Mapping of the Southern Margin of Prairie Evaporite In SE Saskatchewan

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Summary

The available map of the middle Devonian Prairie Evaporite is based on well log data and on seismic anomaly maps by Holter (1969). The margin has a complex shape with large uncertainties. The purpose of this study is updating the work of Holter (1969) and to improve mapping of the SW salt dissolution edge in southeastern Saskatchewan using additional well log and seismic information. In order to increase the resolution of salt edges, we reprocess the data in a uniform manner, with emphasis on the techniques for high-frequency enhancement.

Well data provide only point readings that are further interpolated in order to produce subsurface maps. However, application of different interpolation techniques result in marked differences especially where the salt layer is thin near its margin and the resulting uncertainties in the positions of the edges are at least 1-5 km. Integration of additional seismic and well log data, as well as the use of improved interpolation methods would thus greatly improve the accuracy and resolution of the subsurface map of the Prairie Evaporite.

Introduction

The present research focuses on improving the mapping the southern edge of Prairie Evaporite in Saskatchewan using the available 2D and 3D seismic and well log data. The study area is located in the south-eastern of Saskatchewan southeast of Regina. The middle Devonian Elk point group contains the largest amount of salt deposits in western Canada sedimentary basin. They extend 1200 miles from the Northern United States to Canada's Northwest Territories (DeMille et al., 1964). In the study area, the most extensive of these deposits is the Middle Devonian Prairie Evaporite (PE) Formation. PE salts extend over much of the Williston basin region, with thicknesses varying from 0 at the edges to 200-220 m along the central part of the Basin. One of the most striking and important features related to PE is salt collapse. The association of salt collapses with the deeper oil production is proven in many places such as Hummingbird, Kisbey, Taogwo. Structures created by salt collapses may influence oil entrapment, reservoir enhancements and migration of fluids. Accurate mapping of salt collapses is thus necessary for understanding the processes of salt dissolution, the nature of the basement control, and its impact on hydrocarbon production.

From the perspective of potash mining, understanding of salt dissolution is principally important for reducing mining hazards. Salt collapses structures could produce great amounts of water, and they also could be associated with water infiltration through the overlaying fault zones. Encountering PE collapses could in some cases result in a loss of the mine due to flooding (Gendzwill and Martin, 1996). Therefore, knowledge of the distribution and thickness of the Prairie Evaporate, particularly near its edges or zones of potential collapses is critical for potash miner to avoid mining into a collapse structure that could easily flood the mine.

Objectives

This project focuses on the delineation of dissolution edge along the SW edge of PE formation In SE Saskatchewan. In its utilization of the seismic, well datasets, and interpretation, the project ties in with Dr. Hajnal's (University of Saskatchewan) Weyburn project and Weyburn mapping project (K. Kreis). Our objective is to refine the mapping of the edges of salt dissolution and to correlate them with the underlying structural features (basement, Winnipegosis mounds, faults etc.). Specifically, we aim at: 1) Using the available 2D and 3D seismic data acquired by the industry, to improve delineation of the SW margin of the PE south of Regina. 2) Investigate and develop processing and interpretation techniques to allow identification of thin salt beds and salt collapses near the dissolution edge and seismically evaluate the underlying strata, with particular attention to the Precambrian basement, in an attempt to recognize any structural features which may have influenced the distribution of the present-day salt edge. 3) Evaluate the effects of different mapping (spatial interpolation) techniques on determination of the positions of salt edges.

Seismic imaging

Seismic observations are critical for the present study because they provide the most detailed and continuous coverage that can be correlated with surface and subsurface geological mapping and well logs. The seismic data used in this project were acquired in 1979 and 1984 and donated by Encana, Petro-Canada, Simonson and Olympic Seis. 13 seismic lines were collected using different recording systems and a variety of dynamite and air gun sources. Spread length extended mostly from 1.5 km to 3 km. Station intervals vary from 25 m to 67 m with shot intervals ranging from 125 m to 134 m. Field data were received on magnetic tape in SEG-B and SEG-Y formats and completely re-processed using PROMAX software (®Landmark Graphics).

