Non-tectonic faulting and reservoir enhancement in the WCSB

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Summary

Nontectonic faulting, the vertical displacement of strata independent of large external forces, has resulted in normal faulting that has been observed throughout the Western Canadian Sedimentary Basin. A number of faults in Upper Cretaceous strata identified on 3-D seismic data and well control are presented. The faulting ranges from sparse faulting (< 1 fault/km^2) with minor vertical offset (~5 m) to intense faulting (>10 faults/km^2) with vertical offsets up to 80 m. The faulting can create reservoirs in the fault accomodation space, enhance porosity through fracture creation and/or vertically drop reservoirs to lower structural elevations. An improved understanding of this faulting should decrease the risk of drilling some reservoirs.

Introduction

Cretaceous sediments underlying the Great Plains of North America were deposited in the Cretaceous Western Interior Seaway (WIS, Figure 1). The WIS was an inland sea connecting the Tethyan Sea in the Gulf of Mexico north to the Boreal Sea in Alaska from the mid-Cretaceous to the early Paleogene (Catuneanu et al., 2000). The WIS hosts a succession of sediments, including a large volume of continental muds and clays (Schultz et al., 1980), bentonite, and other fine-grained material (Leckie et al., 2000).

Non-tectonic faulting has been recognized in Upper Cretaceous sediments throughout the Great Plains area. St-Onge (2017) estimated a fault density of 25 faults/km^2 with throws of 10 m or more and average strike lengths of ~500 m for Upper Cretaceous sediments in some regions of the Great Plains area. Furthermore, these were postulated to be non-tectonic normal faults. Eberth (1996) noted smaller, metre-scale normal faulting in mud-filled incised valleys in the Horseshoe Canyon Formation at outcrop near Drumheller, Alberta. All of these normal faults had some component of syndepositional growth faulting (Eberth, 1996). Bhattacharya and Davies (2001) reported cliff exposures of synsedimentary normal growth faults at the base of the Cretaceous Ferron Sandstone at outcrop in central Utah.

The recognition of areas of intense non-tectonic faulting in areas of southeast Saskatchewan led to the inspection of seismic data across western Canada. The data presented here are examples from that work.

Method and Examples

Figure 1 shows the outline of the Pierre Shale Formation in the Great Plains area. This Formation was identified in St-Onge (2017) as hosting the strata with the largest amount of faulting within the Great Plains Polygonal Fault System. The Pierre Shale overlies the Cretaceous Colorado Group within the Upper Cretaceous. The study focused on the inspection of large volumes of seismic data, looking for minor amounts of faulting. Figure 2, an image from a 3-D seismic dataset recorded near Fort MacLeod, Alberta, exemplifies the faulting under investigation. Two faults are identified on the image. The image is interpreted to show normal faulting that results in ~5 m of extra stratigraphic section being preserved between the 2WS and the BFS reflections. This corresponds to the stratigraphic level of the Barons Sandstone, as shown in the presentation.

Figure 3 is an image from the Manitoba/Saskatchewan border that shows numerous faults. All of the faults are normal, with offset that increases with elevation. None of the faults continue to the 1WS reflection. The faults offset the Milk River reflection by ~10 m. Figure 4 is a two well cross section from within the 3-D outline shown in Figure 3. The two wells, ~200 m apart, were correlated by identifying similar log signatures. These correlations were used to construct a correlation throw curve. These curve can determine fault timing, structural variations for the correlations, and the syndepositional nature of the faulting. Closely spaced wells minimize the chance that the correlation variations are not due to lateral depositional isopach variations. Although there is no production from the Milk River in eastern Saskatchewan, the talk will show how this model is applicable to western Saskatchewan and Alberta. The talk will also show how the faulting can increase reservoir deliverability by fault and fracture enhancement.

Conclusions

This paper has presented some examples of non-tectonic faulting in the WCSB. Identification of subtle faulting using seismic data and well control is important in identifying isolated normal faults that can preserve reservoirs such as the Barons Sandstone. The faulting can also enhance reservoirs through fracturing. The identification of subtle faulting within the WCSB is encouraged to identify potential in Upper Cretaceous strata.

