Controlling Chaos: A Core-Based Approach to Managing the Complexity of the Upper Devonian Grosmont Formation Bitumen Reservoirs

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Introduction

The Upper Devonian Grosmont Formation of Alberta is the carbonate host to approximately 64 billion m^3 (400 billion barrels) of bitumen (Wo, et al. 2011). The Grosmont forms an areally-extensive northwest-southeast trending carbonate complex in northern Alberta. The bitumen "belt" trends northwest-southeast along the eastern edge of the platform. Husky Energy has been drilling exploratory wells on their Saleski landholding since 2006.

Husky drilled twenty-four wells in the winter of 2011, and over a kilometre of core with excellent recovery was obtained from eleven of those wells. Added to the existing core database, these new cores facilitate the reservoir characterization. The transition from exploration to pilot project to ultimately, commercialization, requires extensive modelling, both static and dynamic. The Grosmont complexity must be reduced to manageable facies and layers with a view to model upscaling while retaining a fundamental understanding of the reservoir heterogeneity. Two lines of geological workflow are being followed. The first is detailed lithostratigraphic, natural fracture and karst core descriptions. The second is the distallation of this detail into the designation of functional facies – facies in which the porosity and permeability have distinctive geometric aspects.

Discussion

The Western Canada Sedimentary Basin was formed during two compressional events, the Columbian Orogeny and the Laramide Orogeny, which occurred from the middle Jurassic to the latest Cretaceous and into the early Eocene. This Basin is a northwest-southeast trending asymmetric basin culminating at the Precambrian Canadian Shield as it is exposed in the northeasternmost corner of Alberta. This basin geometry is reflected in the gentle southwest dips of the Paleozoic units and the subcropping edges of the Devonian carbonates in the greater Saleski area.

The sub-Cretaceous unconformity is the boundary between the Devonian units and the overlying Cretaceous siliciclastics. This unconformity represents over 200 million years, during which time multiple erosional and karsting events, combined with subtle structural movements and the development of the foreland basin, acted to produce a porous and paleotopographically irregular surface. These events also contributed to the development of the Grosmont as a highly porous and permeable hydrocarbon reservoir. The Cretaceous flat-lying Wabiskaw/ McMurray marine and fluvial siliciclastics were deposited directly over the porous carbonates. Figure 1 illustrates the location of the Grosmont Platform complex in northeast Alberta with respect to Cretaceous oil sands deposits.

The various lithologies of the Upper Devonian (Frasnian) Grosmont Formation of northeast Alberta represent deposition of a spectrum of shallow water carbonate facies on a broad carbonate ramp. Facies range from lower ramp mudstones through upper ramp skeletal grainstones and inner ramp peritidal wackestones to mudstones. Dolomitization is widespread in the upper Grosmont Formation in the eastern part of the study area, adjacent to the present day subcrop against Lower Cretaceous rocks. The Grosmont Formation is time-equivalent to portions of the Leduc, Duvernay and Ireton formations and consists of a series of stacked east to west progradational carbonate ramp depositional cycles, within the Woodbend 2 and Woodbend 3 depositional sequences of Potma *et al,* 2001. In the Saleski area, the key reservoir units are the Upper Grosmont 2 and Upper Grosmont 3 (after Cutler, 1983). These consist of dolomitized inner carbonate ramp subtidal/lagoon to peritidal stacked metre-scale shallowing upwards cycles, often with thinner interbeds of continental-derived fine siliciclastics. It is within the context of this stratigraphic and depositional framework that later episodes of diagenesis (including dolomitization, porosity creation, karstification), fracturing and hydrocarbon emplacement are placed and incorporated into an evolving reservoir model.

An integrated geological workflow has been implemented to maximize the core data and progressively upscale it and other well data into a geo-model, then into a simulation model. The first phase of the geological workflow is detailed core description comprising all aspects: depositional facies and lithologies; fracture types, fill and morphology and any associated stylolites; diagenesis, karst and tectonic deformation.

The next phase is the subdivision of the Grosmont units into “Functional Facies”. These facies are based upon the geometric aspects of porosity and permeability types dominating that particular unit. The approach used for the Functional Facies is based on a qualitative assessment of which feature is likely to dominate flow or distinguish flow within a layer.

Ten very simple Functional Facies have been designated. The subdivision is presented in Figure 2.and briefly described below.

1. Peritidal depositional facies: fine laminations, stromatolites, conveying horizontally dominated porosity and permeability.

2. Mudstone-shale depositional facies: either deep or shallow water deposition, with lower porosities and permeabilities and higher clay content. The matrix characteristics dominate in this reservoir unit.

