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Generation of low-frequency tremor by fluid flow

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We discuss the possibility that flow-induced instability along underground conduit or plane layer causes low-frequency tremor. One example is generation of volcanic tremor, which occurs before or during eruption and lasts more than a few minutes with oscillation period of 0.2-2 seconds (e.g., see Konstantinou and Schlindwein, *J. Volcanol. Geotherm. Res*., 2002). Sakuraba and Yamauchi (*Earth Planets Space*, 2014) showed that a relatively slow magma flow speed of O(1) m/s through a plate-like dike of thickness of around 0.5 m can cause linear instability in flow perturbation and surrounding elastic wave field. The critical magma flow speed decreases in inverse proportion to the Rayleigh-wave wavelength propagating along the dike with flexural deformation. They concluded that natural dike lengths put constraint on the oscillation period, but a subsequent study suggests that a finite dike width may determine the longest wavelength that allows instability. A laboratory experiment is also ongoing to verify the above theoretical prediction that a viscous fluid flow through a plate-like conduit can create self-oscillations. Another example may be found in generation of non-volcanic deep tremor that occurs at subducting plate (Obara, *Science*, 2002). This is still a speculation motivated from a study by Kumaran, Fredrickson and Pincus (*J. Phys. II France*, 1994) who considered Couette flow between two parallel plates, one of which is rigid and the other is moving, but the medium between the plates is two-layered: a fluid layer is placed on a layer of soft (viscoelastic) material. They theoretically showed that flow-induced vibration can occur with a very small shear rate. In an idealized situation in which the solid layer extends infinitely, the critical speed of the moving plate decreases in inverse proportion to the characteristic length scale of the associated wave that propagates at a half the plate speed. Though we have not examined whether this model explain time scales of observations with reasonable physical and material properties, similarity between the above mentioned examples suggests that flow-induced instability may explain some of the tremor events.

Keywords: flow-induced vibration, volcanic tremor, non-volcanic deep tremor