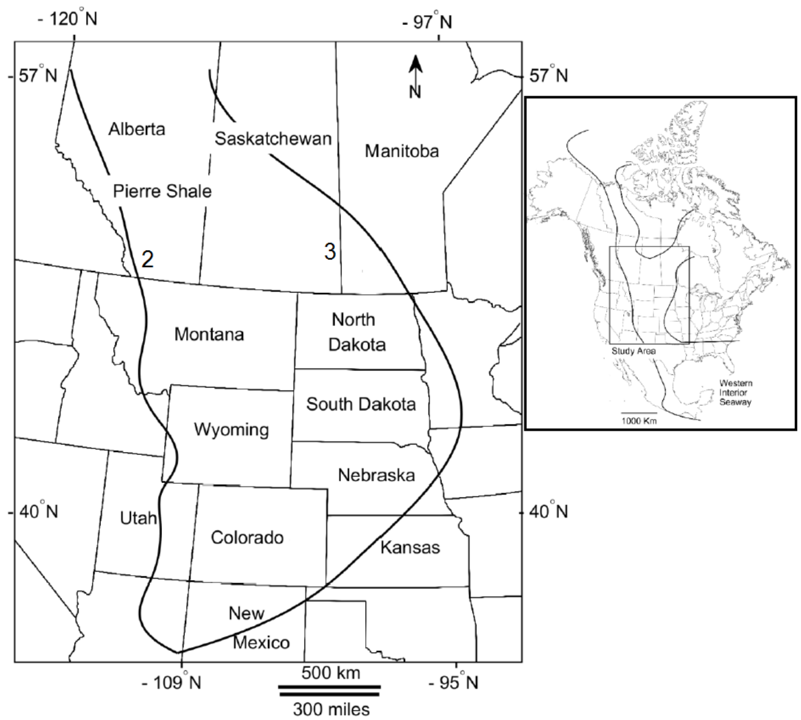

Figure 1. The Great Plains of Canada and the United States showing the outline of the Upper Cretaceous Pierre Shale (Campanian to Santonian) depositional area (modified from Roberts and Kirschbaum, 1995). The number 2 and 3 map are the approximate data locations for the corresponding figure number here.

