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GEOLOGY

Sources of Magmatic Rocks from the Deep-Sea Floor of the Arctic Ocean and the Central Atlantic: Evidence from Data on the U–Pb Age, Hf Isotopes, and REE Geochemistry of Zircons

A. A. Kremenetskiy[a, *], N. A. Gromalova[a], S. G. Skolotnev[b], O. G. Shuliatin[c], and E. A. Belousova[d]

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Abstract—The results of geochronological (U–Pb), isotope–geochemical (Lu–Hf), and geochemical (REEs) studies of young (MZ, KZ) and xenogenic (AR, PR) zircons from magmatic rocks of the Central Arctic rises of the Arctic Ocean (AO) and the crest zone of the Mid-Atlantic Ridge (MAR) are presented. The data obtained show that the depleted mantle could be a source of young (KZ) zircons of the MAR, whereas young (MZ) zircons of the MAR and all xenogenic (AR, PR) zircons of the AO and MAR are from crustal rocks of the continental lithosphere.

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Our study is aimed at solution of the problem of the ancient age of zircons from magmatic rocks delivered from the World Ocean floor [1–7], using the isotope–geochemical methods of estimation of matter sources for ancient and young zircons from the Central Arctic rises of the Arctic Ocean (AO) and the crest zone of the Mid-Atlantic Ridge (MAR) (Fig. 1). Concerning the nature of the sources of these ancient (AR, PR) zircons, there are various assumptions [2–5] and doubts about the preservation of an isotope "clock" for xenogenic zircons during crystallization of basaltic magma in the MAR and other parts of the ocean. As is evident from experimental data [8], zircons in ultrabasic rocks are stable up to 1525–1534°C and even at negligibly low concentrations of ZrO_2 in melts of the ultrabasic and basic compositions may crystallize as zircon, which allows us to correlate the age data of zircons with the age of rocks. There is also some evidence concerning the ability of zircon to retain an isotope "memory" [9, 10] of earlier events in granulites at ultrahigh temperature (up to 1150°C) and pressure (12 kbar), as well as in kimberlite and basalt, in which zircon may preserve radiogenic Pb under the mantle *P–T* conditions for a long time (1.3–2.5 b. y.).

We studied magmatic rocks (basalt, gabbroids, peridotite, and plagiogranite) dredged from the seafloor of the AO and MAR and obtained by deep drilling in the AO [2, 5–7, 11]. The U–Pb dating of zircon ages was performed on a SIMS SHRIMP-II muticollector secondary-ion high-resolution mass spectrometer at the Center for Isotope Investigations, Russian Geological Research Institute. The concentrations of minor elements in zircon were analyzed on an Agilent 7700 quadrupole mass spectrometer with inductively coupled plasma connected to a Photon Machines Excimer 193 nm laser system (GEMOC). The Hf isotope analysis was carried out on a New Wave/Merchantek UP-213 spectrometer with laser ablation connected to an ICP-MS Nu Plazma multicollector (GEMOC).

Figure 2 shows the graphs of U–Pb age probability for the zircons studied. They are commonly characterized by (1) the single-type continuous polychronous age series within 0.2–3200 Ma and (2) by the presence of two genetic generations of zircons in all studied rocks, namely magmatogenic (young) and xenogenic (ancient).

The concordant ages of young zircons in magmatic rocks from the crest zone of the MAR are 0.38–11.26 Ma and increase progressively with distance from the axial zone of the ridge [2]. The ages of zircons are 0.33 and 11.5 Ma in basalt from the Central Rift of

[a] *Institute of Mineralogy, Geochemistry, and Crystal Chemistry of Rare Elements, Moscow, 121357 Russia*
[b] *Geological Institute, Russian Academy of Sciences, Moscow, 119017 Russia*
[c] *Gramberg All-Russia Research Institute of Geology and Mineral Resources of the World Ocean, St. Petersburg, 190121 Russia*
[d] *Macquarie University, Sydney, Australia*
**e-mail: nauka@imgre.ru*

