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Volcanic flux variations along the Hawaiian hotspot track: plume pulsations vs. plume-lithosphere interaction

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Advanced filtering techniques applied to altimetry data have revealed that the volume of volcanic edifices, and therefore the volcanic flux, at Hawaii has been fluctuating a lot in the past 30 Myr. Such successive increases and decreases remain unexplained by classical plume theory, which predicts a maximum volcanic activity as the plume head impinges on the lithosphere, and a subsequently decreasing plume-tail-related volcanism. In particular, an increase of Hawaiian volcanic flux by a factor of $\sim$3 from $\sim$30 to $\sim$15 Ma is associated with an increase of the cross-sectional area of the Hawaiian hotspot swell, as well as an increase in Pacific plate speed from $\sim$60 to $\sim$100 km/Myr. In order to understand the underlying mechanisms for these coupled increases, we explore three-dimensional numerical models of plume ascent through the upper mantle and interaction with the lithosphere. Our models predict that volcanic flux at the hotspot and swell volume decrease as plate speed increases. This predicted decrease is well explained by less efficient erosion of the base of the lithosphere by small-scale convection as the plate moves faster over the hotspot. However, the predicted decrease is in contradiction to the observed boost of volcanism and swell volume. An increase in plume temperature (by $\sim$100 K) or in plume buoyancy flux (by a factor $\sim$2) starting at $\sim$30 Ma is required to offset the effects of increasing plate speed, and to sustain the observed increase of hotspot activity. Further analysis of the temporal evolution of swell cross-sectional area and volcanic flux enables us to separate the influence of plume temperature and plume radius, suggesting a dominant role of plume temperature variations in supporting a plume pulse of increased buoyancy flux. Hence, our findings contribute to a better understanding of the underlying mechanisms of plume pulses, and their relationship to changes in plate motion.