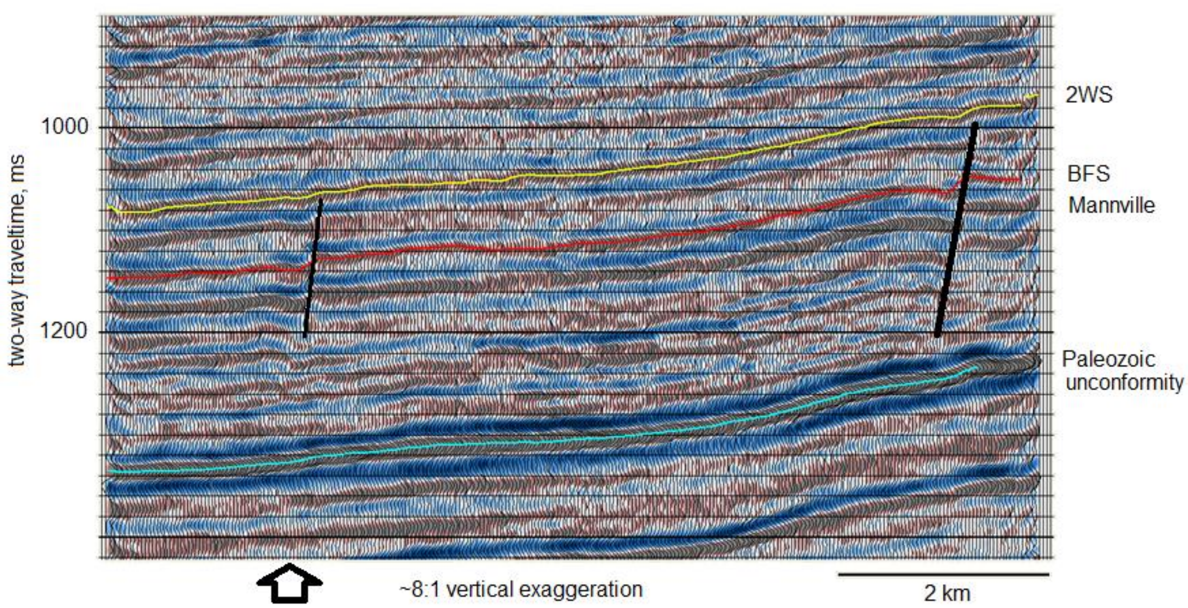

Figure 2. Image from a 3-D seismic dataset recorded in southern Alberta. Two normal faults are interpreted. The BFS marker is faulted down ~5 m across a ~300-400 m distance left of both fault traces. The Barons Sandstone reservoir is created and preserved in some of these faults.

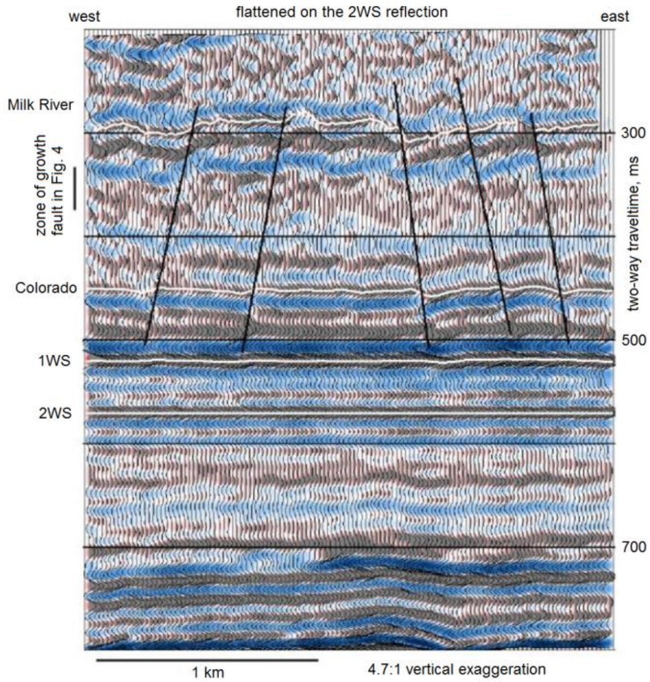

Figure 3. Image from a 3-D dataset near the Manitoba Saskatchewan border. The strata above the 2WS reflection are heavily faulted with growth faults.

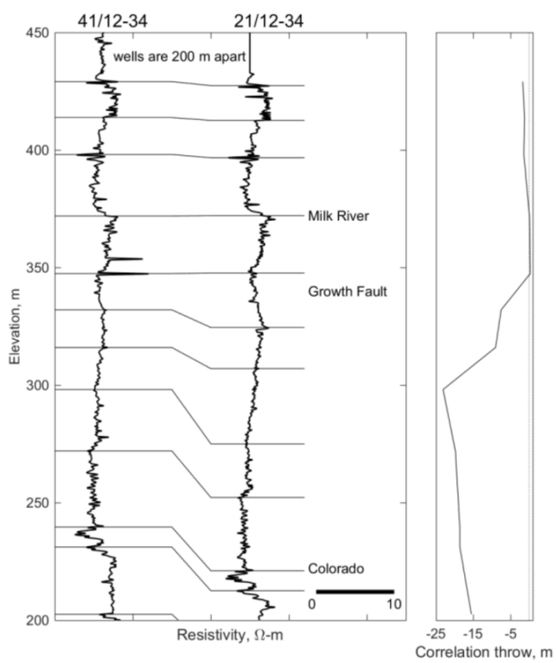

Figure 4. Correlations from two wells ~200 m apart show correlative markers offset by almost 25 m. The Milk River zone is used as a datum.

References

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