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Hydrocarbon trap model for glacial strata in the Great Plains area

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Summary

A model is presented to account for hydrocarbon trapping within glacial sediments deposited across the Great Plains. Hydrocarbons have been encountered while drilling through glacial seidments within the area for the last ~100 years. Although there are economic recoveries of natural gas from glacial sediments in northern Alberta, there is scant production and shows elsewhere. The model is simple – porous strata within otherwise tite glacial till are sourced with biogenic (and possibly thermogenic) natural gas by hydrocarbon migration along faults and fractures within underlyinging Upper Cretaceous strata.

Introduction and Model

A large portion of Upper Cretaceous sediments within the Great Plains area have been glaciated within the last 15,000 years (Richmond and Fullerton, 1986, Figure 1). There is a history of natural gas shows within glacial sediments throughout the Great Plains area. Various provincial and state governments have examined these shows to map and encourage shallow exploration in their jurisdictions. For example, the North Dakota Geological Survey proposed a simple trap model (Figure 2). Natural gas sourced from Upper Cretaceous Pierre Shale strata (Campanian to Maastrichtian) migrates upwards and is trapped by porous beds within glacial till overlain by impermeable clays. As discussed, this model is supported by others and the seismic data and geology used for this study. The data shows that highly fractured and faulted Upper Cretaceous rock and glacial reservoirs can be interpreted using available seismic data.

A large accumulation of shallow gas occurs in northern Alberta (Figure 3). One well has produced ~4.3 BCF of gas with virtually no water from perforations at 39 to 42 m depth. There are no shallow wireline logs in this wellbore; however, a nearby wellbore shows the glacial sands (Figure 4). The Alberta government has encouraged further exploration (see Pawlowitz, et al., 2003) using a model similar to Figure 2. Manitoba's Cretaceous shale sequences have been studied to evaluate the potential for shallow gas resources (Nicolas, et al., 2007). The study reports shallow biogenic gas potential in glacial and Upper Cretaceous sediments. The British Columbia Oil and Gas Division Resource Development and Geoscience Branch (2006) reported that buried glaciofluvial and preglacial sand and gravel may be potential hydrocarbon reservoirs. Although there is no reported production from Quaternary pools in British Columbia, gas blow-outs from valley-fill successions have been noted in drilling reports.

Seismic data were examined from British Columbia east to Manitoba and south to North Dakota. Figure 5 shows an interpreted seismic line; a corresponding simple model is shown in Figure 6. The seismic line shows that highly faulted and fractured Upper Cretaceous sediments beneath the glacial till can be highly fractured and faulted, increasing permeability along vertical pathways. Inspection of the shallow seismic data reveals high amplitude refections which may arising from porous traps within the glacial till.

Conclusions

A simple model for hydrocarbon trapping within glacial sediments enables inexpensive investigation for this shallow resource. Drill rigs equipped with gas detectors while drilling out surface casing may indicate potential glacial reservoirs that would otherwise not be imaged with logging tools. Historic natural gas shows, the potential for pockets of reservoirs to occur over large areas of the Great Plains, the ability to use seismic data to map glacial anomalies and the intense fractuiring and faulting possible within the Great Plains all point to the positive economic potential for hydrocarbon reservoirs in glacial sediments.

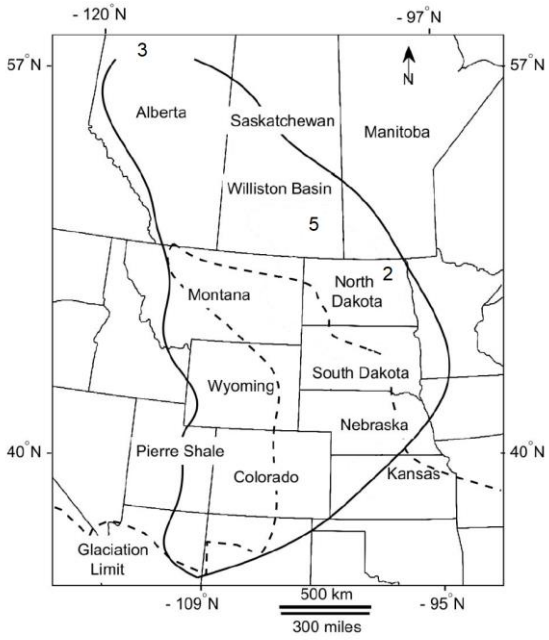

Figure 1. Map of western Canada and northwestern United States showing the Upper Cretaceous Pierre shale depositional area (modified from Roberts and Kirschbaum 1995 and St-Onge, 2017), and the southern limit of Quaternary glaciations (dashed line, from Richmond and Fullerton, 1986). The numbers 2, 3, and 5 approximate the locations for the corresponding figure number here.

