Kimberlite skarns: More common and more complex

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When carbonate-rich and silicate rocks are juxtaposed at high subsolidus temperature, their contrasting elemental chemical potentials trigger metasomatism. Kimberlites in contact with felsic-to-mafic rocks should theoretically develop skarn alteration, replacing both the wall rocks and magmatic rocks. Although some kimberlites are well exposed from mining, metasomatic effects in them are difficult to isolate because of the common presence of marginal country rock breccias and assimilated country rock xenoliths. The volatile-rich nature of kimberlite melts and faulting prior to the emplacement results in country rock brecciation and incorporation of as much as 70% xenoliths in kimberlite. We discuss several examples of mineralogical, textural and chemical zonation at contacts between felsic-to-mafic xenoliths, in-situ country rocks and kimberlites (Renard, Gahcho Kue, Snap Lake and Orapa). The subsolidus skarn reactions are preceded by magmatic assimilation. It partially melts feldspars and forms diopside and phlogopite coronas on xenoliths. To distinguish between incorporation and assimilation of xenoliths and contact metasomatism, we employed an improved isocon analysis that enables estimation of metasomatic contributions to geochemical diversity. Skarn reactions replace the original kimberlite minerals with serpentine, phlogopite, hydrogarnet, while xenoliths are replaced by serpentine, clinopyroxene, carbonate, chlorite, and pectolite. If the mode of felsic-to-mafic xenoliths exceeds 30%, the textures and the mineralogy of the kimberlite altered by assimilation and skarn reactions may resemble those of the Kimberly-type pyroclastic kimberlite (KPK). The distinct mineralogy of the KPK interclast matrix, the correlation between xenolith modes and the kimberlite texture, the spatial distribution of KPK in Renard and Gahcho Kue kimberlites indicate the principal role of crustal xenoliths in the KPK formation. Our data suggest that metasomatic recrystallization of kimberlites is more widespread than previously recognized, but is complex and accompanied by xenolith assimilation.
A fractal model of dike formation and variability based on Cellular Automata

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In the vast majority of cases, magma ascends towards the Earth’s surface occurs essentially through dike propagation. The vast majorities of dikes are arrested in the crust, and transform into sills or assemble into plutons and laccoliths. Magmatic fluids are also the primary metal source for the formation of the magmatic-hydrothermal mineralization. These arrested magmatic dikes are essential to the geochemical and geophysical structure of the Earth’s crust. In addition, upon arrest, the magma might be strongly out of equilibrium with the ambient condition during the process of solidification. It will immediately start to equilibrate by dissolving materials; as a result, most mineral precipitation can be expected to occur at or close to solid dikes or intrusions.

In this study, we consider the effect of density barriers on the arrest of dike propagation. A cellular automaton model was adopted to simulate the formation of dikes. Magma ascent towards the Earth’s surface through a self-organized network of rock cracks as long as the density of the surrounding rocks is greater than that of the magma fluid. If magma rises to a zone with negative buoyancy, it may be arrested, and start to solidify and become immobile; as a consequence, magmatic dikes are formed. Therefore, describing the formation process, and quantifying the irregularity and spatial distribution of the solid dikes are of great significance. Two fractal dimensional measures, Perimeter-Area (P-A) and Number-Area (N-A), were used to quantify the irregularity and spatial distribution of solidified dikes. The fractal dimensional $D_{PA}$ of P-A, as well as the fractal dimensional $D_P$ of the perimeter show that the irregularity of the solid dikes increase as the thickness of the negative buoyancy region increases from 1 km to 5 km. The N-A exponent $D$ reflects the irregular size and spatial scale-invariance of the dikes. The area of dikes is recorded during their temporal evolution, and shows $1/f$ power spectrum, typical of a fractal process. Results of the numerical model demonstrate that dike formation is a self-organized critical process, and demonstrates that a cellular automaton and fractal model is able to capture and quantify the spatial and temporal evolution of complex dike systems.
Geochemistry and geochronology of porphyry deposits in Edrene range, South west Mongolia

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Copper porphyry deposit is main source of world copper production and they genetically associate with magmatic arc, formed under subduction tectonic setting. During long history of evolution of Euro-Asian super continent in the territory south Mongolia developed Paleo Tethyan ocean in Paleozoic period and then it sequenced by subduction setting and due to this a lot copper, copper-molybdenum and copper-gold porphyry deposits formed. Therefore, Mongolia is one of the most promising country with porphyry type copper deposits in the world.

