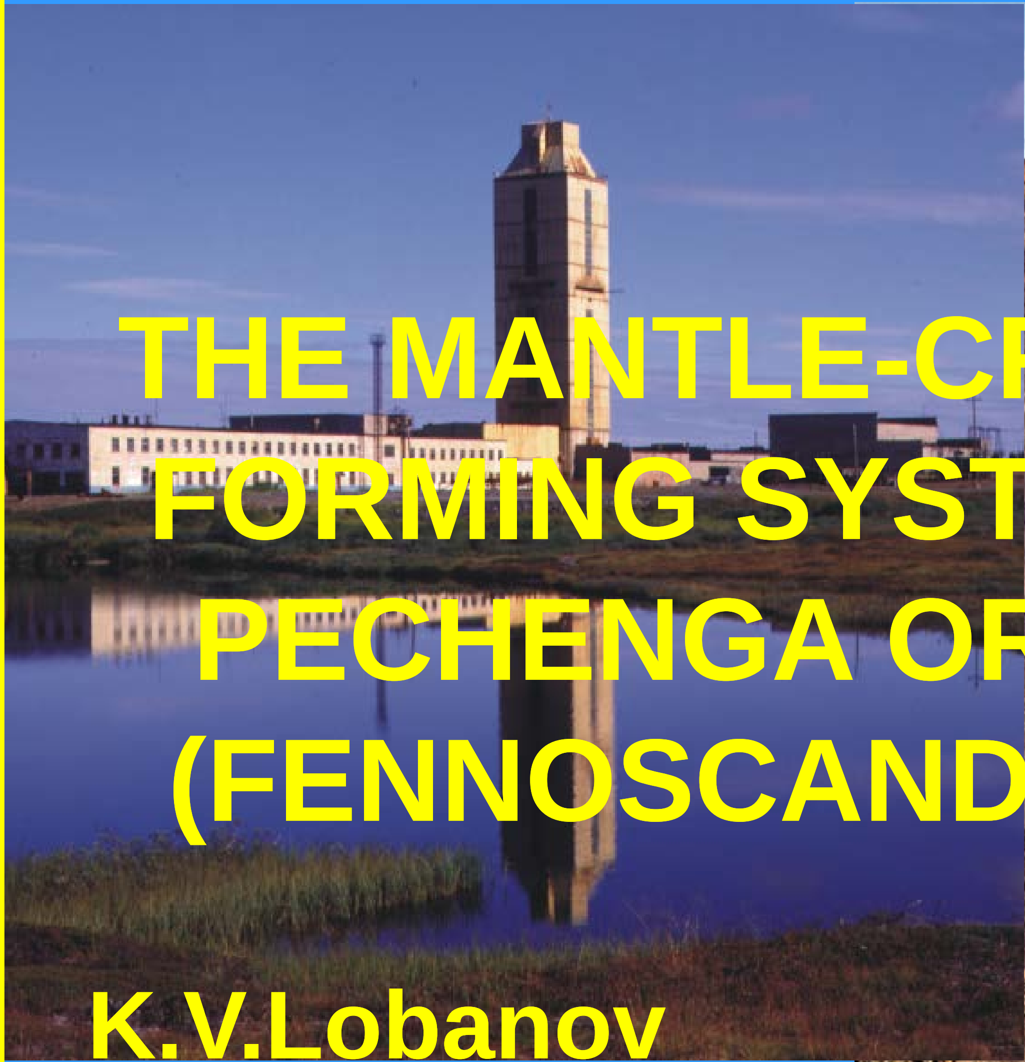


THE MANTLE-CRUSTAL ORE-FORMING SYSTEMS OF THE PECHENGA ORE DISTRICT (FENNOSCANDIAN SHIELD)

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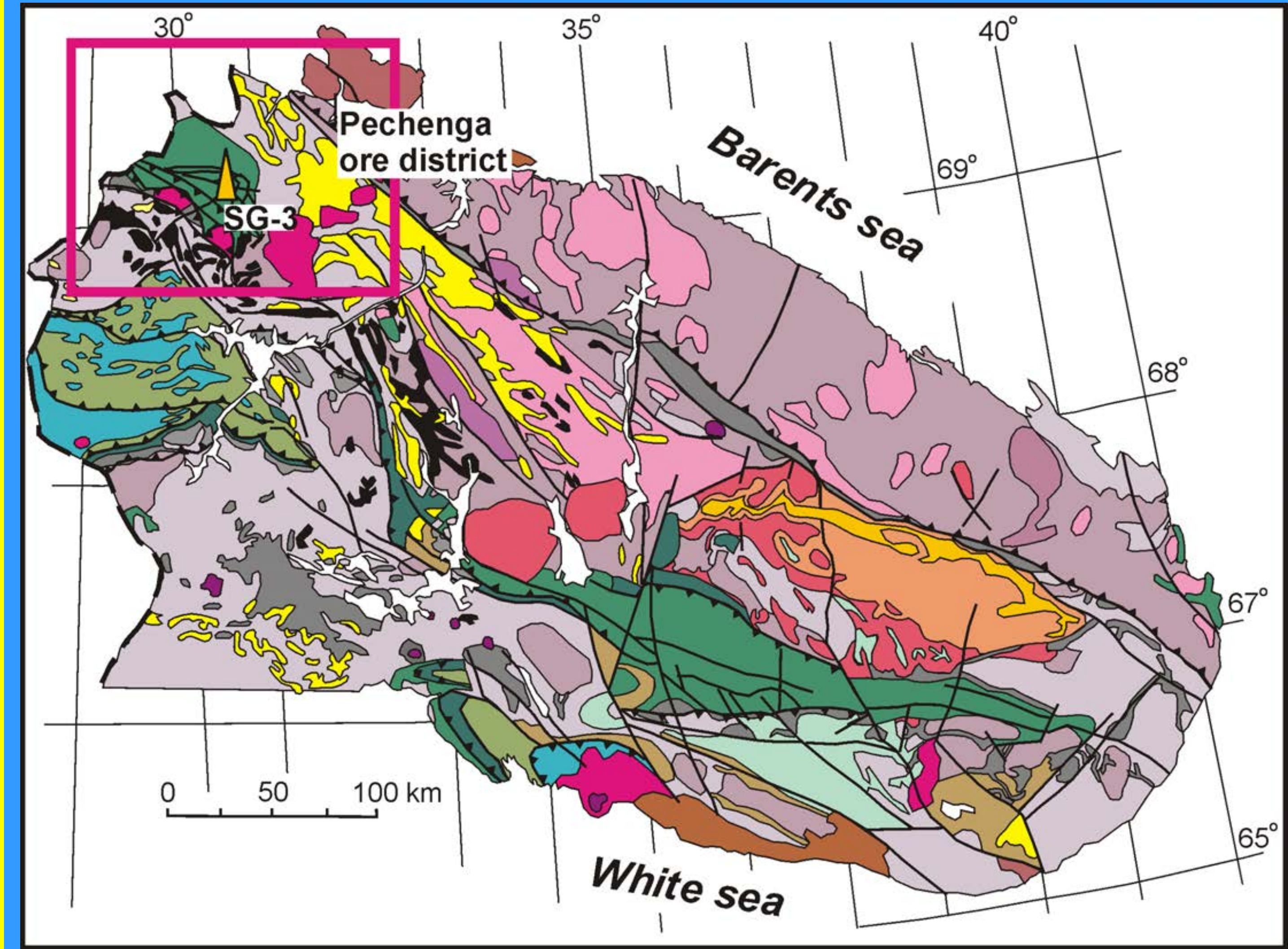
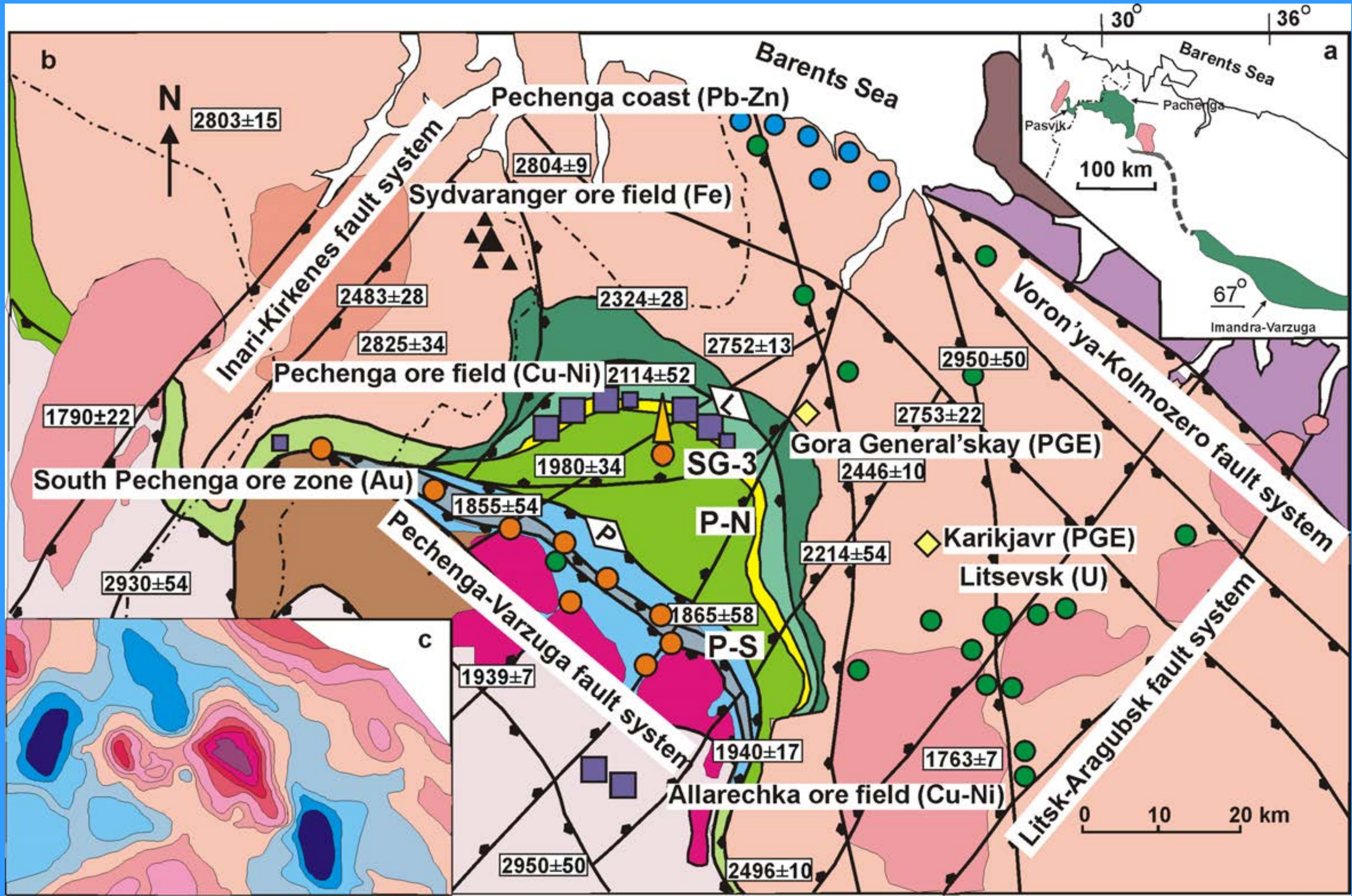