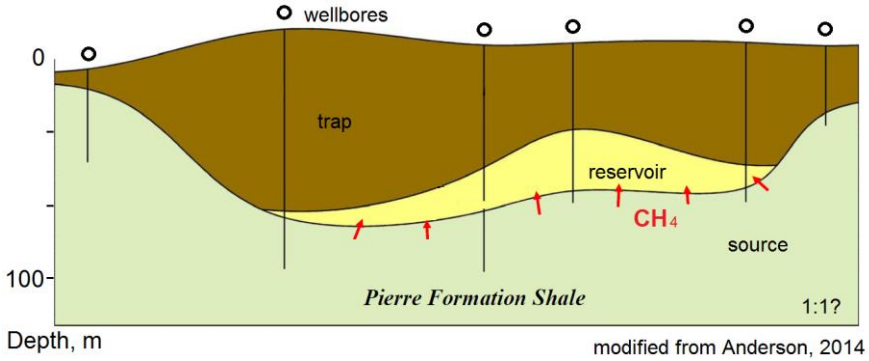

Figure 2. A six well cross section showing a glacial sandstone reservoir overlying Upper Cretaceous Pierre Shale and overlain by tite glacial sediments.

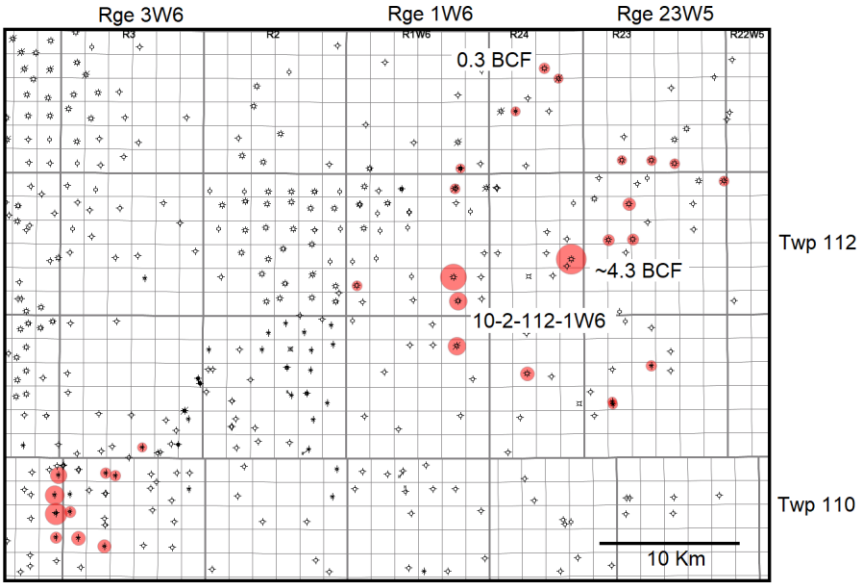

Figure 3. Well base map from northern Alberta showing natural gas production from ~30 wells. The resistivity log for 10-2-112-1W6 is shown in Figure 4.

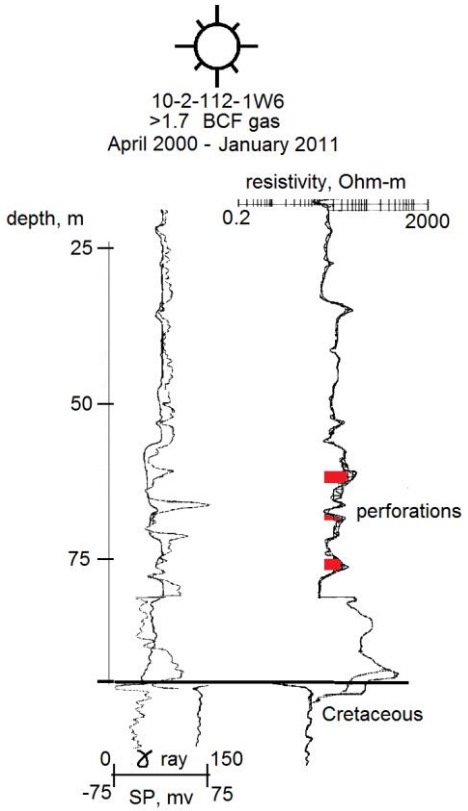

Figure 4. Resistivity well log from northern Alberta showing the productive sandstone stringers producing from glacial strata (modified from Pawlowitz, et al. (2003).

