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Changes in shear-wave splitting before volcanic eruptions

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We have shown that observations of shear-wave splitting (SWS) monitor stress-accumulation and stress-relaxation before earthquakes which allows the time, magnitude, and in some circumstances fault-plane of impending earthquakes to be stress-forecast. (We call this procedure stress-forecasting rather than predicting or forecasting to emphasise the different formalism.) We have stress-forecast these parameters successfully three-days before a 1988 M5 earthquake in SW Iceland, and identified characteristic anomalies retrospectively before ∼16 other earthquakes in Iceland and elsewhere.

SWS monitors microcrack geometry and shows that microcracks are so closely spaced that they verge on fracturing and earthquakes. Phenomena verging on failure in this way are critical-systems with 'butterfly wings' sensitivity. Such critical-systems are very common. The Earth is an archetypal complex heterogeneous interactive phenomenon and must be expected to be a critical-system. We claim this critical system as a New Geophysics of a critically-microcracked rock mass. Such critical systems impose a range of fundamentally-new properties on conventional sub-critical physics/geophysics, one of which is universality. Consequently it is expected that we observe similar stress-accumulation and stress-relaxation before volcanic eruptions to those before earthquakes.

There are three eruptions where appropriate changes in SWS have been observed similar to those observed before earthquakes. These are: the 1996 Gjálp fissure eruption, Vatnajökull, Iceland; a 2001 flank eruption on Mount Etna, Sicily (reported by Francesca Bianco, INGV, Naples); and the 2010 Eyjafjajökull ash-cloud eruption, SW Iceland. These will be presented in the same normalised format as is used before earthquakes.

The 1996 Gjálp eruption showed a $2\frac{1}{2}$-month stress-accumulation, and a ∼1-year stress-relaxation (attributed to the North Atlantic Ridge adjusting to the magma injection beneath the Vatnajökull Ice Cap). The 2001 flank eruption of Etna showed stress-accumulation and stress-relaxation typical of a small earthquake. However, the changes in SWS before the 2010 Eyjafjajökull Eruption, SW Iceland, showed the most distinctive correlations with earthquakes, as it was only ∼90km-west of the 1988 M5 in SW Iceland, which was successfully stress-forecast.

The behaviour of SWS before the M5 earthquake and the Eyjafjajökull flank (ash-cloud) eruption is almost identical both showing linear stress-accumulation increases, and linear stress-relaxation decreases to the earthquake and the onset of the flank eruption, respectively. There are comparable slopes and durations.

We consider this strong confirmation of the universality property of the New Geophysics of a critically-microcracked Earth.

Papers referring to these developments can be found in geos.ed.ac.uk/home/scrampin/opinion.
Also see abstracts in EGU2015 Sessions: Crampin & Gao (SM1.1), Gao & Crampin (SM3.1), and Crampin & Gao (GD.1).