Induced or Triggered Seismicity? A Long Term Approach

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The challenge of linking seismicity with human activity is not new; seismic recording systems were used to monitor induced earthquakes related to coal mining back in the 1900s. Real time seismic monitoring using highly sensitive downhole 3-component sensors, coupled with advanced downhole digital electronics and telemetry systems, have delivered a paradigm shift in spatially locating increasingly smaller earthquake foci in a 3D or 4D space. Real time monitoring and location of such 'microseismic' activity is common practice during unconventional hydrocarbon reservoir injection and depletion, where triggered events can be correlated with the spatial distribution of hydraulically fractured pathways and so indicate and optimise total stimulated reservoir volume and integrity.

Only recently have legal and regulatory bodies begun to formalise the process for instrumenting, monitoring and characterising *all* significant seismic activity related to reservoir activity. The economic incentive for operators and service companies to focus primarily on the very small microseismic events has yet to be extended to the practice of precisely monitoring and defining larger scale activity, especially *after* unconventional operations are completed.

Induced or Triggered?

Recent unconventional operations associated with any 'felt' human-induced seismicity, especially in north-west Europe, have resulted in lengthy disputes between industry, seismologists and an increasingly sceptical public, convoluted further by the lack of any commonly accepted rules for discriminating between induced seismicity and triggered events.

Various workers have attempted to refine these terms, suggesting induced seismicity is related to volume change in the Earth, probably by human action during reservoir depletion. In such cases vertical shear stress is expected to be at a maximum at the edge of the expanding reservoir, leading to dip-slip events. Triggered events, on the other hand, are associated with the release of natural tectonic stress, although microseismicity associated with injecting proppant along a fracture plane can also be said to be triggered, as the effective stress changes trigger shear movement along/across the fracture network.

To differentiate seismic events recorded during reservoir operations by these terms, the spatial and temporal distributions of the foci need to be precisely and reliably resolved. The question of how close a seismic event has to be to the operation to be assumed related remains subjective, particularly in tectonically active regions with frequent natural earthquakes. Seismologists argue that we should integrate the recorded 4D foci distribution, the physical failure mechanisms and the modelled geomechanical regime, to help qualify a triggered/induced probability value for an event.

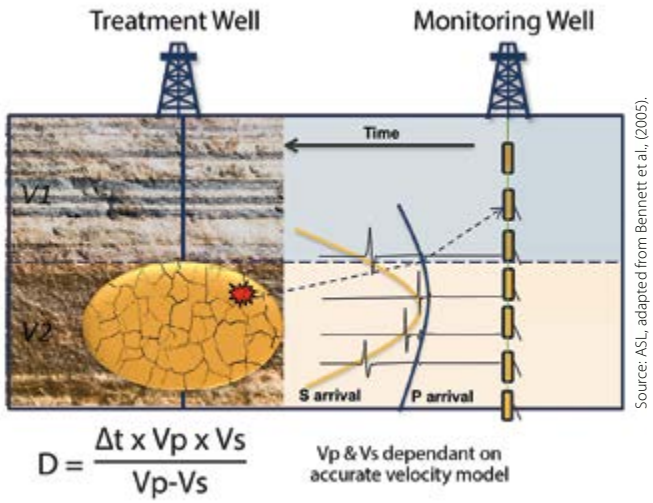
The methodology of acquiring such data is becoming firmly rooted in the practice of permanent/semi-permanent passive monitoring. Continuously recording events before, during and after injection provides a more stable background seismicity model, especially if combined with a known fault map, but this can add significant cost to the process.

Collaboration is Key

Standardising integrated 'big data' into a legal framework presents broad challenges. In Europe, monitoring is mainly a risk management rather than a production task. Demands from insurers and regulators are fragmented and require applied research and specialised niches. Perhaps peak ground velocity/max acceleration would be a more appropriate measurable variable and proportionate to 'felt' seismicity.

Unconventional extraction in Europe can no longer be justified with US analogues. Recent events in the USA, mostly associated with seismicity linked to waste water disposal, has given much unwanted publicity and pressure to hydraulic fracturing and its management. US and European regulatory authorities are watching each other to see what actions will have the first positive perceived impact.

A European network is required to defragment and standardise the operator, regulator and academic regulations, with criteria appropriate for the background seismicity of a region. Permanent monitoring will help constrain uncertainty and protect operators whilst bolstering the seismic recording market. By encouraging bodies to take a multi-disciplinary approach across better regulated industries like geothermal and mining, we will see the beginnings of quantitative, testable rules for the probabilistic discrimination of human-induced, human-triggered and natural earthquakes. ■



Source: ASL, adapted from Bennett et al., (2005).

Schematic of a borehole microseismic monitoring system.