The Origin of Natural Fractures in the Antrim Shale, Michigan*

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Abstract

The Antrim Shale of the Michigan Basin is black organic shale that was deposited in the Late Devonian. The Antrim is the primary unconventional gas target in Michigan and is ranked number thirteen in term of gas volume in the United States. The shale produces from a depth ranging from 300 to 1800 feet in an area of northern Michigan where the Antrim is naturally fractured. The natural gas produced is believed to be biogenic in origin, formed by the influx of fresh water bacteria into the organically rich shale. Fresh waters most likely enter the Antrim outcrop, located immediately north of production, during time of glaciation. Numerous studies have concentrated on the source and generation of natural gas in the Antrim but no theory has adequately explained the localized presents of natural fractures.

The Antrim Shale is present though out most of the Michigan Basin. Extensive drilling in all areas of the Basin has proven that only a several county area of northern Michigan was naturally fractured enough to sustain gas production. Currently the most accepted theories for this localized fracturing are (1) Paleozoic tectonics related to the Mid-Continent Rift or Grenville Front; (2) post glaciation rebound; (3) hydraulic pumping; and (4) frost wedging. The first two of the theories (1 & 2) fail to explain the fractures localization since most of the Michigan Basin has been tectonically active and covered by thick glacial ice. The other two theories (3 & 4) do not define a mechanism for propagating the fractures over 30 miles south from the Antrim subcrop.

Depositional models and cross sections indicate that localized Antrim fracturing in northern Michigan is the result of extensive leaching of the Detroit River Salt below the Antrim. Fresh waters, introduced during Pleistocene glaciation have dissolved the upper Detroit River salts over a four county area resulting in collapse of the overlying beds. The more brittle shales such as the Norwood and
Lachine Members of the Antrim were more intensely fractured during the collapse. Natural fractures have been enhanced by structural flexures but the primary fractures result from collapse. County-wide A1 Salt dissolution in SW Michigan is an example of this process.

References

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Important Components of Shale Plays

1) High Gas (organic) content.

2) Brittle enough to be fraced efficiently.

3) Thick enough to have reserves and avoid fracing out of zone.

4) Existing natural fractures or porous interconnecting layers.
Imaging Logs, MDC Big Wolf Lake Project (CBIL, CAST, UBI Fracture I.D. Logs)
FRACTURE ORIENTATION AND FREQUENCY

<table>
<thead>
<tr>
<th>CORE GR</th>
<th>DEPTH FEET</th>
<th>CORED INTERVAL</th>
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<tr>
<td>1460</td>
<td>ELLSWORTH FORMATION</td>
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<tr>
<td>1500</td>
<td>CHESTER BLACK SHALE MEMBER</td>
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<tr>
<td>1520</td>
<td>Lachine</td>
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<tr>
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<tr>
<td>1605</td>
<td>Norwood</td>
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<td>1660</td>
<td>MUD LAKE GRAY SHALE MEMBER</td>
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<tr>
<td>1680</td>
<td>TRAVERSE LIMESTONE</td>
<td></td>
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</table>
Whither the Fractures?

- Terrane Boundaries (NE-SW)(Grenville Front)
- Mid-Continent Rift (NW-SE)
- Paleozoic Tectonics (Chiefly NW-SE)
- Post-Glacial Isostatic Rebound (Enhanced Near Subcrop)
- Hydraulic Pumping
- Dissolution of underlying Detroit River Salt
Origin of Natural Factures in Antrim

1) Dissolution of Upper Detroit River Salt and subsequent collapse of overlying strata.

2) Minor influence from tectonic deformation.
Traverse Lime Structure
Traverse Lime Structure
Thickness of uppermost Detroit River Anhydrite
Thickness of the “H” Salt
Thickness of uppermost Detroit River Anhydrite
Figure 5. Displacement mechanics along en echelon fractures. A, En echelon fractures with intervening layers; B, combined dilation and shear displacement resulting from rock layers rotating away from adjacent substrates; C, fractures zone "repaired" with imaginary needle and thread. Both stitches and layers are under tension, thereby illustrating the origin of the tensile stress that causes fractures.
Figure 7. Representation of kink band, a familiar geologic structure. A, Dimension B-B’ is increased with relative to original thickness A-A’. B, Geometry of deformation reduces high interlayer friction by separating layers within band, thus enabling deformation to take place.
Figure 8. Mining-induced fractures parallel to the face in longwall mines. A, Hard-rock mine, vertical vein (photo rotated 90° to approximate geometry of flat-dipping coal); B, proposed origin of fractures in coal mines as result of shear displacement along angle of draw.
DETROIT RIVER SALT COLAPSE MODEL
Conclusions

During periods of glaciation fresh water enter the Detroit River and leached the salts. The same fresh waters allowed for microbial gas development.

Subsequent collapse of the overlying formation fractured the more brittle rocks such as the Lachine and Norwood. Some thermogenic gas escaped upward into the Antrim. Difference in salt collapse resulted in some areas more fractured than others.

Further Antrim exploration is limited by few areas left unexplored that have Detroit River Salts close to possible fresh water sources (outcrops).
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