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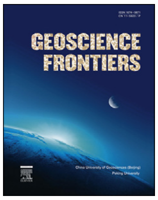

Editorial

Deep seated magmas and their mantle roots: Introduction

In the last decade there has been a considerable effort to better understand the joint evolution of mafic and ultramafic magmatic systems and their deep mantle roots, through integrated petrological and thermo-barometric studies. Magma generation is regarded as the result of complex processes including melting, creation of channels for melt transfer, and interaction with the wall-rocks. Complexities in magmatic systems involve metasomatism and the creation of metasomatic fronts, branching and splitting of magma volumes during their evolution, and variable compositional development during transfer to upper crystallizing horizons. Intrusions and formation of intermediate magmatic chambers in the upper mantle Moho or in the lower crust are often accompanied by melt differentiation according to Assimilation-Fractional-Crystallization processes (AFC). Splitting of polybaric magmatic systems brings the appearance of a wide spectrum of melt compositions. Each magmatic plume leaves its own tracers in the mantle, and can erase signs of preceding mantle magmatic events. Commonly, petrologists may focus on individual magmatic processes through the study of mantle rocks and mantle xenoliths, but there have been recent efforts to produce complex models that take into account the various aspects of such evolving magmatic system, particularly that take account of spatial and temporal changes. Such studies have also made links to modern and ancient geodynamics, and to questions of continental growth, structure of the mantle and modification of the sub-continental lithospheric mantle (SCLM).

Studies of mantle xenoliths allow for the reconstruction of deep-seated magmatic processes through a variety of processes. The papers in this special issue cover a range of these, which include: (1) reconstruction of the structure and composition of mantle roots based on pressure-temperature (P-T) estimates and detailed geochemistry of mantle and lower crustal xenoliths in deep-seated magmas such as alkali-basalts and kimberlites; (2) reconstruction of the conditions and substrate of primary and contaminated mantle magmas using whole rock geochemistry as well as the trace-element and isotope geochemistry of xenocrysts and phenocrysts; (3) discussion of the nature and development of metasomatic agents; (4) models for the origin of the stratification of asthenospheric roots reconstructed from petrological and geophysical data and their influence on the evolution of mantle melts; (5) links between high P-T experiments under mantle conditions and data obtained from the petrology of natural xenoliths and magmas; (6) models of rising mantle melts, xenoliths and xenocrysts, including diamonds, based on theoretical and petrological data; (7) thermodynamic and mathematic modeling of heterophase interaction at the top of mantle plumes; (8) oxygen fugacity of mantle rocks, and fluctuations and their mechanisms; and (9) vertical motions of the melts and solids including ascent of mantle plumes.

The ten papers in this special issue concern various aspects of ancient and modern magmatic systems, including studies on the composition and spatial distribution in the territories of the Siberian platform and adjacent areas, the geochronology and geochemistry of intra-plate magmas in varying geodynamic settings, and their relationship to plume and superplume events, particularly the Devonian superplume.

The first paper in the special issue by Sharkov et al. (2017 – this issue) is devoted to Large Igneous Provinces (LIPs) formed by mantle superplume events and their evolution in time. The transformation from high-Mg melts (during Archean and early Paleoproterozoic) to Phanerozoic-type enriched Fe-Ti basalts and picrites takes place at 2.3 Ga or earlier. As has been shown by previous authors, it was initiated by the appearance in the mantle of essential amounts of H_2O by ~2.7 Ga, and which was accompanied by the wide generation of low-degree partial mantle melts with melt fractions of <1%. The first generation plumes were derived from the depleted mantle, whereas the second generation (thermochemical) plumes originated from the core-mantle boundary (CMB). This study focuses on the second (Phanerozoic) type of LIPs, as exemplified by the mid-Paleoproterozoic Jatulian–Ludicovian LIP in the Fennoscandian Shield, the Permian–Triassic Siberian LIP, and the late Cenozoic flood basalts of Syria. The latter LIPs contains mantle xenoliths represented by green- and black-series, suggested to be the fragments of cooled upper margins of the mantle plume heads, above zones of adiabatic melting. The heads of the thermochemical plumes are comprised of moderately depleted spinel peridotites, and enriched intergranular fluid/melt intrudes the mafic lower crust. The generation of two major types of mantle-derived magmas (alkali and tholeiitic basalts) is related in this study to the fluid regime, concentration and composition of the fluids. The presence of melt-pockets in the peridotite matrix indicates fluid migration through the margins of plume heads, accompanied by secondary melting and the generation of the black series and differentiated trachytic magmas.

