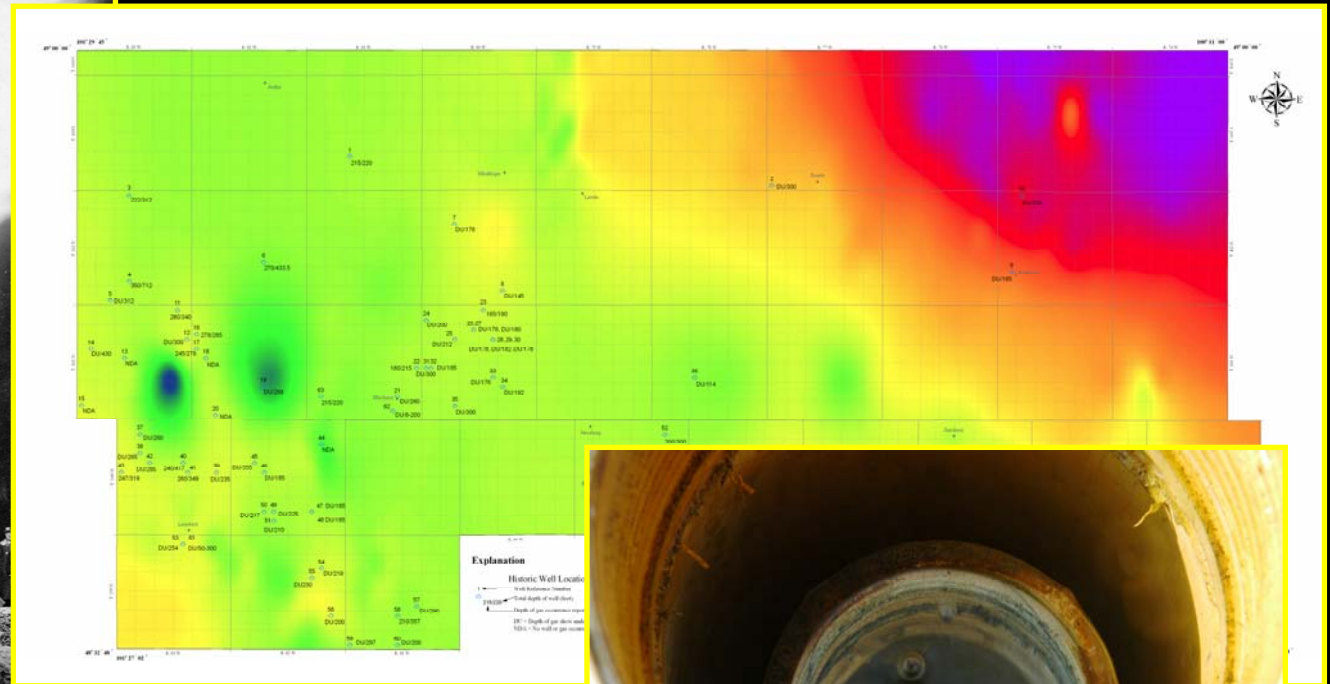
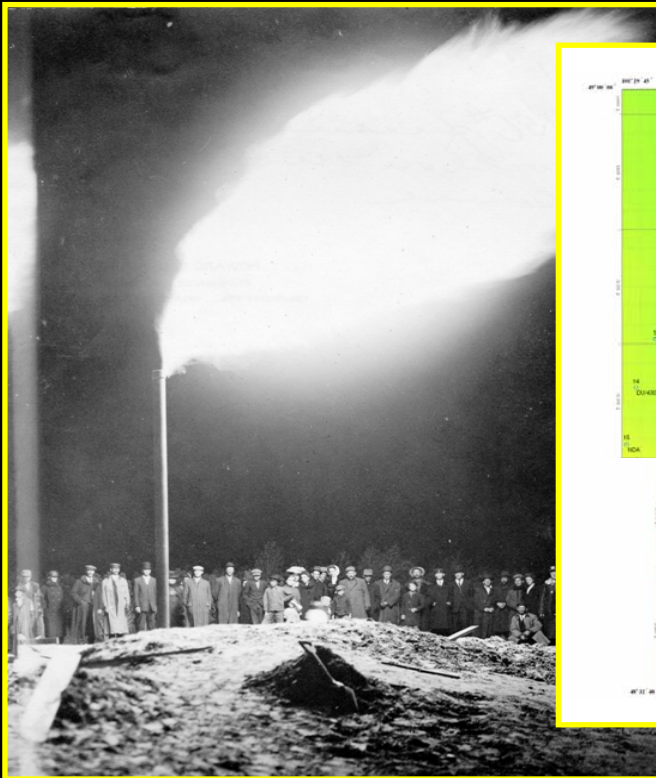


History, Geology, and Potential Hydrogeochemical Indicators of Natural Gas Occurrence and Production from Quaternary Glacial Drift and Upper-Cretaceous Sedimentary Bedrock in North-Central North Dakota



Fred J. Anderson, North Dakota Geological Survey

George W. Shurr, GeoShurr Resources, LLC

David W. Fischer, Fischer Oil & Gas, Inc.



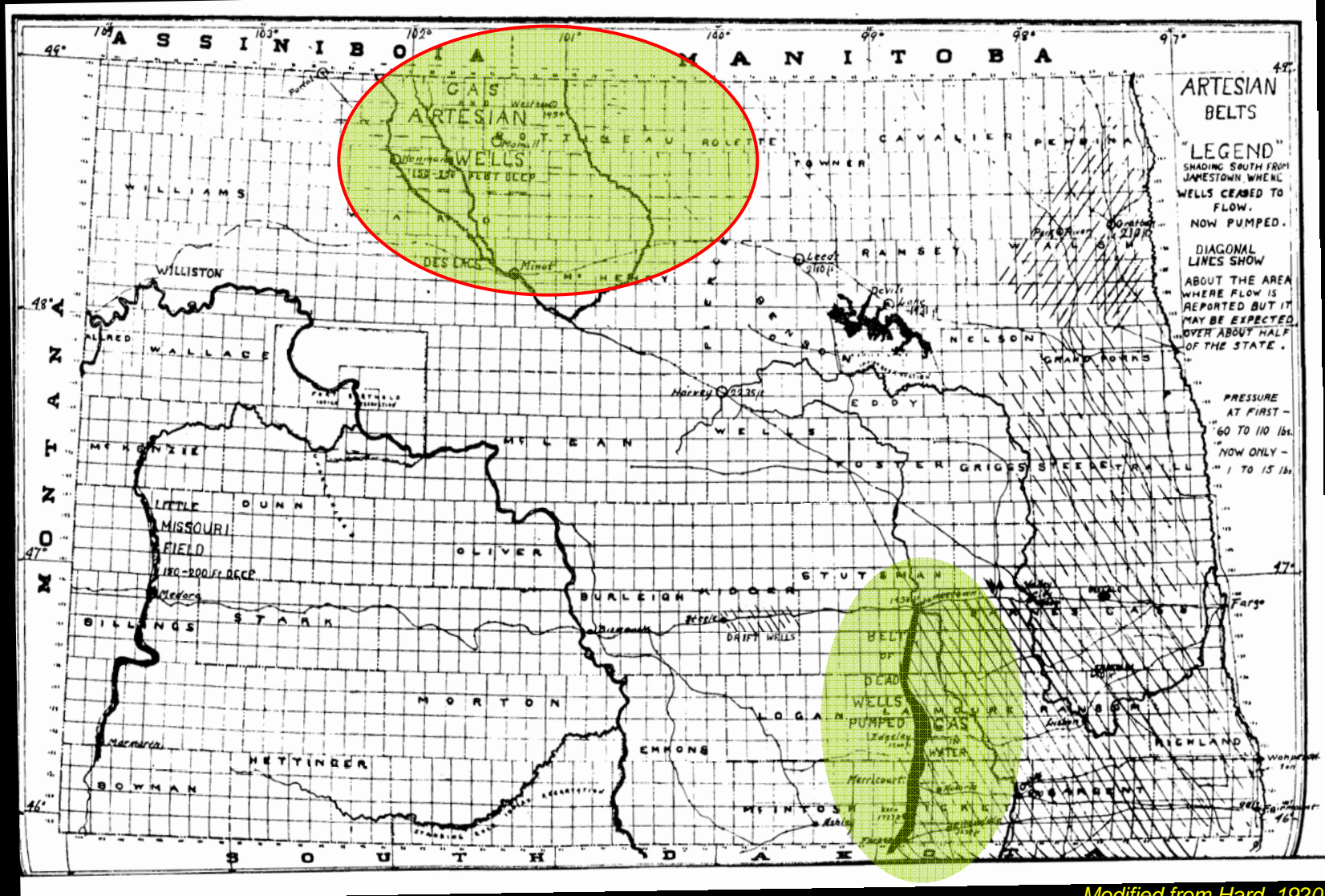
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Historical Shallow Natural Gas Occurrence in ND



Modified from Hard, 1920



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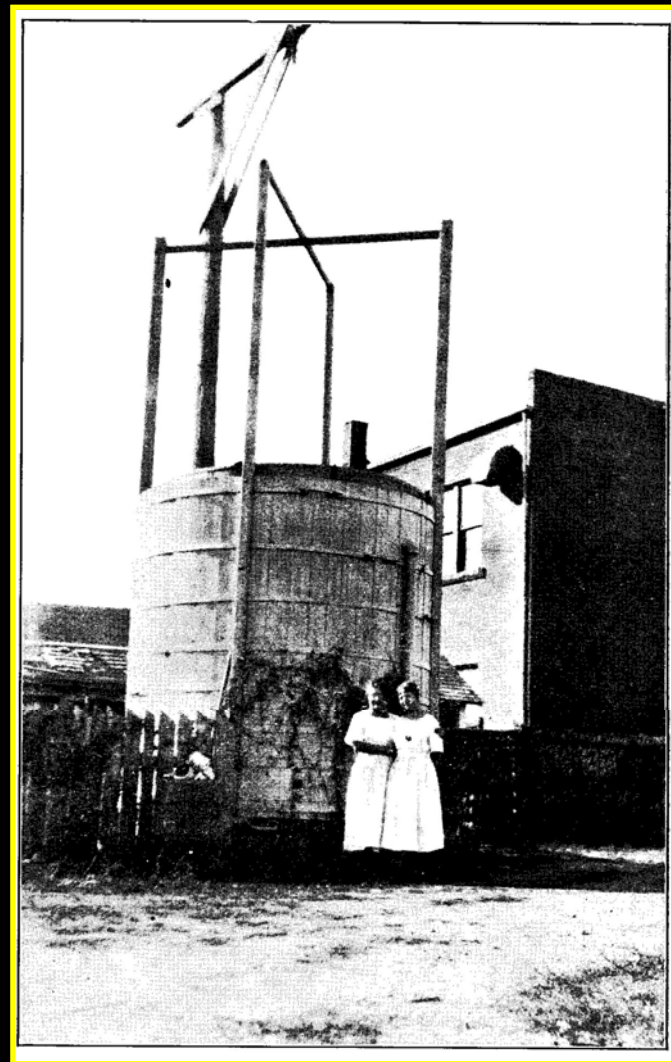
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Historical Shallow Gas Use in North Dakota



Examples of historic shallow natural gas use by North Dakotans likely near Mohall, in Renville Co. around 1919.