Geological seetting of the Pechenga ore district in the Northeastern Fennoscandian Shield (Mitrofanov et al., 1995)

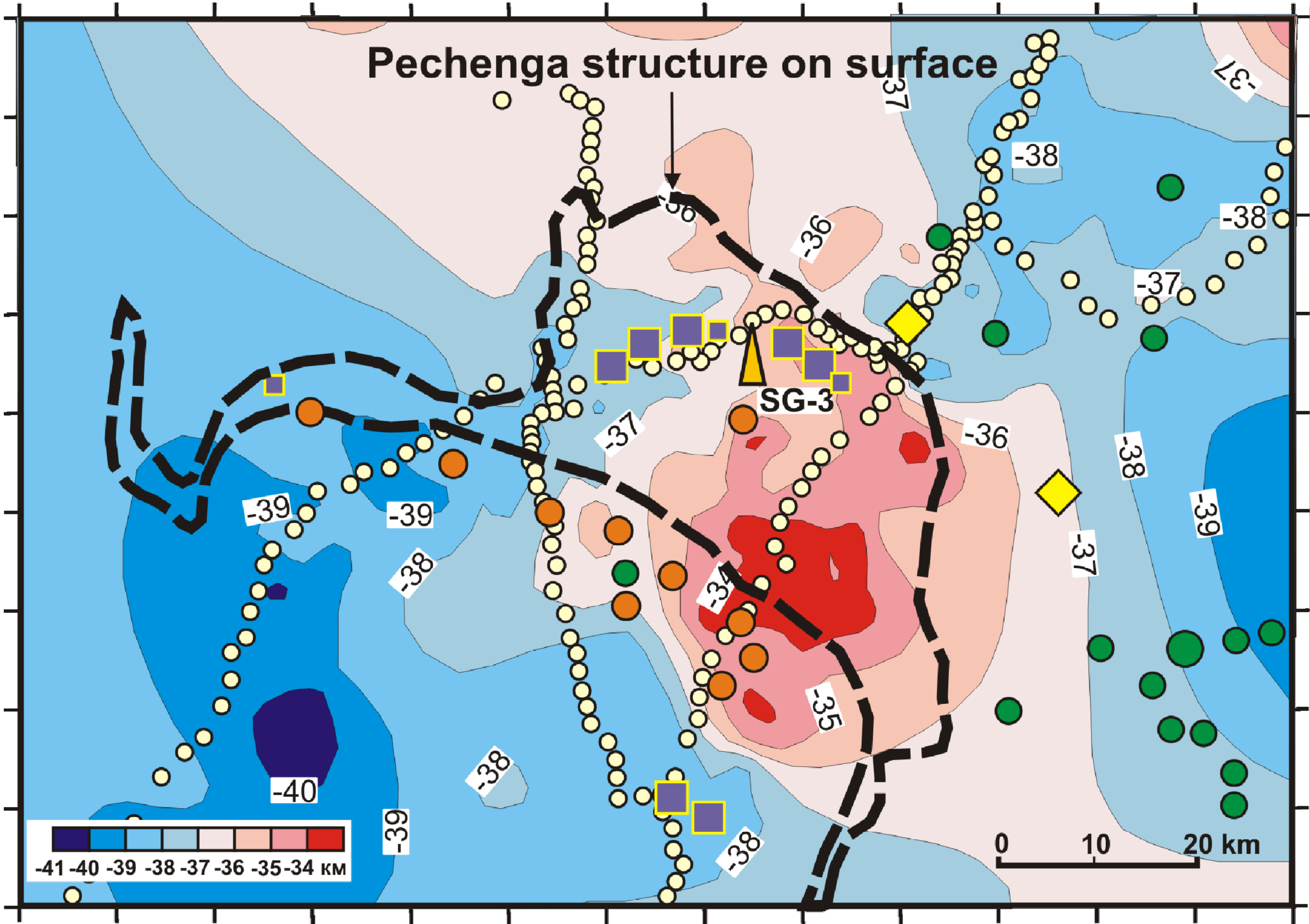
The Pechenga ore district is an isolated segment of the Pechenga-Imandra-Varzuga metallogenic zone. In the northeast the district is bound by the Voron'nya-Kolmozersk fault, in the southeast - by the Litsk-Aragubsk fault, in the northwest - by the Inari-Kirkines fault system, and in the southwest - by a Pechenga-Varzuga fault system. It should be emphasized that the main tectonic elements of the Pechenga ore district are clearly reflected in the regional gravity field.



