Coal Seam Gas, induced earthquakes and underground water

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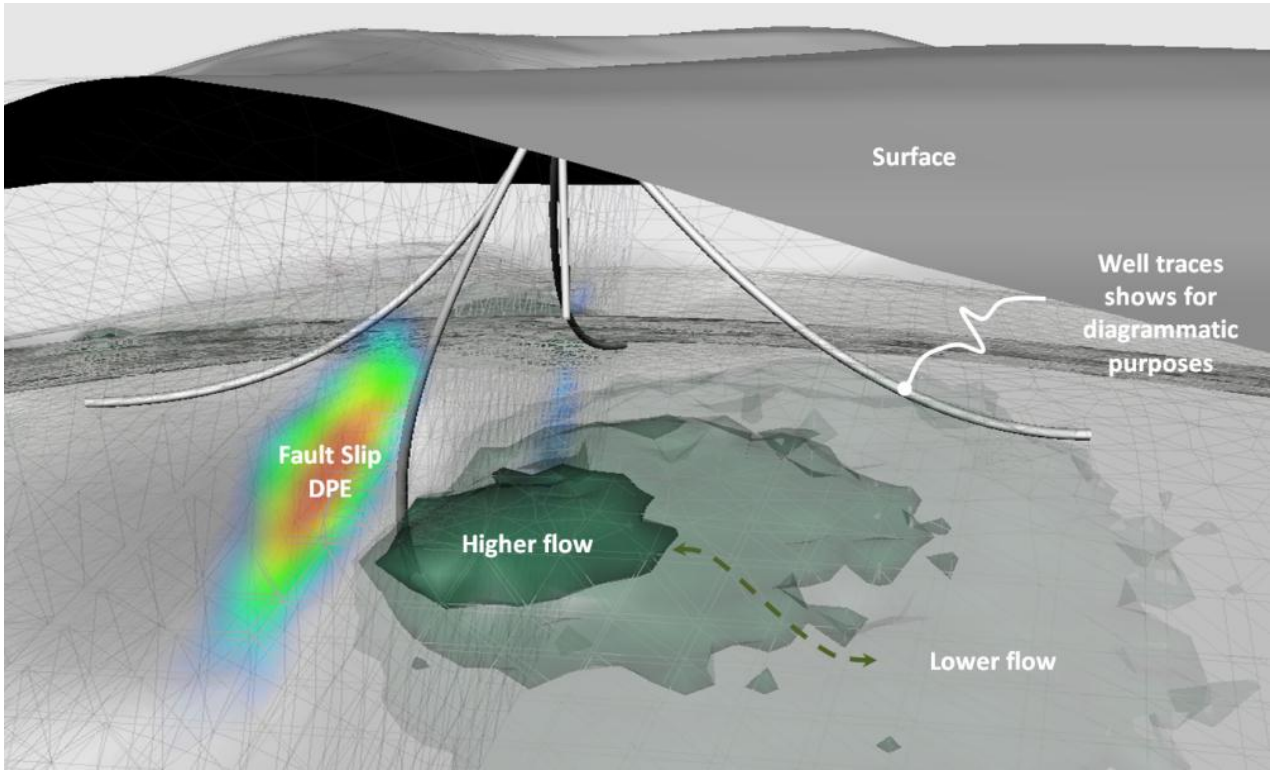

Figure A 3d numerical model of fluid extraction, showing flows and simulated fault slip. Most numerical simulations of fluid or gas extraction assume that all flow is through the rock mass, and ignore the effects of structure on flow and the impacts of induced rock mass damage on flow. This model is unique because it captures these essential impacts

Why CSG?

Australia relies on coal for base-load electricity, but cleaner energy sources are being added to the mix to pursue longer-term emission reduction targets. Coal seam gas (CSG) and other gas-generated electricity sources are intermediate steps towards the goal of lower emissions – they are cleaner than coal, and can compete in the current energy market. Viable, cleaner energy sources, such as CSG that are compatible with existing energy infrastructure should also help build the renewable energy market.

Why are people talking about earthquakes and CSG?

To extract CSG, high-pressure fluids are injected into the gas bearing rock layers. This opens up existing fractures and creates new ones. The injection 'enhanced' network of fractures increases the rate that the gas, which is mainly methane, can flow and increases gas recovery. As water and gas are then extracted, additional movements and stress changes occur, and this too influences the fracture network.

Any time fractures in rock are generated or deformed, the existing stress state in the rock changes and some seismic activity occurs. Interactions like these are unavoidable and part of human history – almost no mining takes place without some seismic activity and mining is an essential part of human life.

Usually, these injection and extraction induced seismic events are small and can only be detected with sensitive equipment, which is why so many people living near mines are not aware of. Planes, trucks and many other human activities generate noise and vibrations that are stronger and more frequent than seismic events associated with most mines or CSG extraction.

Under certain well-understood circumstances, some moderate sized tremors can be induced that may be felt on surface. The mechanisms and risk factors for this are well understood, even if the specific events themselves are harder to predict. These events are orders of magnitude smaller than the devastating earthquakes that we see in the news, but if the vibrations from these events are large enough, some built structures can be damaged if not designed for these vibrations. This is very rare, but has happened so we have to engineer CSG extraction to reduce the risks to acceptable levels.

Why are people talking about CSG and underground water?

The same changes to rock fractures and deformation that are associated with seismicity also change the pathways for fluid and gas flow. New fractures may be generated span different water sources, or else the rock damage and stress changes may lead to higher flows between different areas.

There are concerns that in some circumstances, the injected fluids could interact with important water resources, or that fractures could allow gas to leak.

How do we do engineer to limit seismicity and underground water impacts from CGS extraction?