Gas storage tank at the Northern Hotel, Edgeley, LaMoure Co., around 1920



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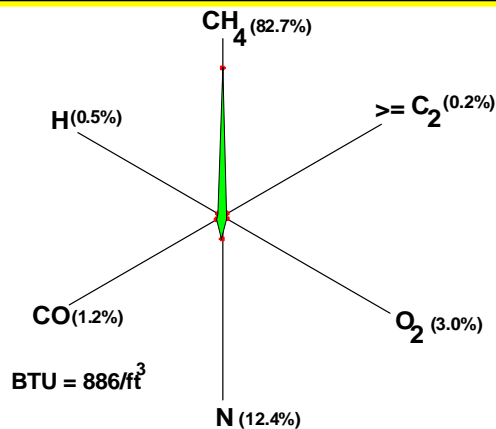
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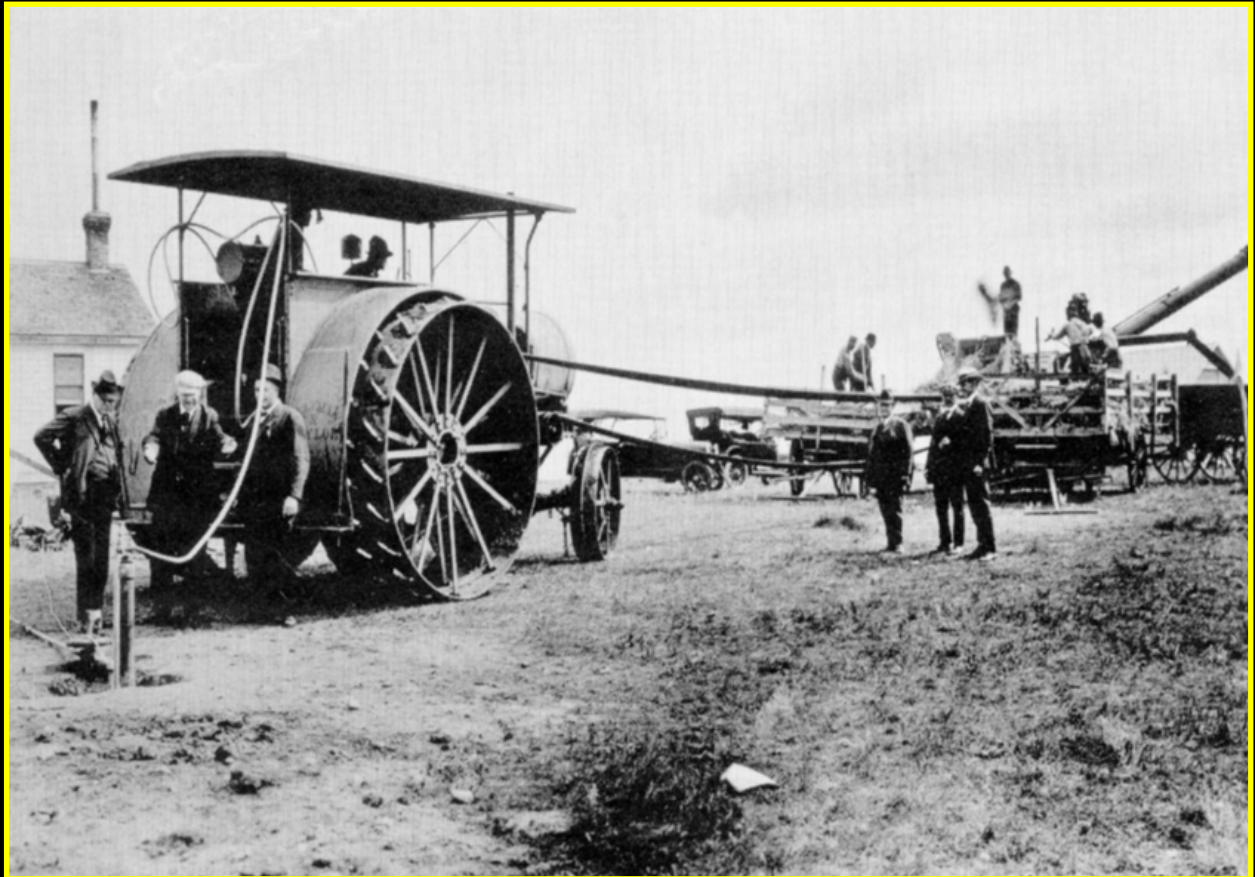


Early Gas Composition Analysis

- Gas Properties (Barry, 1908)
 - 886 BTU
 - 82.7 % Methane
 - 0.2 % Ethane
 - 3.0 % Oxygen
 - 12.4 % Nitrogen
 - 0.5 % Hydrogen
 - 1.2 % Carbon Monoxide (CO?)



Star diagram of gas composition analysis results from shallow gas occurrence within wells located on the Parker Farm (Barry, 1908).



Historic threshing operation utilizing shallow natural gas in north-central North Dakota



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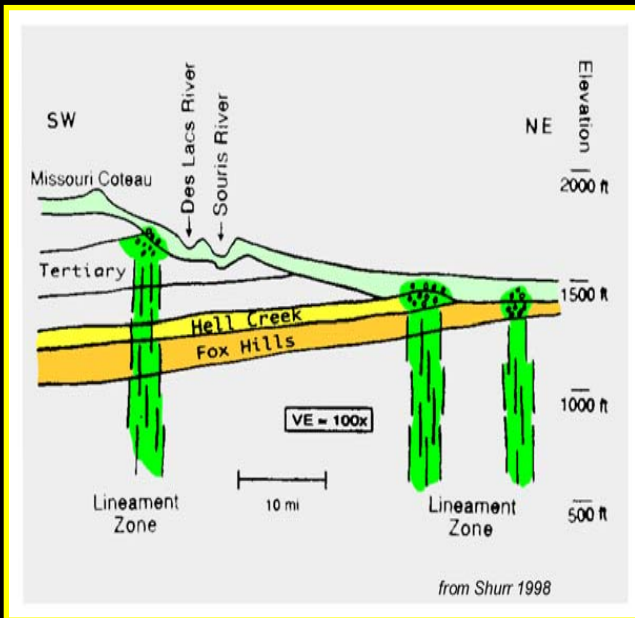
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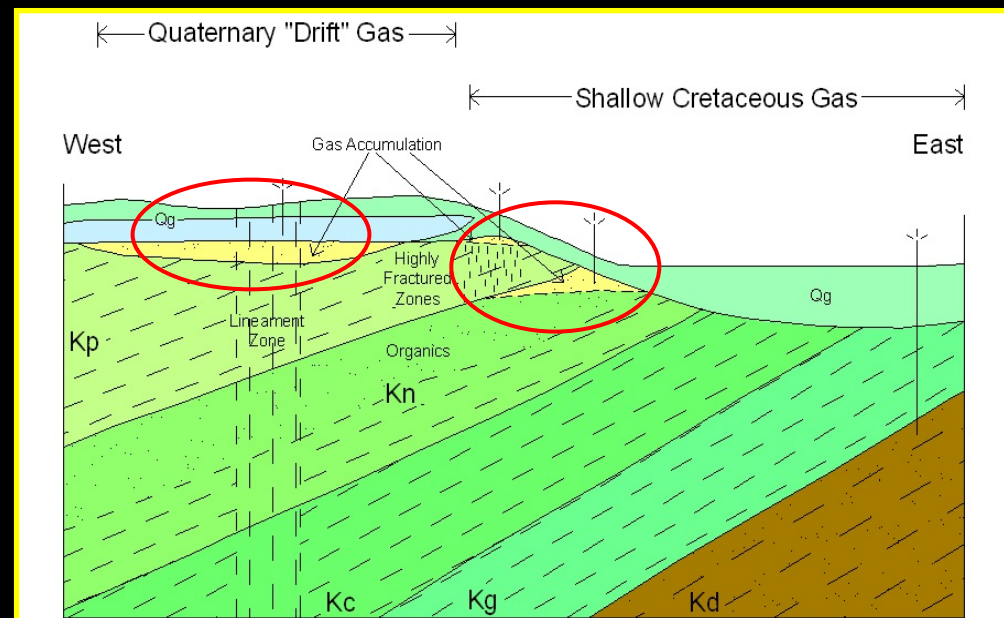


Working Definition of Shallow Gas in North Dakota

- *Natural gas that is generated and accumulated within the near surface geology of the state at depths commonly less than 300m that is typically sourced and contained within permeable organic laden glacial sediments or within sandstone and fractured shale reservoirs of Cretaceous age or combinations of each.*