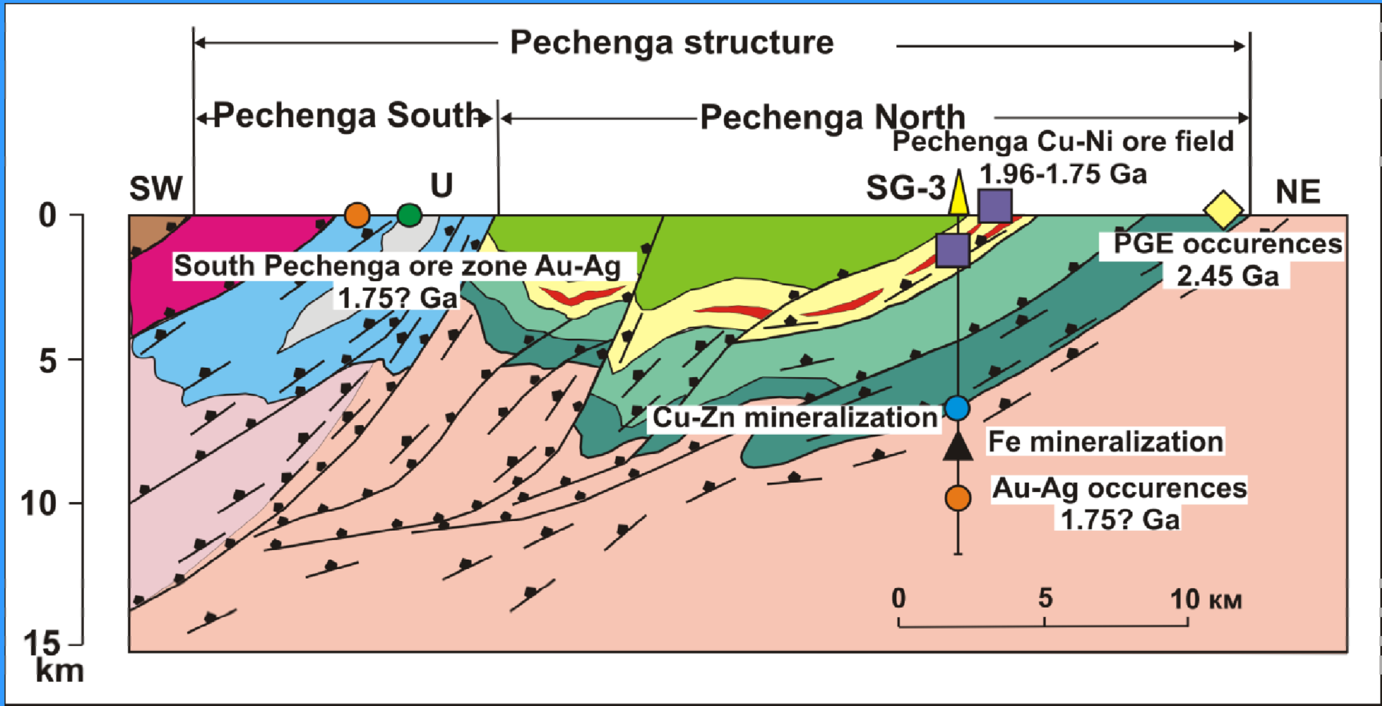
Geographical position (a), schematic geological map (b), gravity field (c) and ore deposits of the Pechenga ore deposit (Kazansky, Lobanov, 2004)

The Pechenga ore district, besides the Pechenga and Allarechka Cu-Ni ore fields, incorporates the Archaean banded iron ores of Sydvaranger, the Early Proterozoic PGE and Ni occurrences of the Gora Generalskaya, Karikjavr, the Late Archaean-Early Proterozoic radioactive mineralization of different types (Litsevsk), the hydrothermal Pb-Zn veins of probable Riphean age, and enigmatic Au-Ag mineralization discovered at deep levels of the SG-3 borehole and surface in the South Pechenga structural zone.

Depth of the Moho discontinuity relief (in km) and the Pechenga ore field (Kazansky, et al., 2002)



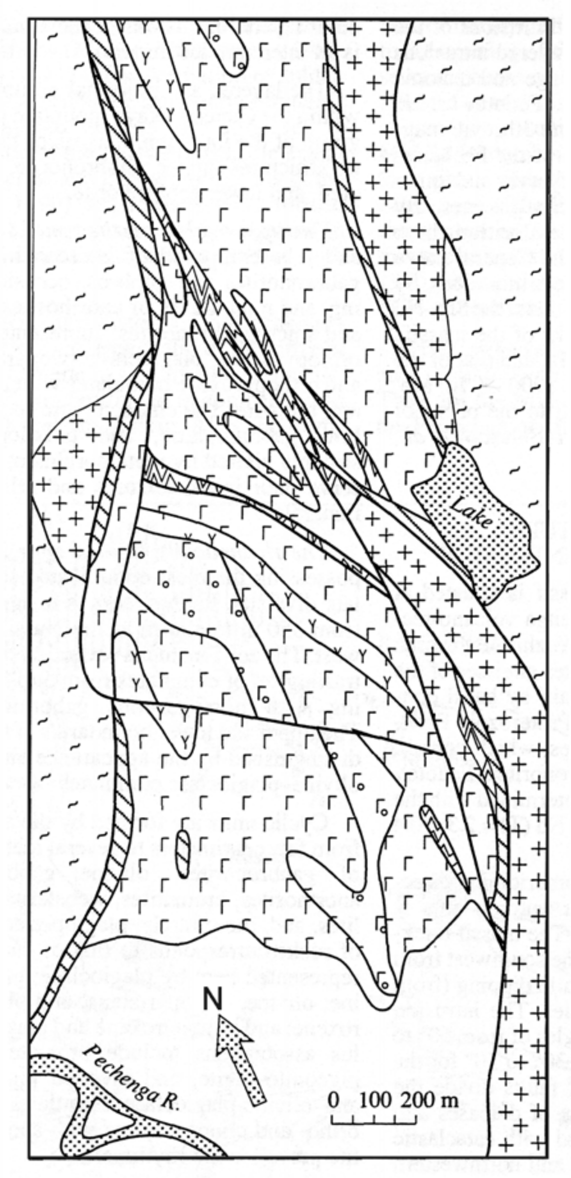
The central part of the Pechenga ore district has been selected for more detailed seismotomographic studies using some additional seismic data. It was established that under the Pechenga structure, the upper boundary of the Moho surface is located at minimal depth of 34-41 km. Based on recent geological, geophysical, petrological and metallogenic information, we regard this Moho uplift as a relict mantle plume which dominated Early Proterozoic geological events.



Geological crossection of the Pechenga structure going through the SG-3 with ore deposits and occurences (Lobanov et al., 2011)