The Edrene range is one of the island arc terrane located at the south west of Mongolia and it has north east trending structure 250 km long and approximately 60 km wide. The Edrene range occurs between the Tseel and Baaran terranes and contains two distinct sequences. The northern sequence consists of Devonian metamorphosed thin-bedded argillite, sandstone, minor chert, fossiliferous limestone, volcanic rocks and Carboniferous conglomerate, sandstone and limestone intruded by Permian alkaline granite plutons. The southern sequence is dominated by Devonian and Mississippian volcaniclastic rocks, volcanic breccia, tuff, chert, clastic sediments, minor limestone, basalt and andesite. The major-and trace-element chemistry of Devonian basalts suggests an arc origin. The terrane is imbricated by thrust faults, and has experienced intense brittle-ductile deformation and greenschist-grade metamorphism.

Recent exploration activity found several Cu-Mo and Mo-Cu occurrences and deposits as well as several epithermal gold occurrences and wide range of alteration zones. We studied ore mineralogy and geochemistry of mineralization related granitoid bodies from several main porphyry deposits. We did zircon U-Pb dating granitoid rock and mineralization age by Re-Os isochrone method on molybdenite.

Granitoid rock related with porphyry mineralization show calc-alkaline magma characteristics formed under island arc setting. Age of granitoid rock range from 300 Ma to 327 Ma and mineralization age ranges from 298.8 Ma to 333.6 Ma.
Application of geoelectrochemical technique to Luoboling porphyry copper-molybdenum deposit in Fujian province, China

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Abstract: Geoelectrochemical technique was undertaken over known a blind porphyry Cu-Mo deposit and assessed the utility of the technique for identifying such deposits in the Luoboling Basin to the west of Zijinshan Cu-Au mine in Fujian province, southeastern China. The method used in the research is a low voltage dipole extraction device which is capable of collecting larger volumes of mobilized metal ions on coated positive and negative electrodes placed in the two holes between 100cm at about 20-40cm depth in the soil, connected with 9V DC battery, poured the 15% concentrated nitric acid, and backfilled the soil and left for about 48h. The electrode units were unearthed, the absorbent coatings were scaled out and digested for analysising Cu, Mo, Au, and W by ICP-MS. The results show the clear geoelectrochemical anomalies of Cu, Mo, Au, and W were detected over the Cu-Mo ore bodies in the granite porphyry body on the profile. The studies we carried out demonstrated that the geoelectrochemical technique can be applied in search for concealed porphyry Cu-Mo deposits.

Key words: Geoelectrochemical technique, Porphyry copper-molybdenum deposit, Luoboling Basin, Fujian province
Baddeleyite from Paleoproterozoic Cu-Ni and Pt-Pd reefs of oceanic and continental crust (N-E part of the Fennoscandian Shield, Arctic region)

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Baddeleyite is the most important mineral compared with zircon for precise U-Pb dating mafic-ultramafic rocks (Heaman, LeCheminant, 1993, Schaltegger, Davies, 2017). Baddeleyite from verlites of Zhdanovskoe open pit Cu-Ni Pechenga largest deposit are located of the Central-Kola megablock gave U-Pb age 1980±2 Ma. In additional similar Sm-Nd isochron age on sulfides and rock-forming minerals have been measured with 1965±87Ma for the same rocks. These isotope data are a very similar ages of the famous Bushveld complex (Mungall et al., 2016, Latypov et al., 2017). Youngest U-Pb age with 1881±9 Ma has been obtained on baddeleyite from clynopyroxenite of Kolvitsa Ti-Mgt deposit from Kandalaksha-Kolvitsa zone. Nevertheless systematically Sm-Nd isotope data for the country rocks from the two ore regions are reflected 2.3-2.5 Ga and suggested about presence of juvenile paleoproterozoic oceanic crust according to εNd value from +2 to + 5. The features of the baddeleyite crystals are characterized by absence of zircon rims and U-Pb system are a very preserve and coordinate points lie on the Concordia line. According to new LA-ICP-MS data for REE distributions and concentrations of Ti and Zr from accessory minerals after (Watson et al., 2006) there are mostly suggested about high closing temperatures (almost 1000°C) of U-Pb system in baddeleyite compared with zircon.