The second paper by Shchukina et al. (2017 – this issue) is devoted to garnet xenocrysts from the V. Grib pipe (Arkhangelsk province, Russia). This study of the trace and major element compositions from a large garnet population (150 garnet xenocrysts) from the V. Grib kimberlite divides the garnets into seven groups

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based on the concentrations of Cr_2O_3, CaO, TiO_2 and rare earth elements (REE). Detailed study and modeling results suggest several stages of mantle metasomatism, influenced by carbonatite and silicate melts. They suggest at first carbonatitic refertilization accompanied by a CaO-Cr_2O_3 trend from harzburgitic to lherzolitic garnet composition. In a second stage, the mantle was subjected to interaction with alkaline picrites. In the last stage, the garnets interacted with melts similar in geochemistry to plume basalts forming Cr-poor megacrysts.

The third paper by Kargin et al. (2017 – this issue) is devoted to the peridotite xenoliths of the Grib kimberlites, and provides new insight to the proto-kimberlite-related metasomatism in the subcontinental lithospheric mantle (SCLM) during kimberlite generation and ascent. Peridotites of the deformed group contain high-Ti, light rare earth elements (LREE), enriched garnets and low-$Mg^{\#}$ clinopyroxenes (Cpx) with low $(La/Sm)_n$. These are subjected to interaction with the carbonate–proto-kimberlite melt at temperatures of 1220 °C and pressures of 70 kbar at the lithosphere base. Low-Ti garnet with normal to sinusoidal rare earth element (REE) patterns and high-$Mg^{\#}$ clinopyroxenes with a wide range of $(La/Sm)_n$, indicates that peridotites were metasomatized by the injection of low-Ti melts percolating through a refractory mantle column (at $T = 730–1070$ °C and $P = 22–44$ kbar). It is suggested that evolution of a kimberlite magma from REE-enriched carbonate-bearing to carbonate-rich ultramafic silicate compositions with lower REE, occurs during the ascent and interaction with a surrounding lithospheric mantle, and this process leads to metasomatic modification of the SCLM.

In the paper of Ashchepkov et al. (2017a – this issue), the differences in the structure and compositional features of the lithospheric mantle beneath the Alakit and Daldyn kimberlite fields are demonstrated by the composition of clinopyroxenes and garnet from five large pipes from each field. Alkaline clinopyroxene and sub-calcic pyropes are typical of the Alakit SCLM, while in the Daldyn field harzburgitic pyropes are more frequent. Eclogitic diamond inclusions in the Alakit field are sharply divided, while in the Daldyn field they show varying compositions and more continuous P-$Fe^{\#}$ trends. The Alakit SCLM is widely metasomatized with phlogopite, Cr-pargasites and richterites; these are very restricted in the Daldyn field. The Alakit Cr-diopsides are LREE and large-ion lithophile element (LILE) enriched and have steeper REE slopes. The mantle geotherms from Alakit are linear, while in Daldyn they are stepped. The enrichment in volatiles and alkalis in the Alakit field possibly corresponds to interaction with subduction-related fluids and melts in the craton margins, while Daldyn SCLM has more similarity to oceanic mantle features.

The paper of Ashchepkov et al. (2017b – this issue) is devoted to mantle xenoliths from the Dalnyaya kimberlite pipe (Daldyn field, Yakutia), and the interaction of the proto-kimberlites with the mantle column is discussed. It produced sheared or porphyroclastic peridotites and ilmenite–clinopyroxene-garnet megacrystalline intergrowths. The orthopyroxene geotherm for the lithospheric mantle beneath Dalnyaya is stepped, similar to that beneath the Udachnaya pipe. Garnets, olivines and clinopyroxenes show trends of increasing $Fe^{\#}$ $(Fe/(Fe + Mg))$ with decreasing pressure, following the melt evolution. Re-fertilized garnets and clinopyroxenes are more enriched in incompatible and high-field strength elements compared to those from the coarse-grained varieties. Low-Cr clinopyroxenes and garnets reveal an oxidized trend (−2 to 0) ΔFMQ, while the minerals from re-fertilized xenoliths show transitional conditions.

The paper by Vladykin and Sotnikova (2017 – this issue) presents a description of the rare-metal hosting Burpala alkaline massif. It contains rocks with more than fifty minerals rich in Zr, Nb, Ti, Th, Be and rare earth elements (REE). The rocks vary in composition from shonkinite, melanocratic syenite, nepheline and alkali syenites to alaskite and alkali granite and contain up to 10% LILE and HSFE, 3.6% of REE and high amounts of other trace elements (4% Zr, 0.5% Y, 0.5% Nb, 0.5% Th and 0.1% U). Geological and geochemical data suggest that all the rocks in the Burpala massif were derived from alkaline magmas enriched in rare earth elements. The extreme products of magma fractionation are REE-rich pegmatites, apatite–fluorite bearing rocks and carbonatites. The Sr and Nd isotope data suggest that the source of primary melt is enriched mantle (EM-II). The massif was formed in the Permian (ca. 295 Ma) by a plume impacting on the metasomatized mantle at the active margin of the Siberian continent.

