

East Gainsborough, Saskatchewan: a Prairie Evaporite salt dissolution and Mississippian erosional unconformity trap

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ABSTRACT

In the fall of 1994, geologists at Upton Resources mapped Mississippian aged reservoir rock potential in southeast Saskatchewan at Gainsborough. Sonic logs from a nearby producing field were used to construct a seismic model to interpret a grid of purchased 2-D seismic data. The 2-D data mapped the discovery well for the Gainsborough East pool. A 3-D seismic dataset and subsequent drilling indicate that the reservoir section was preserved by underlying Devonian Prairie Evaporite salt dissolution in the vicinity of two Devonian Winnipegosis reefs. The 3-D seismic data were also used to map structural trends, areas of preserved Mississippian reservoir section, and possible areas of altered reservoir section.

Play Type Introduction And Geological Setting

East Gainsborough is located at the northern edge of the intracratonic Williston Basin. Oil has been produced here since 1953 (Harris, et. al., 1966). The production is predominantly light gravity oil from Mississippian-aged carbonate beds of the Mission Canyon Formation. Refer to Figure 1. At the Paleozoic contact, cycles of carbonate to evaporate lie in angular unconformity with the overlying Triassic aged Red Beds. In Canada, the Mission Canyon Formation has eight identified cycles of deposition. Traps for these limestone and dolomite reservoirs exist at the subcrop edge or at the lateral transition to anhydrite. The subcrop edges are fairly predictable, as shown in Figure 2. Exploration for Mission Canyon reservoirs can be performed by looking for anomalous areas that have a thick, preserved Mississippian carbonate section that is positioned on a local unconformity high.

Seismic data have been used since 1950 to map the Mississippian beds in southeast Saskatchewan. The initial objective was to map local highs at the unconformity. This objective continues today, as most wells are drilled on local highs. A more recent objective is to detect areas of preserved Mississippian section, and to look for areas of stratigraphic complexity, such as cross cutting channel systems within the Mississippian section (Sturrock, et. al., 1991). The advent of 3-D seismic data and advances in seismic data processing have enabled the mapping of stratigraphic features in the area (Sturrock, et. al., 1991).

East Gainsborough Discovery

The exploration and production of oil from Mississippian reservoirs in southeast Saskatchewan has always been a core focus for Upton Resources Inc. In the fall

of 1994, Upton developed an exploration play looking for preserved Alida beds in the Gainsborough area of Saskatchewan. The area is located 300 km southeast of Regina, just north of the Canada/US border. Refer to Figure 3. Geologists mapped the amount of section remaining above the MC-2 marker to infer areas of preserved section in conjunction with Mississippian structural trends.

Geologic mapping indicated a potential fairway. Sonic logs from a producing field were used to model the seismic response to preserved Mission Canyon beds. Also, six 2-D seismic lines were purchased. Two lines showed an anomaly that tied very well to the seismic model, and a discovery well was drilled at 11-1-3-31W1 using these data.

The 11-1-3-30W1 well was a success with an initial production rate of 270 BOPD of 30° API oil from the upper Alida Glenburn beds at 1030 m. The underlying middle Alida Wayne beds had good core shows and the lower Wayne beds tested oil to surface on a drillstem test, resulting in a total oil column of 28 m. Considering the success of the 2-D seismic data, a 3-D dataset was acquired in the summer of 1995. Upton proceeded to drill five delineation vertical wells into the pool before drilling horizontal wells. Upton has drilled 24 horizontal wells into the pool with its peak production coming in early 1996 at 3200 BOPD. Some 2.6 million barrels of oil have been produced from the Gainsborough East pool, with an expected ultimate recovery of about four million barrels.