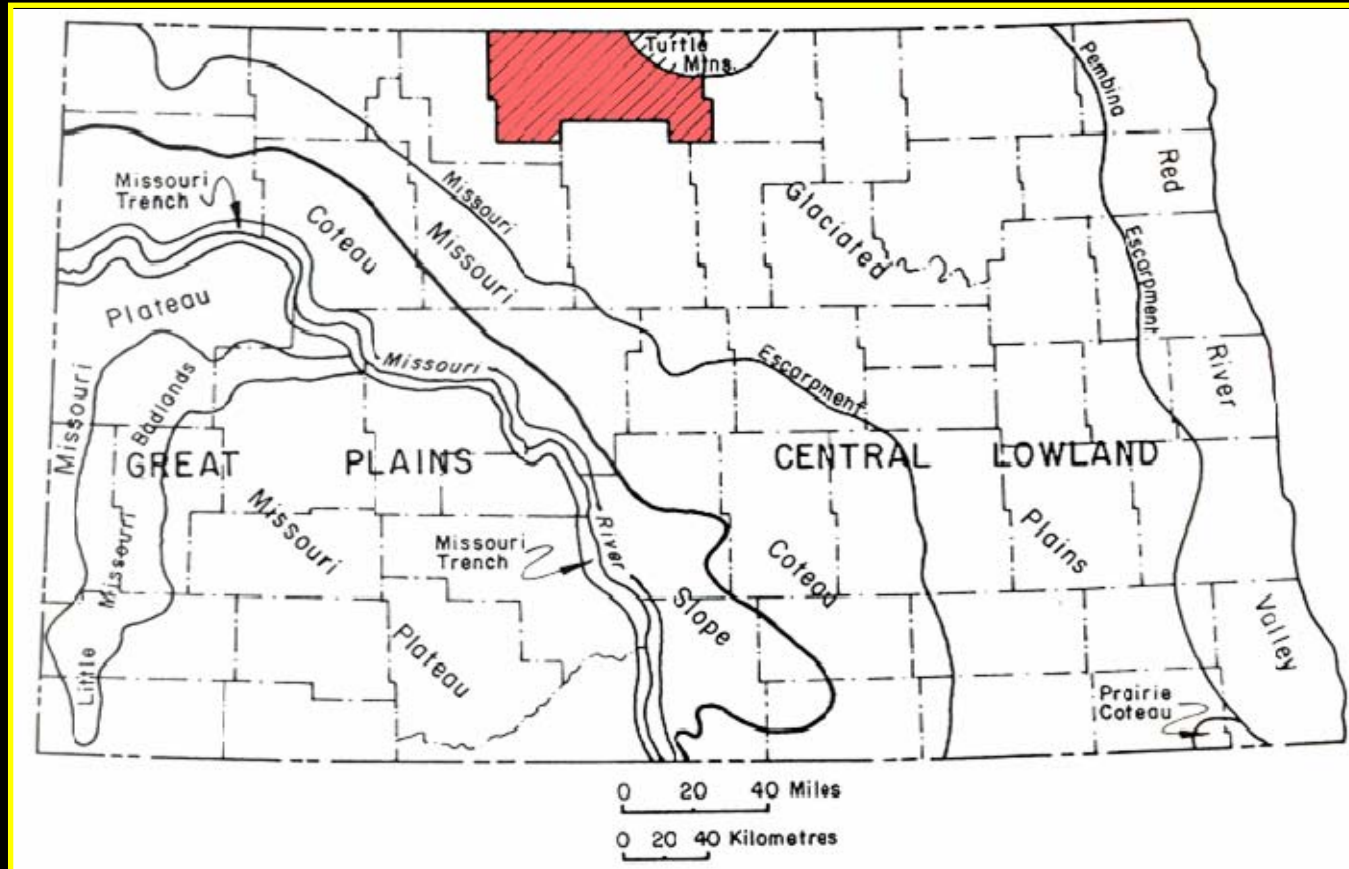
(a) North-Central North Dakota.



(b) Eastern North Dakota.

Conceptual diagrammatic geologic sections depicting typical potential shallow gas settings in north-central (a) and eastern (b) North Dakota.

Physiography and Location of Bottineau County



- Central Lowlands Province
- Glaciated Plains
- Adjacent to the Turtle Mts.

Physiographic Map of North Dakota highlighting the location of Bottineau County (red hachured area) .



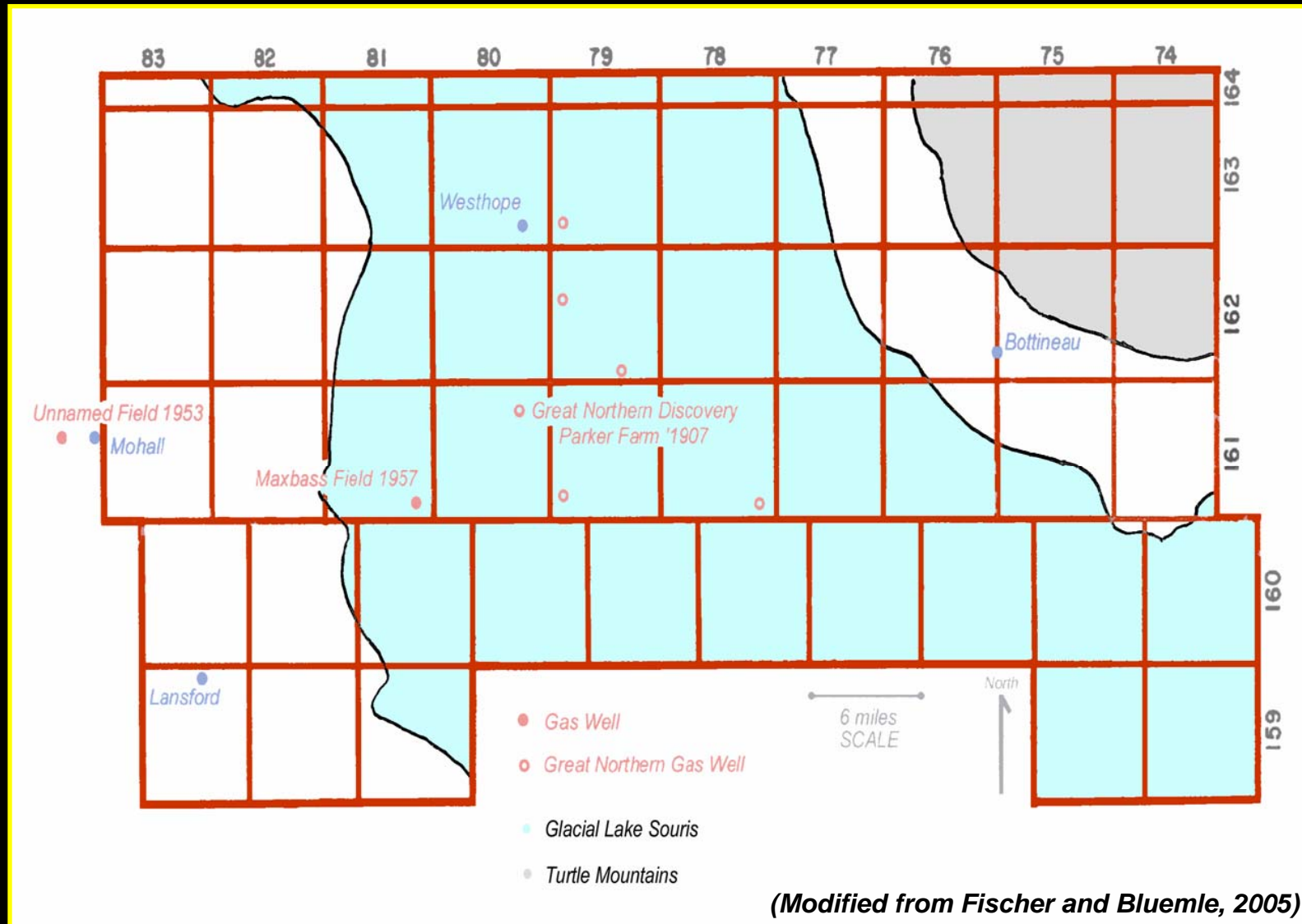
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Surface Geologic Setting in Bottineau County



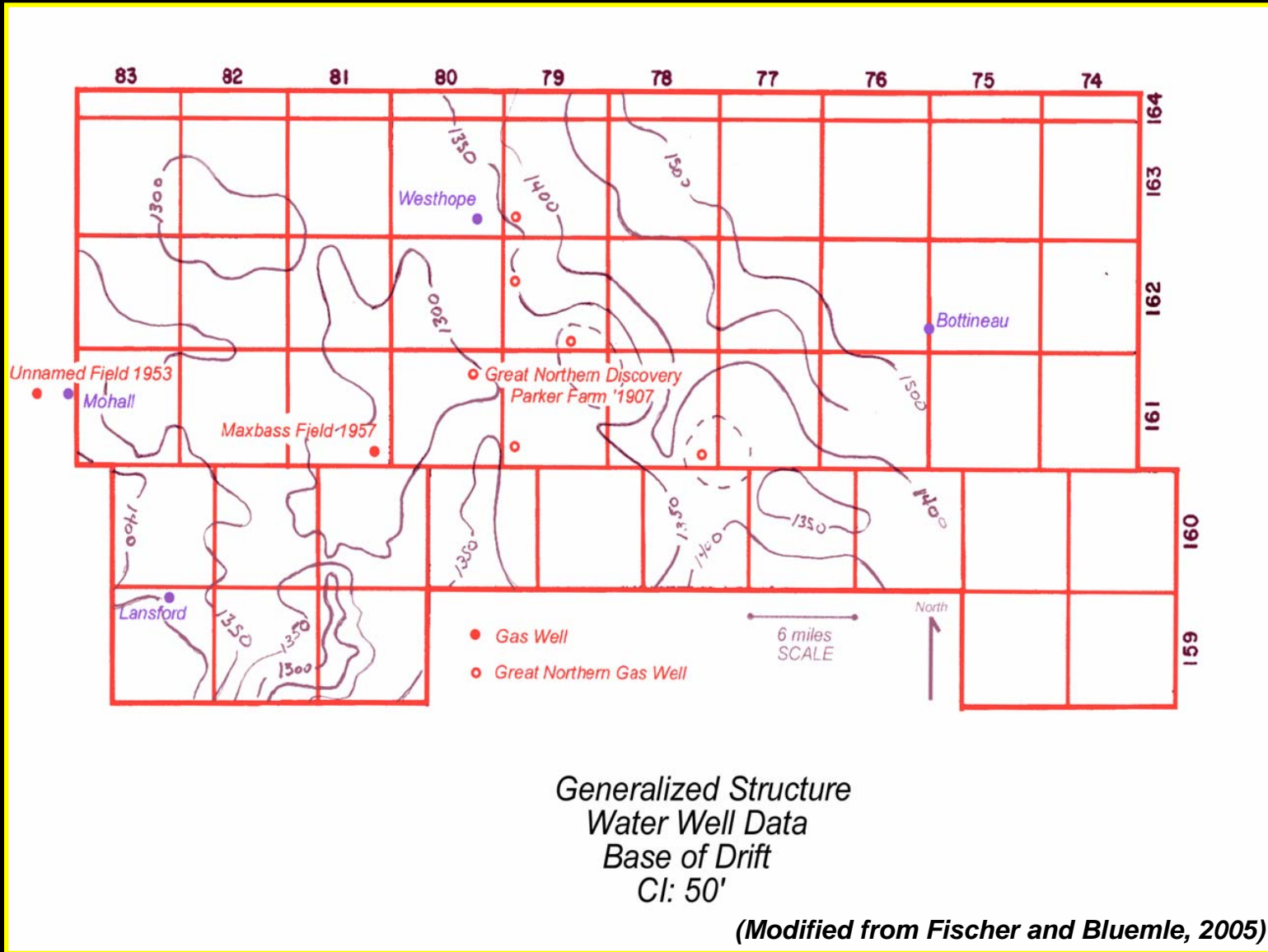
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Potential Influence of Structure on Drift Occurrences