The major steps in the seismic data processing flow include: 1) F-K filter for attenuating the Ground Roll; 2) Deconvolutionfor resolution improvement; 3) Velocity analysis; 4) Accurate residual statics;5) Radon filter for attenuation of multiplies. 6) Stacking. In order to achieve good vertical and horizontal resolution of thin structures near salt edges, seismic imaging resolution is critical. This limit on the recoverable frequencies leads to a maximum depth resolution, which is generally estimated as ¼ λ, where λ is the seismic wavelength. In order to improve the resolution, we tried several techniques for enhancement of high-frequency energy. The resulting optimal procedure includes a combination of trace equalization (Automatic Gain Control) and F-X deconvolution with time-variant spectral whitening. An example from seismic line CBY-5 by (Olympic Seis. Company) (Figure 1) shows migrated stack after using these procedures. In terms of dominant frequencies, this reads to an improvement from ~30 Hz to ~50 Hz from the PE depth, therefore leading to estimated depth resolution of ~20 m. The resulting stacked section shows a marked improvement on detail and continuity of the image.

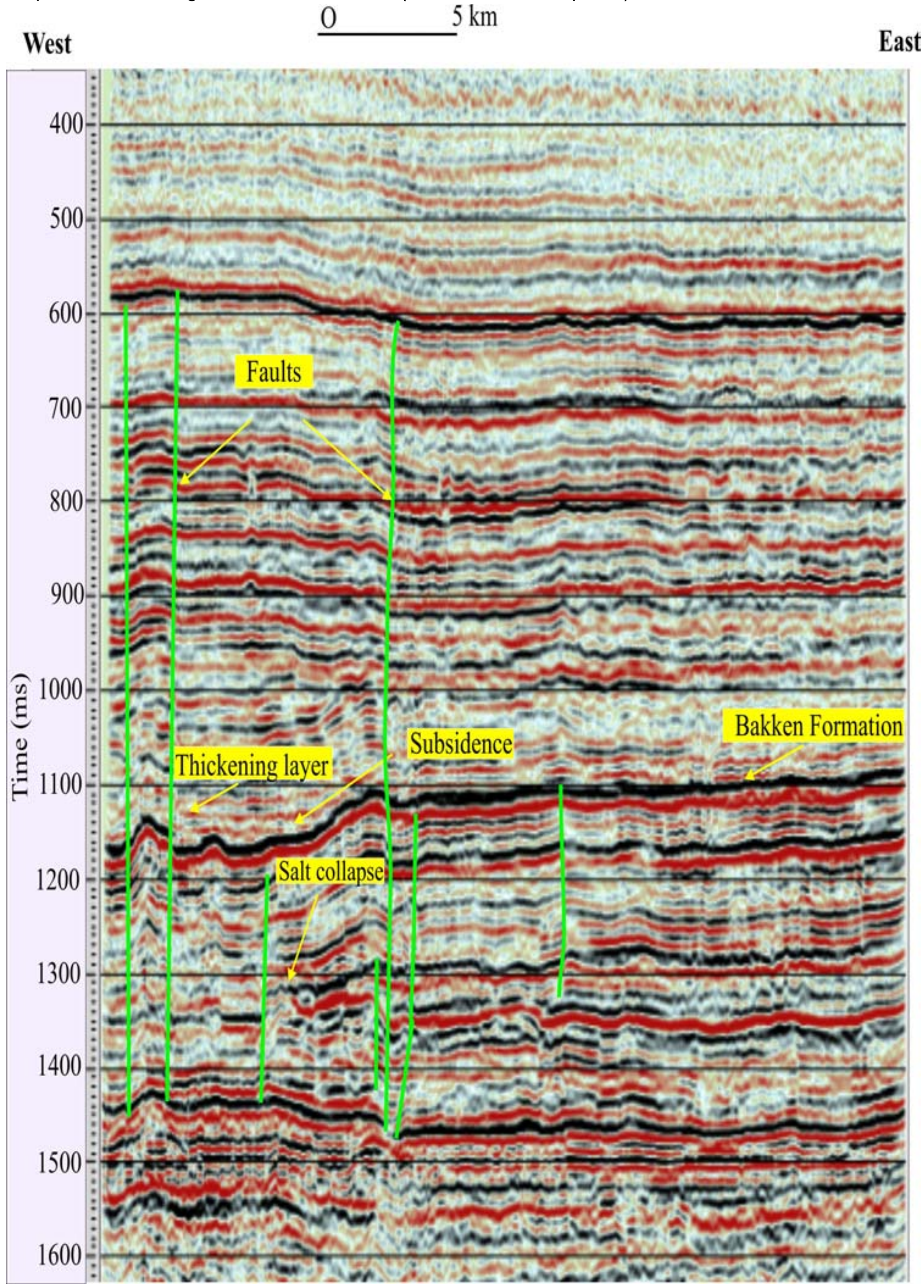

Figure 1. Subsidence caused by the salt collapse does not affect the shallower strata (Line CBY-5)

From Figure 1, features that we generally can recognize after the described processing steps are 1) internal thin beds within the PE can be distinguished; 2) the salt edge can be delineated more accurately, and 3) fault displacement can be measured more accurately from seismic events. Stratigraphic details suggest several deep and