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Evidence for a critical Earth: the New Geophysics

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Phenomena that are critical-systems verging on criticality with 'butterfly wings' sensitivity are common - the weather, climate change; stellar radiation; the New York Stock Exchange; population explosions; population collapses; the life cycle of fruit-flies; and many more. It must be expected that the Earth, an archetypal complex heterogeneous interactive phenomena, is a critical-system, hence there is a New Geophysics imposing fundamentally new properties on conventional sub-critical geophysics.

We shall show that, despite shear waves and shear-wave splitting (SWS) being observationally neglected, azimuthally-varying stress-aligned SWS is nearly universally observed throughout the Earth's crust and uppermost ~400km of the mantle. Caused by stress-aligned fluid-saturated microcracks (intergranular films of hydrolysed melt in the mantle), the microcracks are so closely-spaced that they verge on failure in fracturing and earthquakes. Phenomena that verge on failure in this way are critical-systems which impose a range of fundamental-new properties on conventional sub-critical geophysics including: self-similarity; monitorability; calculability; predictability; controllability; universality; and butterfly wings' sensitivity. We shall show how these phenomena have been consistently observed along millions of source-to-receiver ray paths confirming the New Geophysics. New Geophysics helps to explain many otherwise inexplicable observations including a number of geophysical conundrums such as the Gutenberg-Richter relationship which is used to describe the behaviour of conventional classic geophysics despite being massively non-linear.

The great advantage of the critical Earth is that, unlike other critical-systems, the progress towards criticality can be monitored at almost any point within the deep interior of the material, by analysing observations of seismic SWS. This gives an unrivalled understanding of the detailed behaviour of a particular critical-system. This new understanding of fluid-rock deformation unifies much of the behaviour and has currently-relevant applications:

1) The times, magnitudes, and in some circumstances locations, of impending earthquakes can be stress-forecast (predicted);
2) The times of impending volcanic eruptions can be stress-forecast (predicted);
3) The production of hydrocarbon reservoirs can be, in principle, calculated;
4) Recovery from hydrocarbon reservoirs will be increased if production is slower;
5) Time-lapse of SWS single-well imaging can monitor movement of oil/water contacts;
6) Time-lapse of SWS can monitor behaviour of fluids in fracking reservoirs;
7) Time-lapse SWS can monitor leakage in underground nuclear-waste repositories.

Papers referring to these developments can be found in geos.ed.ac.uk/home/scrampin/opinion.
Also see abstracts in EGU2015 Sessions: Gao & Crampin (SM3.1), Liu & Crampin (NH2.5), and Crampin & Gao (GD.1).