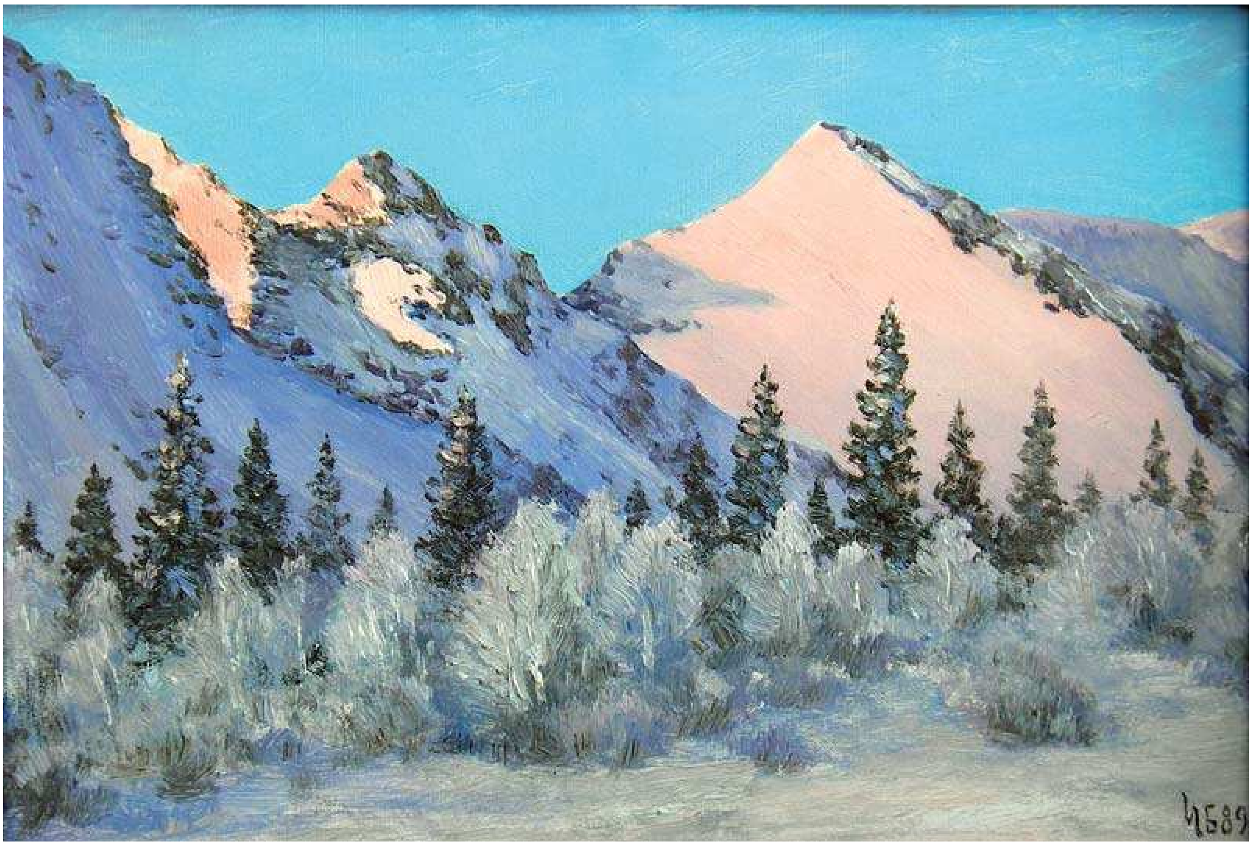
Alkaline Magmatism of the Earth and related strategic metal deposits



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The present volume was prepared for the XXXII international conference Alkaline Magmatism of the Earth and Related Strategic Metal Deposits. It contains short papers representing the frontier of geological, geochemical, petrologic, mineralogical and isotopic research on alkaline rocks, carbonatites and their associated deposits of critical (strategic) metals. The contributions assembled here address key problems of igneous petrology and metallogeny, including lithospheric and sublitospheric mantle processes, evolution of magmas from their mantle sources to highly differentiated systems, and behavior of critical metals in igneous and supergene environments. Some of the contributions discuss current issues facing critical metal exploration and extraction technology.