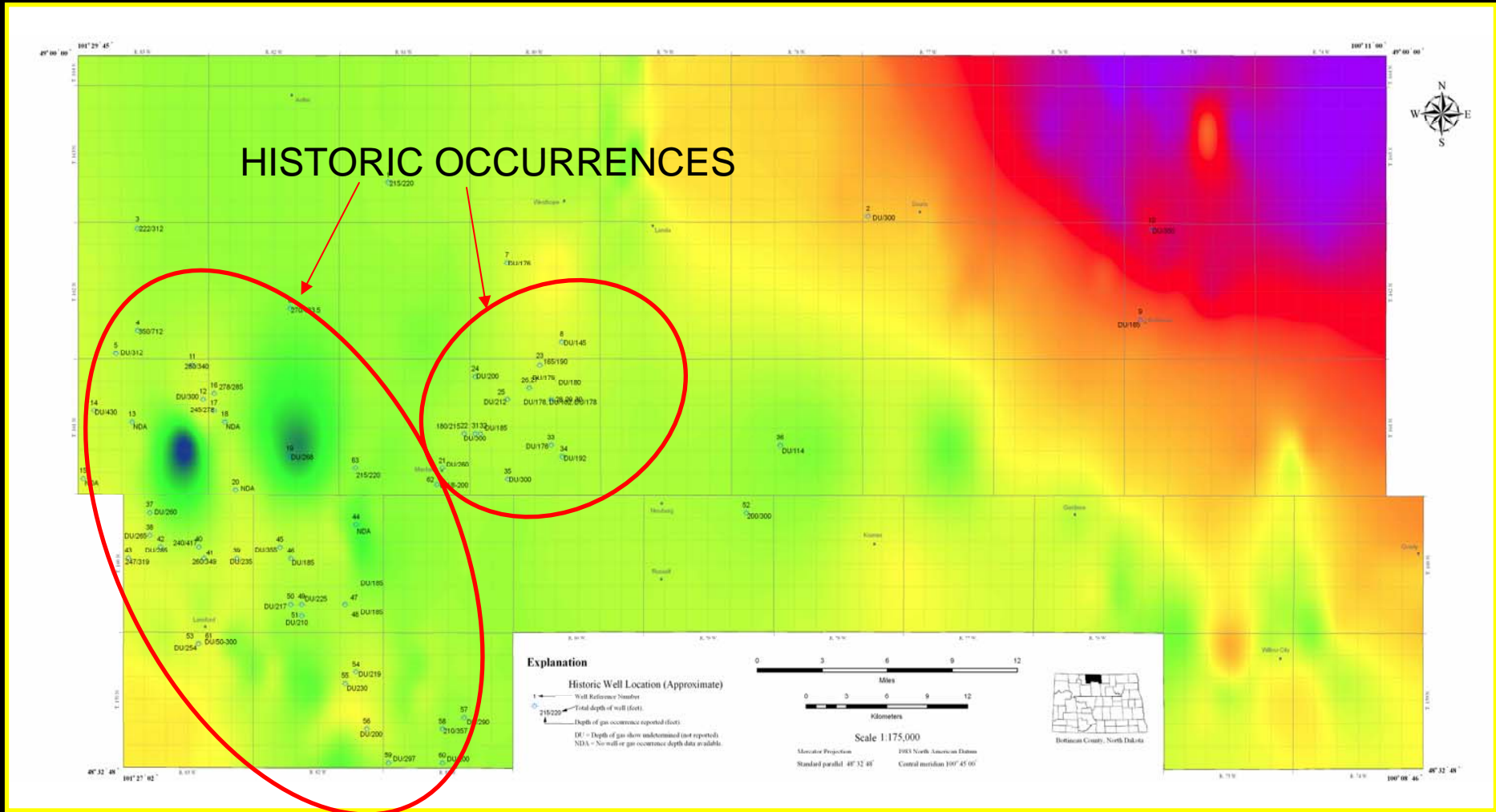
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Relationship of Bottineau County Historic Shallow Gas Occurrences and Bedrock Topography



(Modified from Anderson, 2006)



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Characteristics of Historic Gas Occurrences in Bottineau County

- Shallow artesian ground-water wells
- Depths of 46 to 91 m common
- Producing Zones:
 - Basal glacial outwash sands
 - Upper-Cretaceous bedrock sandstones
- Initial Producing Pressures = 64 psi
- Likely open flow production of 400 to 1000 Mcf/D



Gas producing well in the Mohall, ND area around 1920

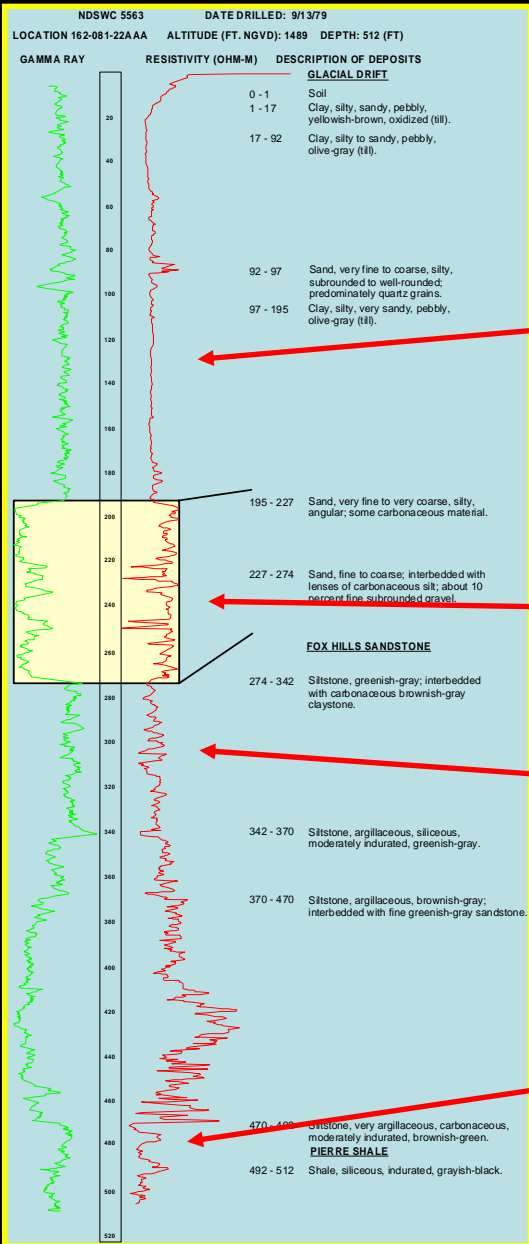


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Typical Log Characteristics and Stratigraphic Relationships

Low permeability glacial sediment (till or glaciolacustrine sediments).

Basal outwash sands (detrital lignite common).

Underlying permeable Cretaceous bedrock (Fox Hills/Hell Creek Formation).

Deeper basal Cretaceous marine shales (Pierre Fm).

(Modified from Randich and Kuzniar, 1984)



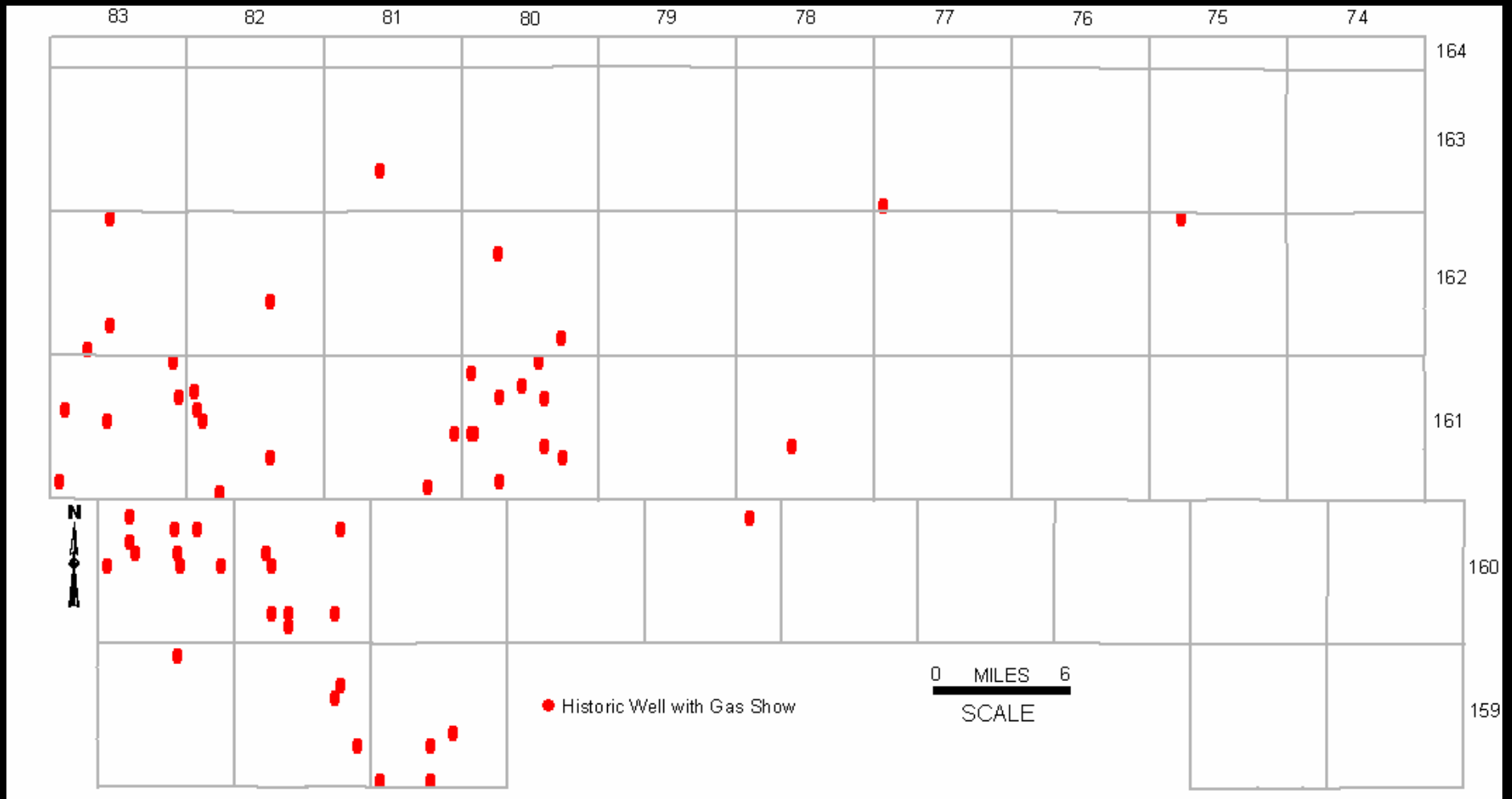
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Historic Wells with Reported Gas Occurrences



