*Fracture Characterization of a Giant Unconventional Carbonate Reservoir, Alberta, Canada

Paul D. Wagner [1], Ronald A. Nelson [2], Jeff S. Lonnee [3], Michael S. Costello [3], Robert H. Whale [1], William J. McKinzie [3], James W. Jennings [3], Maria A. Balzarini [3], Daniel A. Reed [3], Alia S. Al Bhary [3], and Richard C. Watson [3]
[1]Shell Canada Ltd, Calgary, Canada
[2]Broken N Consulting Inc., Fulshear, Texas, USA
[3]Shell E&P Co., Houston, Texas, USA

In 2006, Shell leased 490 square miles of Alberta Crown Land to pursue a very large unconventional hydrocarbon opportunity. The reservoir is composed of Upper Devonian, dolomitic, karstic, platform interior carbonates in northern Alberta. Reservoir depths are less than 400 meters. The resource is a high-viscosity bitumen.

Initial work suggested that a relatively simple, unstructured geology characterized the lease. Subsequent detailed work indicates a very high degree of structural complexity. Fracturing is particularly important. Interestingly, almost none of the fractures in the reservoir are occluded by diagenetic minerals.

However, high-viscosity bitumen acts as a pervasive organic pore-filling material that occludes or partially occludes both matrix and fracture pore spaces. The presence of bitumen greatly modifies effective permeability pathways throughout the reservoir. Future removal of bitumen through thermal production mechanisms is expected to cause extreme permeability increases as product is removed from both fractures and matrix. Effective vertical permeability in some parts of the lease is expected to increase from hundreds of millidarcies to hundreds of Darcies. Localized decreases in effective vertical permeability may also occur due to local geomechanically-induced fracture closures during thermal treatment.

Structural patterns were defined in an integrated study incorporating core, log, hydrologic and seismic data. The updated structural story has three spatial components: First, a genetic family of fractures is defined in the integrated data set that spans a vertical scale from sub-centimeter to several meters. Fractures are dominantly bed-bound over this spatial scale, and follow a consistent mechanical stratigraphy that extends across the lease.

Second, 3D seismic data resolve larger-scaled fracture features interpreted to be low-throw faults and fracture corridors that are spatially oriented in close alignment with smaller fracture sets characterized by cores and logs. These larger-scaled structural features scale vertically ranging from about 5 to more than 100 meters.

Third, fractal scaling is evident between the largest and smallest fracture populations described above. Using these fractal relationships, we modeled some aspects of intermediate-scaled features such as vertical lengths and map-view spacing geometries. Intermediate-scaled fractures are difficult to characterize because they are of a scale not directly observed by our smaller wellbore and larger geophysical data sets; but are particularly important because they are expected to be primary vertical permeability pathways for fluid movement during thermal treatment.

Several structural drivers are indicated. Many of the larger features like faults and fracture corridors share orientations with underlying basement grain features evident on aero-magnetic maps. As smaller fracture populations closely mimic orientations of faults and corridors, we infer episodic basement movements to be at least partially responsible for fracturing at all spatial scales. Far-field effects of lateral compression are also evident in the integrated data set, as are effects of intraformational karst-related evaporite dissolution collapse, deeper-stratigraphic salt dissolution, and likely effects of repeated glacial loading and unloading on the shallow-buried reservoir.