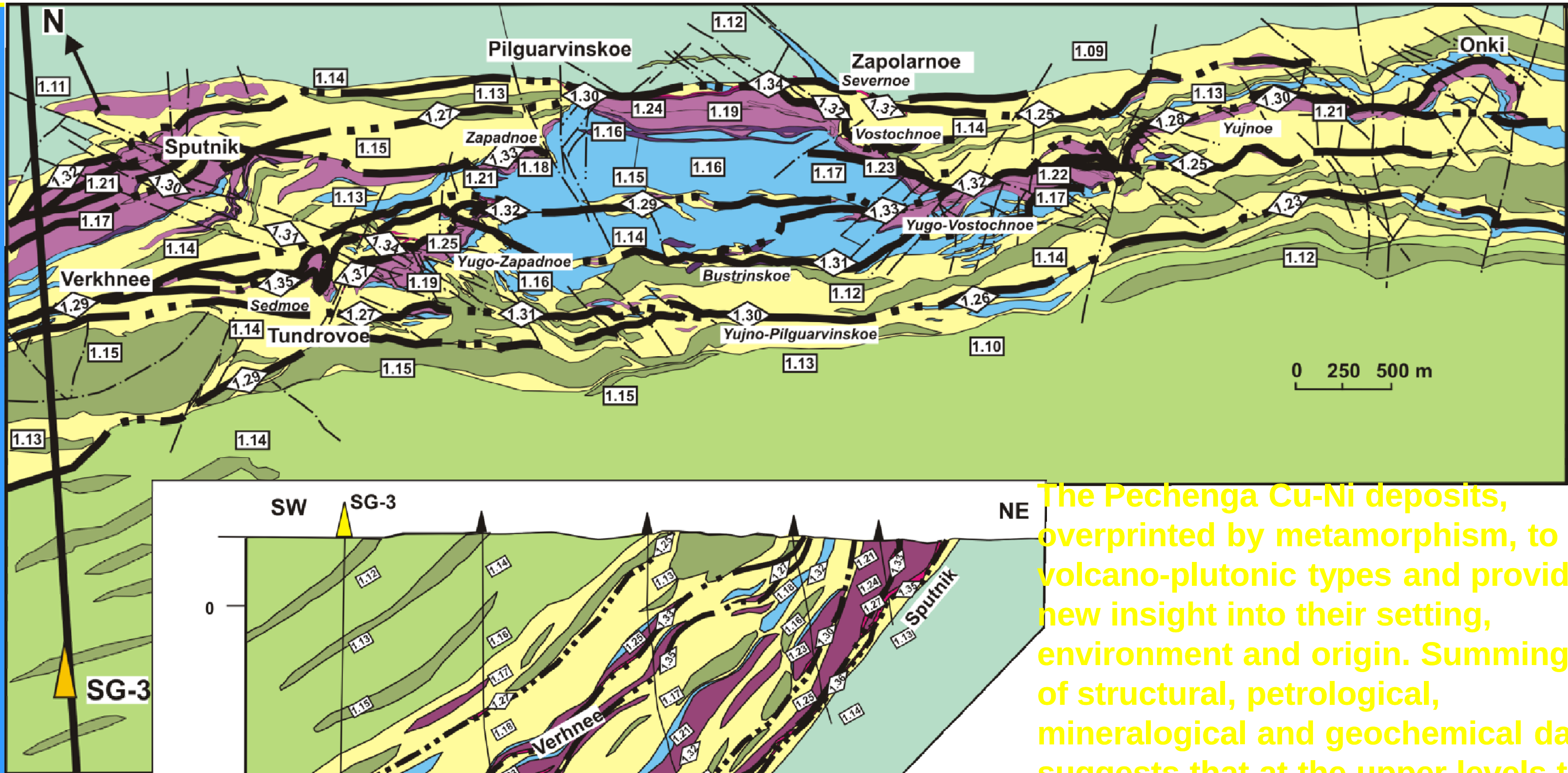
The integrated model regards the Pechenga ore district as a horizontal section of a mantle-derived volcano-plutonic ore-forming system of a central type. The model defines the Northern limb of the Pechenga structure as an imbricated fragment of a volcanic caldera and describes its Southern limb as a sheeted monocline in a juxtaposition with rheomorphic granitoid domes. Development of the system was preceded by rifting of the consolidated sialic crust. The model implies a co-genetic relationship between the Early Proterozoic basaltoid volcanism and the nickel-bearing basic-ultrabasic plutonism.

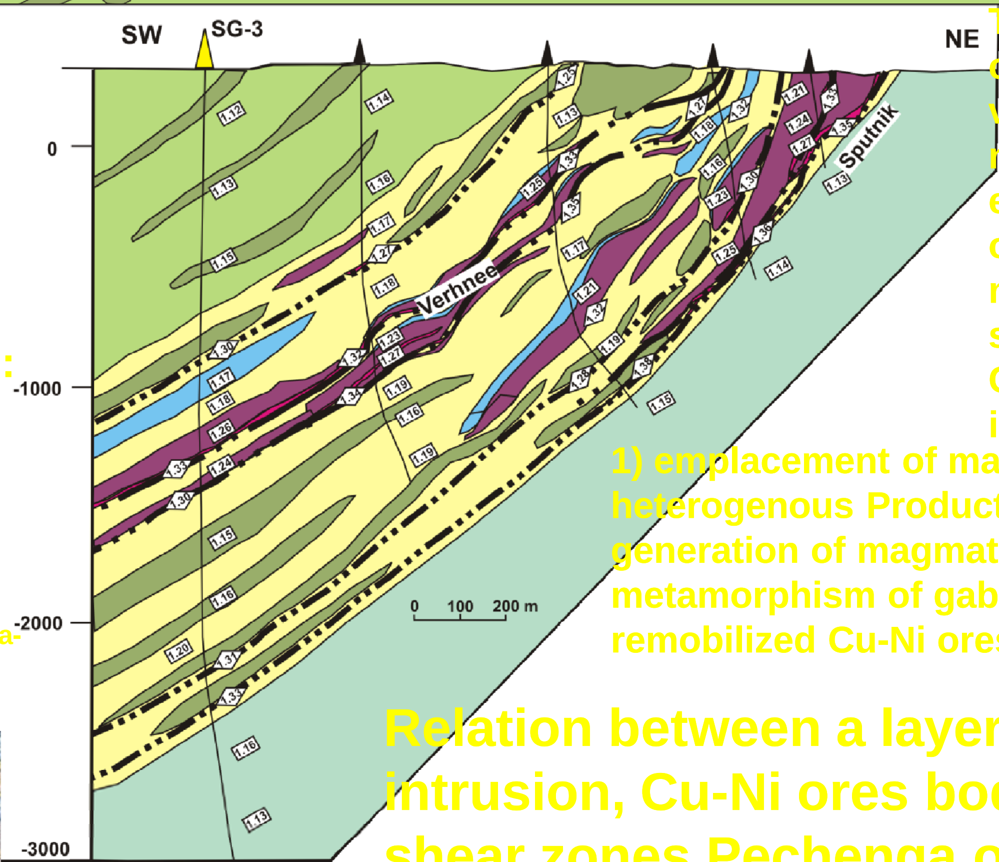
The mantle-crustal ore-forming systems of Pechenga ore district which is known for large deposits of Cu-Ni ores and deposits and occurrences of Pt, U, Au, Pb, Zn. There are three superposed systems: PGE-plutonic, Cu-Ni volcano-plutonic, and U fluid-metasomatic ores which are formed at different geotectonic conditions in the Karelian and Svecofennian (2,4–1,6 Ga) cycles. Processes of tectono-magmatic activization caused by formation of Barents sea shelf lead to transformation of these ore deposits and formation of hydrothermal Pb-Zn mineralization, Au-Ag mineralization in the SG-3 and in the South Pechenga structural zone.



The Early Proterozoic occurrence the Gora General'skaya Ni- and PGE-bearing massif mainly consists of gabbronorites and bears a small portion of olivine-plagioclase cumulates. Sulfoarsenides are characteristic of it's low-sulfide PGE mineralization. The enrichment of poikilitic and taxitic host rocks in volatile-containing minerals, abundance of nonequilibrium assemblages, rather complete PGE fractionation, and prevalence of heavy and rare PGE testify to the existence of a spreading center which was probably associated with a hot spot or a mantle plume (Grochovskaya et al., 1996). The massif was dated by zircon U~ Pb method at 2496+10 Ma (Bayanova et al. 2004).

Geological structure schema of the Gora General’skaya intrusion (Bol’shakov, 1992; Grochovskaya et al., 1996)

