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# Improved reliability of measured in situ stresses by use of independent measurements, stress indicators, or other solid evidence

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Several hydraulic fracturing (HF) stress measurement campaigns are discussed for which independent evidence increased the confidence in the validity of the results.

In the oil field at Rangely, Colorado, USA, unprecedented small magnitude earthquakes were suspected to be the result of 'water flooding' operations that raised the pore pressure in producing zones. HF tests revealed a stress regime favoring strike-slip motion along the existing fault traversing the oil field. Together with the independently determined slip criterion for the fault, HF results were used to compute the threshold pore pressure necessary to induce fault movement. That pressure was surprisingly close to the one monitored during earthquake activity, confirming the reliability of the tests.

At Darlington, Ontario, Canada, HF tests revealed a uniform and highly compressive stress regime within 300 m below the planned foundation of a nuclear power generating station. The calculated stress magnitudes and directions were independently supported by overcoring measurements in the top 100 m that showed practically identical results.

In Korea, measurements in 13 boreholes at five locations from North Seoul to the southern coast indicated a consistent stress regime oriented practically E-W and reflecting strike-slip conditions at depths greater than 500 m. Focal mechanisms in and around the Peninsula confirmed both the directions and the relative magnitudes of the stresses.

On the other hand, stress measurements at Gable Mountain, Washington, USA, a now abandoned potential site for nuclear waste disposal, were rather inconclusive in as much as the HF-determined least horizontal stress was double that estimated from overcoring measurements.

Hostile conditions in geothermal or ultra deep holes often prevent the use of any known direct stress measurement. In the KTB hole, shallow HF measurements were complemented by the use of logged breakouts and the laboratory determination of the rock true triaxial strength to obtain an indirect estimate of the stress regime at greater depths. That was then supplemented by another stress indicator in the form of logged drilling-induced tensile cracks.

Presently there is no way to prove that what we measure are the actual crustal stresses. Only by verification through different stress measurement methods, stress indicators, or other observations, can we gain confidence in the test results. The above examples are meant to illustrate the importance of supporting measured stresses with independent evidence as a means of accepting them.