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# Seismic tomography of the Pacific slab edge under Kamchatka

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ABSTRACT

We determine a 3-D P-wave velocity structure of the mantle down to 700 km depth under the Kamchatka peninsula using 678 P-wave arrival times collected from digital seismograms of 75 teleseismic events recorded by 15 portable seismic stations and 1 permanent station in Kamchatka. The subducting Pacific slab is imaged clearly that is visible in the upper mantle and extends below the 660-km discontinuity under southern Kamchatka, while it shortens toward the north and terminates near the Aleutian–Kamchatka junction. Low-velocity anomalies are visible beneath northern Kamchatka and under the junction, which are interpreted as asthenospheric flow. A gap model without remnant slab fragment is proposed to interpret the main feature of high-V anomalies. Combining our tomographic results with other geological and geophysical evidences, we consider that the slab loss may be induced by the friction with surrounding asthenosphere as the Pacific plate rotated clockwise at about 30 Ma ago, and then it was enlarged by the slab-edge pinch-off by the asthenospheric flow and the presence of Meiji seamounts. As a result, the slab loss and the subducted Meiji seamounts have jointly caused the Pacific plate to subduct under Kamchatka with a lower dip angle near the junction, which made the Sheveluch and Klyuchevskoy volcanoes shift westward.



## 1. Introduction

The Kamchatka peninsula is located at the northwestern edge of the Pacific plate (Fig. 1). The Pacific plate of Cretaceous age subducts beneath the Kamchatka arc and moves along the Bering strike-slip fault at about 8 cm/yr, increasing from 7.7 cm/yr at 55°N to 8.3 cm/yr at 47°N (DeMets et al., 1990; Steblov et al., 2003). Geological studies showed that the volcanism and convergence in Kamchatka ceased at about 55 Ma ago but resumed about 30 Ma ago (Watson and Fujita, 1985). About 10 Ma ago, island-arc magmatism extended to the north of the Aleutian–Kamchatka junction along the mid-Kamchatka volcanic belt, but those are extinct now (Honthaas et al., 1995). A chain of active volcanoes, Holocene in age (Braitseva et al., 1995), along the eastern coast of Kamchatka are underlain by about 100-km depth-contour of the subducting Pacific slab (Gorbatov et al., 1997). The Sheveluch and Klyuchevskoy volcanoes have shifted northwestward from the volcanic front. Between 54°N and 55°N, the Meiji seamounts, the northernmost segment of the Hawaii-Emperor seamount chain, enter the Kamchatka trench (Fig. 1).

The configuration of the Pacific slab under the Kamchatka region was studied by using the distributions of regional earthquakes occurring in the slab, which shows that the dip angle of the slab decreases northward from about 55° to 35° (Gorbatov et al., 1997). The maximum depth of earthquakes becomes shallower along the subduction zone from ~600 km beneath southern Kamchatka to ~100–200 km near the junction (Davaille and Lees, 2004).

Seismic tomography is a powerful tool for determining 3-D velocity structure and dynamic processes in the Earth. Until now several tomographic studies have been performed for the Kamchatka peninsula. Gorbatov et al. (1999) applied the tomographic method of Zhao et al. (1992) to study a 3-D P-wave velocity structure down to a depth of 200 km, and their results showed a prominent low-velocity (low-V) anomaly beneath the volcanic front and a high-velocity (high-V) zone associated with the subducted Pacific slab. But their study region was in the southeastern Kamchatka arc because of the distribution of seismic stations available for them. In order to obtain tomographic images in Northern Pacific, Gorbatov et al. (2000) conducted a regional tomographic inversion and they revealed a slab-like fast anomaly from the Earth's surface down to 900 km depth beneath southern Kamchatka, while a high-V anomaly associated with the Wadati–Benioff zone was not imaged near the junction. A surface-wave tomography shows that the subducting Pacific lithosphere terminates at the Aleutian–Kamchatka junction and no relict slab underlies the extinct northern Kamchatka volcanic arc (Levin et al., 2002a). Although Levin et al. (2002a) suggested two episodes of slab loss under northern Kamchatka, their tomographic images could not reveal the detached slab because their model is limited to 200 km depth. Recently, Lees et al. (2007) determined P-wave teleseismic tomography which showed evidence for slab shoaling toward the

