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Earthquake-induced tectonic stress triggering an eruption. Case studies of a viscoelastic shell delay response at Tungurahua, Villarrica and Popocatépetl volcanoes.

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One of the outstanding questions in volcanology is whether volcanic eruptions can be triggered by small magnitude external forcings, and whether this can be modelled in a way which improves the chances of our being able to predict future activity at certain sorts of volcanoes. Maintained stress or changes in the stress fields in active volcanoes can trigger eruptions even in systems remaining below a limit-stress condition. A rock volume holding magma may undergo a material failure if a subcritical stress is set and maintained for a long enough time. The material failure process produces a characteristic release of strain that may be detected by nearby monitoring stations as an accelerating rate of seismic energy. The shape of the accelerating seismic energy release pattern provides information about the stress history leading to an eruption. Although these precursory accelerating patterns do not always appear, they can be successfully applied to predict the time of an eruption when detected. Real-time monitoring devices at Tungurahua, Villarrica, and Popocatépetl volcanoes in 2003, 2000 and 1999 respectively, permitted detecting the characteristic accelerating pattern leading to eruptions. In all cases, the onset of the pattern was marked by regional tectonic earthquakes. The analysis of the cumulative seismic energy indicates that the regional earthquakes imposed a stress on each volcano that increased in an approximately lin-

ear way with time, producing a logarithmic increase pattern of the seismic rate. After the stress stopped its increase, it remained constant, producing a hyperbolic increase of the seismicity rate, until the holding material failed, causing the eruptions. The duration of the increasing-stress stage is interpreted as related to the relaxation time of the viscoelastic media surrounding the magma. Assuming a material rigidity in the order of 5˜10 GPa, the behavior in both volcanoes is consistent with a bulk viscosity component of the order of 105˜6 GPa s.