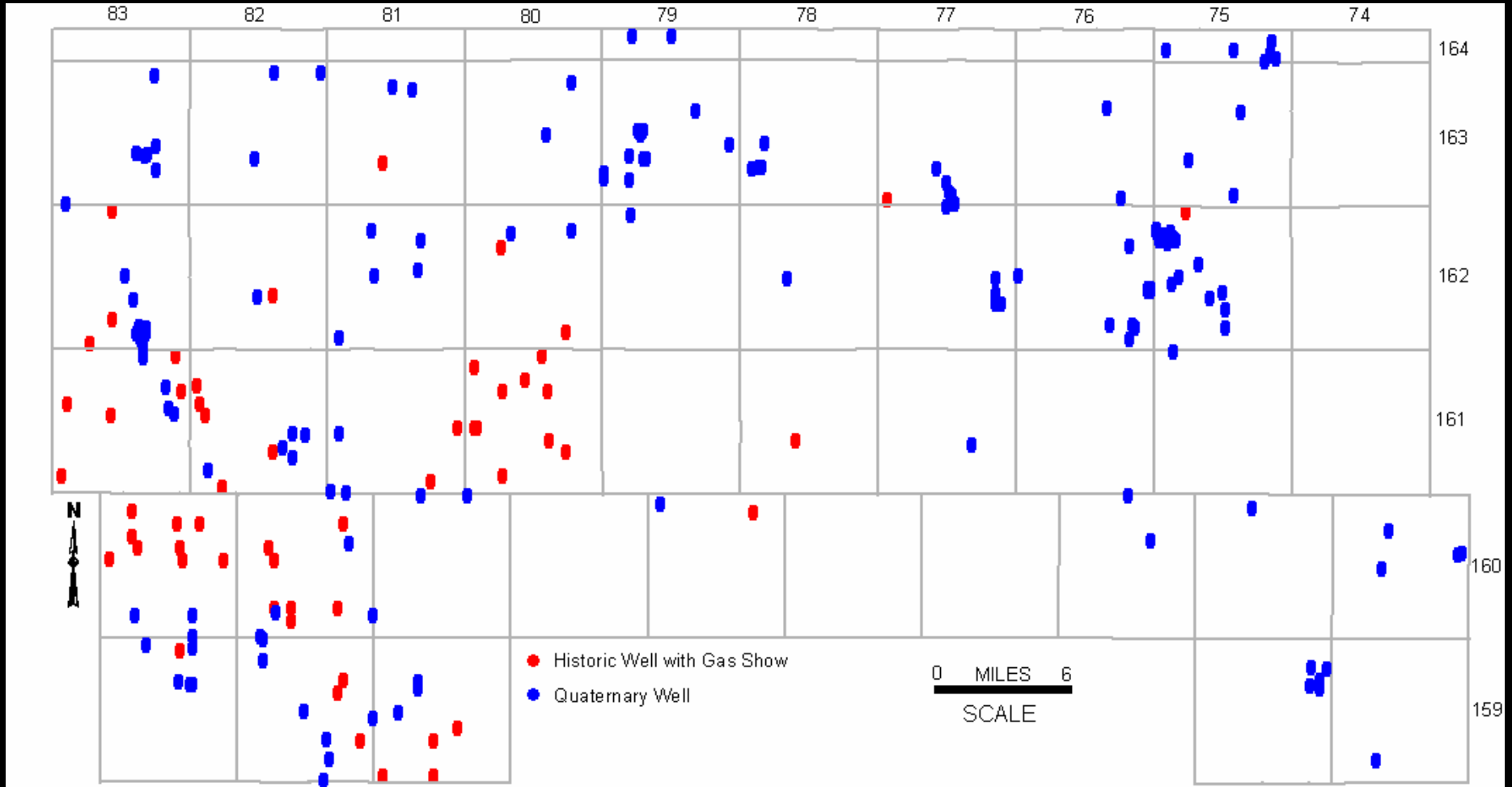
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Quaternary Glacial Drift Wells



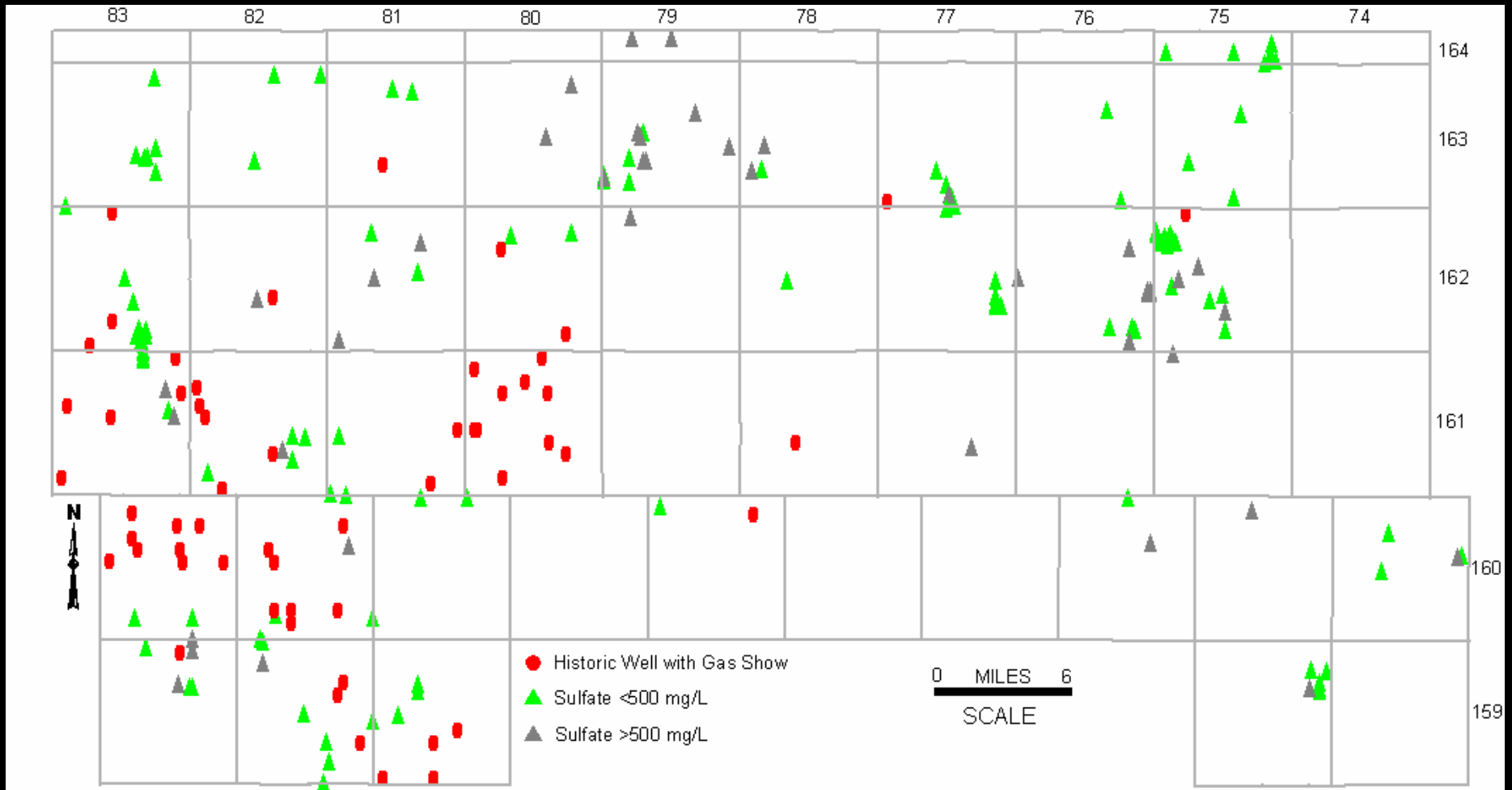
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Relationship of Sulfate Concentrations in Quaternary Glacial Drift Wells to Wells with Historic Gas Shows