3. Small-vug dissolution facies: biomolds and/or vugs on a millimetre-scale. The biomolds are typically Amphipora. Connectivity is usually good and permeabilites can be in the Darcy range.

4. Big-vug dissolution facies: vugs and/or biomolds on a centimetre-scale. The biomolds are typically stromatoporoids, gastropods or brachiopods. Non-biomoldic vugs include those generated through matrix dissolution, strain vugs and dilatation zones. Connectivity is variable, but can be very good.

5. Cretaceous-fill karst brecciation facies:framework clasts and matrix dominated by Cretaceous lithologies.

6. Devonian-fill karst brecciation facies: framework clasts and matrix dominated by Devonian lithologies including “dolo-fudge” fill.

7. Tectonic fault brecciation facies: rare, but present with deformed bedding, sulphide deposition, tied to seismic and magnetic fault signatures.

8. Short fracture facies: colloquially known as “tension gashes”. Short, 1-2cm long, wedge-shaped radiating fractures focussed on an iden and typically filled with bitumen.

9. Long fracture facies: typically vertical and sub-vertical hairline and conjugate shear fractures with varying apertures. Several to10s of centimetres long, may be lined with sulphides. Contribute to vertical permeability and connectivity in the reservoir.

10.“Dolo-fudge” or bitumen-supported sucrosic dolomite.

The ordering of the Functional Facies in Figure 2 is representative of the sequence of events from deposition to advanced alteration. The determination of these events and the multiple episodes is ongoing work, with the integration of detailed core studies and petrographic work.

Although simple, these units have proven to be correlatable from cored well to cored well, and can therefore be extrapolated to wells lacking core control. Following this geological workflow has facilitated reducing the Grosmont complexity to manageable facies and layers for model upscaling while retaining the fundamental and critical reservoir heterogeneity.

Conclusions

The Grosmont reservoirs are challenging and complex but the heterogeneity and post-deposition alteration are not random. Core-based modelling integrated with other data sources is essential for appropriately-designed and oriented production schemes.

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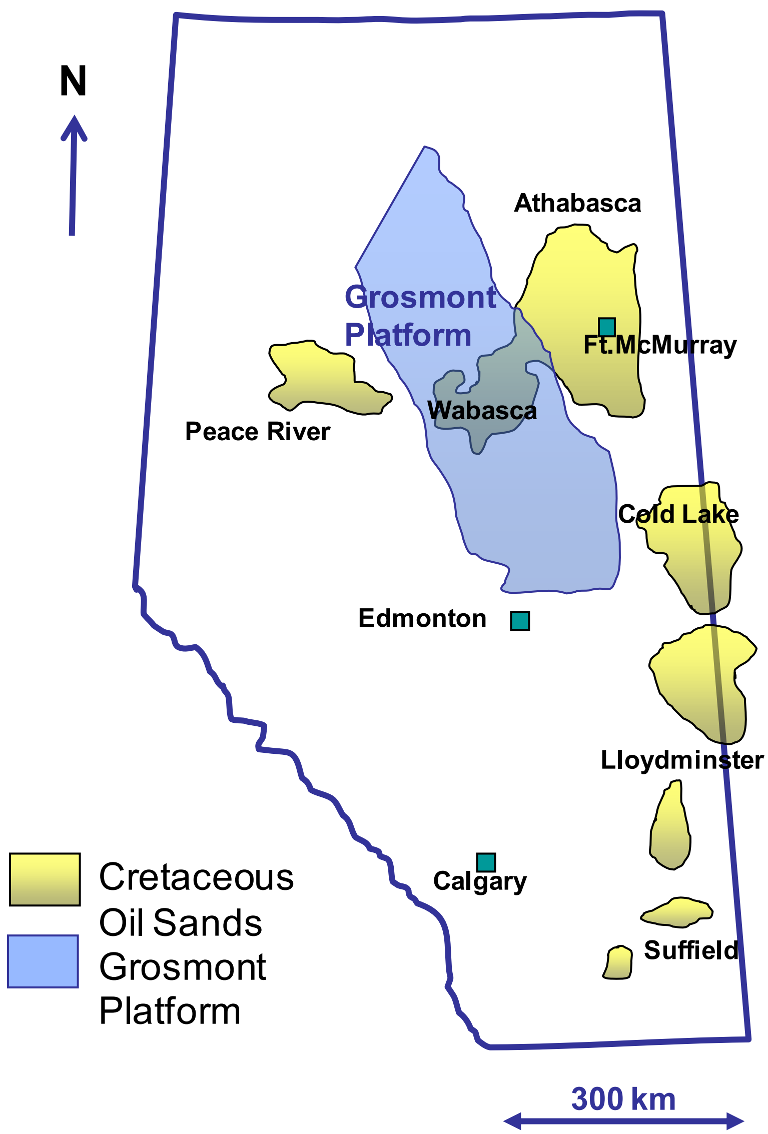

Figure 1: Map of Grosmont Platform.