2-D And 3-D SEISMIC INTERPRETATION

The wells in Figure 4 were used to construct the synthetic seismic model shown in Figure 5. There are two important observations to make with this model. The MC-2 marker bed is a fairly consistent reflection, and the Paleozoic to MC-2 isochron increases as the isopach increases. Mapping this isochron on data should show areas of preserved Mississippian section. The results of a similar model (using wells from a pool six miles to the West) were used to interpret the 2-D seismic lines shown in Figure 3. The east/west seismic line through the 11-1 discovery well is shown in Figure 3 as a green line. Note the high quality of the seismic data. Stacked data frequency slices indicate useable frequencies up to 120 Hz at the Paleozoic traveltimes. The data tie to zero phase synthetics.

The 11-1-3-30W1 discovery location (see Figure 7) was picked using a Second White Specks to Paleozoic Unconformity Isochron local high and a Paleozoic to MC-2 Marker isochron thick. The well encountered a thickened section of Mission Canyon, as was indicated by the latter map. After the discovery of this well, Upton tried to lease all available land within the area, and preceded to layout a six square mile 3-D seismic program.

Upton recorded the 3-D seismic program outlined in Figure 8, in July of 1995. The Mississippian unconformity travelttime map and the Mississippian to MC-2 Marker isochron map are shown in Figures 8 and 9. The travelttime map was

compared to the twelve wells that tied that dataset in the fall of 1995. The wells tied to within 6 m on a crossplot. The Mississippian to MC-2 isochron predicted the thickness of this interval to within 6 m for most of the wells.

Gainsborough East Pool Description

The pool produces oil from the upper Alida Glenburn beds and the middle Alida Wayne beds. The Alida Beds are characterized by a variety of open marine carbonate facies dominated by high energy oolitic grainstone shoals, inter-shoal bioclastic mudstones to wackestones and higher energy bioclastic packstones to grainstones. The reservoirs have good to excellent limestone porosities ranging from 10% to 25%, with subsequent permeabilities from 0.2 to 1.5 Darcies. Inter-shoal areas are characterized by low porosities and permeabilities and generally result in lateral trapping of oil within the pool. Because of the variety of rock textures found, reservoir characteristics vary both laterally and vertically within the pool. Horizontal drilling has been the development tool of choice to access these complex reservoirs more effectively. Horizontal wells and a strong bottom drive increases the productivity, longevity and recovery from the pool.

Gainsborough East Pool Morphology

The 1-10-3-30W1 well, drilled in December, 1995, led to a discussion on the pool morphology. The objective of this well was to drill the thickest Mississippian section that was mapped by the seismic data. In this regard the well was a success, as it encountered 80 m of section from the unconformity to the MC-2 marker. The well encountered Lower Frobisher section below the unconformity (as an outlier) that can be correlated to wells 20km to the Southwest. However, the Lower Frobisher beds are non-reservoir at 1-10. The productive zones at Gainsborough are structurally low at this location because of the amount of overlying section. Upton recognized that the reservoir quality Mission Canyon rock was likely to be contained within the 30 to 38 msec contour on Figure 9. This corresponds to about 44 to 67m of Paleozoic to MC-2 marker isopach. The 1-10-3-30W1 well established the thickest limit. Wells that have a thin isochron value, such as 6-12-3-30W1, established the erosional limit, where the Alida section may be partially or fully eroded.

Figure 11 shows an arbitrary seismic line from the 3-D dataset that ties the 1-10-3-30W1 well. There are two Winnipegosis reefs on the survey; their positions are indicated on Figure 9. A maximum of 16 msec of Prairie Evaporite salt dissolution has taken place over top of the reef. The presence of Winnipegosis reefs can affect fluid flow, perhaps providing an easier pathway for fluid flow, and subsequent salt dissolution (Hassler, G., 2003, personal communication, Upton Resources Inc.).

The isochron of the Prairie Evaporite was examined to estimate the amount of salt dissolution. The volume of the reefs was ignored, and a regional salt thickness of 52 msec was assumed. These assumptions result in a calculation of

about 0.215 cubic kilometers of salt dissolution. It is believed that the salt solution occurred at different stages during and after the deposition of the Paleozoic rock. Post Mission Canyon but pre-Triassic dissolution is required for the preserved section of Lower Frobisher encountered across this anomaly.

