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The New Geophysics: advances in understanding shear-wave splitting

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Stress-aligned shear-wave splitting, caused by pervasive distributions of stress-aligned fluid-saturated cracks in almost all igneous, metamorphic and sedimentary rocks, has been recognised for some 25 years. There have been extensive investigations of wave propagation in such anisotropic rocks but, until recently, there has been little understanding of the behaviour or geophysics of fluid-saturated cracks or microcracks. The breakthroughs came during the various EC-funded projects in Iceland, PRENLAB, SMSITES, and now PREPARED. The persistent low-level seismicity, where transform faults of the Mid-Atlantic Ridge run on shore, and the access to extensive seismic waveform data over the Internet, have allowed substantial advances in understanding of shear-wave splitting and the behaviour of stress-aligned fluid-saturated microcracks.

The fluid-saturated stress-aligned microcracks are so pervasive and closely spaced that they are critical systems verging on fracture-criticality and failure by fracturing. Consequently, they possess self-organised criticality with all the implications that this implies, including “butterfly wing’s” sensitivity to miniscule changes in initial conditions, deterministic chaos when fracturing does occur, and calculability of low-level deformation, so that the almost parameterless Anisotropic Poro-Elastic (APE) model of microcrack deformation matches an enormous range of phenomena relating to cracks, stress, and shear-wave splitting. As a result, behaviour of microcrack geometry can be *monitored* with shear-wave splitting, *modelled* by APE, and future behaviour *predicted* if the changes in rock mass conditions are known. This means that if the intended result is known, the degree of aligned fracturing in water-flood operations in hydrocarbon reservoirs, say, the behaviour can be potentially *controlled* by feedback. In particular, the accumulation of stress before earthquakes (and at volcanic eruptions, see VGP6 presentation, can be recognised by analysis of shear-wave

splitting, and the time and magnitude of impending earthquakes estimated from the time the increase of Band-1 time-delays reaches fracture criticality.

A recent advance is understanding the reason for the ±80% scatter in measurements of shear-wave time-delays above small earthquakes. This is now recognised as due to the 90º-flips in shear-wave polarisations due to critically high pore-fluid pressures in all seismically-active fault zones interacting with the positive time-delays in the normally pressurised ray paths above the fault to the surface.

I shall review these various advances which appear to be a new understanding, a *New Geophysics*, of the behaviour of pre-fracturing deformation of fluid-saturated microcracked rock.