shallow faults with basement uplifts, with some deep faults rooted in the basement and extending to the surface. In the upper part of the sections, we also identify shallow faults penetrating into the Devonian strata. As suggested by Holter (1969), such basement uplifts and faults could allow water to circulate through the salt and control salt dissolution. Our data (Figure 1) also suggest that the locations and the origins of the salt dissolution areas could be associated with basement faults. In our study area, close relations are noticed between the basement features, Precambrian tectonic boundaries, and salt collapses.

Line CBY-5W shows that the Prairie Evaporate formation decreases in thickness from approximately 110 m to zero near the western end of the seismic line. Note the depression of the reflecting horizons that could be caused by salt dissolution (Figure 1). The reflections from the PE to Bakken Formation show a depression, with layers thickening between ~1180 ms to ~980 ms above the Bakken, However, the shallower reflections are less affected, and the strata overlying the Bakken appear to be flat. Apparently the only conclusion that could be drawn from this observation is that the dissolution took place during the late Devonian. More accurate estimate of thickening can be made from log data, which is the next step of this research. By contrast, seismic line NOR-833341 (by Petro- Canada) (Figure 2) shows a similar depression in the evaporite that affects all the reflecting horizons above it, with no thickened layers present. This might be an indication of a salt collapse that occurred more recently compared to the cross-section in Figure 1.