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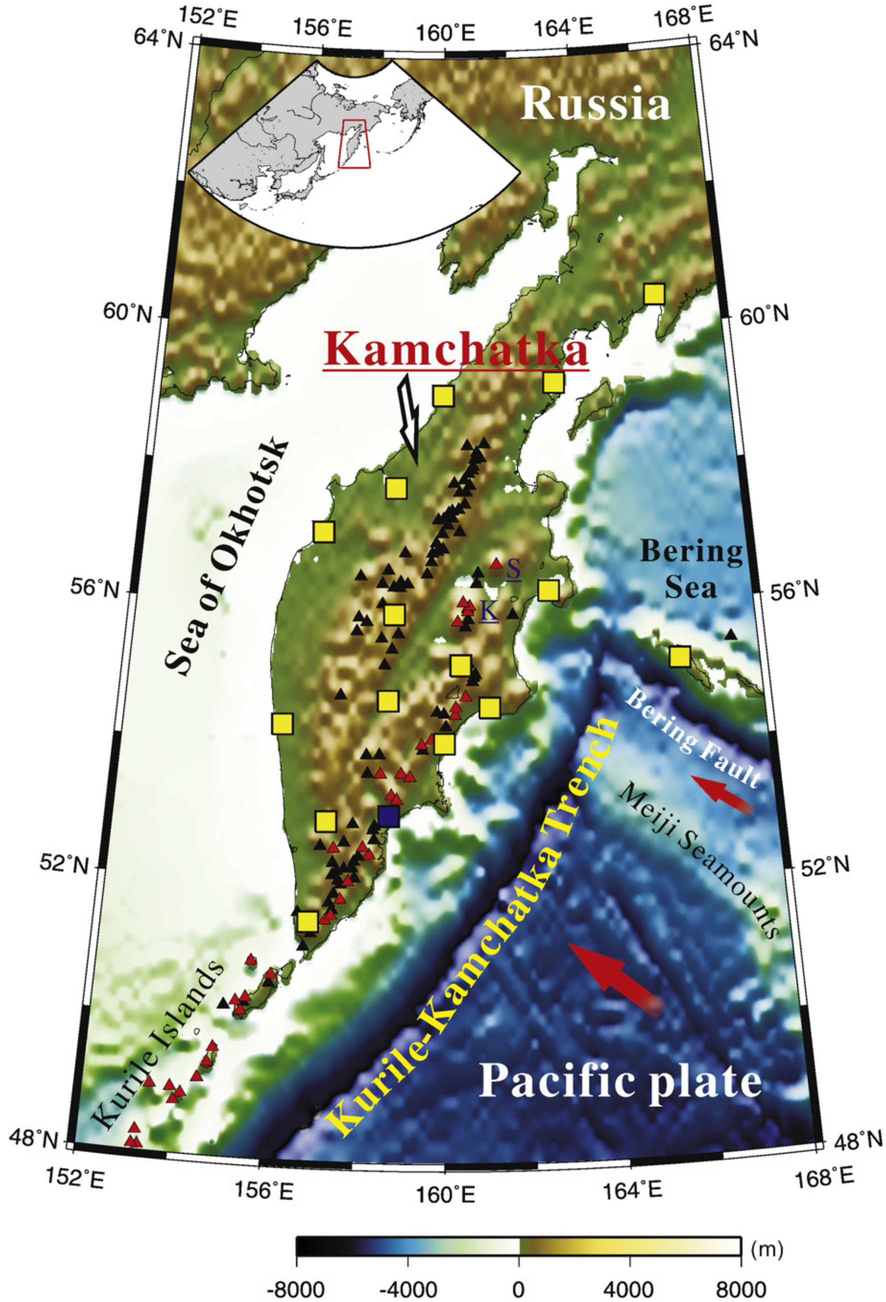


**Fig. 1.** Map of the study area with surface topography shown in colors (its scale is shown at the bottom). Yellow squares show the locations of 15 portable seismic stations deployed for the SEKS experiment in the Kamchatka region. The blue square denotes a permanent station (PET). Red arrows denote the motion direction of the Pacific plate subducting along the Kurile–Kamchatka trench and transcurrent motion along the Bering Fault. Red and Black triangles represent the active and inactive volcanoes, respectively. S, Sheveluch volcano; K, Klyuchevskoy volcano. The insert map shows the location of the present study area.

northern edge of the subducted Pacific slab, and they considered the thermal ablating related to asthenosphere as a possible cause for the feature.

Shear-wave splitting studies suggested that trench-parallel strain follows the seismogenic Wadati–Benioff zone, but rotates to trench-normal beyond the slab edge (Peyton et al., 2001; Portnyagin et al., 2005), indicating that the asthenospheric flow passes through a slab window beneath the junction, similar to that observed in Apenines (Wortel and Spakman, 2000). In addition, thermal modeling of the reheating of a torn slab shows that the Pacific lithosphere was already thinner well before entering the trench due to delayed thickening of the lithosphere below the Meiji–Hawaiian hotspot (Davaille and Lees, 2004).

In the present study we use teleseismic tomography to determine a 3-D P-wave velocity structure down to 700 km depth under Kamchatka. Our results provide new evidence for the loss of the Pacific slab at the slab edge, which may improve our understanding of the dynamic processes under this region.

## 2. Data and method

We used teleseismic data recoded by 15 portable broad-band seismic stations in Kamchatka from the SEKS experiment conducted in 1998–1999 (Lees et al., 2000), and by one permanent station PET. Fig. 1 shows the distribution of the 16 seismic stations used. All the waveform data were downloaded from the web site of IRIS