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The New Geophysics: stress-forecasting earthquakes

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Investigations of shear-wave splitting above small earthquakes in the EC-funded projects in Iceland (see previous NH4.04 presentation) indicate that the accumulation of stress before earthquakes can be monitored by increases in shear-wave time-delays along ray paths in the Band-1 solid angle of the shear-wave window. Such increases have been recognised before some 15 earthquakes in Iceland and elsewhere ranging in magnitude from a $M1.7$ swarm event in northern Iceland to the *Ms* 7.7 Chi-Chi in Taiwan. On one occasion, the time, magnitude, and fault break of a $M5$ earthquake in SW Iceland was successfully stress-forecast in real time.

The scarcity of suitably persistent swarm activity to provide sources of shear-waves means that routine stress-forecasting requires controlled-source seismics in Stress-Monitoring Sites (SMSs) between closely separated boreholes deep enough (1 – 2km) to avoid near surface stress-release anomalies.

Observations from the prototype SMS adjacent to the Húsavík-Flatey Transform Fault (HFF) in northern Iceland, the EC SMSITE project, confirmed both the science and technology of SMSs for stress-forecasting impending earthquakes. Very well recorded anomalies in the *P*-, *SH*-, *SV*-waves travel times (where 100-fold stacking led to accuracies of $\pm$0.2ms), *SV*-*SH* time-delays (the most sensitive measurement), NS and EW GPS measurements, and a 1m decrease in the level of a water-well immediately over HFF, all correlated with small scale seismicity on a neighbouring transform fault 70km NNW of the SMSITE wells. The total energy release of the seismicity was equivalent to a $M \sim 3.5$ event, a comparatively small earthquake. This means that the well-recorded anomalies at SMSITE were observed at several hundred times the conventional source dimension.

Extrapolation indicates that variations before M 5 events, that is all damaging earthquakes, would be observed at 400km distance. This means that a grid of borehole

SMSs on a 400km grid would stress-forecast all damaging earthquakes within then grid. GEMS, a global network of SMSs has been suggested to forecast all damaging earthquakes worldwide (U3 presentation).

These phenomena are a new understanding of fluid-rock deformation, a *New Geophysics*, where low-level deformation can be: *monitored*; *modelled*; in some cases, future *calculated*/ *predicted*; and in principle future behaviour potentially *controlled* by feedback.