Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.10553

Thermal structure of oceanic lithosphere constrained from the petit-spot mantle xenoliths

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We examined equilibrium temperature and pressure conditions of five peridotite xenoliths newly collected from Site B petit-spot volcanic field off the Japan Trench [1] to constrain the geothermal gradient of old oceanic lithosphere (~136 Ma; Fig1 [2]). The studied xenoliths are subdivided into three groups based on the mineral assemblage: a lherzolite contains fresh garnet, two lherzolites are spinel-bearing, and the other two lherzolites do not contain aluminous mineral phases. The application of a two-pyroxene thermometry [3] revealed that the equilibrium temperatures controlled their mineral assemblages: spinel lherzolites were at low temperatures (low-*T*: <600°C), garnet lherzolite was in medium temperature (mid-*T*: ~900°C), and other two lherzolites without aluminous mineral phases record very high temperatures (high-*T*: >1200°C). An equilibrium pressure of the garnet lherzolite was determined to be 1.9 ± 0.1 GPa by Al partitioning of garnet-orthopyroxene [3], and those of the high-*T* group was determined to be 2.3-2.8 GPa by Ca partitioning of olivine-clinopyroxene [4].

The obtained geotherm is consistent with the plate model (GDH1) explaining variations in bathymetry and heat flow data on the global seafloor, whereas it is inconsistent with the anomalous high-T/P geotherm previously estimated from fluid inclusions in other petit-spot xenoliths [5] or low-T/P geotherm predicted for the half-space cooling model and its updated version (PROM1). Judging from the chemical zoning of the constituent minerals, the high-*T* group might have been influenced by thermal perturbation related to the petit-spot magmatism. However, the garnet lherzolite records homogeneous mineral compositions, and pyroxenes in the low-*T* spinel lherzolites exhibit a pronounced exsolution texture developed under a steady cooling history. These observations led us to make two important implications: (1) thermal perturbation of the oceanic lithosphere is restricted in the deep section, and (2) the geotherm of the old oceanic lithosphere is consistent with the plate model rather than the half-space cooling model.

[1] Akizawa et al. (2022) Mar. Geol. 444, 106712. [2] Müller et al. (2008) Geochemistry, Geophys. Geosystems 9, Q04006 [3] Brey and Köhler (1990) *J. Petrol.* 31, 1353–1378. [4] Köhler and Brey (1990) *GCA* 54, 2375–2388. [5] Yamamoto et al. (2014) *Chem. Geol.* 268, 313-323.

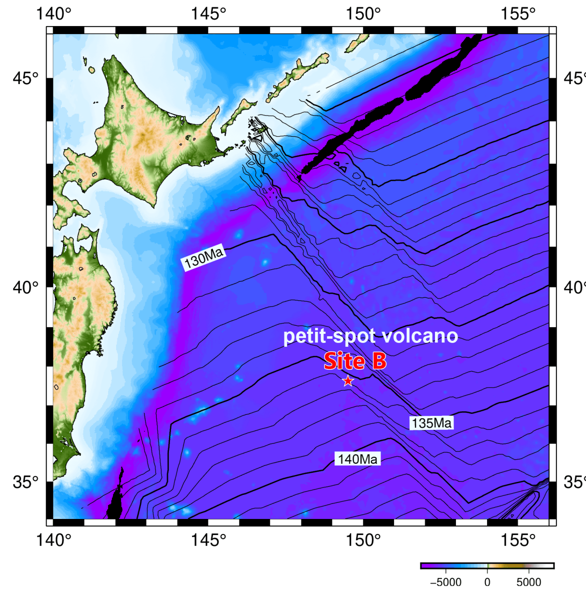

Fig1: the locaity of Site B petit-spot volcanic field. Seafloor age gridded data for GMT software are from Müller et al. (2008).