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The cover picture of "Pink mountains" (Khibiny, oil on canvas, 1989) was painted by artist Belkov I.V.

Belkov Igor Vladimirovich was doctor of geology-mineralogy sciences, director of the Geological Institute KFAN the USSR from 1961 to 1985. He was greatest scientist in the field of geology, geochronology, petrology, mineralogy and metallogeny of granites and genesis of metamorphic rocks. Together with Batyeva I. D., he discovered the Sakharyok and Kulyok alkaline massifs in the Kola Peninsula.

Composition of mineral-forming environment of Kulemshor rare metal occurrence (Subpolar Urals)

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Rare, REE, radioactive metal mineralization is localized in cataclased and albitized granites in the Kulemshor area in the southern part of Torgov-Keftalyk granite massif (upper courses of the Torgovaya River, Subpolar Urals) (Udoratina et al., 2014b).

Ore-bearing granitoids are located in Riphean metamorphites of Central Ural uplift (southern part of Lyapinsky anticlinorium). The granitoids show changing microstructures from graphitic granite to structures of initial cataclase and to emergence of signs of initial milonitization. Dynamometric transformations are defining for localization of complex mineralization.

The sampled rocks were studied in transparent thin sections made on epoxy base and polished sections, because the crushed samples do not reveal ore minerals. Large quantity of zircon is observed together with uranium-thorium, rare metal and REE minerals, which is dispersed inside veinlets and composed of micrograined (1-10 mcm) aggregates.

Minerals, forming the rare metal-rare earth mineralization, are as follows (Udoratina, 2014d): (a) main – fergusonite, yttrialite, aeshynite, baestnesite; (b) rarer: thorite, fergusonite (including Yb- or Dy- selectively enriched), xenotime, monacite, synchysite, calcioancylite, brannerite, policrase, columbite, Nb-rutile, baddeleyite; (c) single: herenite-(Y), thorianite, various thorium phosphatosilicates. Primary minerals of niobium are fergusonite, columbite, Nb-rutile as inclusions in ilmenite or small separate individuals, for thorium – thorite (inclusions in primary zircon). REE primary minerals are monacite, xenotime and zircon. Imposed minerals are observed as fringes and margins of grains of rock-forming minerals and also fill the fractures and intergranular space. Imposed mineralization formed as a result of primary accessories transformation – allanite, titanite, apatite, zircon under influence of potassium-carbon dioxide metasomatosis.

BSE images revealed relation between rare metal ore minerals with zircon generation without certain crystalline shape and with rather specific look (Udoratina et al., 2014a). Distribution of ore minerals and zircon underlines cataclastic microstructure of the rocks. In these local zones, enriched by ore accessories, total Th+U, Nb+Ta, Zr, HREE content sharply, in tens times, increases.

Two types of zircons were found: primary crystals Zrn_1 (fig. 1, a), and plumose-lens-like aggregates of small crystallites Zrn_2 located in intercataclase space and with a complex look (fig. 1, b). We consider this zircon as newly formed.

