lake Ladoga and in the Olonets Province . He said, "I visited many places with favourable conditions for their formation, such as Kivach Falls, Porporog and Girvas, but I didn’t see any boilers".

At that time the water level on the Suna River was very high. Therefore, the “giant boilers”, which one can see now on Kivach Falls, were then under the water surface. The biggest known “boiler” is located on a second cascade in the river channel, near the left-hand bank.

The structural-denudational, glacial and aqueo-glacial types of relief predominate in Kivach Reserve predominate. The last Late Weichselian ice cover had retreated from the area described about 11 500 years ago, but the biggest part of the reserve was covered by water of ancient Lake Onega till mid-Boreal time 9000–8500 Ma ago.

After examining the geological sites, you can walk around to enjoy the beautiful nature or visit the Kivach Reserve Museum, which has many interesting and informative exhibits.

References:

Ananjin, I.V. 1980. Russkaya ravnina i Ural. In:Seismicheskoje rajonirovanije territorii SSSR. Moskow, Nauka,p. 109-114.

A guide to the geological field trips held as part of the 12th All-Russian Petrographic Meeting "Petrography of igneous and metamorphic rocks". Petrozavodsk: Karelian Research Centre, RAS, 2015, 96 p. (references are therein).

Golubev A.I., Svetov A.P. Geochemistry of Kaelia’s basalt produced by platform volcanism. Petrozavodsk: Karelia, 1983. 192 p.

Demidov I.N. Varved clay formation and deglaciation in the northern Lake Onega area.// Contribution to the origin of Quaternary deposits and their resources in Finland and northwestern part of the Russian Federation. GSF. Espoo. 1997. P.57-65.

Demidov I.N. Quaternary deposits // Biotic diversity of Karelia: conditions of formation, communities and species. Karelian research Centre. Petrozavodsk. 2003. P 17-23.

Ekman I, Iljin V. Deglaciation, the Young Dryas end moraines and their correlation in Russian Karelia and adjacent areas. // Glacial deposits in North-East Europe. Balkena. Rotterdam. 1995. P.195-209

Ekman I., Bakhmutov V., Zagniy G. Upper Valdai-Veiksel (Valdai-Weichselian) chrono- and magnetostratigraphy in southeast Fennoscandia. Examples from Russian Karelia // Contribution to the origin of Quaternary deposits and their resources in Finland and northwestern part of the Russian Federation. GSF. Espoo. 1997. P.75-85.

Ivanovskaya, L.V., Firsova, D.B., Homenjuk, U.V., Schukin, U.K, 1998. Dolgovremennoje prognozirovanije seismicheskoi opasnosti po kompleksu geologo-geophizicheskih dannih. Moskow, Nauka, p.108.

Kulikov V.S., Kulikova V.V., Lavrov B.S. et al. Paleoproterozoic Suisari picrite basalt complex, Karelia: key sequence and petrology. Petrozavodsk: KarRC, RAS, 1999. 96 p.

Lukashov A., Ekman I., Iljin V. Guidebook for excursion, A-4 C-4. XI CONGRESS INQUA. Moscow, 1982. 57 pp.

Lukashov A.D. Paleoseismotectonics in the northern part of Lake Onega // Geological Survey of Finland. Report YST-90. Espoo, 1995. 36 pp.

Lukashov A.D. Geomorphological characteristics // Biotic diversity of Karelia: conditions of formation, communities and species. Karelian research Centre. Petrozavodsk. 2003. P 12-17.

Medvedev P.V., Makarikhin V.V. Stromatolites in the Palaeo-Proterozoic ^{13}C-Enriched Carbonate Successions of the Fennoscandian Shield. //EUG XI, Sinip. EVO4, Strasburg, 2001, p. 191-192.

Melezhik V.A., Fallick A.E., Medvedev P.V., Makarikhin V.V. Extreme $^{13}C_{carb}$ enrichment in ca. 2.0 Ga magnesite-stromatolite-dolomite-"red beds"association in a global context: a case for the world-wide signal enhanced by a local environment. //Earth-Science Reviews, 48, 1113. 1999, p. 71-120.

Melezhik V.A., Fallick A.E., Medvedev P.V., Makarikhin V.V. Palaeoproterozoic magnesits: lithological and isotopic evidence for playa/sabkha environments. //Sedimentology, v. 48, №2, April 2001, p. 379-397.

Melezhik Victor A., Fallick Antony E.,Makarikhin Vladimir V., Lyubtsov Valery V. Links between Palaeogeography and rise and decline of stromatolites: Fennoscandian Schield. //Prec. Research, 82, 1997, p. 311-348.

Ojakangas R.W., Marmo J.S., Heiskanen K.I. Basin evolution of the Paleoproterozoic Karelian Supergroup of the Fennoscandian (Baltic) Shield). // Sedimentary geology, 2001, v. 141-142, p. 255-285.

Panasenko, G.D., 1980. Seismichnost vostochnoi chasti Baltijskogo schita. In: Seismichnost I sovremennije dvizhenija zemnoi kori vostochnoi chasti Baltijskogo schita. Apatity, p.7-24.

Pisarevsky S.A. and Sokolov S.J. The magnetostratigraphy and a 1780 Ma palaeomagnetic pole from the red sandstones of the Vazhinka River section, Karelia, Russia. Geophys. J. Int. (2001) 146, p. 531-538.

Resources and geochemistry of Karelia's underground waters. Petrozavodsk, 1987, 151 p.

Saarnisto M., Gronlund T., Ekman I. Lateglacial of Lake Onega - contribution to the history of the eastern Baltic basin // Quaternary International. Vol. 27. 1995. P. 111-120.

Saarnisto M, Saarinen T. Deglaciation chronology of the scandinavian Ice Sheet from the lake Onega basin to the Salpausselkya End Moraine //Global and Planetary Changes.31. Elsvier Science. 2002. p. 383-405.

Svetov S. A., Smolkin V.F. Model P–T Conditions of High-Magnesia Magma Generation in the Precambrian of the Fennoscandian Shield // Geochemistry International, Vol. 41, No. 8, 2003, pp. 799-812.

Svetov S.A., Svetova A.I. Accretion-collision model for the formation of Archean greenstone belts in the central Karelian craton // in Weihed P, Golubev A. (eds) Abstract volume & Field trip guidebook, 3rd annual GEODE- Fennoscandian field workshop on Paleoproterozoic and Archaean greenstone belts and VMS districs in Fennoscandian Shield, Russia, SC "Mineral"& Karelian Research Centre, 2001, pp.82-83.

Svetov S.A. New data on geochemistry of the oldest 2.95-3.05 Ga andesite association in Eastern Fennoscandia //Doklady Earth Sciences, Vol. 389, No. 2, 2003, pp. 195–198.

Svetov S.A., Huhma H., Svetova A.I., Nazarova T.N. The Oldest Adakites of the Fennoscandian Shield // Doklady Earth Sciences, Vol. 397, No. 6, 2004.

Yelina G., Lukashov A., Yurkovskaya T. Lateglacial and Holocene in the East Fennoscandia (palaeovegetation and palaeogeography), Karelian research centre. Petrozavodsk 2002. 241pp. (in Russian.)

Wohlfarth B., Bennike O., Brunnberg L., Demidov I., Possnert G., Vyahirev S. AMS ^{14}C measurements and macrofossil analyses of a varved sequence near Pudozh, eastern Karelia, NW Russia // BOREAS v.29 . Oslo, 1999. P.575-586.

Translated by G. Sokolov