Building an Appropriate Dynamic Model of a Structurally Complex, Naturally Fractured Foothills Field for Field Development Planning*

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Abstract

The Moose Mountain Field, 50 km southwest of Calgary, is a folded thrust sheet containing sour (13% H_2S) natural gas in tight, naturally fractured carbonate rocks. The so-called 'Main Pool' came on-stream in 1986 and the 'West Imbricate' came on-stream in 2002; the latter being the focus of this article. The West Imbricate is not unitized and as there are multiple interest holders, there is a strong business driver to have a dynamic simulation model to be able to assess the value of potential infill locations (given one well per section), based on an accurate representation of the sub-surface heterogeneity. A static and a dynamic model were constructed by an integrated team, which incorporated scale-appropriate representation of the porosity distribution, 3D fault geometries and the natural fracture system, and facilitated a coherent strategy for field development planning.

Subsurface Heterogeneity

Production from the West Imbricate comes from the Mississippian age Mount Head and Turner Valley formations, which have a range of porosity, principally developed in dolomite, between 3-6% at a burial depth of ~1600 m TVD. Given this low porosity, the intersection of a conductive fracture network is critical to the initial rate, deliverability and hence the economic success of a well in the Moose Mountain Field. Of the 8 gas producers in the West Imbricate, initial rates varied from approximately 100 up to 400 e3m3/d, and this range is thought to primarily represent heterogeneity in the fracture network.

Integral to the successful construction of any dynamic model, and typically difficult for Foothills reservoirs, is the ability to distinguish the level of detail of geological heterogeneity relevant to flow. Moreover, any visit to Rocky Mountain outcrops of Mississippian carbonates clearly shows that there are many more discrete fractures than any geologist could hope to measure, or any software could hope to capture.

However, fractures, or groups of fractures, are typically organized as shown by many studies from around the globe from every tectonic setting (e.g. Nelson, 2001), and this heterogeneity can be characterised at the appropriate scale.

Modeling Rationale and Workflow

Given the potential for complexity in Foothills reservoirs, our underlying philosophy was to keep models as simple as possible, without losing any detail that could impact flow. A Petrel model was built, based on seismic interpretation of a series of 2D lines and the geometries of the faults were simplified. This was deemed valid for flow modeling, as the carbonate on carbonate juxtaposition across many of the internal faults suggests minor baffling behavior and most producing wells are interpreted, at this early stage in field life, to be in pressure communication. A structural cross section provided a 'health-check' to ensure that the geometrical assumptions and short-cuts implemented in the model are geologically valid.

A large discrepancy between core-permeability (several mD) and well test permeability (hundreds of mD), however, highlighted the importance of fractures to flow rate and moreover to connectivity. The fracture network was characterised using a Shell proprietary software package called SVS (Rawnsley et al., 2004), through integration of well tests, FMI, PLT, log data and the geometrical properties of the top structure. The key to modeling fractures at Moose Mountain was to place less emphasis on the discrete fracture data-set, as observed from image logs and outcrops, and more emphasis on the information contained within flow data, such as rates, well-tests and inter-well communication. Therefore, a map of flow domains was interpreted for the West Imbricate using a methodology outlined by Wei (2003) in which the character of pressure transient tests is used to determine the relative fracture connectivity in the reservoir. The interpreted flow-domains were translated into areas of enhanced transmissibility between grid cells in the simulation model.

Results and Business Impact

Two other scenarios of fracture connectivity, based on curvature and depth, were tested against the production data to determine the uniqueness of the fracture distribution as governed by the flow domains. Although the differences between the scenarios were not marked, mainly due to the short time-scale of the production data, the flow domain model was preferred.

The principal result is a history-matched simulation model, which accounts for the difference in fracture permeability and connectivity observed by the wells. The simulation model was then run in forward mode, allowing quantification of new volumes for remaining *potential* well locations, and the effect on the existing well configuration, to be quantified. It is suggested that this approach to the dynamic modeling of structurally complicated, heterogeneously fractured Foothills reservoirs could aid business decisions and assist in increased accuracy in recoverable volumes calculations.