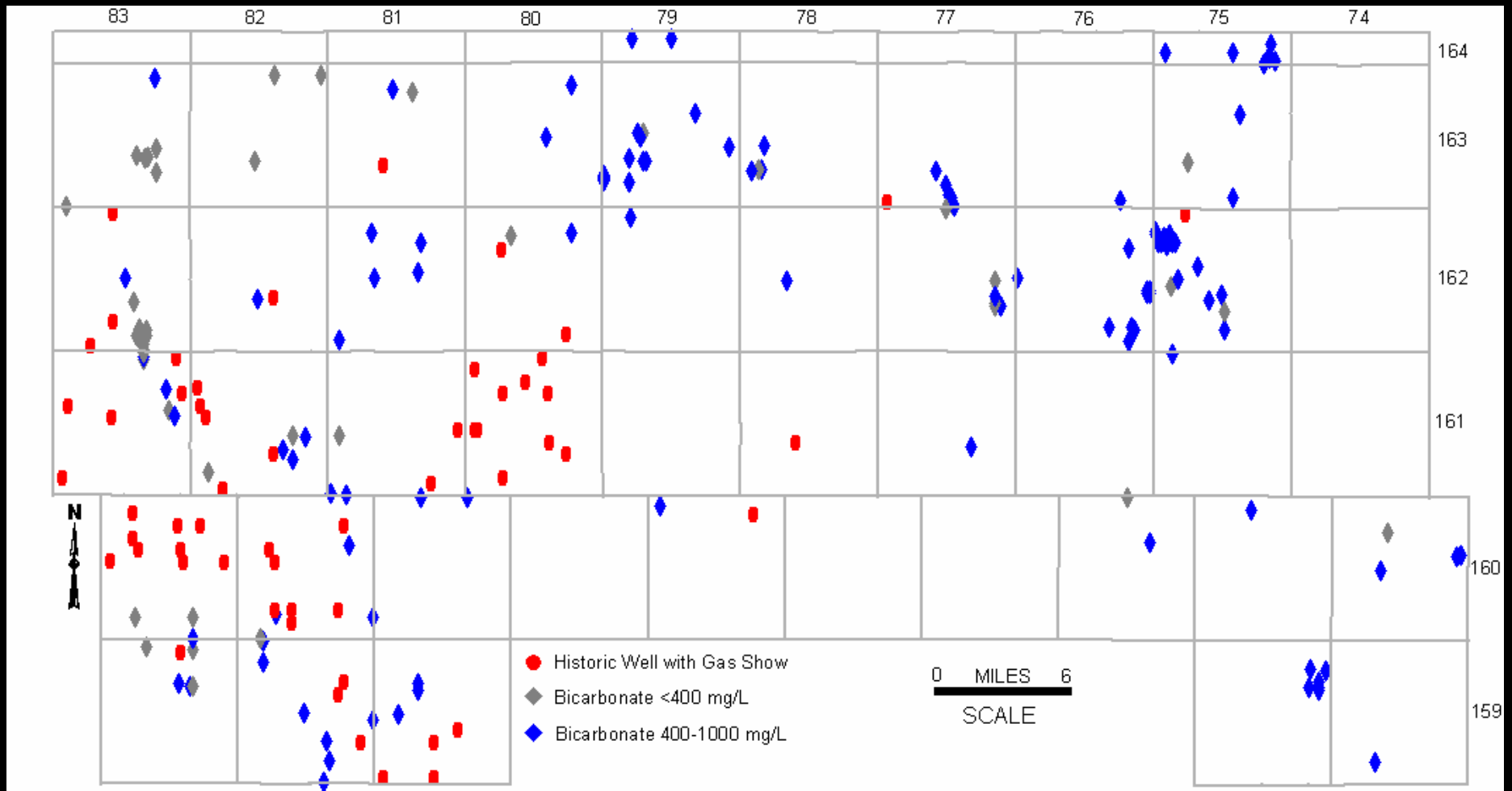
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Relationship of Bicarbonate Concentrations in Quaternary Glacial Drift Wells to Wells with Historic Gas Shows



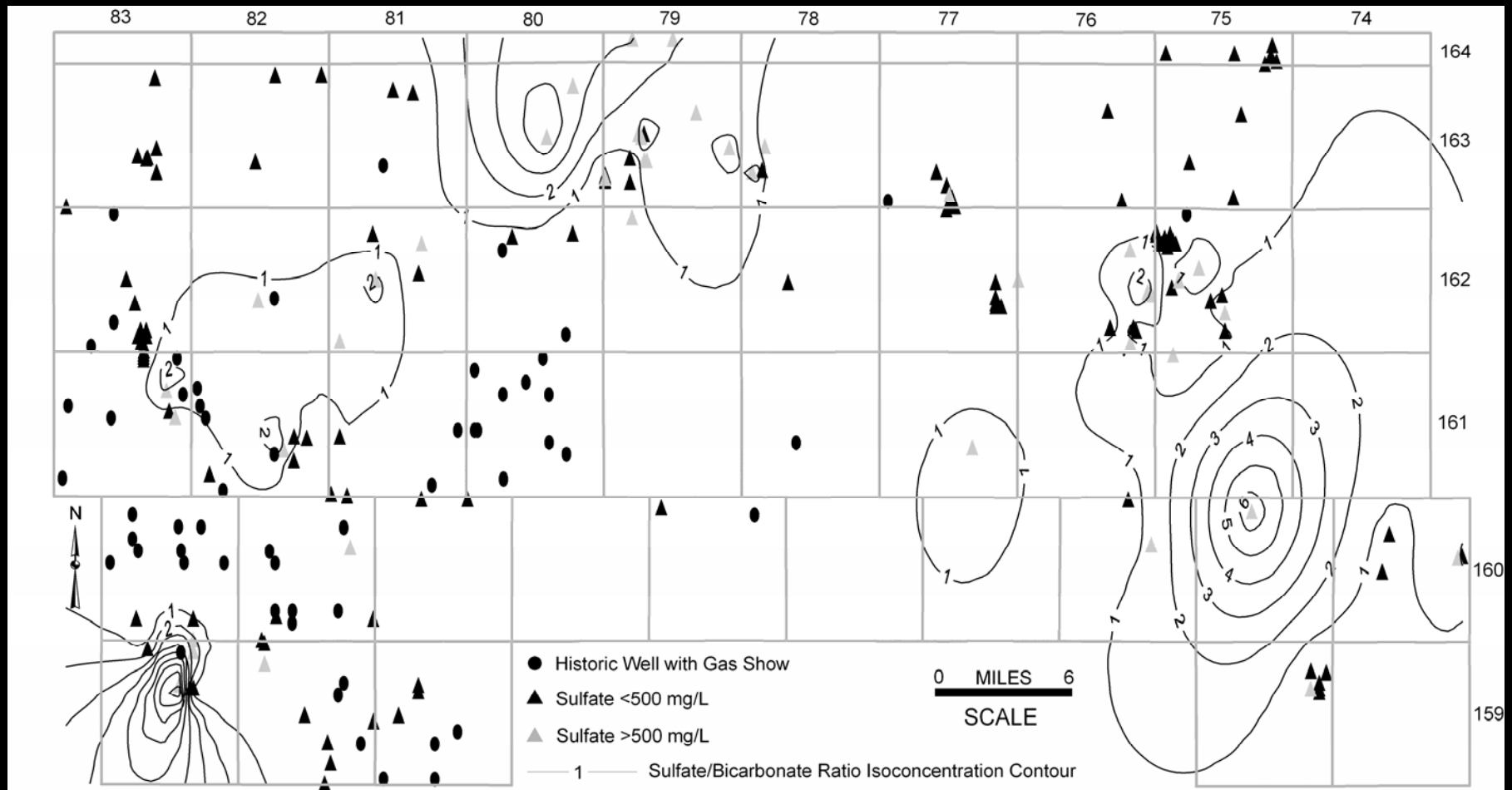
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Relationship of Sulfate/Bicarbonate Ratio Isoconcentrations to Wells with Historic Gas Shows and [Sulfate]



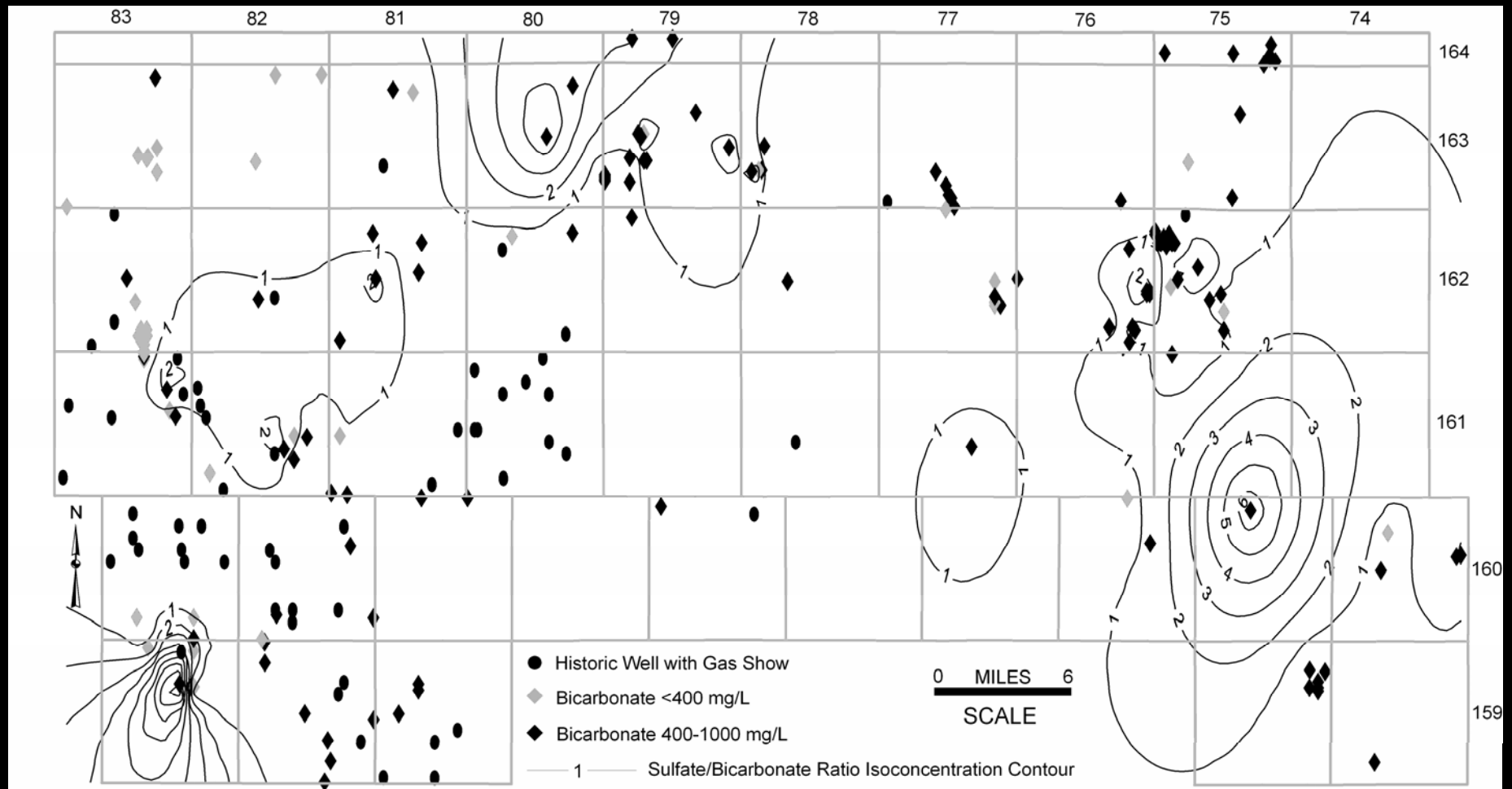
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Relationship of Sulfate/Bicarbonate Ratio Isoconcentrations to Wells with Historic Gas Shows and [Bicarbonate]