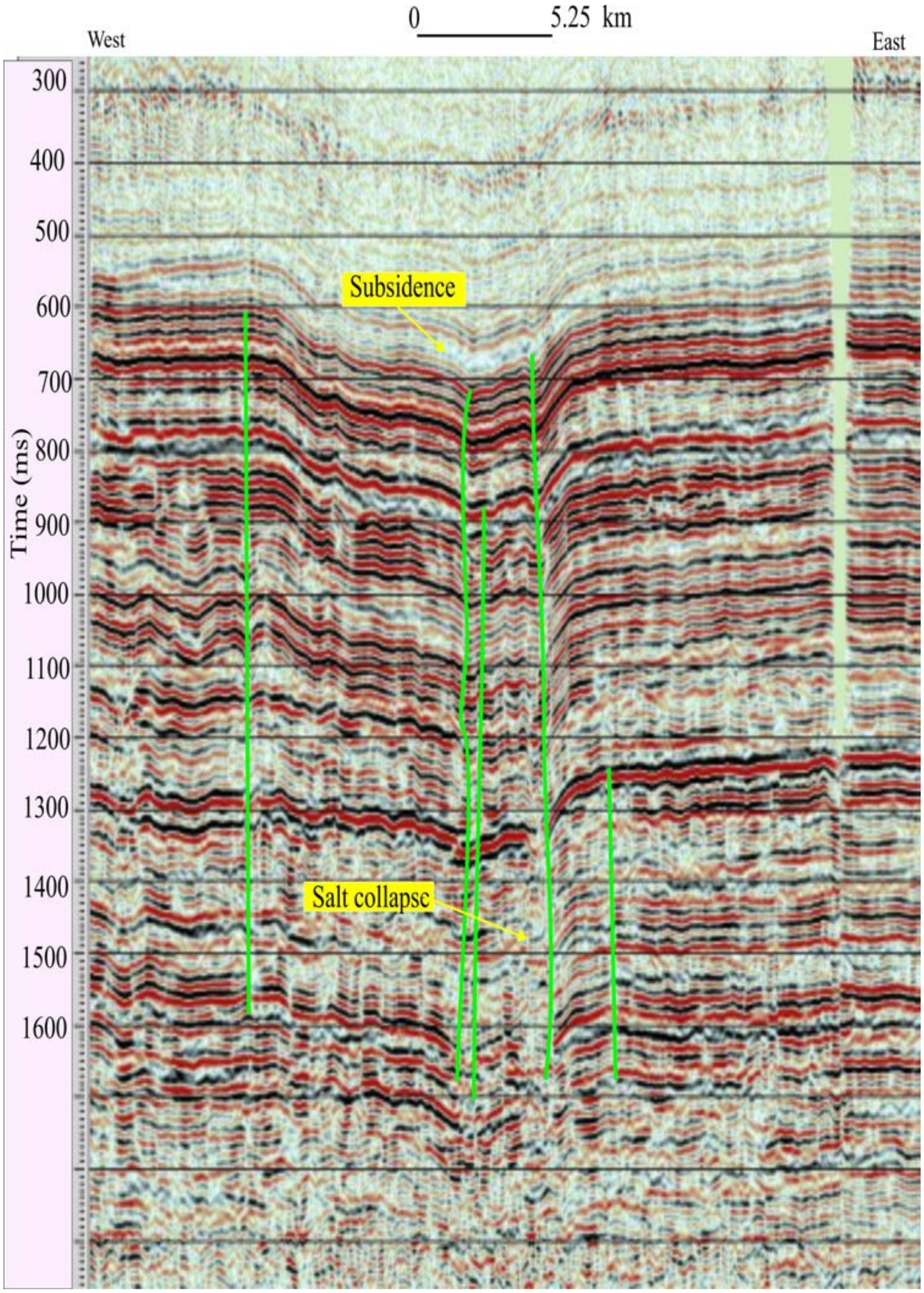

Figure 2. Effect of a salt collapse on seismic events (Line NOR-83341). Note that this collapse must have occurred more recently then in Figure 1, with all of the overlying strata disturbed by it.

Sub-surface Map Interpolation

Seismic and well data provide point or linear readings that have to be interpolated in order to produce subsurface maps. However, such interpolation is non-unique and may depend on the method employed. This is particularly important for the edges of data coverage, such as the salt edges of this study, where the mapping is actually relying on spatial extrapolation. In order to evaluate the dependence of isopach contours on the interpolation techniques, we perform mapping using Matlab and Generic Mapping Tools (GMT) routines, and compare the results to Surfer maps.

We used maps based on well log interpretation of the middle Devonian strata in Weyburn project area obtained from SIR database. After several experiments, GMT was chosen as the preferred option. There are two advantages in using GMT programs: 1) The interpolation methods are published (Smith and Wessel, 1990), the code is open- source, and thus the details of algorithms can be understood and adjusted if necessary; 2) GMT programs offer a choice of the spline tension parameter T, with tighter splines resulting in smoother maps. To assess the sensitivity of interpretation to the choice of T, several values of spline tension parameter T were used (Figure 3). The resulting maps show marked differences, especially near the edge of the salt where its thickness is low. GMT maps are similar yet somewhat differ in detail from the results of Matlab and Surfer interpolations (by K.Kreis). These differences, and particularly their implications for imaging salt collapses, will need to be evaluated in the future work. The map with tension T=0 was chosen as the preferred option because it shows the data trends with minimal “bull's eye” artefacts around isolated data points.