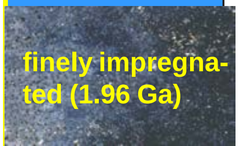




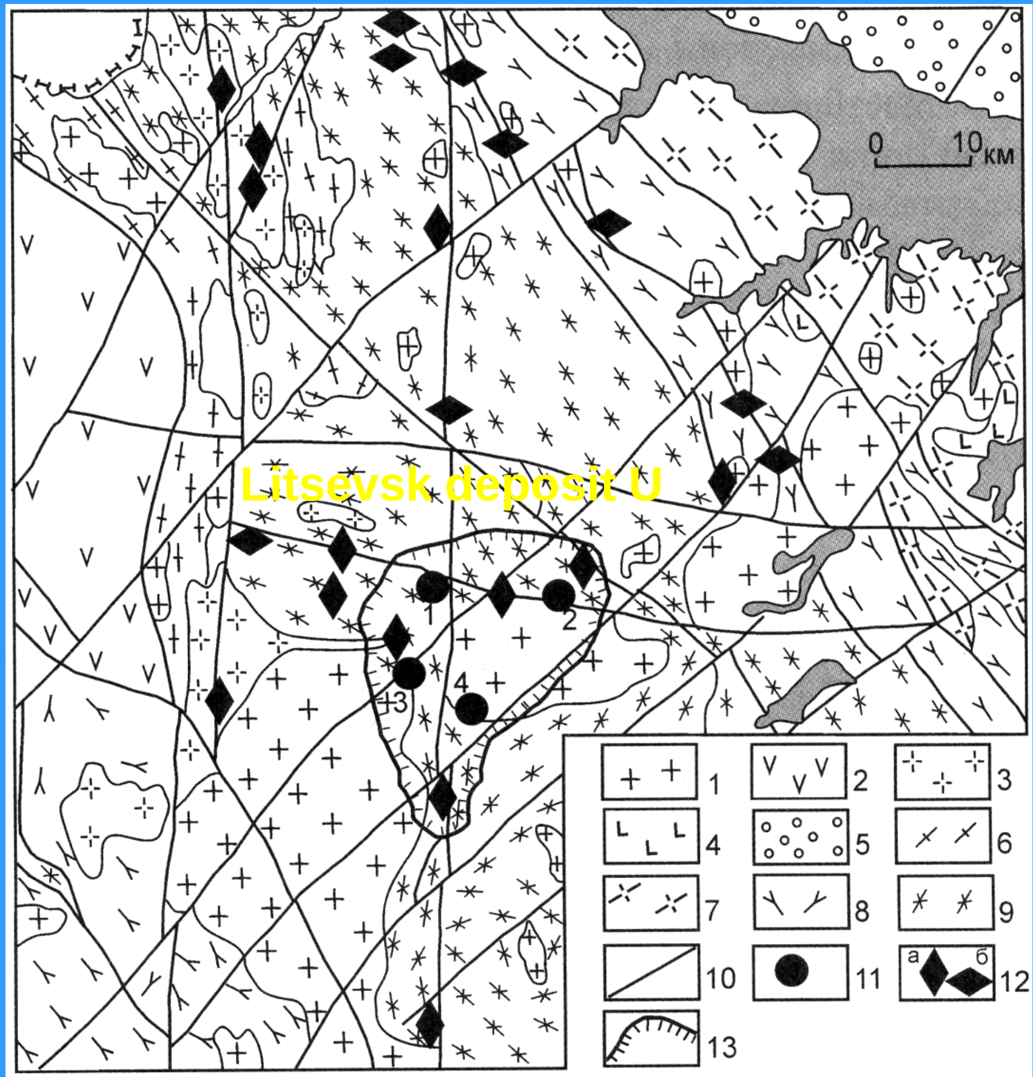
The Pechenga Cu-Ni deposits, overprinted by metamorphism, to the volcano-plutonic types and provides a new insight into their setting, environment and origin. Summing up of structural, petrological, mineralogical and geochemical data suggests that at the upper levels the Cu-Ni ore-forming system developed in two stages:

1) emplacement of mantle-derived gabbro-wherlite sills into heterogenous Productive formation, their differentiation and generation of magmatic Cu-Ni ores; 2) dislocation and metamorphism of gabbro-wherlite sills and deposition of remobilized Cu-Ni ores in synmetamorphic shear zones

Cu-Ni ores:

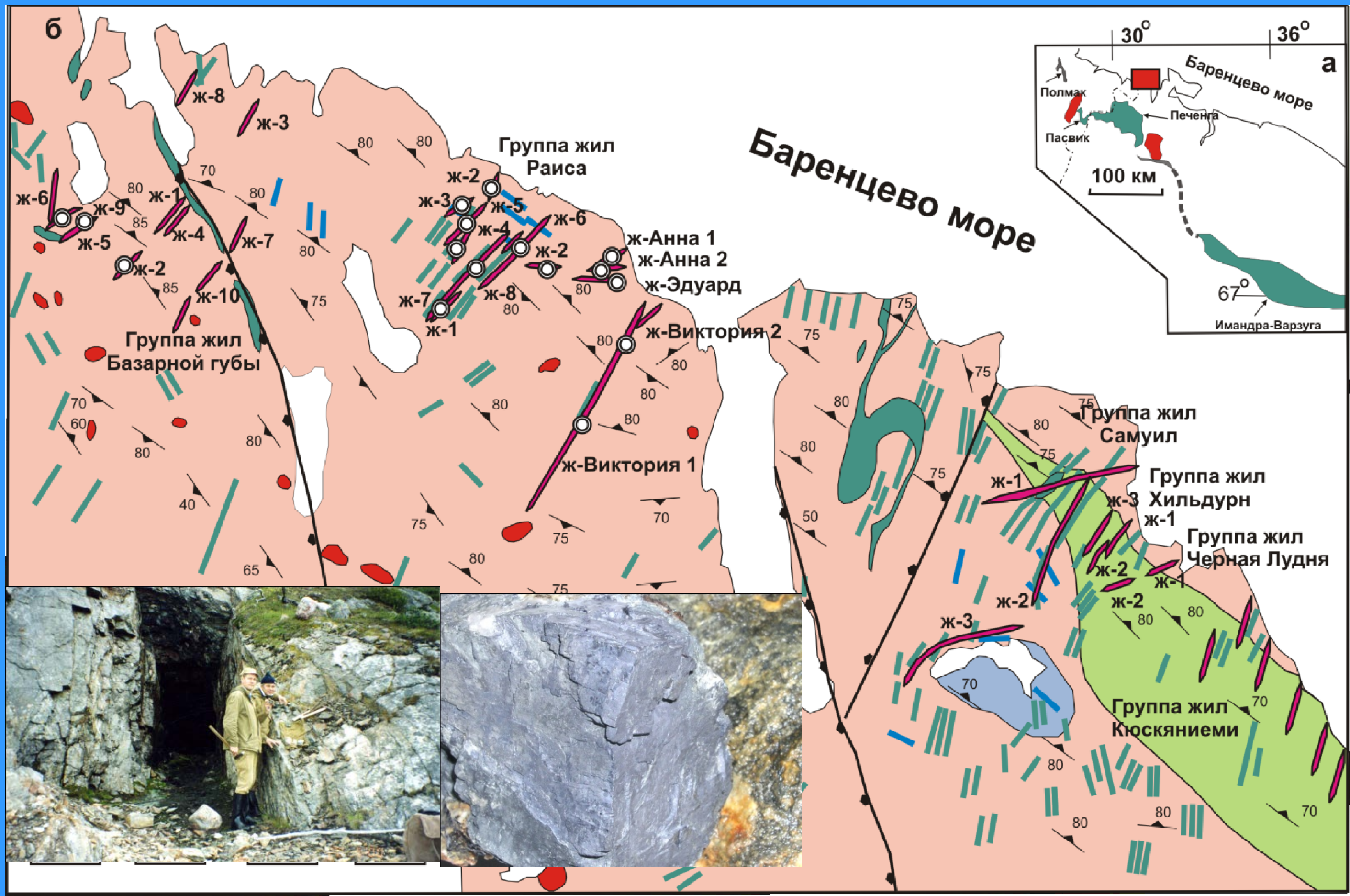


Relation between a layered gabbro-wherlites intrusion, Cu-Ni ores bodies and synmetamorphic shear zones Pechenga ore field (Lobanov, 2008)