Single grains of baddeleyite were separated from gabbronorites, anorthosites and dykes complexes of the layered intrusions from Monchegorsk ore reion with Cu-Ni and Pt-Pd reefs, low sulfides Fedorovo-Pansky massif with Pt-Pd reefs (Mitrofanov et al., 2013, Chashchin et al., 2016) and Cr-Ti-V Imandra lopolith of the Central Kola megablock. All these giant deposits and ore regions are formed or have at the basement continental crust with TTG and grey gneisses of Eoarhaean and Paleoarhaean U-Pb zircon ages from 3.7 to 3.1 Ga (Bayanova et al., 2016). Precise U-Pb ages on single zircon-baddeleyite grains from the main gabbronorite phases of the Cu-Ni and Pt-Pd reefs of the 3 regions yielded 2.5 Ga. The second impulse with 2.45 Ga of magmatic activity with Pt-Pd reefs are connected with anorthosites from the layered intrusions of the Fedorovo-Pansky and Monchegorsk ore regions due to U-Pb data on baddeleyite-zircon gechronometer. Isotope Sm-Nd dating sulfides minerals from the gabbronorite and anorthosite the same massifs have a coeval ages with U-Pb data. Baddeleyite from gabbronorite dykes complexes of the Imandra lopolith with U-Pb age 2.4 Ga data are finale of the more than 100 Ma plume basite-ultrabasite primary fertile (EM-1,OIB, E-MORB, N-MORB) reservoirs of superlarge multimetal deposits with unique reefs (Bayanova et al., 2009, 2014, Nerovich et al., 2014, Yang et al.,2016, Huhma et al., 2018).

Features of baddeleyte crystals from Pt-Pd and Cu-Ni reefs on continental crust are characterized by less preserve U-Pb systems and points of coordinate have a small discordances. New LA-ICP-MS researches REE and closure temperatures in U-Pb system using Ti and Zr concentration in grains are suggested about low (850-900°C) temperatures of crystallization compared with baddeleyite from Cu-Ni reefs which origin in oceanic crust. Studies of PGE concentrations by laser ablation techniques on sulfides minerals implied more Pd in pyrite and Pt in pyrrhotite from the Cu-Ni and Pt-Pd reefs in oceanic and continental crust (Mitrofanov et al., 2013).

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Petrogenesis of the olivine-oxide-rich layered intrusion associated with Proterozoic Damiao anorthosite complex, China: Implications for parental magma composition

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An uncommon olivine-oxide-rich layered intrusion is revealed beneath Proterozoic Damiao anorthosite complex by deep drilling, which is in fault contact with overlying Damiao anorthosite, and is intruded by underlying Paleozoic ultramafic intrusion. It has a buried depth from 696 m to 2170 m under the surface [1, 2]. This layered intrusion is sill-like body that strikes N-E with controlled extension of 1000 m and dips S-E at about 30° with controlled depth of 1020 m [1, 2]. It is composed of alternating olivine-oxide-rich dark layers and plagioclase-rich light layers.

Precise SIMS baddeleyite Pb-Pb dating of the gabbronorite in the light layers constrains an emplacement age of 1736.4±3.1Ma. This age is consistent with the latest emplacement age (1733.8±7.3Ma) of the Damiao anorthosite complex, as constrained by baddeleyite Pb-Pb dating of the most evolved vein-like nelsonite. Close field relations, similarities in REE patterns and overlapping Nd-Hf isotopic compositions between this layered intrusion and Damiao anorthosites indicate that they formed by differentiation from a common parental magma. The narrow age span of emplacement indicates a short-lived magma chamber. Based on well-defined linear compositional trends, the composition of the parental magma is estimated as ferrobasaltic, from which high-Al basaltic magma that generally considered as directly parental to anorthosites is evolved. The olivine-oxide-rich layered intrusion represents the detached complementary mafics.