geoconvention
Calgary • Canada • May 13-17 2019

Borehole image analysis and core evaluation of fractures/vugs distribution and impact on Nisku enhanced oil recovery

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The intent of this paper is to understand the impact of fractures and vugs on reservoir quality within the Bigoray and Cynthia members of the Nisku Formation in the Bigoray area. Another aspect of the study is to answer the question of spatial distribution of fracture network in what is commonly referred as the "D" and "E" reefs (Fig. 1).

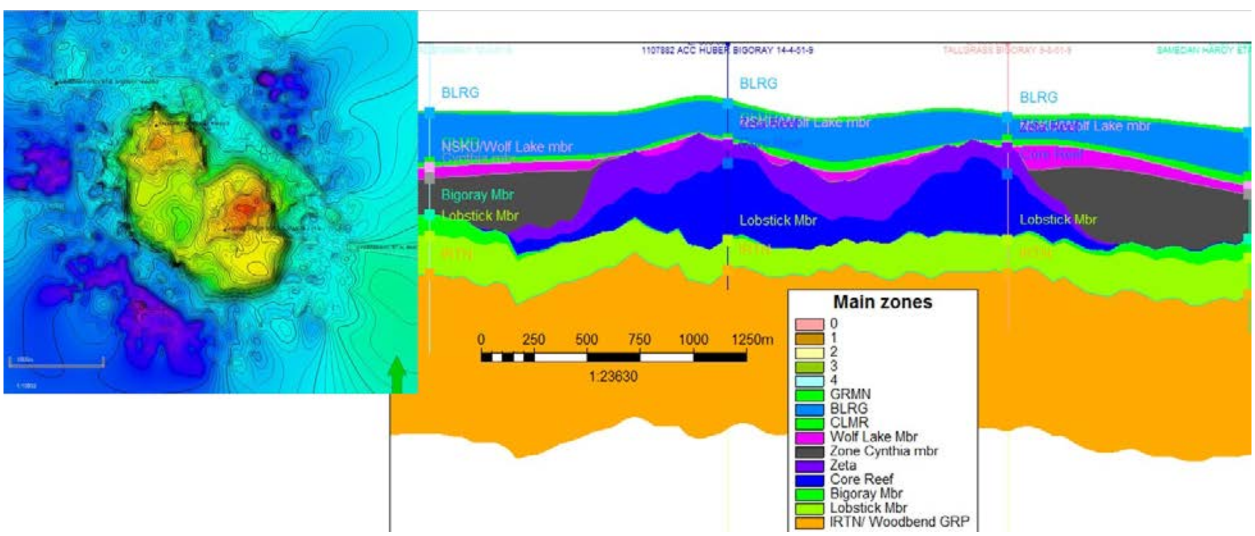

Fig. 1 Structure contour map of the "D" and "E" reef on the left. The cross section on the right was used to build a conceptual framework. The tighter carbonates of the reef (Core Reef, blue) are below the higher porosity section of the Zeta Reef (purple). The reefs are on top of the Bigoray, Lobstick and Ireton Formations. The Cynthia Shale (grey onlaps the reefs. This Nisku Wolf Lake carbonate and Calmar Shale are the top seal for the reefs)

Fracture and vug analysis was performed on the borehole image of HRC BIGORAY 12-4-51-09 slanted well together with core mapping of ten vertical wells in both reefs.

Formation microimager (FMI) revealed the presence of ten faults with the dominant “NE-SW“ trend (Fig. 2). These are usually followed by the high density of conductive fractures. The fan plot of fracture orientation from the image shows distinctively unimodal orientation within the “NE-SW” quadrants.

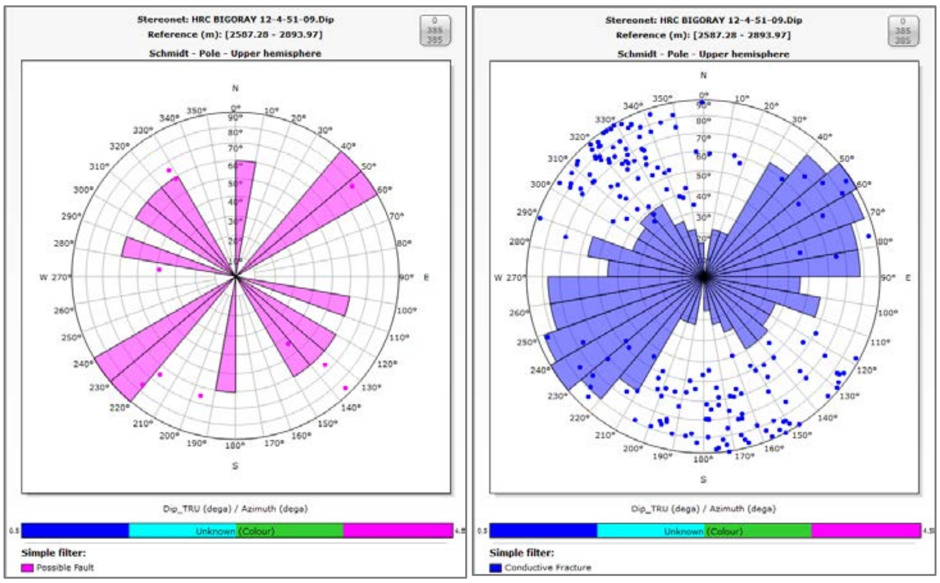

Fig. 2 Fan plot of faults (in pink on the left) and fractures strike orientations based on the FMI study in Bigoray area.

