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The role of viscous magma mush spreading in volcanic flank motion at Kilauea Volcano, Hawai'i

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Multiple mechanisms have been suggested to explain seaward motion of the south flank of Kīlauea Volcano, Hawai‘i. The consistency of flank motion during both waxing and waning magmatic activity at Kīlauea suggests that a continuously acting force, like gravity body force, plays a substantial role. Using finite element models, we test whether gravity is the principal driver of long-term motion of Kīlauea's flank. We compare our model results to geodetic data from Global Positioning System and interferometric synthetic aperture radar during a time period with few magmatic and tectonic events (2000–2003), when deformation of Kīlauea was dominated by summit subsidence and seaward motion of the south flank. We find that gravity-only models can reproduce the horizontal surface velocities if we incorporate a regional décollement fault and a deep, low-viscosity magma mush zone. To obtain quasi steady state horizontal surface velocities that explain the long-term seaward motion of the flank, we find that an additional weak zone is needed, which is an extensional rift zone above the magma mush.
The spreading rate in our model is mainly controlled by the magma mush viscosity, while its density plays a less significant role.We find that a viscosity of 2.5 x 10^{17} – 2.5 x 10^{19} Pa s for the magma mush provides an acceptable fit to the observed horizontal surface deformation. Using high magma mush viscosities, such as 2.5 x 10^{19} Pa s, the deformation rates remain more steady state over longer time scales. These models explain a significant amount of the observed subsidence at Kīlauea's summit. Some of the remaining subsidence is probably a result of magma withdrawal from subsurface reservoirs.