The Paleozoic to MC-2 isochron calculates 0.112 cubic meters of extra section, if the 28 msec value is used as regional. This value is less than the calculated amount of salt dissolution. Some of the solution may have occurred after the deposition of the Mission Canyon beds. The 16 msec of salt dissolution at 1-10-3-30W1 corresponds to about 35 m of extra section. This is approximately equal to the amount of extra section at that well -- section that can be correlated to wells approximately 12 miles to the Southwest.

The authors believe that the oil pool at East Gainsborough exists because of the fortuitous timing of salt dissolution. The 3-D seismic data allowed the development of this model. The ability of the 3-D dataset to determine the morphology of the deposition at Gainsborough could lead to the use of seismic data for similar traps beyond presently defined erosional edges.

3-D Stratigraphic Analysis

The Mississippian peak amplitude map for the survey is shown in Figure 10. Note the low amplitude area running in a south to north direction in section two. This anomaly was almost tested at the 5-2-3-30W1 location. The well encountered a thickened Alida zone that contained a dolomite with a velocity much lower than the reservoir section. This may have diminished the Mississippian amplitude reflection. The high amplitude areas in Figure 10 may correspond to areas of thick anhydrite at the unconformity. The 8-1-3-30W1 well was drilled in January of 1996, to test the eastern limit of the pool. The well encountered section that had been altered for the first 10 m down from the unconformity. This well was plugged and abandoned.

Conclusions

The Mississippian reservoir section at Gainsborough, Saskatchewan is imaged well with 2-D and 3-D seismic data. Both types of data can map Paleozoic erosional highs with possibly thick reservoir sections. The 3-D seismic data were able to predict the depth to the top of the Paleozoic to within 8 m for most of the vertical wells, and the Paleozoic to MC-2 isopach to within 6 m for most of the wells. The 3-D data were also able to image areas of altered reservoir section, which corresponded to low velocity channels, or high velocity, anhydrite plugged reservoir. The 3-D interpretation indicated the presence of pre Mesozoic Prairie Evaporite salt dissolution that preserved reservoir section.

References

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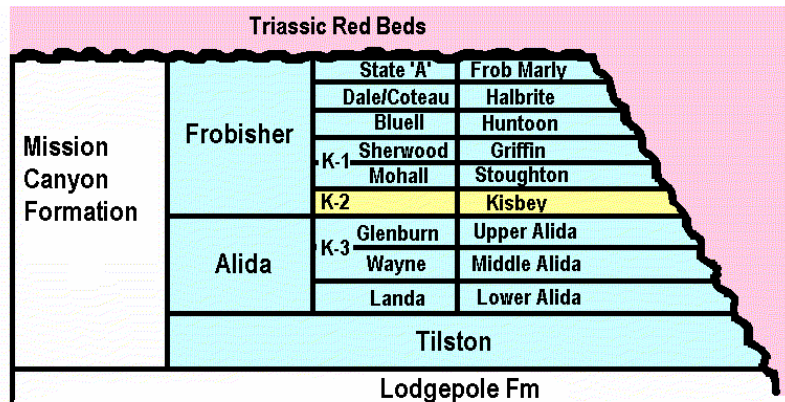


Fig. 1: Stratigraphic chart for southeast Saskatchewan with American and Canadian nomenclature.

