Special Circumstances: geophysical and geochemical evidence for an auxiliary magma source of Klyuchevskoy volcano lavas

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Volcanoes of Central Kamchatka Depression (CKD) form the most active arc volcano system in the world, and among them the Klyuchevskoy volcanic group (KG) stands out as the single most vigorous volcanic center. Notably, the tectonic setting of the KG is far from the textbook case. Besides being close to the junction of two major plate boundaries (the Kamchatka subduction zone and the locally transcurrent Aleutian Arc), the KG has one of the largest distances (>170 km) to the top of the subducting plate where the flux feeding arc magmatism is expected to arise.

A number of geophysical observations suggest complexity of the upper mantle structure beneath the KG. Early studies of regional seismic wave attenuation, tomographic imaging, and, most recently, studies of the mode-converted body waves all point to the presence of a region of distinct seismological properties at depths ~100 km. This region may be best characterized as a planar body with lower seismic velocity that is bound by relatively sharp (~2 km) gradients in seismic properties, has a thickness of a few tens of km, and appears to dip to the north. This body is clearly separate from the subducting Pacific plate.

The geochemical signature of KG lavas has been studied extensively. Very high rate of magma production, a clear subduction signature, extremely high δ - O^{18} and H_2O content, a lack of slab-melt and sediment inputs all have been noted. On the basis of its first-order geochemistry, the KG is a quintessential island arc volcano. A well-recognized distinctive feature of the KG is the simultaneous eruption of low-Al and high-Al lavas, a fact that inspired numerous explanations. Using recently compiled databases of geochemical analyses (specifically, GEOROC) we report a previously un-noted bi-modal distribution of Zr/Nb concentration ratios in lavas of the Klyuchevskoy Group. In Central America, this ratio correlates closely with the depth to the slab, growing larger as the slab becomes less deep. We speculate that distinct values of Zr/Nb ratios derive from different depths beneath the KG as well.

On the basis of our geophysical results combined with geochemical evidence we argue for the presence of a distinct body of rock ~100 km deep in the upper mantle beneath the KG, that contributes magmas to the volcanic center. The origin of this body is enigmatic, with possible explanations being a fragment of the previously subducted lithosphere that has been left behind due to plate boundary reorganization, or alternatively a plume of sediments originating from the subducting slab and propagating into the wedge.