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Analysis of Finely Bedded Intervals in the Frontier Formation Using High Resolution Logs

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ABSTRACT

The Frontier Formation in the Powder River Basin contains a mixture of coarse-grained fluvial deposits interbedded with marine strata. The bedding can be on the order of a few tenths of a foot or less causing standard logging tools to average over the bedding response. High resolution logging suites have been recorded to calculate parameters such as net-to-gross and mechanical anisotropy to better delineate the reservoir. Bedding density has been mapped along the reservoir section with an X-tended Range Micro Imager and compared with near-bit accelerometer estimates of mechanical properties at 0.017ft. and 0.1ft. resolution, respectively. Assuming the bedding density is correlated with sand volume, there is strong agreement between the two methods. By applying simple logical arguments to the high resolution measurements we can generate a new net-to-gross estimate. The updated net-to-gross is different than the estimate using low resolution logs, and may affect the lateral target and economic viability of the prospect. The accelerometer measurements also suggest the bedding density is anti-correlated with mechanical anisotropy. Higher mechanical anisotropy will generate higher minimum horizontal stress, possibly affecting hydrofracture growth and completion strategy. The mineralogy has been estimated along the vertical pilot with an elemental analysis tool calibrated to cuttings measurements. The estimated mechanical anisotropy is well correlated along the vertical with clay content, and drifts toward higher anisotropy with increasing depth. This observation can be explained by the reorientation of clay particles with depth, generating a larger anisotropic response for the same clay volume as the clay platelets align under increasing stress. The anti-correlation between bedding density and mechanical anisotropy suggests the fine layering observed by the microimager is not generating a significant amount of mechanical anisotropy in comparison to the clay content. By applying Backus averaging to the mechanical properties we can confirm that fine layering of isotropic units is not sufficient to generate mechanical anisotropy on the order of observed values in shale core studies, suggesting the additional stress generated by mechanical anisotropy is driven primarily by clay content. This additional stress should be considered when planning lateral targets and completions. Obtaining high resolution logs that can estimate stress and net-to-gross in finely laminated media is critically important for reservoir characterization and completions strategy, and should be considered best practice for finely layered media. The Frontier Formation in the Powder River Basin contains a mixture of coarse-grained fluvial deposits interbedded with marine strata. The bedding can be on the order of a few tenths of a foot or less causing standard logging tools to average over the bedding response. High resolution logging suites have been recorded to calculate parameters such as net-to-gross and mechanical anisotropy to better delineate the reservoir. Bedding density has been mapped along the reservoir section with an X-tended Range Micro Imager and compared with near-bit accelerometer estimates of mechanical properties at 0.017ft. and 0.1ft. resolution, respectively. Assuming the bedding density is correlated with sand volume, there is strong agreement between the two methods. By applying simple logical arguments to the high resolution measurements we can generate a new net-to-gross estimate. The updated net-to-gross is different than the estimate using low resolution logs, and may affect the lateral target and economic viability of the prospect. The accelerometer measurements also suggest the bedding density is anti-correlated with mechanical anisotropy. Higher mechanical anisotropy will generate higher minimum

horizontal stress, possibly affecting hydrofracture growth and completion strategy. The mineralogy has been estimated along the vertical pilot with an elemental analysis tool calibrated to cuttings measurements. The estimated mechanical anisotropy is well correlated along the vertical with clay content, and drifts toward higher anisotropy with increasing depth. This observation can be explained by the reorientation of clay particles with depth, generating a larger anisotropic response for the same clay volume as the clay platelets align under increasing stress. The anti-correlation between bedding density and mechanical anisotropy suggests the fine layering observed by the microimager is not generating a significant amount of mechanical anisotropy in comparison to the clay content. By applying Backus averaging to the mechanical properties we can confirm that fine layering of isotropic units is not sufficient to generate mechanical anisotropy on the order of observed values in shale core studies, suggesting the additional stress generated by mechanical anisotropy is driven primarily by clay content. This additional stress should be considered when planning lateral targets and completions. Obtaining high resolution logs that can estimate stress and net-to-gross in finely laminated media is critically important for reservoir characterization and completions strategy, and should be considered best practice for finely layered media.