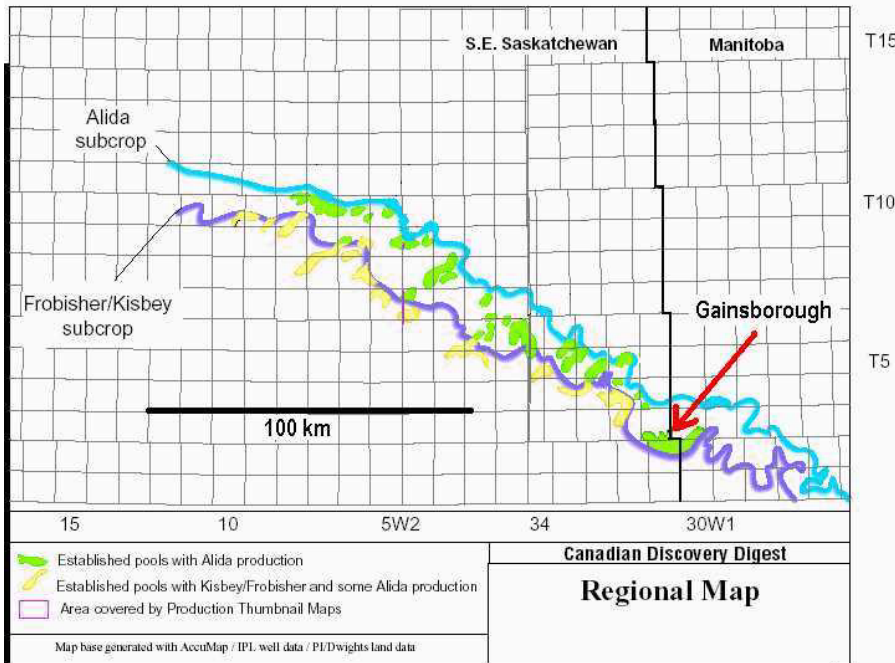


Fig. 2: Frobisher and Alida subcrop edges for southeast Saskatchewan.

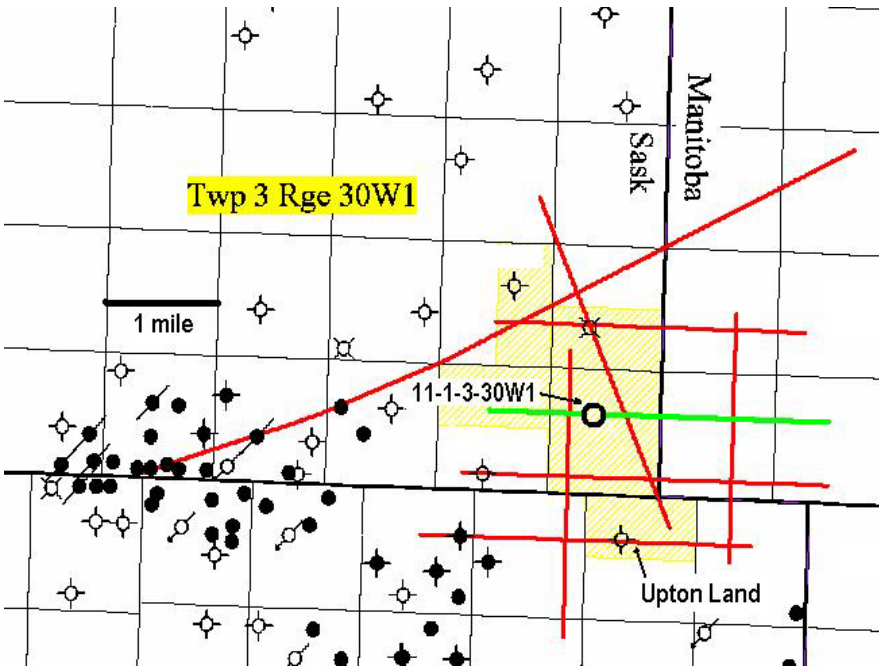


Fig. 3: Gainsborough Area 2-D seismic grid and well control as at May 1, 1995. Upton land is shown in yellow on the Figure and Figures 8, 9, and 10. Figure 6 is the green line.