The paper by Kiseleva and Zhmodik (2017 – this issue) concerns the PGE mineralization of the Ospino-Kitoi and Kharanur ultrabasic massifs from the eastern Sayan ophiolites, Southern Siberia, Russia. The paper describes the mineralogy of the podiform chromitites; classified into Type I and Type II based on their $Cr/(Cr + Al)$ ratio ($Cr^{\#}$). Type I chromitites occur within the Southern ophiolite branch and are represented by the osmium-iridium-ruthenium system, while type II chromitites of the northern branch are represented by the osmium-iridium-ruthenium-rhodium-platinum system. The parental melt compositions, in equilibrium with podiform chromitites, are in the range of boninitic melts and vary in Al_2O_3, TiO_2 and FeO/MgO content. PGE mineralization in the northern branch was formed by a fluid-rich boninitic melt during active subduction. However, the chromitites and PGE mineralization of the southern branch could have formed in a spreading zone environment.

The paper by Rasskazov and Chuvashova (2017 – this issue) proposes a comprehensive model for deep dynamics of Asia based on the available seismic tomography data, stress analyses and geodynamic reconstructions. The model assumes an important role of the Gobi, Baikal, and North Transbaikal transition-layer melting anomalies in the production of the mantle melts. In the early to late Cretaceous, slab material stagnated beneath the closed fragments of the Solonker and Ural-Mongolian paleoceans and the Mongol-Okhotsk Gulf of Paleo-Pacific, producing lower mantle melt fluxes. Since the India–Asia collision, Asia was involved in east–southeast movement, and the Pacific plate subducted west under Asia. Weakened upper mantle melting anomalies are related to the opening of the Japan Sea and the Honshu-Korea flexure of the Pacific slab. In the early–middle Miocene, the low-velocity domains are associated with the development of rifts and orogens. Deviated flowing mantle material, initiated under the moving lithosphere in the Baikal region, caused extension at the Baikal Rift. The tectonic stress transfer from the Indo-Asian interaction created the Hangay orogen.

The paper by Chuvashova et al. (2017 – this issue) describes models of Cenozoic volcanism in the Vitim Plateau, Siberia. High-Mg lavas in the mid-Miocene erupted at 16–14 Ma, and were followed with voluminous moderate-Mg lavas at 14–13 Ma. The initial stage included: (1) contaminated and (2) uncontaminated high-Mg basanites and basalts of transitional (K–Na–K) compositions, and (3) picrobasalts and basalts of K series (raised from 150 km). The 14–13 Ma rock sequence is derived from garnet-free and low garnet-bearing mantle sources. The transition from high- to moderate-Mg magmatism was due to the mid-Miocene thermal impact on the lithosphere by hot sub-lithospheric mantle material from the Transbaikalian low-velocity (melting) domain, with a potential temperature of ~1500 °C. This thermal impact triggered rifting in the lithosphere of the Baikal Rift Zone.

In the final paper of this special issue, Ashchepkov et al. (2017c – this issue) present the calibration and application of new versions of the garnet and clinopyroxene mono-mineral thermobarometers. New versions of the universal jadeite-diopside exchange

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clinopyroxene barometer for peridotites, pyroxenites and eclogites, and also for the garnet barometer for eclogites and peridotites, were developed and checked using large experimental data sets for eclogitic (~530) and peridotitic (>650) systems. The precision of the universal clinopyroxene barometer for peridotites is close to that of the Cr-Tschermakite method developed by Nimis and Taylor (2000). The resulting positions of eclogite groups in mantle sections are similar to those determined with another new garnet–clinopyroxene barometer developed by Beyer et al. (2015). The Fe-rich eclogites commonly mark pyroxenite-eclogite layers at 3–4 GPa. Ca-rich eclogites including grospydites occur near the pyroxenite layer and lower, near the SCLM base. The diamondiferous Mg Cr-less group are common near 5–6 GPa. Commonly re-melted eclogites and their PT estimates trace a high-temperature convective branch. The mantle sections beneath Cenozoic alkaline basalts were also reconstructed for different geodynamic conditions; the geotherms are close to 90 mW/m^2, and are slightly colder in post-subduction mantle domains.

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