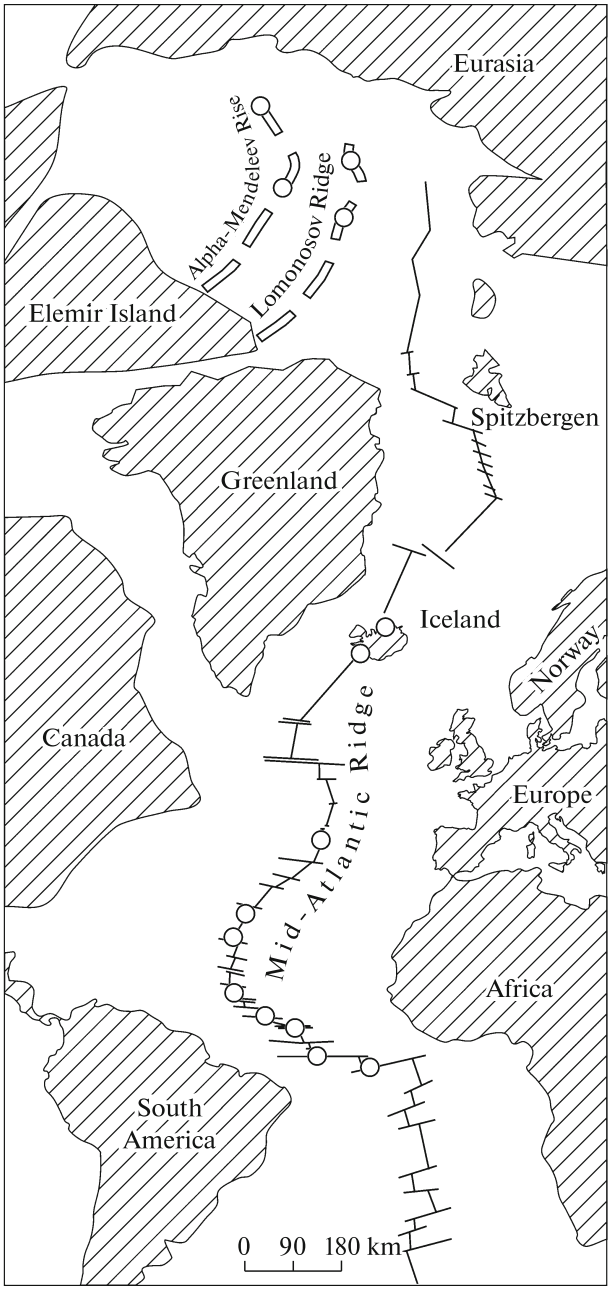

Fig. 1. Scheme of sampling (circles) for isotope–geochemical and isotope–geochronological studies of zircons from rocks of the AO and MAR seamounts.

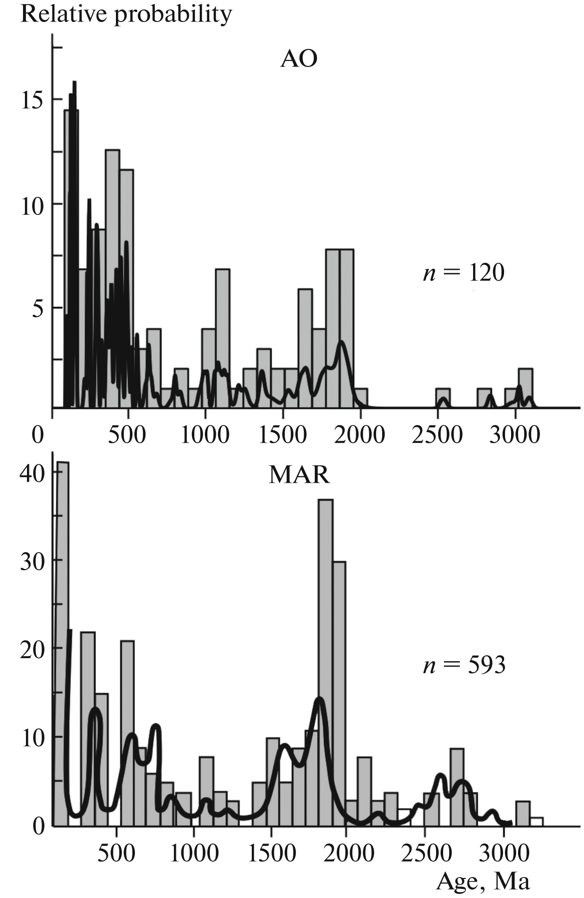

Fig. 2. Graphs of the U–Pb age variability for zircons from basalt and gabbro-dolerite of the AO and MAR.

Iceland; 128 ± 1.3 Ma, in basalt from the AO; and 151 ± 2 and 237 ± 1.5 Ma, in gabbro-dolerite from the AO. These data provide evidence for at least two age peaks in late magmatism within the crust segment studied: the Late Cenozoic for the MAR and Iceland and the Late Mesozoic for rises in the AO.

Precambrian zircons from the AO and MAR demonstrate three age peaks at 1250, 1850, and 2500 Ma with a clear predominance of the cluster of 1500–2000 Ma (Fig. 2). Zircons of the latter have the following concordant ages: 1881 ± 30 and 1805 ± 18 Ma, in basalt and gabbro-dolerite of the AO; 1880 ± 25 Ma, in basalt of the Central Rift of Iceland [6]; 1805 ± 18 and 2103 ± 27 Ma, in gabbroids of the MAR [2, 5]. Similar ages (2200 Ma) were obtained for zircon from peridotite dredged from the Hakkel Paleogene–Neogene submarine volcanic ridge in the AO [12].

As a whole, the initial ratios of the Hf isotopes in the ancient zircons studied with the concordant ages of 1805 and 1881 Ma have similar values ($^{176}Hf/^{177}Hf$) in magmatic rock of the AO (0.28130–0.28195) and MAR (0.28133–0.28196). The values of $\varepsilon_{Hf}(T)$ are heterogeneous and vary from –13.05 to +13.14 plotting symmetrically along the chondrite line (Fig. 3a), which provides evidence for the common crustal–mantle source for the matter of ancient zircons of the AO and MAR.

The young late magmatic zircons of the MAR strongly differ from the same zircons of the AO by higher values of $^{176}Hf/^{177}Hf$ = 0.28310–0.28332 and by higher positive values of $\varepsilon_{Hf}(T)$ (up to +21.81), which corresponds to the parameters of the depleted mantle (Fig. 3b). The young late magmatic zircons of the AO