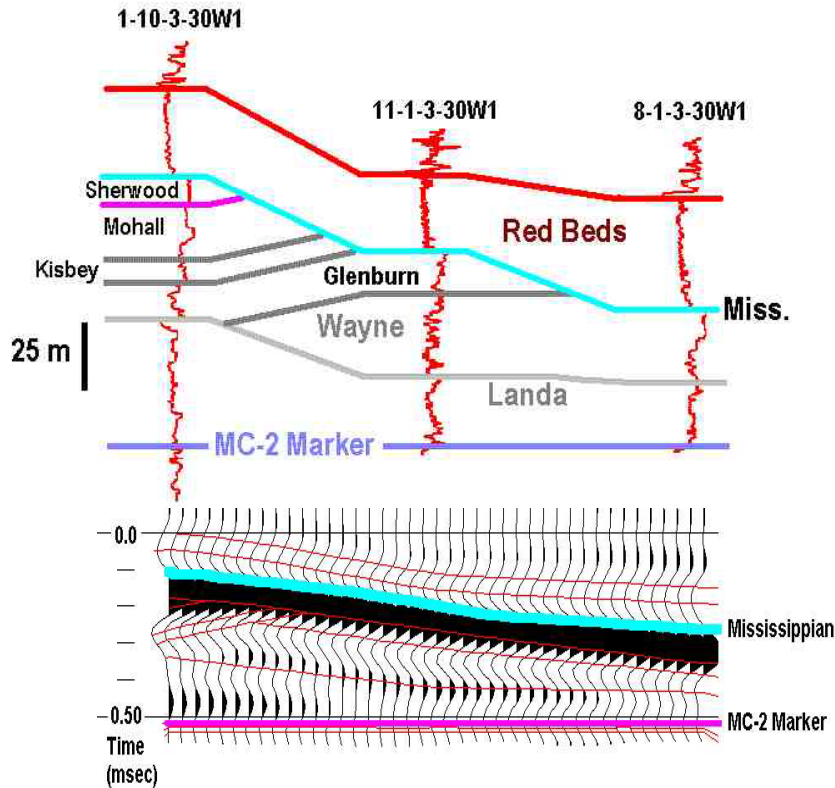


Fig. 4: (cross section) and 5 (model) – The 1-10 well shows a thicker Paleozoic to MC-2 isopach, which is reflected in the model. The MC-2 Marker does not show up well at 11-1 and 8-1, due to shallow sonic log coverage.

