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What's shaking?: Understanding creep and induced seismicity in depleting sandstone reservoirs

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Subsurface exploitation of the Earth's natural resources, such as oil, gas and groundwater, removes the natural system from its chemical and physical equilibrium. With global energy and water demand increasing rapidly, while availability diminishes, densely populated areas are becoming increasingly targeted for exploitation. Indeed, the impact of our geo-resources needs on the environment has already become noticeable. Deep groundwater pumping has led to significant surface subsidence in urban areas such as Venice and Bangkok. Hydrocarbons production has also led to subsidence and seismicity in offshore (e.g. Ekofisk, Norway) and onshore hydrocarbon fields (e.g. Groningen, the Netherlands).

Fluid extraction inevitably leads to (poro)elastic compaction of reservoirs, hence subsidence and occasional fault reactivation. However, such effects often exceed what is expected from purely elastic reservoir behaviour and may continue long after exploitation has ceased or show other time-lag effects in relation to changes in production rates. One of the main hypotheses advanced to explain this is time-dependent compaction, or 'creep deformation', of such reservoirs, driven by the reduction in pore fluid pressure compared with the vertical rock overburden pressure.

The operative deformation mechanisms may include grain-scale brittle fracturing and thermally-activated mass transfer processes (e.g. pressure solution). Unfortunately, these mechanisms are poorly known and poorly quantified. As a first step to better describe creep in sedimentary granular aggregates, we have derived a universal, simple model for intergranular pressure solution (IPS) within an ordered pack of spherical grains. This universal model is able to predict the conditions under which each of the respective pressure solution serial processes, i.e. diffusion, precipitation or dissolution, is dominant. In essence, this creates a generic deformation mechanism map for IPS in any granular material. We have used our model to predict the amount and rate of compaction for depleting reservoirs, and compared our predictions to known subsidence rates for reservoirs around the world. This gives a first order-comparison to verify whether or not IPS is an important mechanism in controlling reservoir creep.