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Research paper

# Late Palaeogene emplacement and late Neogene–Quaternary exhumation of the Kuril island-arc root (Kunashir island) constrained by multi-method thermochronometry

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ABSTRACT

The Kuril islands constitute a volcanic island arc-trench system, stretching from eastern Hokkaido (Japan) to Kamchatka (Russia) along the northwestern Pacific subduction system. The current arc consists of several volcanic islands mainly with Neogene basement and capped by several, predominantly andesitic, active subduction stratovolcanoes. Kunashir Island is the southwestern-most island of the arc, just off the Hokkaido coast and represents the study area in this paper. The island is composed of a Lower Complex of mainly late Miocene to Pliocene volcanic rocks, covered by an Upper Complex of younger (basaltic) andesitic lava flows and tuffs on which currently four active volcanic edifices are built. In the Lower Complex sub-volcanic and deeper-seated intrusives of the so-called Prasolov and Dokuchaev magmatic complexes are found. More differentiated, tonalitic–granodioritic rocks were collected from these small intrusive bodies. An early Oligocene zircon LA-ICP-MS U/Pb age of 31 Ma for the Prasolov Complex was obtained, showing that the basement of Kunashir Island is older than previously thought. Thermochronometry (apatite fission-track and U-Th-Sm/He and zircon U-Th/He analyses) further shows that the magmatic basement of the island was rapidly exhumed in the Pleistocene to present levels in a differential pattern, with He-ages ranging from 1.9 to 0.8 Ma. It is shown that the northern section of the island was hereby exhumed more intensely.



## 1. Introduction and tectonic setting

The Kuril Islands represent a volcanic island arc in the Northwest Pacific Ocean, outlining the convergent plate boundary between the Pacific and Okhotsk plates (Fig. 1). Along the Kuril–Kamtchatka trench the Pacific Plate subducts (north)westwards at an average rate of 78–79 mm/yr (Seno et al., 1996). The Okhotsk Plate is thought to be a distinct lithospheric plate in between the North American, Eurasian, Pacific, and Amurian plates (Cook et al., 1986; Seno et al., 1996; Apel et al., 2006) and is largely covered by the current Okhotsk Sea (Fig. 1). Collision of the Okhotsk block with the eastern Siberian margin of Eurasia is thought to have occurred in the late Cretaceous–early Paleocene (~65–55 Ma; e.g., Worrall et al., 1996; Schellart et al., 2003). The geochemistry and petrogenesis of the Kuril Island volcanic rocks have been described by Bailey et al. (1987, 1989), Zhuravlev et al. (1987), Avdeiko et al. (1991), Bailey (1996), Bindeman and Bailey (1999) and Martynov et al. (2010a).

The Kuril arc and trench links the Russian Kamchatka peninsula with Hokkaido, Japan and connects the Aleutian with the Japanese arc-trench (Fig. 1). The Kuril island arc (or Great Kuril Chain), is composed of a sequence of volcanic islands (active subduction

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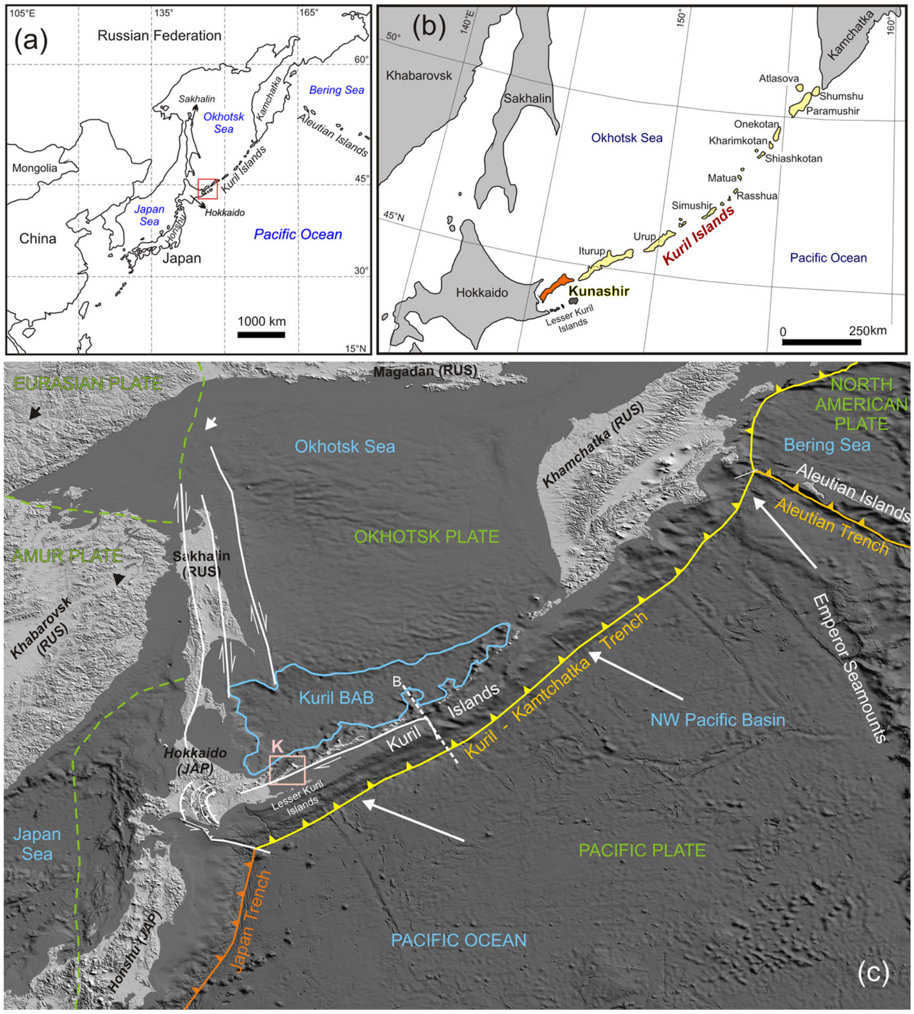