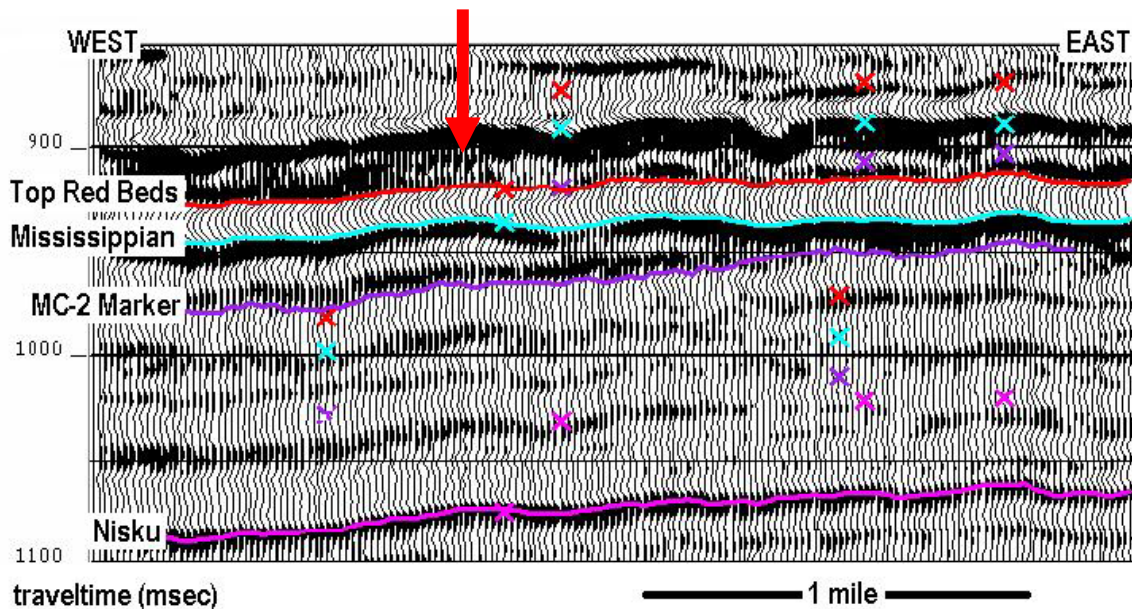


Fig. 6: Portion of the green E/W seismic line from Figure 3. Note how the Mississippian to MC-2 marker isochron thins to the East. The 11-1-3-30W1 well was drilled at the red arrow.

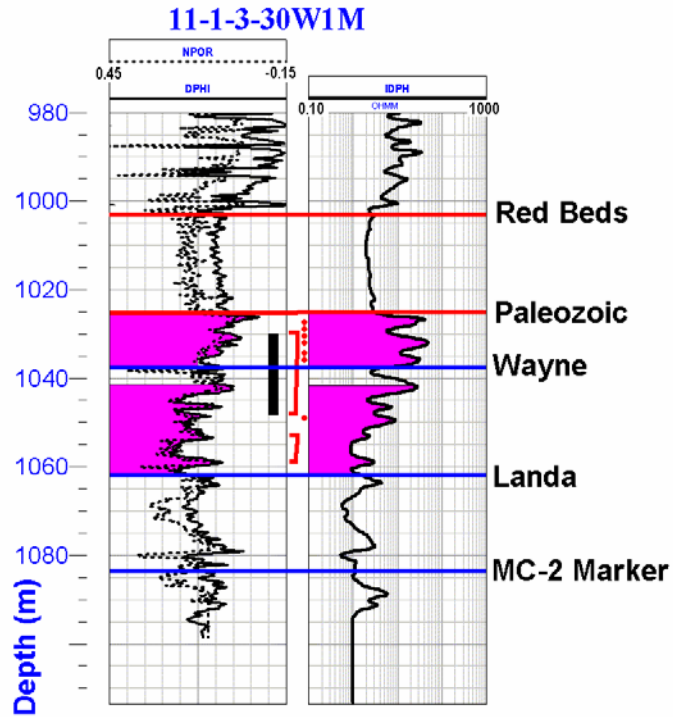


Fig. 7: The 11-1-3-30W1 well was rig released on May 27, 2003. The density porosity and resistivity curves are shown, as well as the cored interval in black, the test intervals in red lines, and subsequent perforated intervals as red dots.