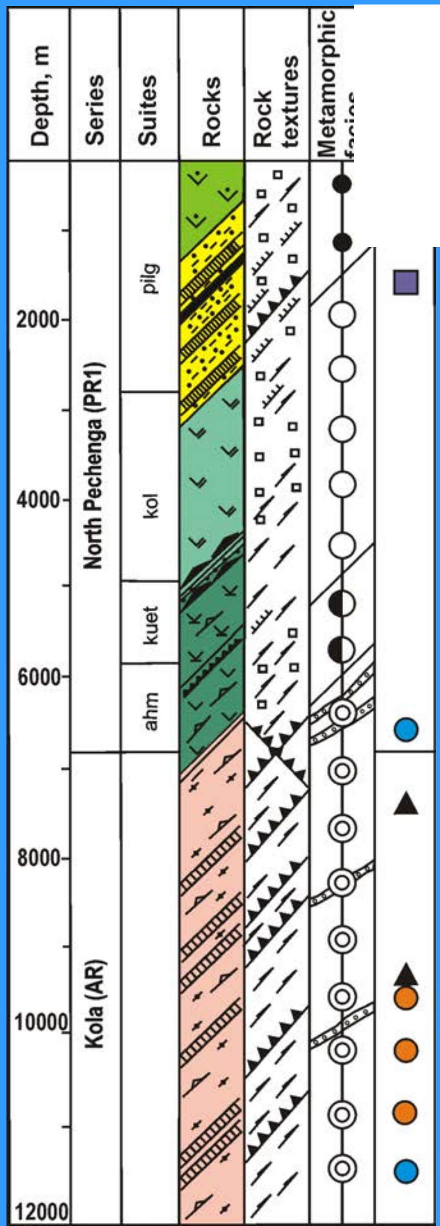
The types of uranium mineralization :
1) REE-Th-U in pegmatoid granites, quartz-plagioclase-microcline metasomatites (2750-2650 Ma);
2) U in albite-chlorite and albite metosomatites (2200-2100 Ma);
3) Th-U in quartz-albite-microcline and quartz-microcline metasomatites (1850-1750 Ma);
4) U in albite-hidromica-chlorite metosomatites (400-300 Ma)
The uranium mineralization is concentrated close to the Litsevsk and Lebyazhinsk granitoid massifs (1,76 Ga). The ores are throught to be formed by the postmetamorphic hydrothermal solutions of deep origin.

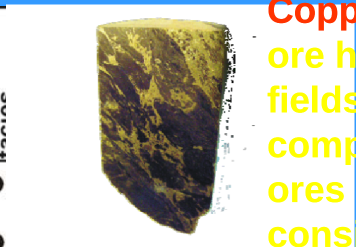
Schematic geological map Litsevsk uranium ore field of the Pechenga ore deposit (Savitsky et al., 1995)



Geographical position (a), schematic geological map (b) of Pb-Zn mineralization of the Pechenga seacoast of the Barents Sea (Kazansky et al., 1999)

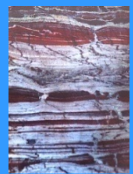
The hydrothermal lead-zinc mineralization at the Pechenga seacoast and the copper-zinc mineralization in the SG-3 section are superimposed on the Karelian structures. The detailed studies of lead-zinc and copper-zinc mineralization and regional investigations of the northwestern Baltic shield and the adjacent territory of the Barents Sea. These combined data are used to characterize the transitional zone "Land-Sea" in the Pechenga ore district and to suggest that the polymetallic ore mineralization is associated in space and time with Riphean structures of this zone. The polymetallic mineralization was formed during the Baikalian stage of the Barents shelf plate development when the Pechenga ore district was situated within a passive continental margin.



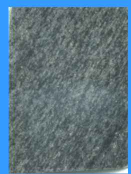


Copper-nickel ores accompany the largest intrusion (1541-1677 m), ore here occupy the same geological position, as in of Pechenga fields : confined to dealing with metaperidotite, phyllite, schist zone complicated by a consonant. For mineral composition and genesis of ores are similar to those which fall to the surface, which proves the consistency of Cu-Ni sulfide mineralization down dip to 2.5 km.

Hydrothermal sulphide mineralization in areas of established regression dislocation metamorphism in the range of 6,2-12 km. Along with disseminated most widely used sulfides - pyrrhotite, pyrite and chalcopyrite - it is represented by chlorite-carbonate-quartz veins in which there are more rare and more diverse composition of sulfides – sphalerite, galena, bornite, molybdenite, argentopentlandit



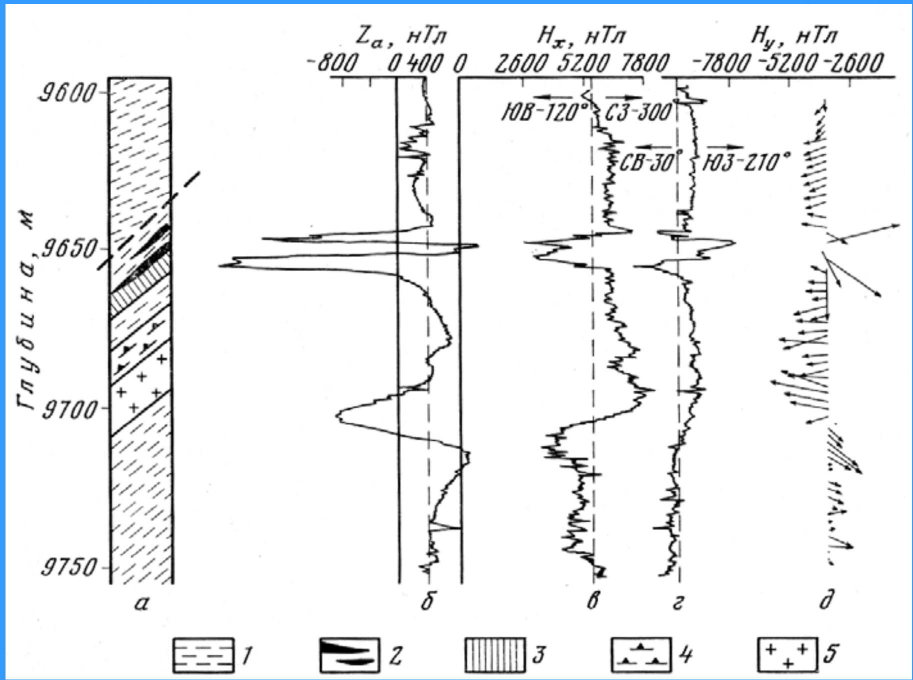
Ferruginous quartzites were found in the Kola series. They are characterized by thin alternating bands enriched in magnetite, biotite and quartz. Magnetite content of which reaches, which is typical of erruginous-siliceous formations of the Precambrian on the surface.



The iron-titanium mineralization in melanocratic biotite amphibolite Kola series found at a depth of 8711 m Based on chemical analyzes, biotite amphibolite to metamorphic ore were melanocratic gabbro.

Gold mineralization in SG-3 was found at depths of 9500-11000 m. Detailed core analysis revealed the presence of native gold is represented by lenticular segregations and irregular-shaped grains, the size is usually less than 10 microns, which are enclosed in metamor-phic minerals. The flakes of gold are located on the cleavage of biotite. Gold does not form intergrowths with other ore minerals.

Vertical ore zonality in the section of the Kola superdeep borehole SG-3 (Kozlovsky et al., 1988)

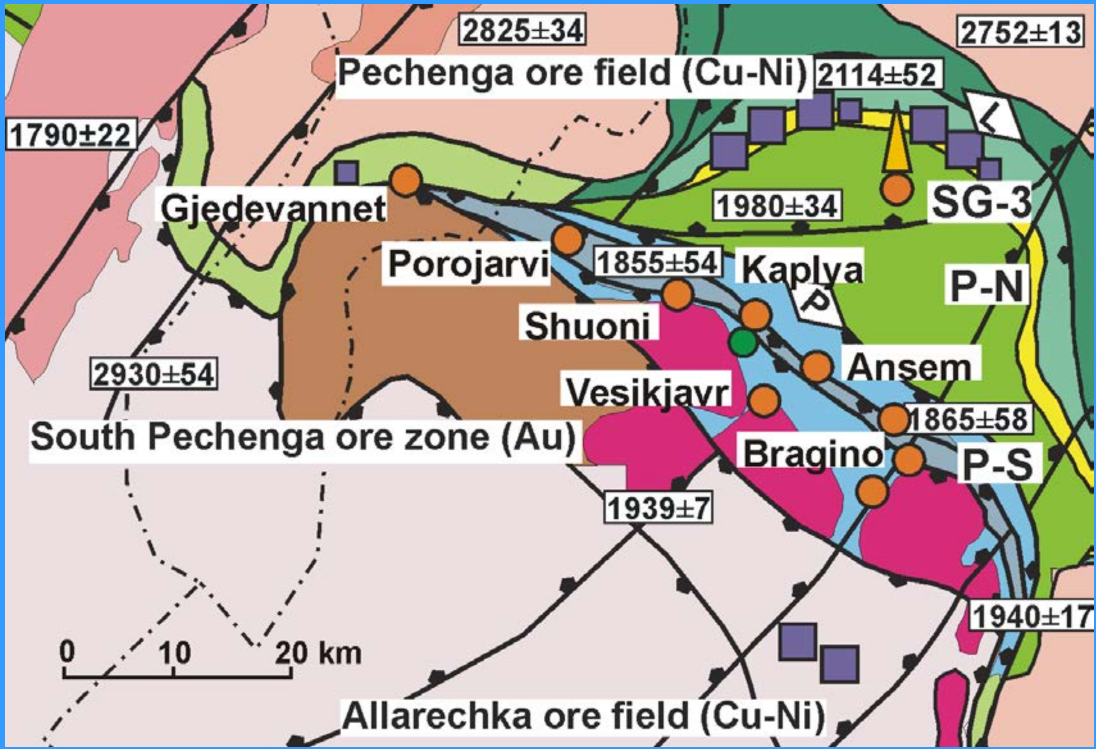


The structure of the fault in the Kola series in the interval 9600-9750 m:

