Is The Geosphere Secure? Assessing The Presence Of Deep-Penetrating Faults In The IEA Weyburn CO2 Study Area, SE Saskatchewan

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ABSTRACT

Summary

As part of the IEA Weyburn CO_2 Monitoring and Storage Project, investigations were conducted into the nature of faulting within an area up to 200 x 200 km around the Weyburn Field. This study is an essential element in assessing the integrity of the geosphere for CO_2 storage. A specific concern is whether faults are present that may penetrate from the Mississippian Midale Beds to shallower levels in a smaller Assessment Area focussed on 10 km beyond the limits of the CO_2 flood. These faults may represent potential conduits for migration of CO_2 in the subsurface.

Methods of investigating fault and fracture distribution have involved surface lineament studies using remote sensing data, a widely spaced grid of approximately 2000 km of 2D seismic data provided by 28 exploration and data-exchange organizations, and High Resolution AeroMagnetic (HRAM) data provided by GEDCO.

Faults have been identified on most of the seismic sections within the region of interest. Some faults are associated with dissolution edges of the Devonian Prairie Evaporite, and these we suggest often have correlative surface expression as determined through remote sensing analysis. The vertical extent of these faults or fracture zones needs to be more thoroughly examined; in some areas this may lead to acquisition of high resolution geophysical data. As there is only very marginal salt dissolution in the immediate vicinity of Weyburn Field, the above process and its consequences are not significant factors in the Assessment Area. There are, however, several faults in the regional study area which penetrate from the basement through the entire section, as defined on all three data sets. Specific examples include a fault zone associated with the Missouri Coteau escarpment, and the Souris River Fault, which is partially within the Assessment Area.

Determining whether any of these faults are potential conduits for CO_2 migration cannot be addressed at this stage of investigation. The occurrence of significant hydrocarbon reservoirs in the Mississippian strata, the lack of observed hydrocarbons in overlying section, and the hydrogeological data examined as part of the IEA Weyburn study all suggest, however, that significant fluid migration along these faults has not occurred during the past 50 million years.

Results

1. A number of faults and fault zones have been identified on the seismic data within the assessment area. HRAM data has proven very useful to help correlate faults identified on separate seismic lines to develop a regional framework that helps to guide the integrated interpretation effort. We have one map that combines the seismic and magnetic evidence into one integrated interpretation.

A general observation is that the surface lineaments are oriented NW/SE and NE/SW, reflecting systematic fault and fracture sets. For the NE striking faults, the deep lineaments interpreted from magnetics with seismic control are oriented with a slightly more easterly strike than the surface lineaments (060º for the magnetics as compared to 045º for the lineaments). Curiously, the NW faults seem to be more similar in strike on both the magnetics and seismic and the surface lineament interpretations.

An interesting hypothesis is that this difference in orientation of interpreted NE faults and fractures, one deep and one shallow, may indicate a change in orientation of basin stresses between pre-Devonian, Devonian and post-Laramide times.

2. The Missouri Coteau Fault Zone is well imaged on the magnetics, seismic and on the surface lineament data sets. Several faults interpreted along the fault zone from seismic profiles trending E-W and N-S form a flower structure. This fault zone is located in an area of total Prairie Evaporite salt dissolution. The surface geology in this area also reveals a fault zone several kilometres in width. Kupsch (1958) points out that the stratigraphy indicates a complex history of vertical motion along these faults.

There is a strong correlation on seismic between a broad basement structural high and salt dissolution (Prairie Evaporite) in the Hummingbird Trough. The faulting associated with the Hummingbird Trough correlates well with the magnetics trend. By and large, the surface lineaments do not reflect this basement structure.

3. There are several examples of basement-rooted faults that extend upward to relatively shallow depths in the larger study area, particularly in the general vicinity of the Missouri Coteau Fault Zone. Within the Assessment Area, we identified four examples of deep-rooted aeromagnetic trends that correlate with

surface lineaments. The strongest correlation within the Assessment Area is the long NNW-striking fault (which we refer to as the Souris River Fault) that parallels the strike of the western side of the Nesson Anticline but lies well to the west. This fault (Figure 1) is clearly imaged on the magnetic data at both deep and shallow levels and on several seismic sections (Goussev et al., 2004, this conference). Also, the regional NW-SE trend of the Souris River deviates to a nearly north-south direction where it overlies this fault. The depth migrated version of seismic line SOU-06 shows this fault particularly well.

4. What can we say about the shallow and deep faults? Shallow faults inferred through remotely sensed lineament trends tend to follow trends parallel to dissolution patterns within the Prairie Evaporite, suggesting a possible structural connection between deep-seated structures and the surface. However, more study is required to understand the mechanisms responsible for such a correlation. Correlation of aeromagnetic trends with salt dissolution areas suggests that basement uplift in post-Devonian time has likely played a role in salt dissolution of the Hummingbird Trough. Salt dissolution has also been associated with the location of underlying Winnipegosis mounds, many of which may be located near or on basement faults. Bunge (2000) shows a good example under a tributary of the Souris River.