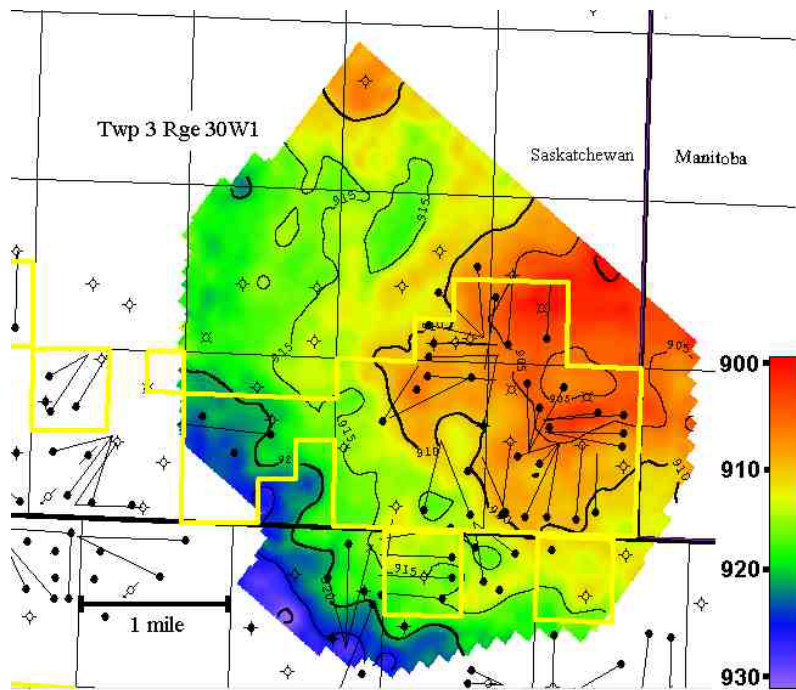


Fig. 8: Paleozoic time structure map in milliseconds for the 1995 3-D seismic program. The high outlined in red confirmed the geological mapping for the area.

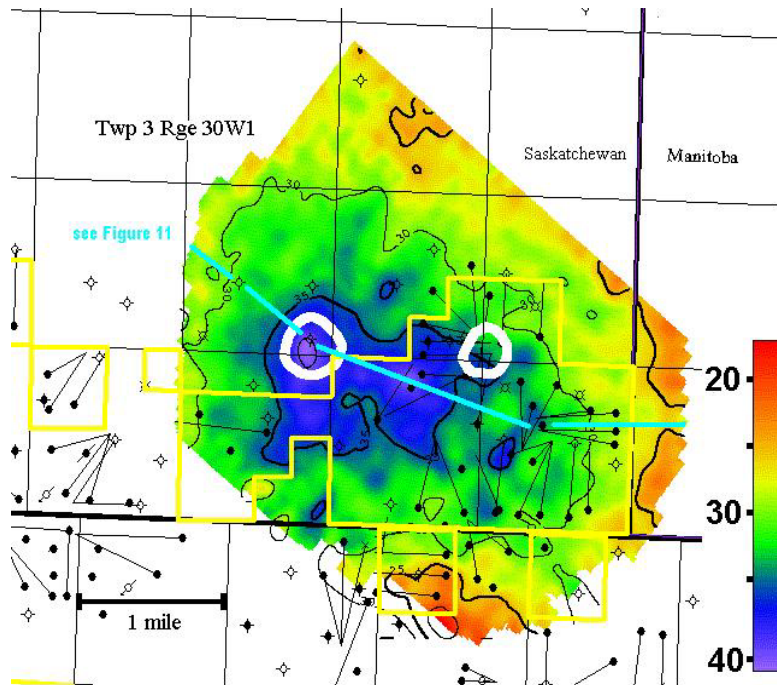


Fig. 9: Paleozoic to MC-2 Marker isochron in milliseconds for the 1995 3-D seismic program. The outlines for the two underlying Devonian reefs are shown in white. It is believed that Devonian salt dissolution started near these reefs is the cause for the preserved Mississippian section.