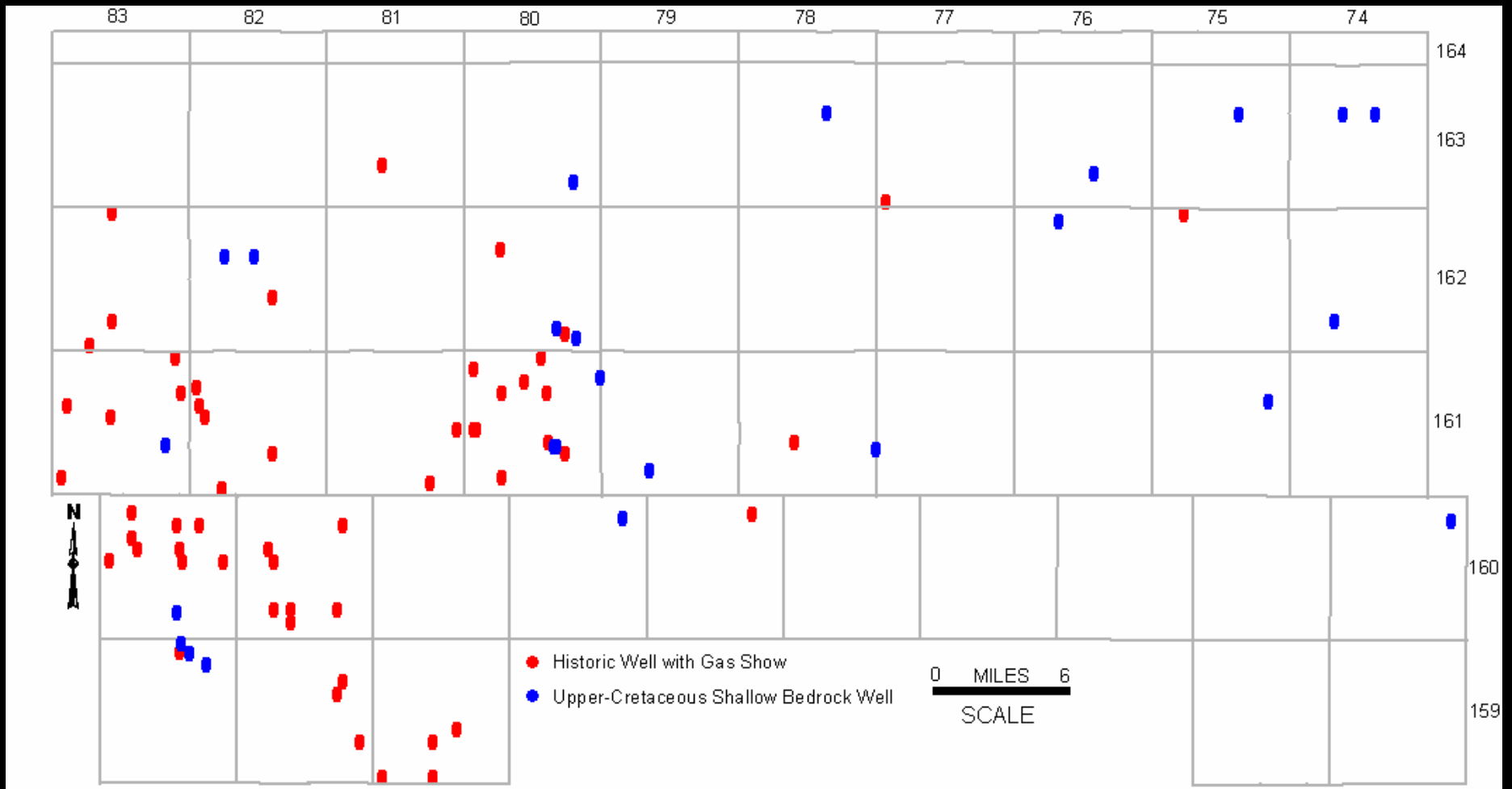
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Upper-Cretaceous Shallow Bedrock Wells



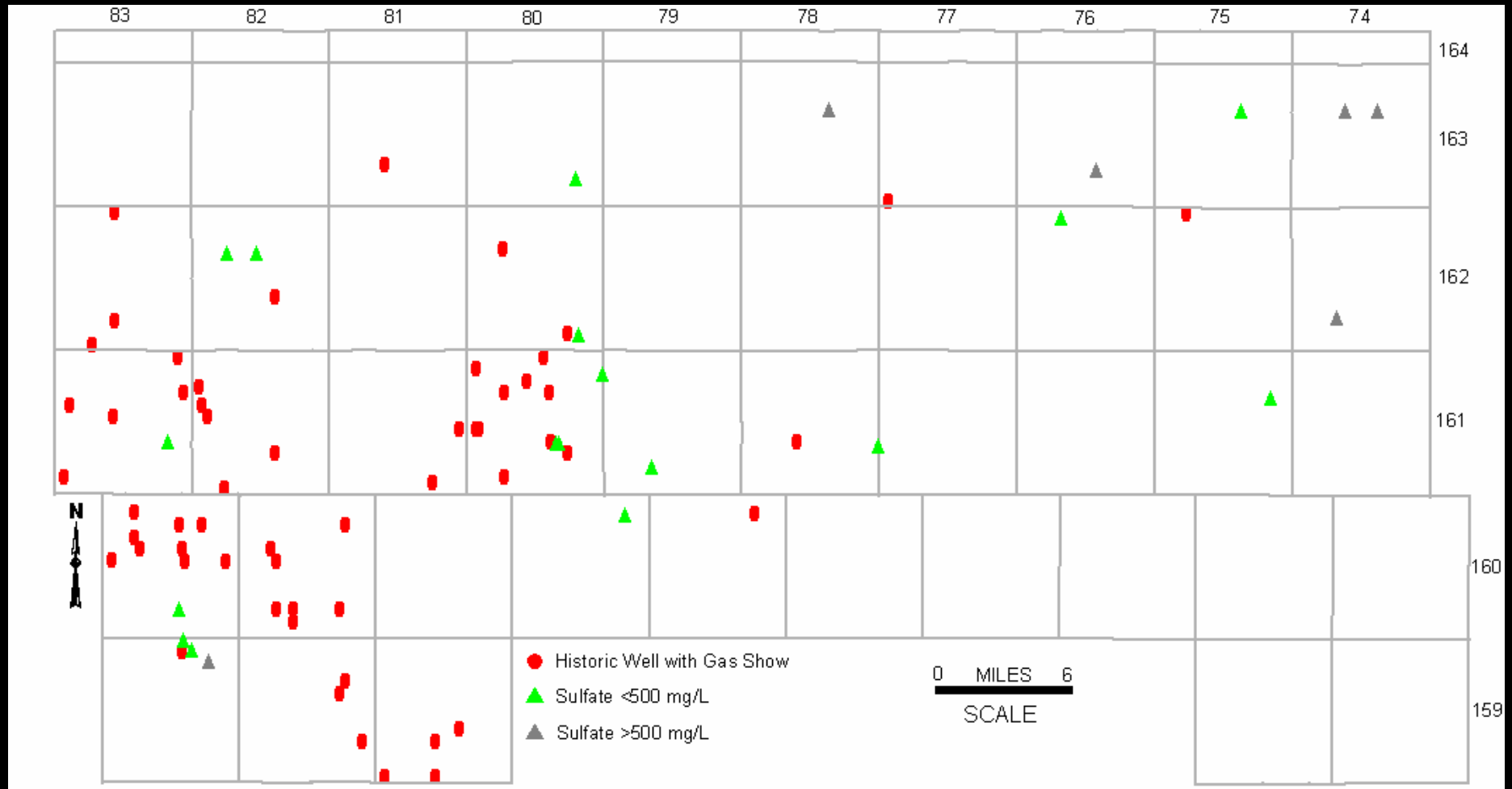
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Relationship of Sulfate Concentrations in Upper-Cretaceous Shallow Bedrock Wells to Wells with Historic Gas Shows



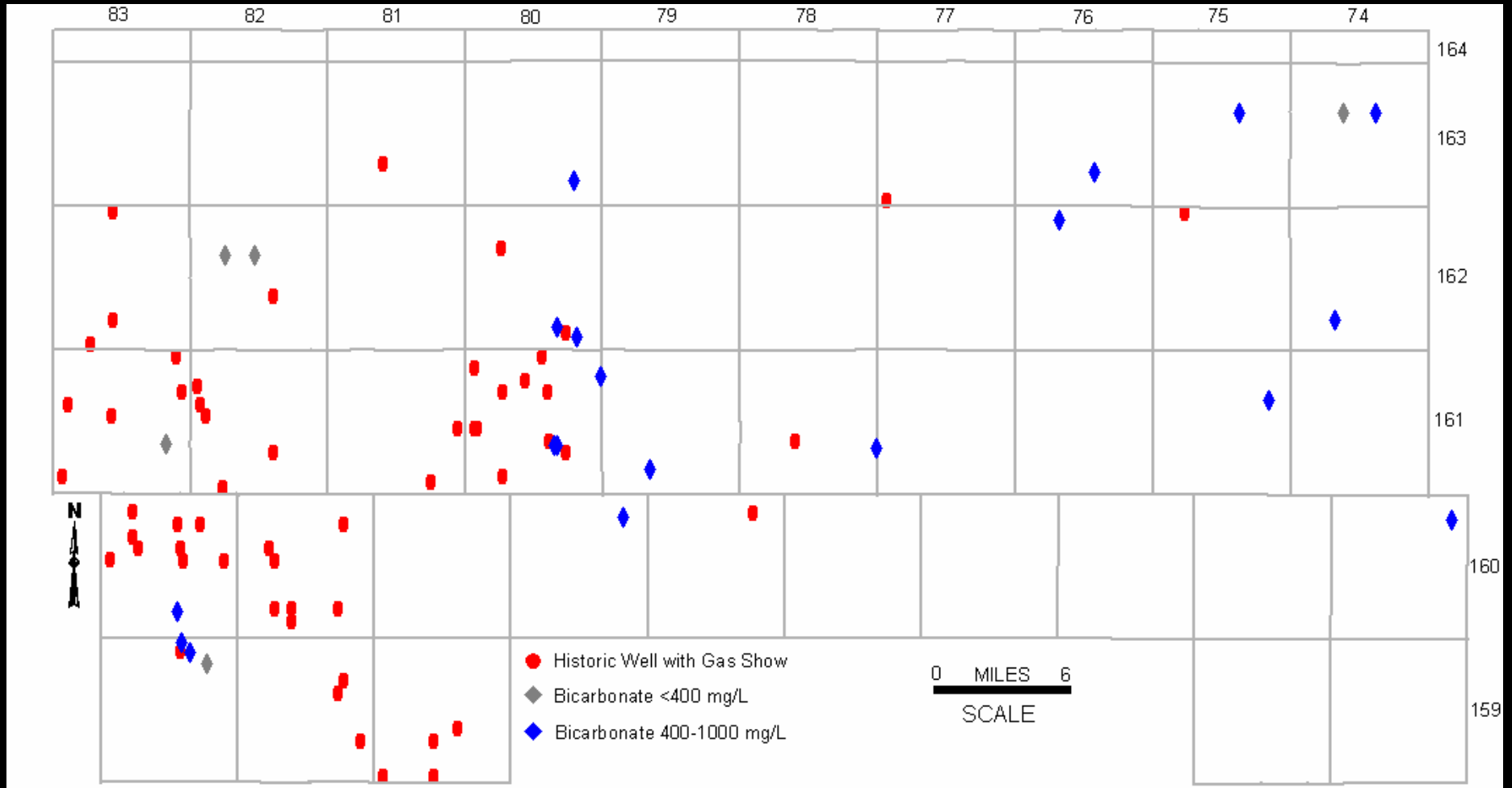
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Relationship of Bicarbonate Concentrations in Upper-Cretaceous Shallow Bedrock Wells to Wells with Historic Gas Shows



