Time-evolving surface and subsurface signatures of Quaternary volcanism in the Cascades Arc

Daniel O’Hara1,2, Leif Karlstrom1, and David W. Ramsey3

1Department of Earth Sciences, 1272 University of Oregon, Eugene, Oregon 97403, USA
2Department of Geography, Vrije Universiteit Brussel, Pleinlaan 2, 1050 Elsene, Belgium
3U.S. Geological Survey, Cascades Volcano Observatory, 1300 SE Cardinal Court, Bldg. 10, Ste. 100, Vancouver, Washington 98683, USA

We thank Dave Sherrod for his constructive Comment (Sherrod, 2021). The Cascades are Quaternary extrusion volume we incorrectly attributed to Sherrod and Smith (1990) was derived from preliminary calculations using the post–Crater Lake rate of 1.3 km³/km²/m.y. presented in Sherrod and Smith (1988) for central Oregon. We converted extrusion rate to volume by multiplying this rate by a segment length of 260 km and 2 m.y., giving 676 km³ in central Oregon and a total Cascades extruded volume of 2520 km³ (mistyped as 2570 km³ in our paper; O’Hara et al., 2020). The 5100 km³ total volume suggested by Sherrod falls between the 4540–6100 km³ that arise from converting 3–6 km³/km²/m.y. extrusion rate (Sherrod and Smith, 1990) to volume, including off-axis volcanism.

Being the most recent comprehensive compilation of ongoing Cascades volcanic fieldwork, we used the ~6400 km³ estimated by Hildreth (2007) for Cascades Quaternary extrusion in our paper. As such, the erroneous representation of Sherrod and Smith (1990) does not impact our quantitative results, but does show how dispersed deposits can alter volume estimations. Differences between published volume estimates (e.g., O’Hara et al., 2020, our table S1; Sherrod and Smith, 1990, their table 1) that arise from how erosion is accounted for and how the edifice basal contour is defined highlight continued challenges in quantifying long-term eruptive output, particularly for methods that leverage digital elevation models. This is an opportunity for future work.

Our estimation that edifice volumes represent ~50% of total extruded volumes is an average over the entire arc. We agree with Sherrod that partitioning between edifices and distributed deposits likely varies alongside the physical controls on volcanism, depending both on the scale of measurement and environment. For example, Grosse et al. (2020), comparing mafic monogenetic cone volumes to associated lava flows in the Andes, found a 1:1 relationship between volumes. However, seismic imaging of submarine volcanoes in the South China Sea implies that edifices are 3–50% of total erupted products (Sun et al., 2019). In the central Oregon Cascades, a 50% value for edifice volumes is likely an overestimate. Considering a 3–6 km³/km²/m.y. extrusion rate for central Oregon (2010–3570 km³, including Newberry), comparison with volcano volumes in the same area (985 km³) suggests that edifices represent at most 27–49% of total extruded volume for this region.

Finally, from the standpoint of reconciling upper crustal geophysical data with geologic observations, it is interesting to compare the metrics $G$ and $\lambda$ in our paper, measuring subsurface volcanic influence and volume-weighted edifice vent distribution, respectively, to along-arc Quaternary extrusion rates. Taking across-arc summations of these quantities, we see that high $\lambda$ co-locates with high extrusion rates from Sherrod and Smith (1990) (Fig. 1). The summation of $G$, however, highlights a dichotomy between the northern and southern sections of the arc. South of 46°N, $G$ is large, suggesting extensive subsurface magmatic modulation, and probably Basin and Range tectonic influence. North of 46°N, $G$ is low, except near major submarine volcanoes, suggesting localized crustal magma transport. Highest $G$ values occur in central Oregon, corresponding to the peak in extruded volume noted by Sherrod and Smith (1990). This provides a framework for future interrogation of the physical processes responsible for spatially variable surface/subsurface magmatic connections at an arc scale.

In conclusion, we again thank Sherrod for the opportunity to correct our misstatement and to re-articulate exciting scientific opportunities that remain in Cascades volcanology.

REFERENCES CITED

Grosse, P., Ochi Ramacciotri, M.L., Escalante Fochi, F., Guzmán, S., Orihashi, Y., and Sumino, H., 2020, Time-evolving surface and subsurface signatures of Quaternary volcanism in the Cascades arc: Geology, v. 48, p. 1088–1093, https://doi.org/10.1130/G47706.1.

Sherrod, D.R., Karlstrom, L., and Ramsey, D.W., 2020, Time-evolving surface and subsurface signatures of Quaternary volcanism in the Cascades arc: Comment: Geology, v. 49, p. e525, https://doi.org/10.1130/G48815C.1.

Sherrod, D.R., and Smith, J.G., 1988, Quaternary extrusion rates of the Cascade Range, northwestern United States and British Columbia, in Muffler, L.J.P., ed., Proceedings of Workshop XLI: Geological, Geophysical, and Tectonic Setting of the Cascade Range: U.S. Geological Survey Open-File Report 89-178, p. 94–103, https://pubs.usgs.gov/of/1989/0178/report.pdf.

Sherrod, D.R., and Smith, J.G., 1990, Quaternary extrusion rates of the Cascade Range, northwestern United States and southern British Columbia: Journal of Geophysical Research, v. 95, B12, p. 19465–19474, https://doi.org/10.1029/JB095iB12p19465.

Sun, Q., Jackson, C.A.L., Magee, C., Mitchell, S.J., and Xie, X., 2019, Extrusion dynamics of deepwater volcanoes revealed by 3-D seismic data: Solid Earth, v. 10, p. 1269–1282, https://doi.org/10.5194/se-10-1269-2019.