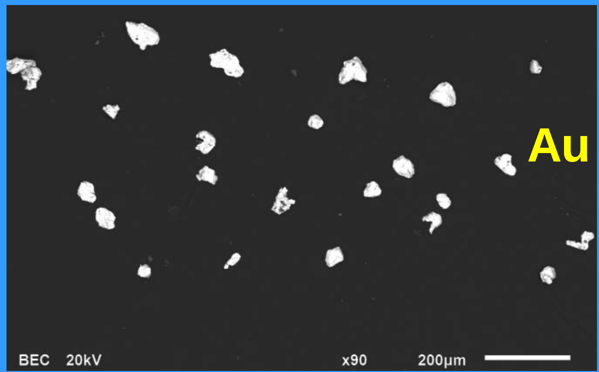
a - well cut, b - d - the results of measurements of vertical and two horizontal components of the magnetic field, Dr. - building on the field vectors in terms of: 1 - gneisses and migmatites,
2 – ferruginous quartzites, 3 - hornblendites,
4 – talc-tremolite-phlogopite schist, 5 - Proterozoic granite (1,76 Ga)

This interval is selected a length of 430 m with a high content of gold from 1 to 6.7 g/t.
Studies revealed the presence of native gold, containing approximately 25% silver and presented in small (up to 10 mk) scales, and irregular-shaped grains in biotite, hornblende, plagioclase. Gold mineralization is spatially coincides with zones of regressive changes imposed on the gneisses of the Kola series, but due dissemination gold with chloritization, sericitization, epidotization enclosing metamorphic rocks of amphibolite facies have been recorded.
It is established that the upper bound of this interval coincides with a major fault, dissecans Kola series at a depth of 9500-9700 m. It is fixed by a sharp transition from the flatlying biotite-amphibolite gneiss and steeply ferruginous quartzites, hornblendites, talc-tremolite-phlogopite schists and dykeEarly Proterozoic (1.76 Ga) granite Litsk-Aragubsk complex.
The complex internal structure of the magnetic measurements confirm the fracture in the well.
It follows from the assumption that the structural control of gold mineralization.

The origin of gold mineralization remain obscure. Two possibilities are discussed: 1) redistribution of primary concentration in metamorphic rocks; 2) deposition from reducing subcrustal fluids.

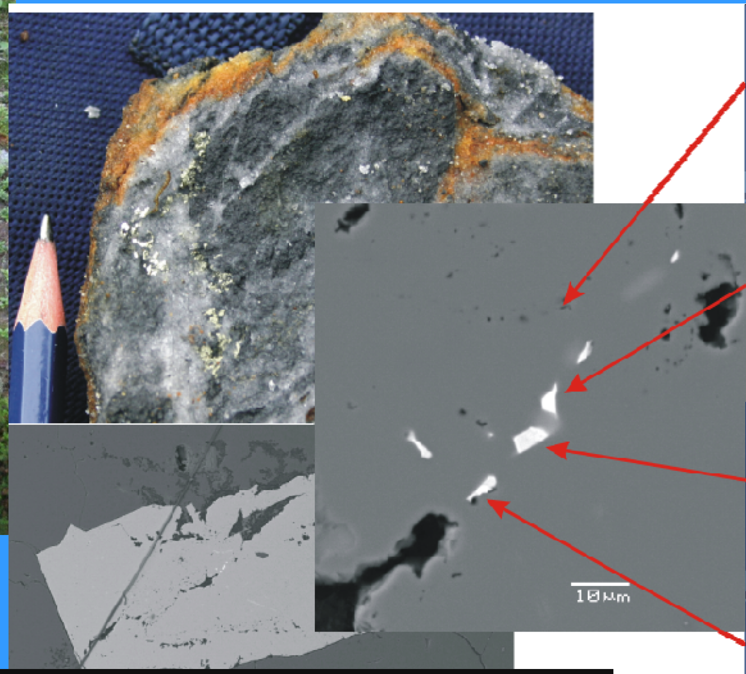


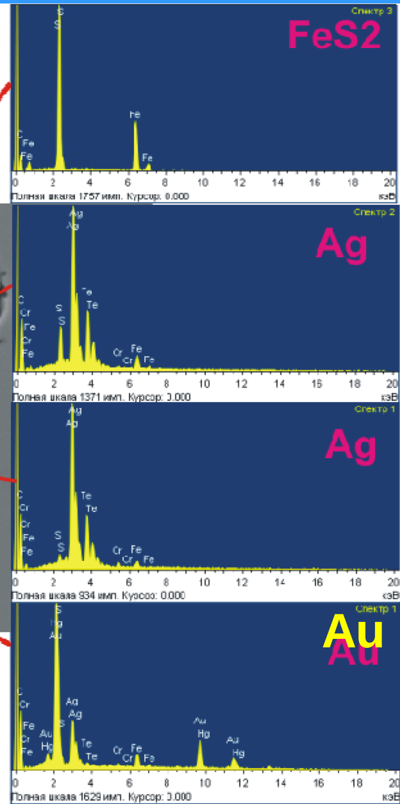
Schematic geological map of Au-Ag mineralization in the South Pechenga structure zone of the Pechenga ore district (Lobanov et al., 2011)

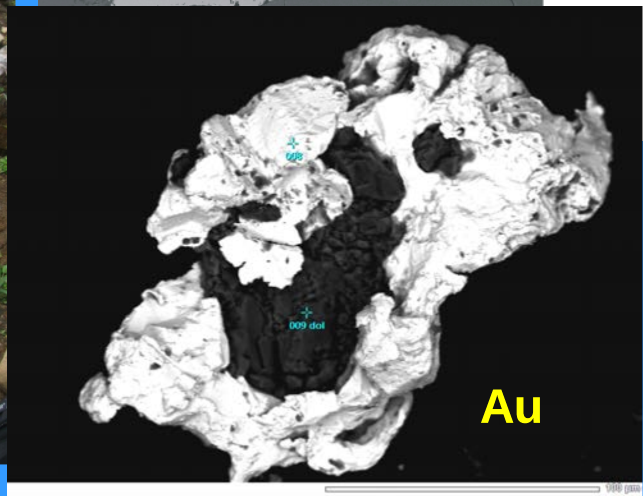


The South Pechenga structure zone as installed many occurrences of gold content on these sites varies and is determined by the composition of volcanic rocks (1,86 Ga) the nature of the changes the direction of faulting, deformation features, developed in a particular manifestation, and finally coupled with small granitoid intrusions and basic composition. Are the most important occurences of Au with lenticular horizons of quartzite and metasomatic silicification zones. Depending on the source of formation of transverse faults and occurences of later superimposed processes vary their power, the length of the horizons, mineral composition and character of gold-bearing specialization.

In all types of occurences of Au forms a self-selection of different sizes, forming a fusion of mainly pyrrhotite, ferrous carbonate, similar in composition to the siderite, and much less with a nickel-containing pyrite, arsenopyrite, magnetite, native galena. Microprobe studies of Au particles and minerals associated with them showed that they are relatively high-grade Au, containing a relatively small amount of silver.

