History of Significant Petroleum Geomechanics Advances in Western Canada and a Look at the Future

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Summary

Western Canada has a rich history of geomechanical analyses and mapping studies dating back to the late 1970's and continuing today. Petroleum geologists and engineers may not be aware of the abundance of geomechanical data in the public record that can be used to help make decisions in everything from exploration to secondary recovery. This talk is meant to serve as a reminder of how geomechanics *has been* applied, *is being* applied and *should be* applied in the Western Canadian oilpatch. It highlights past innovations, changing focus areas (geographic and technological) and continuing workflow adjustments due to new data types, new resources, changing economics and evolving geological and engineering concerns.

In the Beginning

In the late 1970s it was first recognized that borehole cross-section enlargement, as measured by caliper logs, showed a consistent Northwest-Southeast orientation across a wide swath of the Western Canada Sedimentary Basin (Babcock, 1978). Although originally attributed to subsurface joint sets, the consistency in wellbore ellipticity, known as borehole breakouts, was soon found to be the result of a dominant horizontal tectonic stress oriented Northeast-Southwest, perpendicular to the borehole elongations (Bell and Gough, 1979). Decades of research since, in Canada and abroad, have reinforced this conclusion, and the link between stress orientation and plate tectonic forces, for example as illustrated by the World Stress Map (Heidbach, et al., 2018), is undeniable.

Geomechanics in the Spotlight

The 1980s and 1990s saw a growing interest in, and application of, geomechanics, with some of the highlights being:

- The creation of the Geomechanics Special Interest group in the Petroleum Society of CIM (now SPE), 1985
- Publication of a dedicated chapter in the Geological Atlas of the Western Canada Sedimentary Basin (Bell et al.,1994)
- Widespread adoption of wellbore stability analyses for challenging Foothills and horizontal and deviated wells (McLellan, 1996)
- Beaufort Sea well casing designs in permafrost and gas hydrates
- Heavy oil and oilsands geomechanics, including cold heavy oil sand production with sand (CHOPS), steam fracturing in cyclic steam stimulation (CSS), and geomechanical effects on steam-assisted gravity drainage (SAGD) (e.g., Dusseault,1993)
- Large-scale geomechanical modelling of thrust fault and fold tectonics in the Canadian Rockies and Foothills with a focus on the Triangle Zone (CSPG Bulletin Triangle Zones and Tectonic Wedges: A Special Issue, 1996)

- Early recognition of injection and or production induced earthquakes in Alberta (Wetmiller 1986; Horner et al., 1994)

Gas hydrates, coal-bed methane and carbon sequestration (Hawkes et al, 2005) geomechanics also garnered a lot of attention into the late 90's and early 2000's. At the same time the industry was shifting away from naturally fractured carbonates and clastics in the Foothills, which meant changes for geomechanics as well.

The Rise of Unconventionals

The early 2010s saw the rise of unconventional resources to the forefront. Several changes occurred in industry during this period: drilling shifted from exploration to "manufacturing" wells; trajectories changed from predominantly vertical to predominantly horizontal; enormous completion budgets overshadowed drilling budgets. Fundamental to this change was the typical reservoir rock itself, which went from permeable and homogeneous to tight and anisotropic.

The field of geomechanics also underwent very significant changes during this time. With the rise of multi-stage hydraulic fracturing, in-situ stress and the mechanical behavior of the reservoir and bounding layers became mission-critical. The word "geomechanics" became somewhat of a buzzword and took on a variety of meanings. In the WCSB there was a small spike in published geomechanics studies, but most were focused primarily on stress orientations and minimum stress magnitude. Maps of minimum stress and vertical stress were plentiful, many adding incrementally to the knowledge from the original Bell et al. (1994) atlas data, but published efforts to fully constrain all three principal in-situ stresses were rare (for an exception, see Bell et al., 2015). Of course, much proprietary work has been done but is not available publicly.

Another important change was in the well data being collected. Less exploration meant fewer well logs and cores. Low permeability unconventional rocks meant fewer classic pressure build-up tests. Mini-frac tests (a.k.a. DFITs, or diagnostic fracture injectivity tests) emerged as an important source of in-situ stress and pore pressure data, and with them came new interpretation challenges.

What's Next?

As we come up on 2020, hydraulic fracturing continues to dominate the Western Canadian oil and gas industry. While injection-induced seismicity has been recognized since the 1970's, it is receiving increased scrutiny because of its more recent link to hydraulic fracturing. The Fox Creek area in Alberta and the Kiskatinaw area in British Columbia are two current examples where events exceeding magnitude 4.0 have industry, regulators and the public concerned. Full stress mapping is the first step in trying to understand the phenomenon, and what to do about it (Shen, et al., 2018).

In addition, preliminary research results coming out of drill-back and mine-back projects are proving that our existing hydraulic fracture models are far from accurately capturing what is happening in the subsurface during a fracturing operation (Rassenfoss, 2018). A general realization seems to be emerging that using linear elastic, single planar crack models in many cases simply isn't good enough. It is also becoming increasingly clear that rock quality (variously defined and often affected by geomechanics) matters in placing laterals and selecting the completion type and number of stages.

Some other areas where geomechanics could soon see significant application in Western Canada in particular are the development of geothermal resources, waste water management and hybrid solvent- thermal recovery projects.

Over decades of geomechanics in Western Canada, one thing has remained constant: change and innovation in our concerns, our models, our data and our interpretations will continue to drive success in the oil and gas industry.

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