# 44. VOLCANO HEIGHT AND PALEO-PLATE THICKNESS

Peter R. Vogt, Naval Research Laboratory, Washington D.C.

In this note I shall apply the age data from the New England Seamounts to test a hypothesis that volcano height is limited by plate age. Vogt (1974a) showed that when the heights of major young oceanic volcanoes above the basaltic basement are corrected for the buoyancy of their submerged bases, the heights increase with the square root of basement age. This result is compatible with an isostatic model for the height of magma in the volcanic conduit. As plates thicken with increasing age, the length of magma columns in isostatic equilibrium with the adjacent plate also increases. Volcano height thus appears to be limited primarily by plate thickness rather than, for example, by the speed of a plate over a hot spot, or the hot spot's productivity.

If young volcanoes are height limited by present plate age, then old, extinct ones should have heights corresponding to plate age at the time the volcanoes were formed. In order to test the hypothesis of Vogt (1974a) one needs to estimate present crustal age and time of volcanism at the three sites. Drilling on Leg 43 provided information on the ages of two seamounts in the New England chain: Nashville (Site 382) and Vogel (Site 385). My preferred age estimates for completion of these volcanic edifices are 80-85 and 87-92 m.y.B.P., respectively (see Vogt and Tucholke, and Houghton et al., this volume).

Bermuda is a third volcanic feature that we could date from drill-core data. The results from Site 386, as well as isotope dating on Bermuda itself (Reynolds and Aumento, 1974), suggest that the final stages of volcanism had been completed about 30-35 m.y.B.P. The main mass of the volcanoes was probably in existence by 40-45 m.y.B.P.; for the present I shall take an age of 40 m.y.

The present crustal ages at the three sites may be estimated from plate-kinematic studies (e.g., Pitman and Talwani, 1972) calibrated by deep-sea drilling results (Vogt et al., this volume). I estimate present crustal ages of about 95, 120, and 110 m.y., respectively, for Nashville, Vogel, and Bermuda volcanoes (see Vogt and Tucholke, this volume). The crustal ages at the times these volcanoes were formed would therefore have been about 13, 30, and 55 m.y., respectively.

To compute the isostatically adjusted volcano height (Vogt, 1974a), one needs to determine the original height of the three volcanoes above the surrounding basement. For Nashville and Vogel seamounts the present height above basement can be used, since the features were not (or at least not significantly) truncated by subaerial erosion. For Bermuda, the original height may be estimated from an empirical relationship between the areas and peak elevations of presently active volcanic islands. Elevations appropriate to the bank areas of Plantagenet, Challenger, and Bermuda are in the range 1 to 3 km above sea level. Pirsson (1914) extrapolated the submarine profile of the edifice to obtain an original maximum elevation of 3.5 km for the main Bermuda edifice. I shall take 3 km as a reasonable estimate, realizing that the actual value may be 1 km or so different. For all three volcanoes (Nashville, Vogel, and Bermuda) I also calculated a small isostatic correction (Vogt, 1974a) for the sediment thickness that existed in the areas at the time the volcanoes were active (see Tucholke, this volume, for a discussion of regional lithostratigraphy).

Using the age of volcanism, the sediment thickness at the time of eruption, the age of the oceanic crust, and the height of the volcano above the adjacent basement, one can compute an "adjusted volcano height" according to the method of Vogt (1974a). This is the height the volcanoes would have reached if there had been no sediment or sea water to give the magma column extra buoyancy. The adjusted volcano height calculated for Nashville, Vogel, and Bermuda seamounts is plotted in Figure 1 together with data for

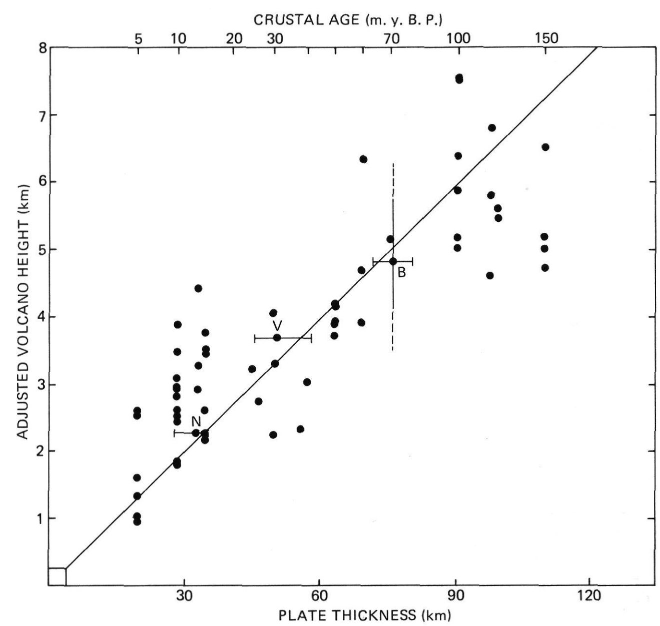


Figure 1. *Adjusted volcano height versus plate thickness for Nashville, Vogel, and Bermuda seamounts and presently active oceanic volcanoes.*

presently active oceanic volcanoes. The three ''paleo-volcanoes'' fit the distribution well within the scatter of present-day volcanoes. Thus, the greater relief of Bermuda over Vogel, and of Vogel over Nashville, can be explained as an isostatic consequence of progressively greater plate age—hence, plate thickness—at the time of volcanism. Note that I assumed an age of 40 m.y. for the Bermuda volcanoes. Had one accepted the inference of Reynolds and Aumento (1974) that Bermuda volcano reached sea level already 90-110 m.y.B.P., its height would not fit the square root law (Figure 1), and furthermore would imply unreasonably great crestal depths (4.5 to 5.5 km) for the Aptian Mid-Atlantic Ridge. I propose that the high isotope ages obtained by Reynolds and Aumento (1974) for the pillow lavas on Bermuda are substantially in error, a possibility those authors did not exclude.

Finally, it is worth noting that the relatively close ($\sim$40 km) volcano *spacing* of seamounts of the New England chain is also consistent with the hypothesis that they were erupted at a time when the lithosphere was still relatively young—of the order of 1-5 $\times$ $10^7$ years compared to present crustal ages of 1-2 $\times$ $10^8$ years (Vogt, 1974b).

## REFERENCES

Pirsson, L. V., 1914. Geology of Bermuda Island: The igneous platform, *Am. J. Sci.,* v. 38, p. 189-206 and 331-340.

Pitman, W. C., III, and Talwani, M., 1972. Sea-floor spreading in the North Atlantic, *Geol. Soc. Am. Bull.,* v. 83, p. 619-646.

Reynolds, P. H. and Aumento, F., 1974. Deep Drill 1972: Potassium-argon dating of Bermuda drill core, *Canadian J. Earth Sci.,* v. 11, p. 1269-1273.

Ridley, W. I., Watkins, N. D., and MacFarlane, D. J., 1974. The Oceanic Islands: Azores. *In* Nairn, A. E. M and Stehli, F. G. (Eds.), *The ocean basins and margins,* v. 1: The North Atlantic: New York (Plenum Press), p. 445-483.

Vogt, P. R., 1974a. Volcano height and plate thickness, *Earth Planet. Sci. Lett.,* v. 23, p. 337-348.

________, 1974b. Volcano spacing, fractures, and thickness of the lithosphere, *Earth Planet. Sci. Lett.,* v. 21, p. 235-252.