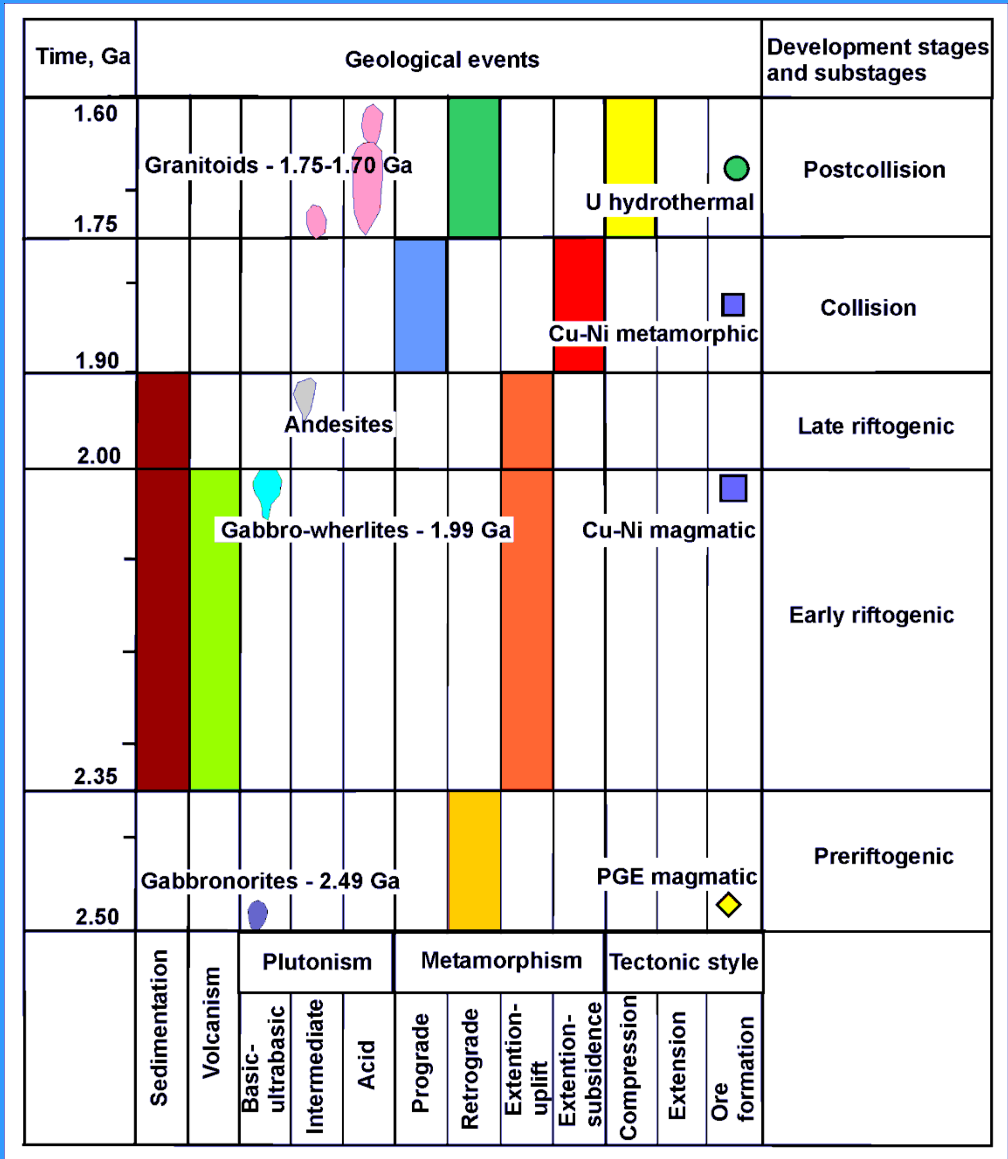






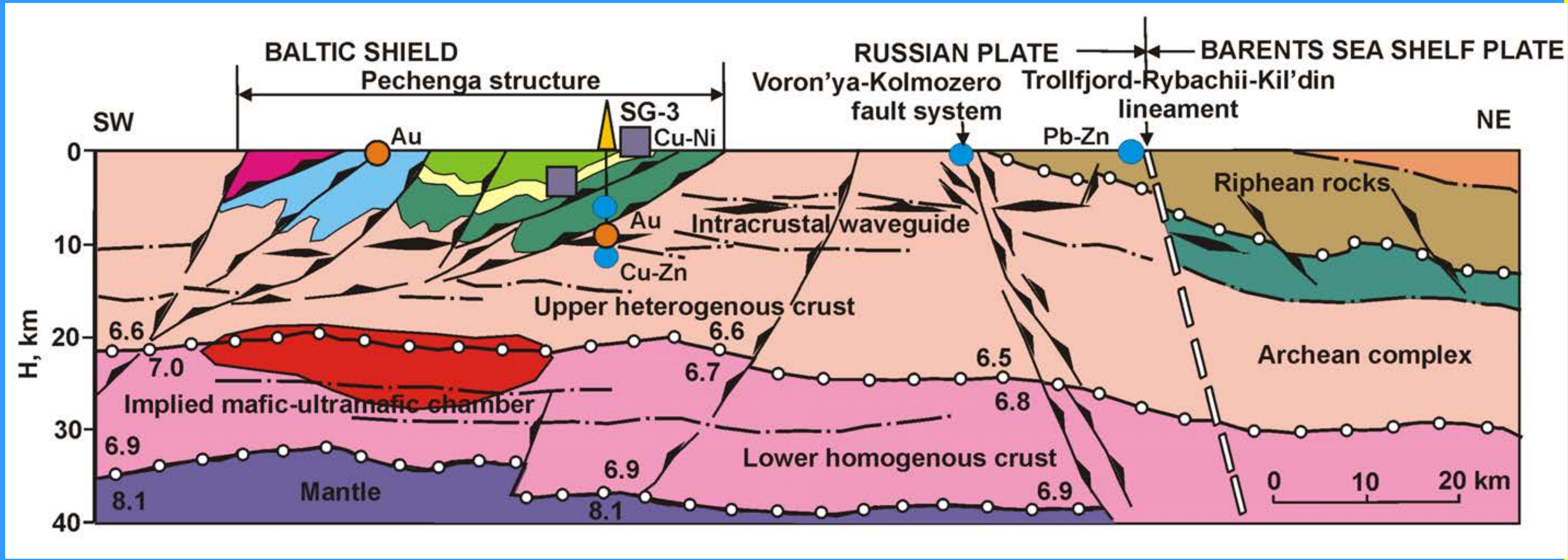
The gold mineralization in metasomatic quartzites of the Porojarvi deposit

The gold mineralization are associated with zones of cataclasis, and metasomatic alteration of rocks by developing South Pechenga structural zone. Gold in quartzites is presented in the form of small (micron) precipitates, distributed unevenly among the micrograins quartz, as well as sulfides (1,75 Ga?).



The Early Proterozoic metallogeny of the Pechenga ore district was determined by the mantle-crust interaction. During the Karelian and Svekofennian cycles (2.5-1.6 Ga), the role of the mantle sources and processes gradually decreased, while the significance of the crustal phenomena increased. Consequently, the Ni-PGE mineralization of Gora General'skaya was followed by the Cu-Ni deposits of the Pechenga ore field, and then, by U-bearing alkalic metasomatites (Litsevsk deposit). The combination of geological and seismic data allows us to correlate the Early Proterozoic metallogeny of the Pechenga district with the evolution of a mantle plume.

Time-event chart for the Karelian and Svekofennian cycles in the Pechenga ore district (Kazansky et al., 2009)



Relation between mantle and crustal structures of the Pechenga ore district (Kazansky et al., 2005)

The analysis of the available seismic, geological, and petrophysical data provides the basis for distinguishing three types of first-order seismogeological boundaries: (I) the base of the Earth's ancient continental crust, (II) interface between the lower homogeneous and upper heterogeneous layers of the crust, and (III) interface between the Precambrian basement and unmetamorphosed Riphean rocks. All of these boundaries affect the metallogenic zoning of the Pechenga ore district. Seismogeological boundaries I and III are more important. The distribution of ore deposits of the Karelian and Svekofennian cycles correlates with boundary I, while the low-temperature hydrothermal polymetallic mineralization superimposed on the Karelian structures is generally confined to boundary III.


Au
Thank you for your attention!