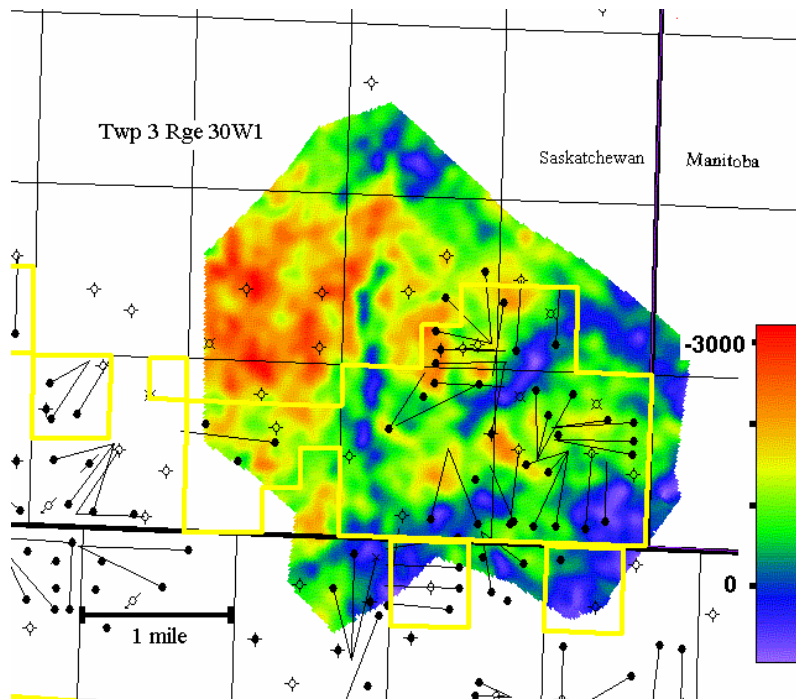


Fig. 10: The Glenburn trough amplitude maps the trough below the Mississippian peak reflection. The areas of blue may indicate later areas of channeling, while red and green areas may indicate areas of secondary anhydrite deposition.

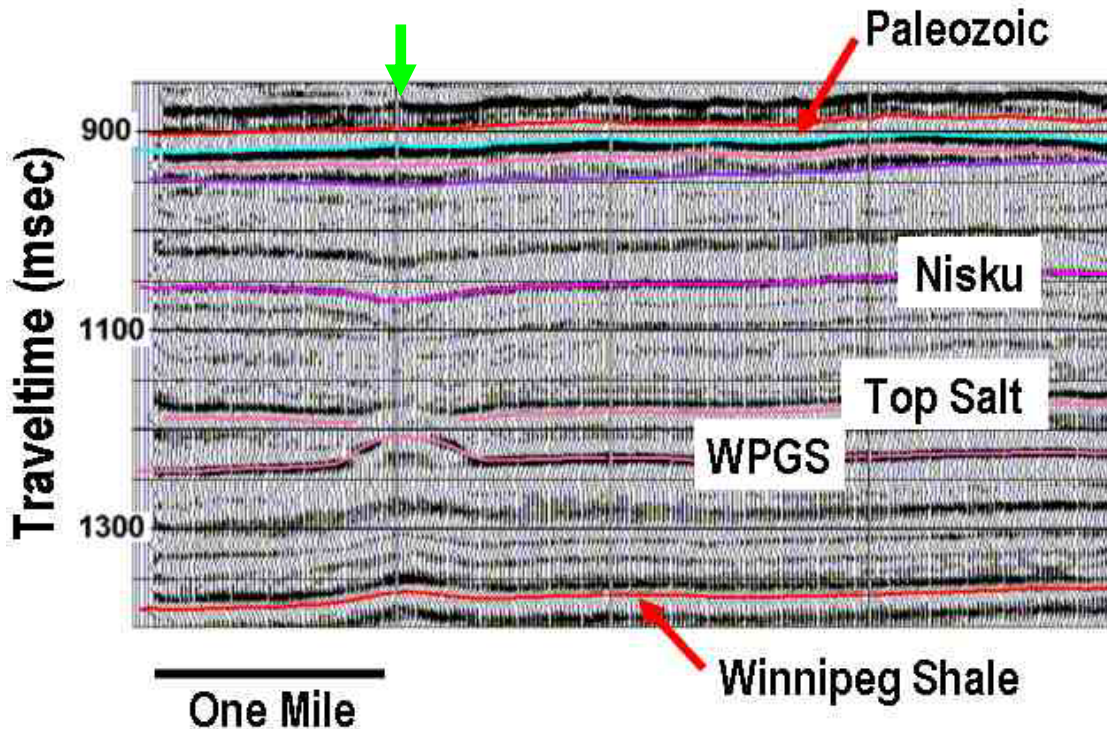


Fig. 11: Portion of a 3-D seismic line across the western reef outlined in Figure 9. It is felt that after deposition of the reef, there may have been some slight pre-Nisku dissolution. However, the sag in the Nisku and the thickened Paleozoic to MC-2 Marker (the purple marker at 950 msec) indicates post Nisku but pre Mesozoic salt dissolution. This would have preserved Sherwood aged Mississippian anhydrite over top of the reef at the 1-10-3-30W1 location (blue arrow).