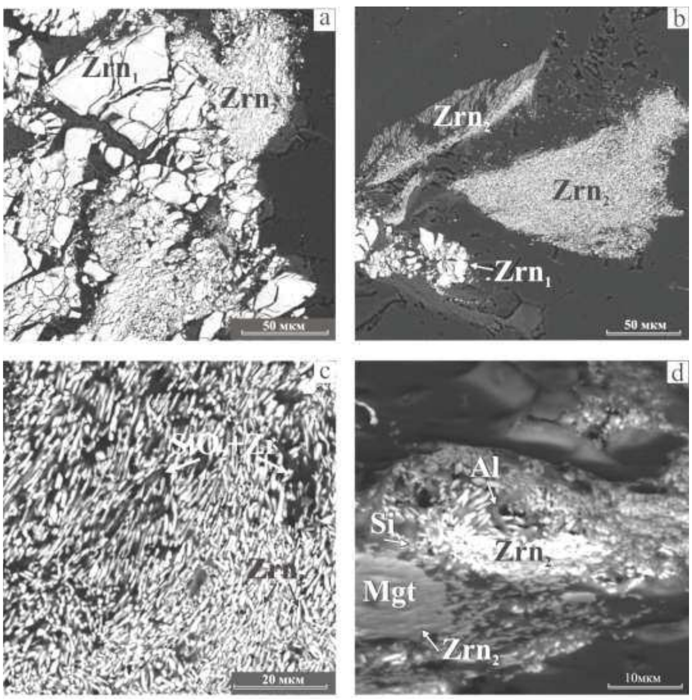

Fig.1 Examples of morphology of crystals and zircon aggregates: a – crystals of primary cataclased zircon Zrn_1; b – "flowing" structure generated by regenerated crystals of zircon Zrn_2, their intrusion in minerals; c – view of the regenerated crystals of zircons; d – regenerated crystals Zrn_2 in the alumosilicate matrix

The conducted isotope-geochemical studies revealed (Udoratina et al., 2014c) that apart from newly formed crystallites Zrn_2 the newly formed (non-cataclized) crystalline zircon Zrn_3 (grey in cathodoluminescent imaging) occurs here. The studies revealed that Zrn_1 substance was inherited and redistributed, but newly formed Zrn_3 shows sharply increased content of light rare earth elements. The age of magmatic (primary, cataclase) zircon Zrn_1 is 540.0±8.1 Ma, the age of newly formed crystallites Zrn_2 is impossible to determine due to small sizes less 20 mkm, the age of newly formed (non-cataclased) zircon Zrn_3 is 249.0±30 Ma.

Thus, we determine that the observed zircon structures formed in the process of metamorphic and hydrothermal-metasomatic transformation of primary zircon as result of cataclase (1), insignificant transfer (2) and regeneration of fragments to full crystals (3).

We studied environment where newly formed zircon crystals, associated with ore (radioactive - rare earth - rare metal) minerals, were located. According to microprobe studies it is a heterogeneous pseudoamorphous phase, in which alumosilicate matrix was observed during scanning. In some of analytic points albite and quartz was determined, but it was often impossible to determine the composition of alumosilicate, in which zirconium content is increased – protosubstance for its crystallization from heterogeneous solution (fig. 1 c-d). We think that the heterogeneous solution (suspension) transferred in intergranular space and fractures, formed at cataclase, and liquid and solid phases occurred within this solution. The crystallization of newly formed zircon crystallites occurred from hydrothermal solution enriched with ore elements and existing at temperatures and pressures that not exceeded level of epidote-amphibole and even greenshist faces.

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Titanium behavior in the Kryvbas rocks (Ukraine)

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The Kryvy Rig iron basin is a complicated Precambrian structure composed by the Kryvy Rig series strata including volcanogenic, terrigenous, sedimentary-volcanogenic and terrigenous-chemogenic beds metamorphosed at different stages of regional metamorphism. The Kryvy Rig series consists of five suites.

The dominantly volcanogenic beds of the New Kryvy Rig suite covering the Archean granitoids represent the oldest beds of the series. The New Kryvy Rig suite, up to 1500 m in thickness, occurs as amphibolites and basic schists resulted from the amphibolite alterations during later metasomatism and metamorphism. The Skelevatsk suite represents arkose-fillite beds covering the New Kryvy Rig rocks. These formations occur as clastogenic (metasandstones, metagravelites, metaconglomerates) and fillitic (quartz-sericite and quartz-chlorite schists) beds, but also as talc-carbonate metamorphic schists derived from ultrabasic volcanic rocks. The Skelevatsk suite thickness varies from tens to 300-400 m. The Saksagan suite, up to 1500 m thick, covers the Skelevatsk rocks and represents the strata of sedimentary-volcanogenic and chemogenic-sedimentary rocks consisting of seven schistose horizons divided by seven ferrous horizons. The Gdantsi suite covers different horizons of the weathered Saksagan beds represented by metaconglomerates, metasandstones, and calcareous and mica schists. Marbles and quartz-calcareous rocks are of limited occurrence in the suite. The Gdantsi suite thickness reaches 2000m. The uppermost Gleyevatsk suite units terrigenous beds consisting of metasandstones, microgneisses and quartz-calcareous rocks in the bottom section and metasandstones, metagravelites and metaconglomerates in the top section.