**Figure 1.** (a) General location of the Kuril Island arc in the Northwest Pacific, (b) position of Kunashir Island in the Kuril arc and general regional geographic setting, and (c) tectonic sketch map of the Kuril island arc. The study area, the island of Kunashir (K), is indicated by the red box.

strato-volcanoes) of 1150 km with average basal width of ~100–200 km (Martynov et al., 2010b). The westernmost Island, Kunashir, represents our study area. To the NE, larger (e.g., Iturup, Urup, Simushir, Onekotan, Paramushir, Shumshu) and smaller (e.g., Rasshua, Matua, Shiashkotan, Kharimkotan) islands delineate the arc (Fig. 1). It is thought that the current volcanic arc developed from late Oligocene to early Miocene.

A second arc, the Lesser Kuril Islands (or Nemuro-Shikotan arc), is located on the Pacific side, south of Kunashir, and includes the Nemuro Peninsula of Hokkaido (Fig. 1). It is envisaged that this paleo-arc constitutes the basement of the modern Kuril arc (Maeda, 1990). While eastern Hokkaido is part of the Kuril arc, central and western Hokkaido are part of the Japan arc (e.g., Wakita, 2013). Oblique subduction of the Pacific Plate along the Kuril trench and associated relative southwestward movement of the Kuril fore-arc eventually led to the Kuril-Japan arc-arc collision in the Miocene (~12 Ma) (Maeda, 1990; Bazhenov and Burtman, 1994; Kusunoki and Kimura, 1998). This collision is ongoing and results in compressive forces in the region and is responsible for the development of the Hidaka Mountains (central Hokkaido) (Fig. 1c; Kimura, 1981, 1986; Kusunoki and Kimura, 1998). The late Miocene arc–arc collision effectively resulted in the exhumation of the lower crustal rocks of the Kuril arc in eastern Hokkaido (Kusunoki and Kimura, 1998).

The Kuril Basin is a prominent wedge-shaped back-arc basin (Fig. 1) where sea-floor spreading occurred in the late Miocene (Savostin et al., 1983; Maeda, 1990; Fournier et al., 1994; Jolivet et al., 1994; Worrall et al., 1996; Baranov et al., 2002; Schellart et al., 2003). The Sakhalin–Hokkaido extensional system still constitutes an active dextral shear system, defining the boundary between the Okhotsk and the Eurasian (Amurian) plate (Fig. 1). Kinematics changed dramatically during the late Miocene from transtension to transpression (Worrall et al., 1996). The latter authors link these movements to far-field effects of the India-Eurasia collision (e.g., Molnar and Tapponnier, 1975; De Grave et al., 2007). The Okhotsk Sea now covers most of the thinned continental crust of the Okhotsk plate, along with the oceanic crust of the deeper (~3300 m) Kuril back-arc basin. The extension and thinning in the Okhotsk plate mainly occurred during the Eocene until the early Miocene (Worrall et al., 1996), while opening of the Kuril Basin is a posterior event, lasting until the late Miocene (early Pliocene?) (e.g., Maeda, 1990; Schellart et al., 2003). High heat flux and the presence of Pleistocene (0.84–1.07 Ma) submarine volcanic rocks suggest that the Kuril back-arc basin might still be active or was active far later than previous thought (Tararin et al., 2000; Baranov et al., 2002; Martynov et al., 2010a).

Late Cretaceous–Paleocene clastic sediments shed off the southern margin of the Okhotsk block were included in the