It is clear that there are faults in the regional study area that are rooted in the basement, as defined by both seismic and magnetic data, and some of these are related to regions of salt dissolution. Many of these deep faults or fracture zones are interpreted to penetrate to the Mississippian, and some penetrate through to higher levels, including the surface.

Conclusions

So, is the Geosphere secure? The reservoir is encapsulated by several anhydrite units and the regional Lower Watrous Formation. These strata provide a regional seal to much of the Mississippian section in the northern part of the Williston Basin. In addition, there are a number of thick, predominantly shale packages that serve as regional aquitards throughout the region. As determined by this work, however, several faults do extend through the succession, including one in part of the Assessment Area. Whether or not these faults represent potential migration pathways is unknown. However, the sealing capacity of the anhydrites and shales together with the indirect evidence that fluid migration has not been historically significant, suggests that this is unlikely. This question will be addressed further in a subsequent phase of this project.

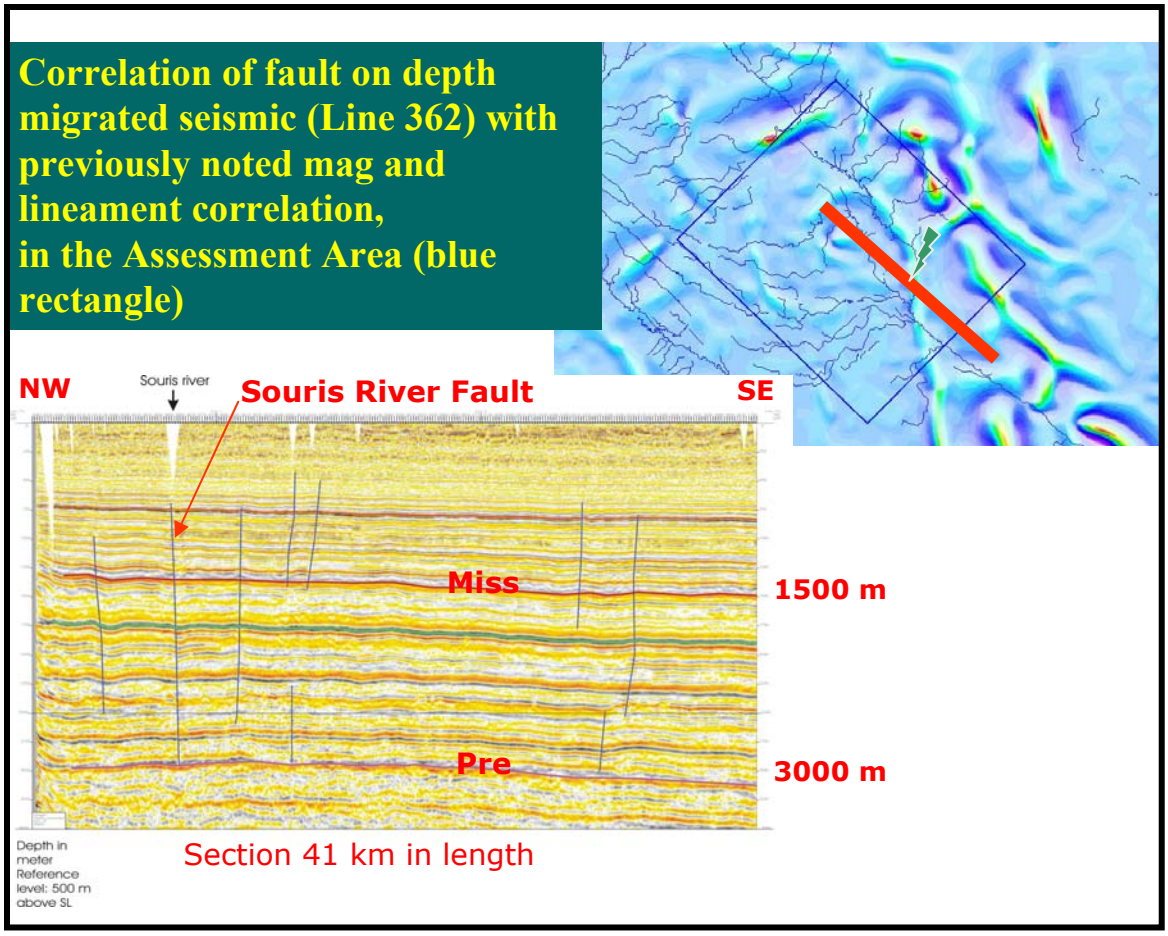

Figure 1. Correlation of fault on a depth migrated seismic (Line SOU-06) with magnetic and lineament correlation (N/S segment of the Souris River), in the Assessment Area. Basement is at a depth of about 3000 m subsurface and the Mississippian is at roughly 1200-1500 m depth subsurface. Elevations in the area are 600-800 m.

References

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