



Multi-level magma storage zones feeding the 2023–2024 eruption sequence at Shiveluch volcano (Kamchatka): petrologic and seismic constraints

Natalia Gorbach¹, Alexandra Shakirova², and Andrey Chemarev²

¹Institute of Volcanology and Seismology, Institute of Volcanology and Seismology FEB RAS, Petropavlovsk-Kamchatsky, Russia (n_gorbach@mail.ru)

²Kamchatka Branch of the Geophysical Survey RAS, Petropavlovsk-Kamchatsky, Russia (shaki@emsd.ru)

The 2023–2024 eruption sequence of Shiveluch volcano (Kamchatka) demonstrates that complex dome-building volcanic systems can rapidly activate and evacuate magma storage zones at markedly different crustal depths. The sequence began on 10 April 2023 with a major explosive eruption (VEI ~4) of Young Shiveluch, the principal Holocene eruptive center of the volcano. The eruption destroyed the active lava dome and produced a 15–18 km-high ash column [1], widespread tephra fallout, and pyroclastic density currents extending up to 19–20 km from the vent. Juvenile products are amphibole–plagioclase andesites typical of modern Young Shiveluch activity, derived from a shallow upper-crustal reservoir at ~5–6 km depth [e.g., 2]. As in previous modern eruptions [3], the 2023 andesites contain olivine-bearing mafic enclaves, recording interaction between resident evolved magma and an injected mafic component.

Only one year later, in April 2024, a new eruptive center formed on the western flank of the volcano, ~5.5 km from the Young Shiveluch crater. The newly formed lava dome produced amphibole-rich basaltic andesites [4], a rare magma type in arc volcanoes and previously unknown at Shiveluch. These rocks contain up to 30 vol.% amphibole, sparse pyroxene, reaction-rimmed olivine, and no plagioclase phenocrysts. Amphibole thermobarometry indicates crystallization at 912–948 °C and 410–632 MPa, corresponding to mid- to lower-crustal storage at ~16–24 km and high pre-eruptive H₂O contents (7.4–8.7 wt%).

Petrological data therefore show that the 2023 and 2024 eruptions tapped two distinct magma storage zones that were activated within only one year. Two end-member mechanisms may explain this rapid succession: (1) evacuation of the shallow reservoir in 2023 induced decompression and stress redistribution, triggering ascent of a volatile-rich deep magma batch; or (2) increased mafic input from the mantle pressurized several crustal reservoirs nearly simultaneously.

Seismic observations support aspects of both models [5]. The 2023 eruption was mainly accompanied by shallow seismicity associated with the upper-crustal reservoir, whereas earthquakes consistent with deep mafic magma input have been recorded since 2021. A distinct cluster of seismicity at depths of ~20–26 km developed immediately after the April 2023 eruption,

indicating renewed magma transport in the lower crust prior to the 2024 flank eruption.

Overall, the Shiveluch case demonstrates that deep magma storage zones can be rapidly mobilized following major explosive eruptions, generating new vents outside the main crater area and magmas with contrasting compositional properties. This behavior complicates hazard assessment, as future eruptions may involve deeper, volatile-rich magma capable of producing unexpected eruptive styles, highlighting the importance of integrating petrological and seismic constraints into monitoring of large, long-lived dome-building volcanoes.

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