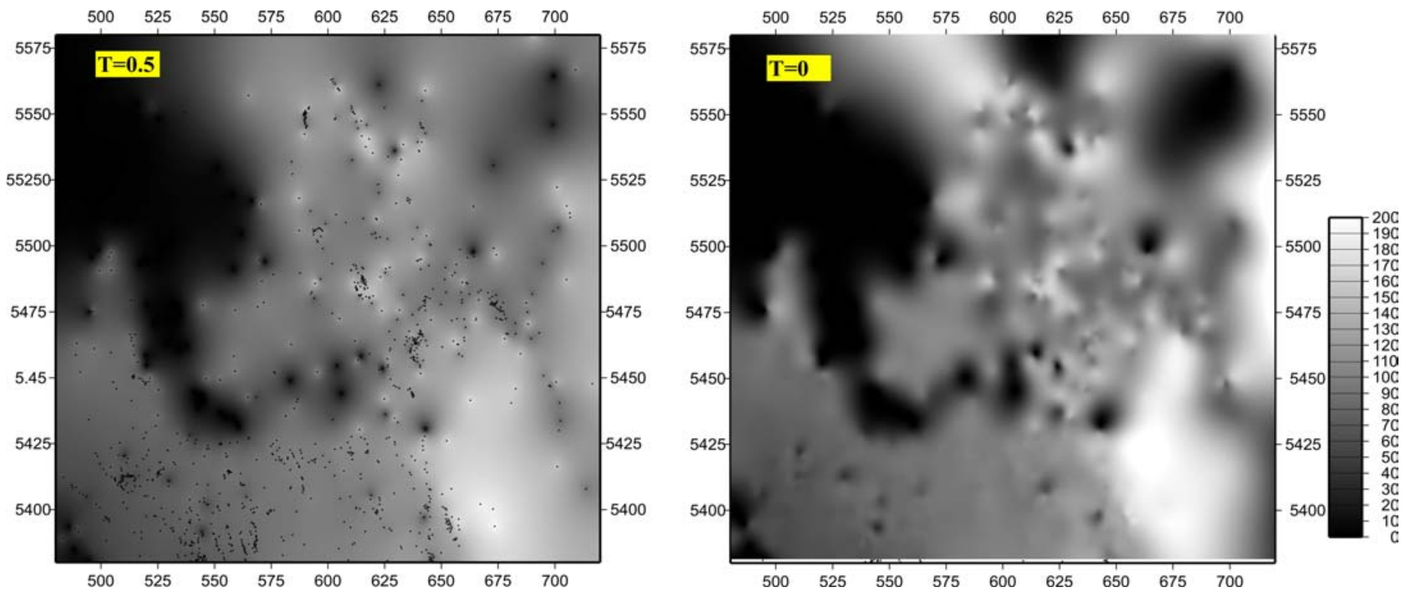

Figure 3. Prairie salt maps interpolated using GMT programs (Smith and Wessel, 1990), using two values of spline tension parameter *T*, as labelled. *T* typically varies from 0 to 1, with larger values corresponding to smoother interpolations. Note the differences between maps using different interpolation parameters. Coordinates are UTM in km, black dots in the plot on the left indicate the wells used for interpolation.

Conclusions

1) Seismic sections, even those recorded in the 70’s, provide critical contribution to mapping the salt dissolution edges. 2) High-frequency enhancement of seismic data is useful to improve resolution and result in improved images of the salt edge and thin beds. 3) Spatial interpolation of well picks used in subsurface mapping results in uncertainties of the positions of salt edges of ~ 1-5 km. Consequently, seismic studies should still be critical for accurate location of the edges.4) In the seismic sections analysed to date, we observe indications of a late Devonian and a more recent salt collapses.

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