We need to plan CSG extraction to minimise the risk of large seismic events and adverse effects on underground water. This could involve controlling the extraction sequence and controlling the fluid injection and extraction rates throughout the CSG field, optimising the placement of wells and also by carefully constraining the extraction rates and volumes.

An essential part of this planning process is 3d CSG field scale simulation, which involves simulating the interaction between rock stress, fracture behaviour and seismic activity with computer models. We can use these models to design resilient, well-managed CSG extraction strategies and to understand field measurements during extraction to continuously improve CSG extraction plans. It is feasible to use these models to differentiate inherently safe wells and ones that may pose some risk.

The underlying physics of the hydraulic fracturing and induced seismicity in CSG fields is well understood, and the 3d discontinuum computer simulation methods are well developed.

The minimum requirements for sufficient simulation are:

- The damage processes: Couplings between stress, strain, strength, structure and fluid must be simulated. This necessitates discontinuum, non-linear simulations.
- The stress deformation path: The gradual changes in stress and strain induced as fluid is injected and removed must be captured.
- The existing geological structure, and faults in particular, must be modelled in three dimensions. Two or one dimensional models simply don't capture the essential physics.
- Fluid flow on faults and structures must be simulated. Some homogenisation is necessary because we can’t assume that the rock or coal is an equivalent porous medium at all length scales.
- BE believes that the models must be fully hydromechanically coupled. This means that the damage can evolve in the rock more naturally, and we can directly compare the energy changes in the model to the energy changes (including seismicity) measured in the field.
- The models must be ground-truthed and calibrated in a transparent way. This means comparing the measured subsidence, borehole damage seismic monitoring data and pumping rates to modelled values, and continuously improving the models over time so that engineers can update and optimise the extraction plan to minimise the potential for larger seismic events.

- The models should be used in a collaborative way and transparent way to better plan to minimise risks and make better decisions at every stage from planning through to closure.

Models that meet these specifications are available using existing technology.

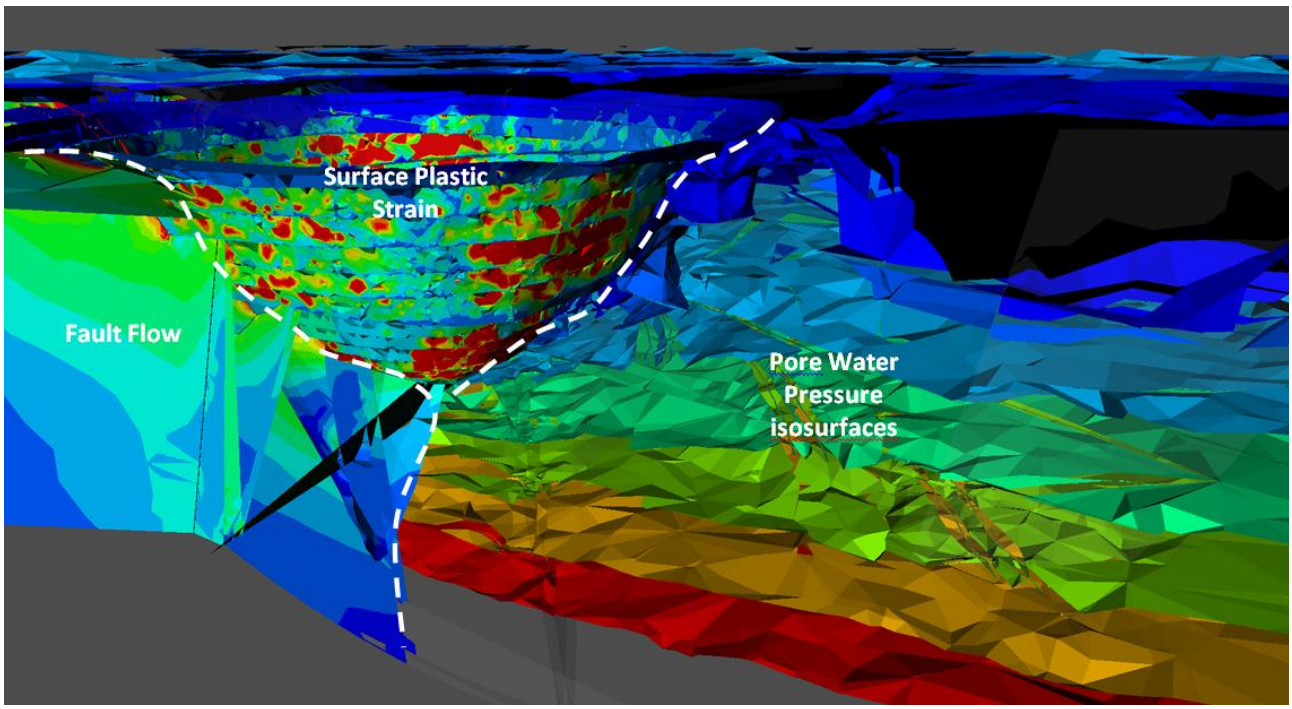

Figure Cut away view showing simulation of underground water pressure, rock damage and fluid flows on faults. 3d simulation like this is feasible for CSG planning, and will improve the reliability and resolution of forecasts of well performance and properly estimate the limits of the influence of wells

The next step?

The risk of large seismic events can be minimised to achieve an acceptable balance between the relatively low risks from induced seismicity and the rewards of cleaner energy sources. Interactions with water can also be forecast with higher resolution, allowing greater transparency and more rational planning.

BE specialises in this kind of simulation. If you want to better understand high similitude forecasting of induced seismic potential and couplings between CSG extraction and underground water, BE would be pleased to discuss this with you.

Getting CSG extraction right is very important: We need cleaner energy sources as the step to a sustainable economy.

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