References Cited

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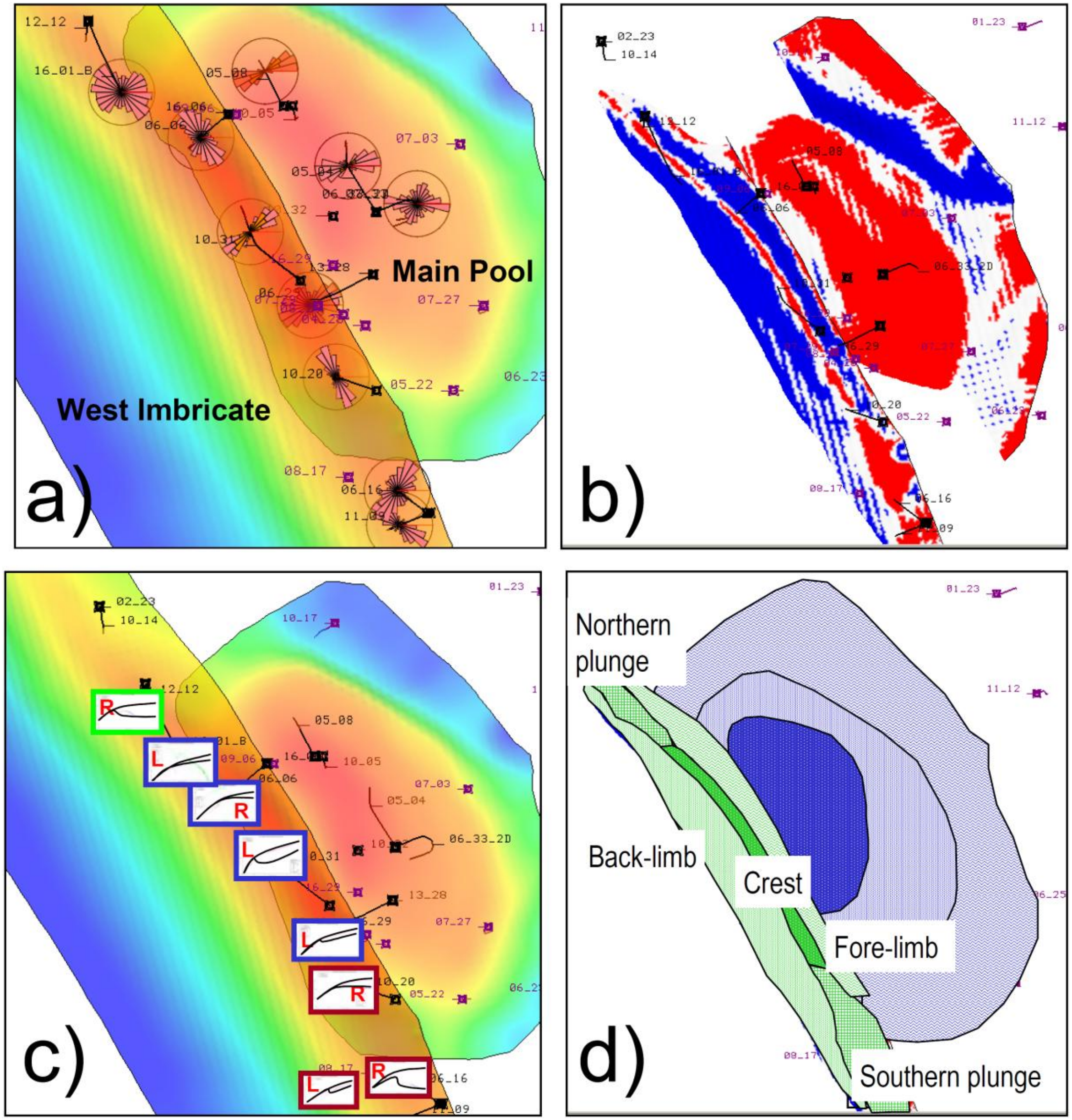

Figure 1. (a) Depth map and rose diagrams of conductive natural fractures for the West Imbricate and the Main Pool. (b) Dip domain map across the structure (red = 0-10°, white = 11-20°, blue = 21-30°). (c) Flow and pressure build-up data located in map view and coloured based on similar pressure response (L = linear flow; R = radial flow). (d) Interpreted "flow domains" based on integration of all of the data.