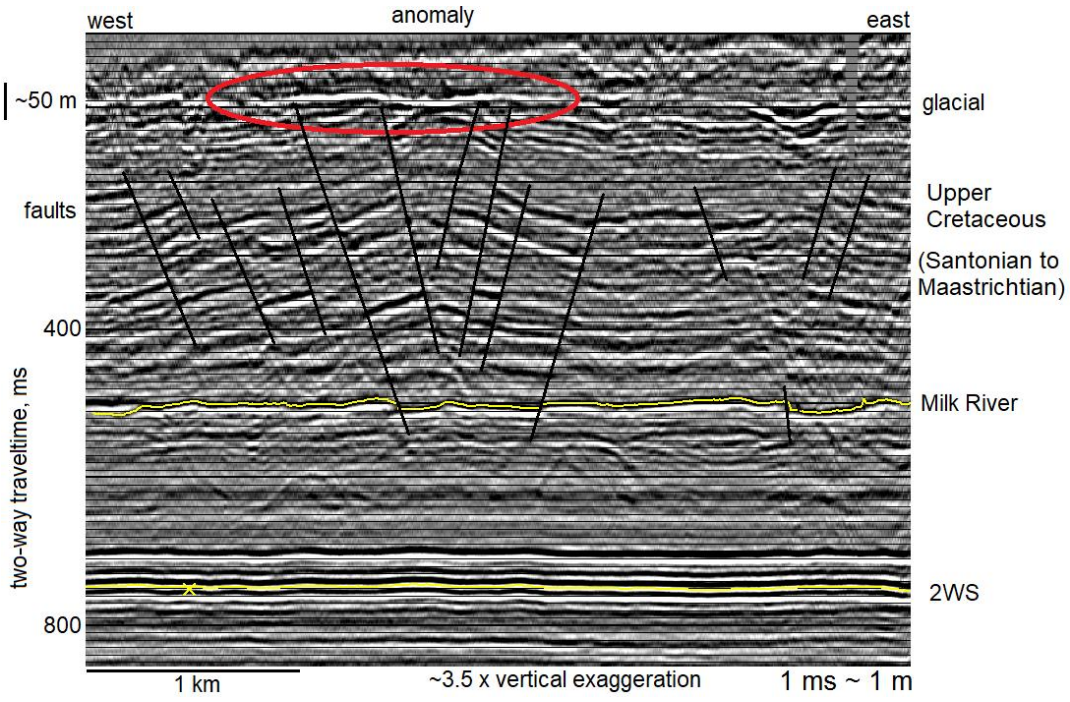

Figure 5. A 2-D seismic line from southeast Saskatchewan imaging highly faulted Upper Cretaceous strata above the Milk River (Santonian). These strata are unconformably overlain by glacial till that may contain lenses of porous and permeable reservoir sands as circled in red.

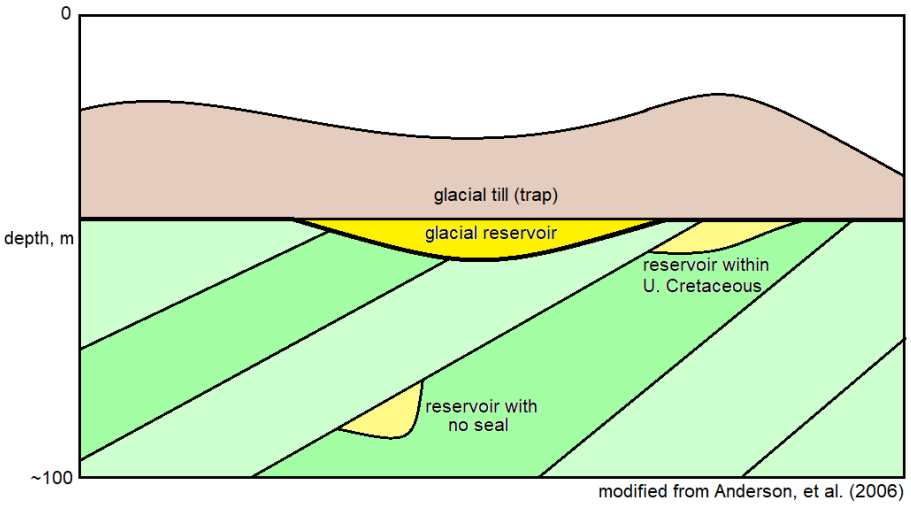

Figure 6. Cartoon sketch (modified from Anderson, et al., 2006) to show the angular unconformity between glacial sediments and Upper Cretaceous that may enhance hydrocarbon movement. Also, any reservoir in the Upper Cretaceous that is trapped by the fault geometry may be prospective for shallow gas.

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