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Glaciation control of melting rates in the mantle: U–Th systematics of young basalts from Southern Siberia and Central Mongolia

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Eastern Sayans, Siberia and Hangay, Central Mongolia are mountainous uplifts effected by Quaternary volcanism, but only the former area was covered by glaciers that were as thick as 500 m. Glaciation time intervals were marked by moraines and sub-glacial hyaloclastite-bearing volcanic edifices, whereas interglacial ones were exhibited by sub-aerial "valley" flows and cinder cones. To estimate temporal variations of maximum rates of melting and mantle upwelling in the glacial and glacial-free areas, we measured radionuclides of the U–Th system for 74 samples of the Middle-Late Pleistocene through Holocene basalts by ICP–MS technique (Chebykin et al. Russian Geol. Geophys. 2004. 45: 539–556) using mass-spectrometer Agilent 7500ce. The obtained U–Th isochron ages for the Pleistocene volcanic units in the age interval of the last 400 Kyr are mostly consistent with results of K–Ar dating.

The measured (230Th/238U) ratios for the Holocene basalts from both areas are within the same range of 1.08–1.16 (parentheses denote units of activity), whereas the 50 Kyr lavas yield, respectively, the higher and lower initial (230Th0/238U) ratios (1.18–1.46 and 1.05–1.13). This discrepancy demonstrates contrast maximum rates of melting in conventional garnet peridotite sources. We suggest that this dynamical feature was provided by the abrupt Late Pleistocene deglaciation that caused the mantle decompression expressed by the earlier increasing melting beneath Eastern Sayans than beneath Hangay.

In the last 400 Kyr, magmatic liquids from both Eastern Sayans and Hangay showed the overall temporal decreasing (230Th0/238U) (i.e. relative increasing rates of melting and upwelling of the mantle) with the systematically lower isotopic ratios (i.e. increased mantle activity) in the former area than in the latter. The 400 Kyr phonotephrites in Hangay showed elevated concentrations of Th (6-8 ppm) and Th/U (3.7-3.9). The high (230Th0/238U) (4.3-6.0) reflected slow fractional melting, accompanied by rapid removal of melts. In episodes of 50-35 and ∼9 Kyr, the ratio decreased from interval 1.23-1.52 to 1.08-1.22, indicating a relative increase of the porosity, maximum rates of melting, and upwelling of the mantle. The 350 Kyr magmatic melts in Eastern Sayans revealed the lower concentrations of Th (∼2 ppm) and Th/U (2.7-2.9) due to more depleted composition of the source region, but their high (230Th0/238U) (2.7-2.9) also demonstrated slow fractional melting and upwelling. The defined maxima of melting and upwelling of the mantle beneath this area at 170 and 50 Kyr (Mmax = 1.1 × 10-3 kg/m3/yr, Wmax = 11 cm yr-1) were separated from each other by a minimum at 150 Kyr. These variations are interpreted in terms of temporal control of the mantle dynamic parameters by growing and thawing glaciers.

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