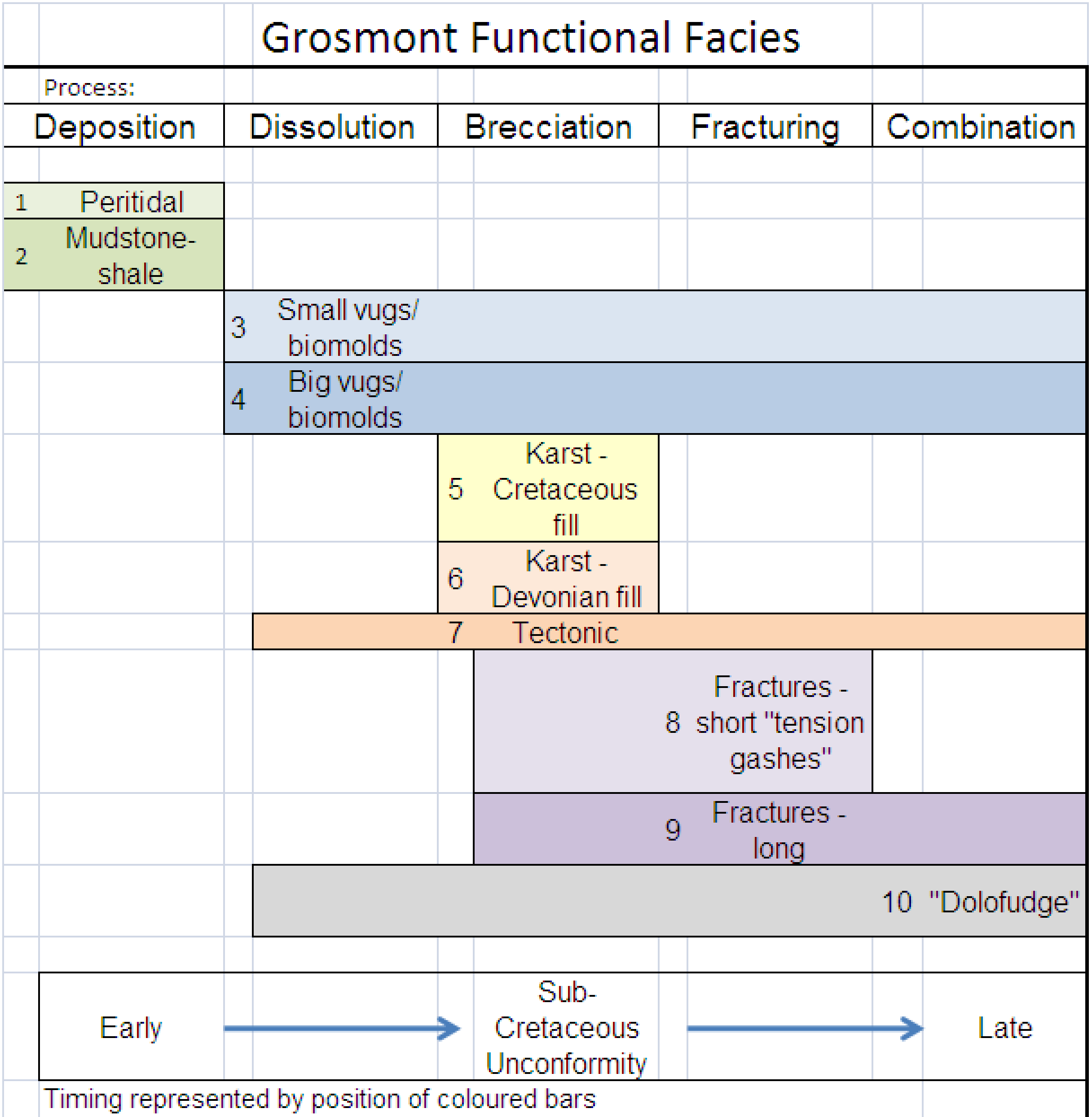

Figure 2. Grosmont Functional Facies with associated process and approximate timeline.

Figure 3: Core example of Reservoir Facies 9, long fractures. Note grey patches of sulphide mineralization, bitumen fill in fractures (Husky Liege AA/06-24-89-21W4, 286.8m).