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THE NEED FOR CONTROLLED-SOURCE STRESS-MONITORING SITE FOR STRESS-FORECASTING EARTHQUAKES

ABSTRACT

Recent evidence suggests that the time and magnitude of earthquakes can be stress-forecast by analysing seismic shear-wave splitting over appropriate ray paths. Theory (APE*-modelling) and observations demonstrate that the aspect-ratios of stress-aligned fluid-saturated grain-boundary cracks and pores are modified by the build up of stress before earthquakes. Changes in crack aspect-ratio can be monitored by changes in the time-delays between split shear-waves. Such observations require a specific source-receiver geometry (and proximity to the impending earthquake). If small earthquakes are used as the shear-wave source, this requires persistent swarms of small earthquakes, which are very uncommon. Consequently, such changes have been observed before only four earthquakes worldwide where conditions are appropriate (there are no contrary indications). The breakthrough came when shear-wave splitting was monitored for four years in the highly seismic transform zone of the Mid-Atlantic Ridge, which is onshore in SW Iceland. Changes in shear-wave splitting, indicating the build up of stress, were observed almost routinely before earthquakes and volcanic eruptions, and the time and magnitude of a M5 earthquake was successfully stress-forecast.

Anisotropic Poro-Elasticity (APE) models the deformation of stress-aligned fluid-saturated grain-boundary cracks and pores by fluid-movement along pressure gradients between microcracks at different orientations to the stress-field.

In the absence of reliable swarm activity, observations of changes in shear-wave splitting require controlled-source seismology in Stress-Monitoring Sites (SMSs) using crosshole seismics between 1km to 2km-deep boreholes. The first SMS is being developed in the EC-funded SMSITES Project in a seismic gap where the Húsavík-Flatey Fault (HFF), in the Tjörnes Fracture Zone of the Mid-Atlantic Ridge, runs onshore at Húsavík in northern Iceland.

SMSITES is recording spectacular data. The LHS diagram (Fig. 1) shows the variation in shear-wave travel times (over nine-days) along a 315m horizontal path at 500m depth showing a well-observed 2ms-amplitude "S"-shaped relaxation-curve (resolution ~±0.04ms). The RHS diagram (Fig. 2) shows: seismic shear-wave velocity (inverse of LHS); correlating with comparatively small sei-

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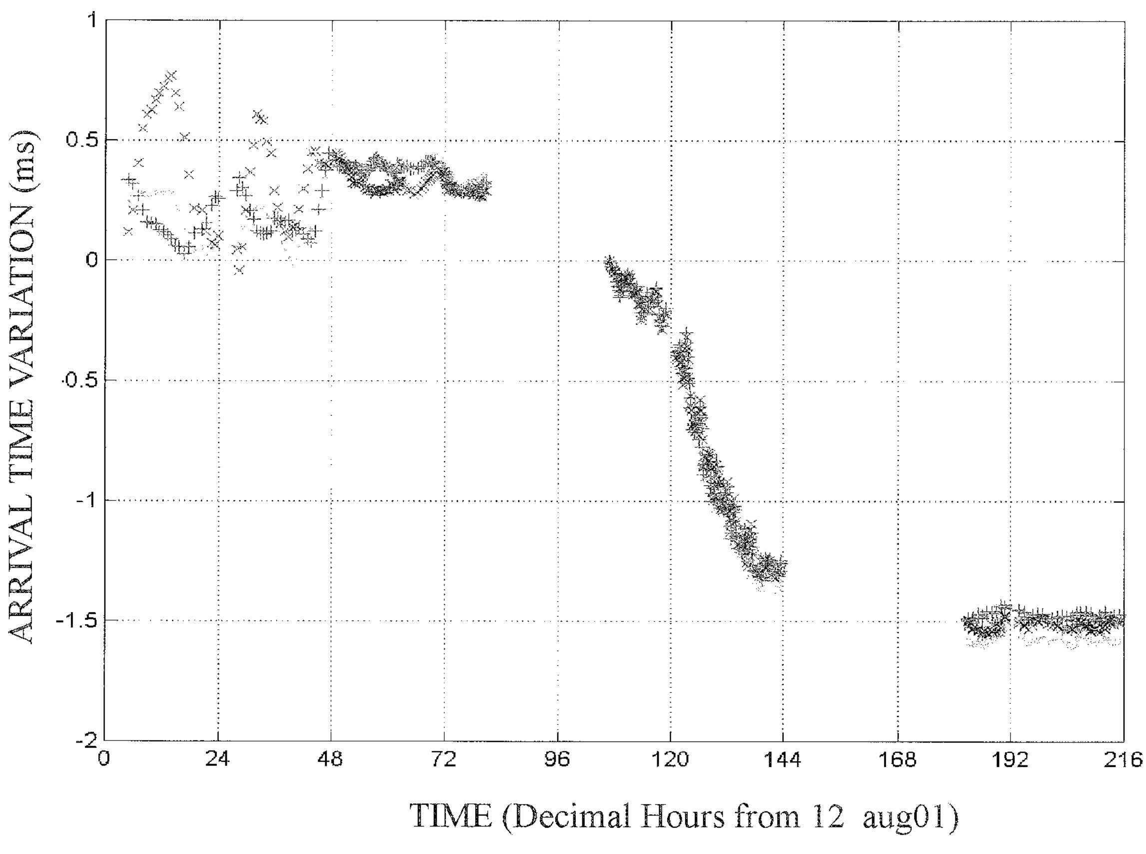

Fig. 1 - S-Wave Arrival time temporal variation (pilot 13).

