From the slab to the surface: Origin, storage, ascent, and eruption of volatile-bearing magmas

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Does the volcano know about the slab? Our work in the central-eastern Aleutian was aimed at this question (Fig. 1). Spanning from Seguam volcano (west) to Shishaldin volcano (east), our corridor is marked by significant variations in magmatic water contents, seismicity, deformation, and style and frequency of eruption. By contrast, most subduction parameters, such as slab age and velocity, remain constant. One significant exception is the depth of the slab below the frontal arc volcanoes, which transitions from a near global minimum in the west (~65 km below sea level (BSL) to a more typical depth in the east (~100 km BSL). This makes our corridor an ideal locality to isolate the role of slab depth in driving magmatic processes. After a one-year-long seismic deployment, forty five-gallon buckets of new rock samples, two stints aboard the *R/V Maritime Maid*, and one PhD dissertation, we arrived at some answers.

Our own analysis of seismic S-P times for earthquakes measured using local stations confirms the variation in slab depth published previously using global catalogs. We investigate new major, trace, and volatile elements in melt inclusions and bulk rock samples from eight volcanoes, which exhibit systematic trends with slab depth (Fig. 2). Maximum water contents of inclusions vary from ~2 wt.% (Fisher) to ~5 wt. % (Akutan), spanning most of the global range (1-7 wt.%). Correlations between H_2O/Ce and H_2O/K_2O and non-volatile trace element ratios (e.g., Nb/Ce, Ba/La) give strong evidence that maximum water content melt inclusions preserve undegassed concentrations. Variation in water contents is reflected in calc-alkaline vs. tholeiitic differentiation, consistent with earlier work. We find that all of these geochemical ratios, including those involving H_2O, are negatively correlated with slab depth.

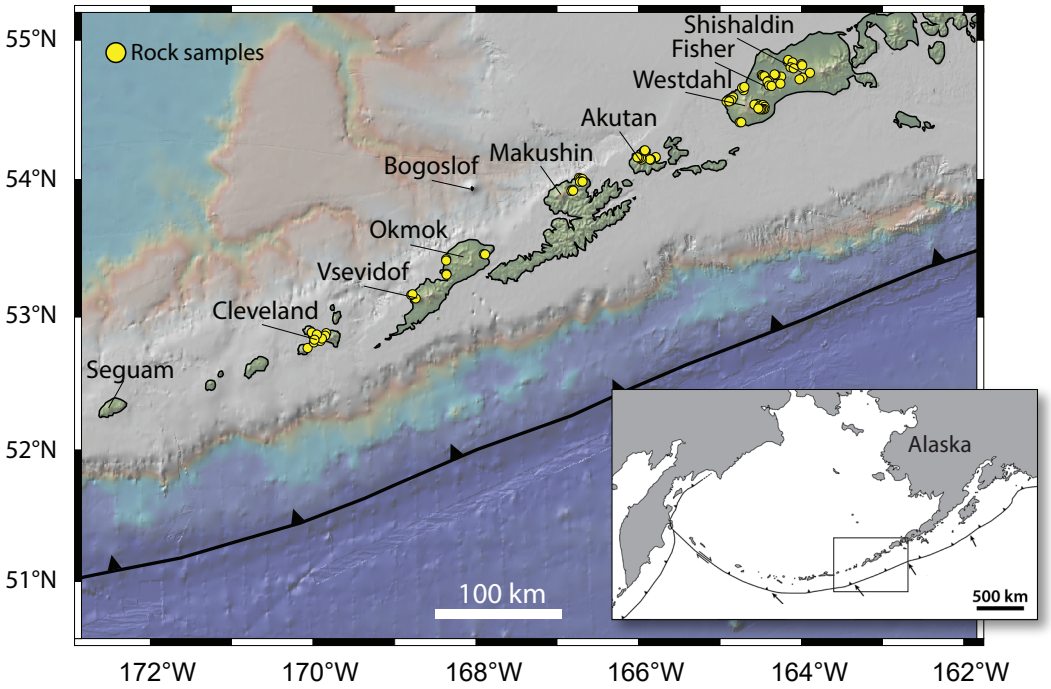

Figure 1. The central-eastern Aleutian arc. Map of the field area with historically active volcanic centers labeled.

joint GeoPRISMS, Alaska Volcano Observatory, and Deep Carbon Observatory field party in 2016 onboard the R/V Maritime Maid.

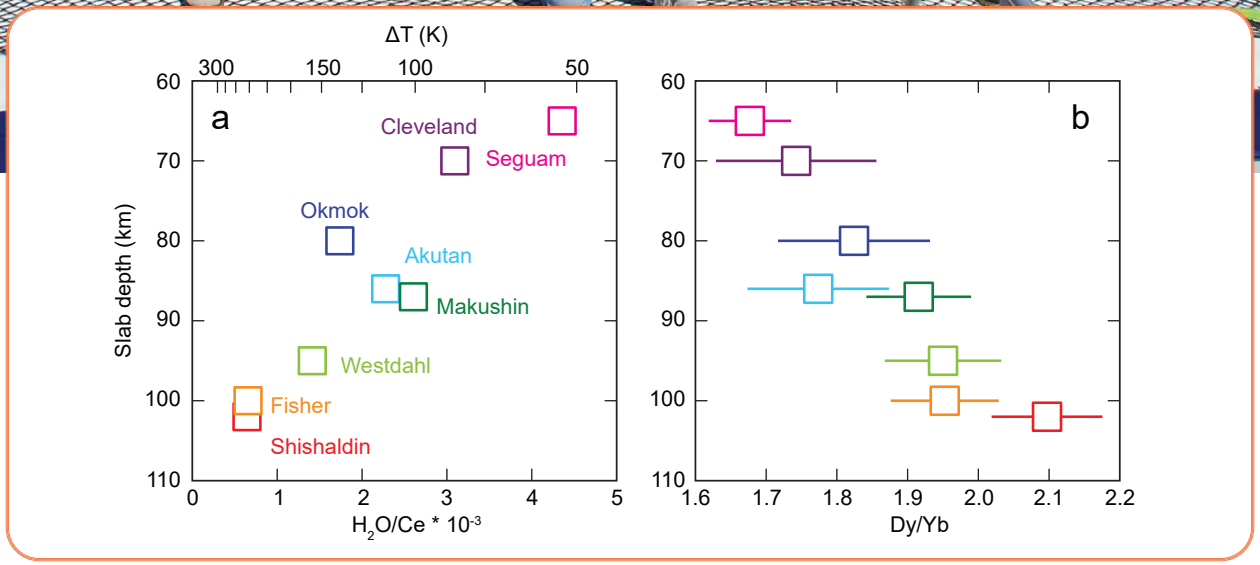

Figure 2. Variation in volatile and trace element compositions of magmas with slab depth (Rasmussen et al., 2019). (a) H_2O/Ce is a proxy for slab temperature. Temperature relative to the wet sediment solidus (ΔT) is calculated using the thermometer of Plank et al. (2009). (b) Increased Dy/ Yb may indicate an increased role of garnet with depth in the slab.

Moreover, the geochemical variations are consistent with higher slab temperature and mantle melting pressure for those volcanoes that overlie greater depths to the slab, consistent with nominally vertical transport paths from slab to the surface. Slab-mantle coupling depths must be shallower (~ 50 km) in the western part of this corridor than is typically inferred worldwide (~80 km).

These results indicate that slab depth controls the composition, differentiation and volatile content of arc magmas. We speculate that the range in slab depths in the central-eastern Aleutians relates to the thickness of trenchfill sediments, which decreases from west (Seguam) to east (Shishaldin). ■

References

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