The observed fracture density (5 fractures/m) suggests discreate fracture zones throughout the well which was also confirmed with core fracture mapping (Fig. 3). In addition, comparison of fracture densities between FMI image and core confirms the higher the number of fractures in the image due to geometry of the well.

Several types of vugs were observed in both the borehole image and in the core; these were classified based on their size: from large vugs (>7mm), to medium (4-7mm) and small vugs (>4mm).

An attempt to classify the relationship of fractures and vugs was completed. It was observed that no clear relationship can be established since some of the fractures are associated with vugs (i.e. vugs distributed along fracture plane). However, also seen in the image and confirmed with core analysis is that fractures are cross-cutting vugs at various angles. Fractures and vugs are mostly confined to the middle and upper Nisku Formation. The integration petrophysical evaluation and the geological interpretation revealed that the zones with highest permeabilities are the ones that show presence of large vugs and open fractures.

A new approach of vugular porosity estimation has been addressed using core photography. The idea behind it is to classify the core photos spectrally into bins and then extract the vugs as a separate category (bin) in order to estimate porosity values (Fig. 3). The statistical analysis shows that small vugs represent up to 10% of the total porosity, medium vugs represent up to 18% of the total porosity and large vugs represent up to 27% of the total porosity.

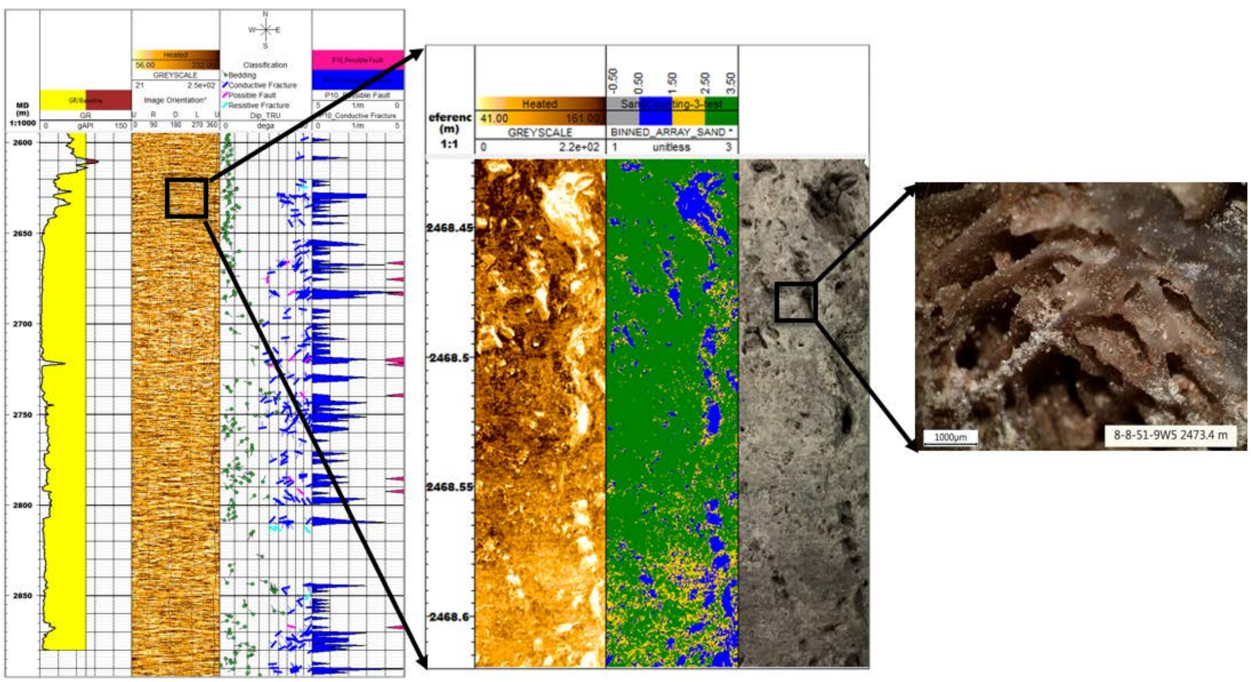

Fig. 3 Left part of the figure showing the full length of the FMI image with tadpole plots and fracture/fault density (last track in blue). Middle part of the image is zoomed in interval showing comparison of the image and the core (last track). Further zooming in shows the microscopic nature of vugular texture of Bigoray member.

The above described fracture analysis and petrophysics was integrated with 3D seismic interpretation to develop a petrophysical model of these reefs in Petrel. The lateral heterogeneity of porosity and permeability within the storage complex was statistically interpolated.

In the area surrounding the reef, public data was assembled, and formation tops (19 wells) were interpreted to develop a geological framework. 3D seismic data from 1990 was purchased, reprocessed and interpreted. To characterize the complex reef structure, a velocity model was developed to convert the seismic interpretation and seismic attributes to the depth domain.

Based on the petrophysical analysis, the reefs were subdivided into the Zeta Reef (higher porosity zone) and Core Reef (lower porosity zone). Seismic Ant Tracking was successfully used to identify and interpret this porosity contrast in the interwell space. As part of the discreet fracture network generation, the Ant Tracking was used to guide the fracture intensity interpolation within the reservoir.

With the framework of the geomodel developed, porosity, permeability and water saturation were interpolated within the reservoir and oil in place calculations were completed.