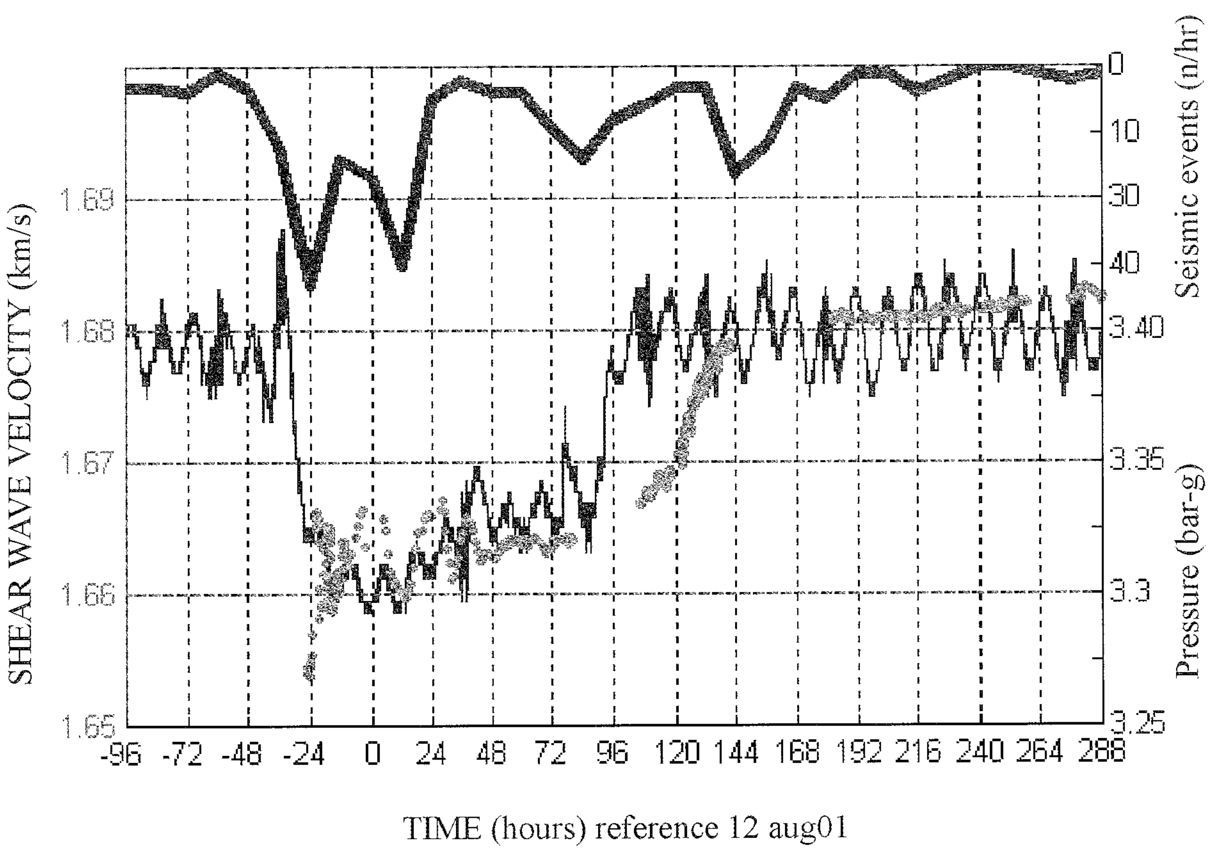

Fig. 2 - Shear-wave velocity, seismicity, Well pressure.

smic activity; and with 1m water-level changes in a neighbouring well (The water-level changes also show the effects of oceanic tides).

Associations of well-level changes with seismicity (and tides) are well known, but this is believed to be the first observation of relaxation curves in shear-wave arrival-times. Their importance is that shear-waves can be directly inverted for the stress causing the changes in microcrack geometry.

These observations confirm that the concept and techniques of stress-monitoring sites (SMSs) are valid and can be used for stress-forecasting earthquakes. Consequently, we seek collaborators to set up SMSs in optimum localities in earthquake-vulnerable locations elsewhere.

KEY WORDS: Shear-wave velocity, seismic activity, transform zone