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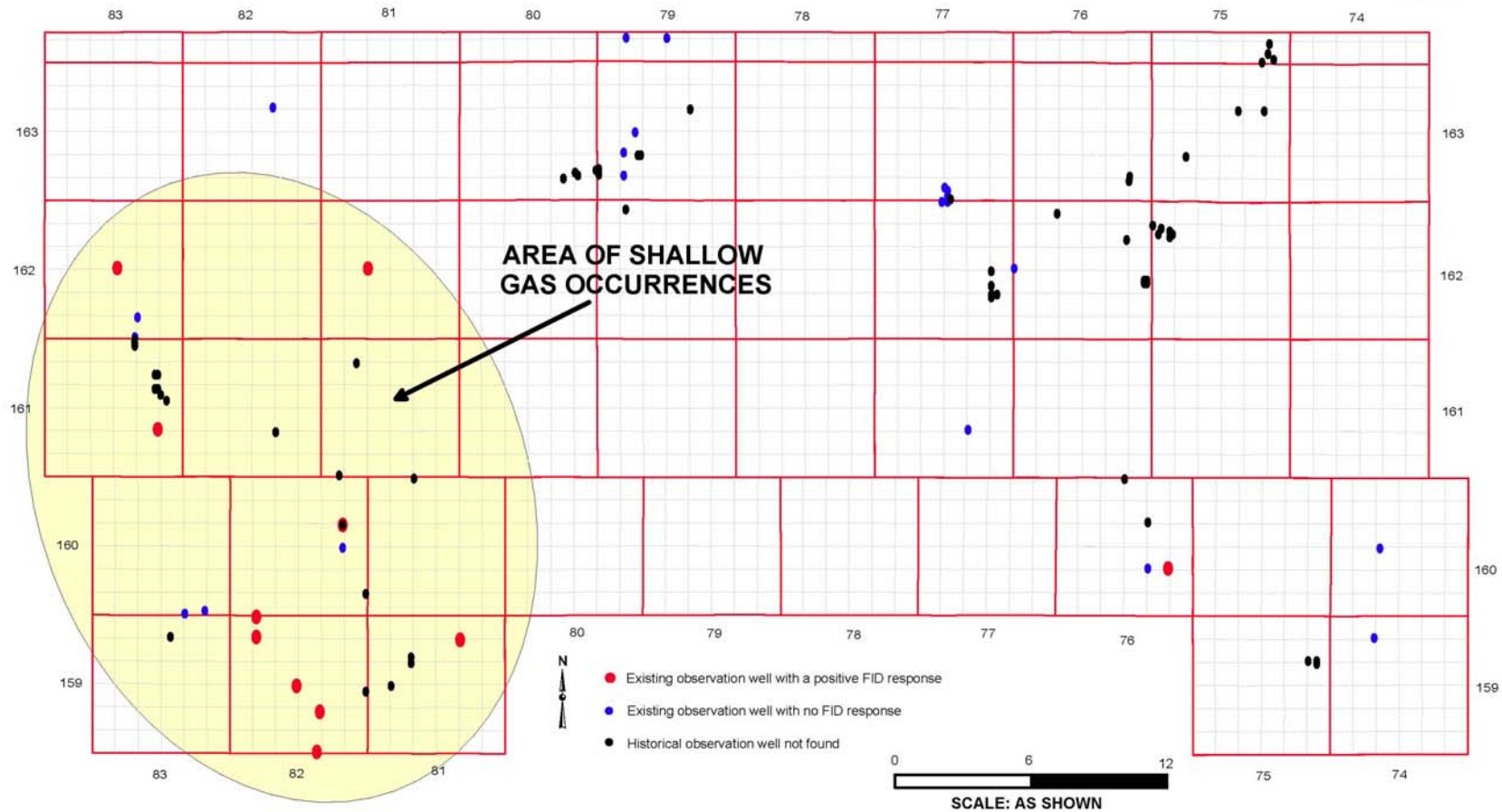
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GROUND-WATER OBSERVATION WELL SHALLOW GAS FID FIELD SCREENING BOTTINEAU COUNTY, NORTH DAKOTA



NDGS, 2006



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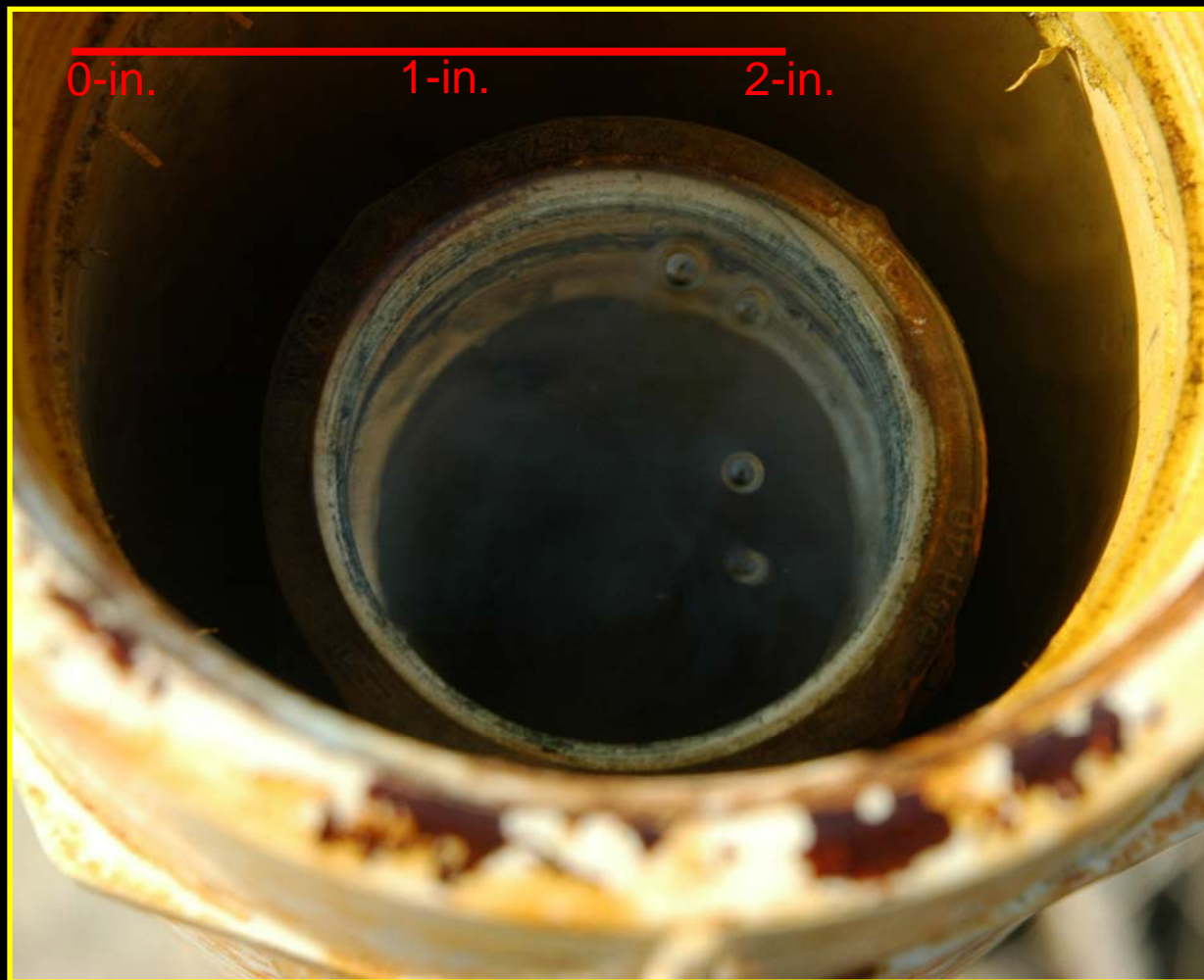
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Recent Shallow Gas Occurrences in Bottineau County

- **Observation Well:**
T162N-R83W-15CCC
- **FID Instrument**
Response = 236 ppm
(as methane at TOC)
- **Flowing head well**
(<1 gpm)
- **[Methane] in**
groundwater = 8.3 mg/L
- **Located in area of**
historic shallow natural
gas occurrence
(western Bottineau Co.)
- **Bubbling continuously**
at top of well
(approx 2-3 bubbles/5 sec.)
- **Screened Interval:**
 - 235 – 238-ft
(71.6-72.5m)
- **Bedrock (K_f) Depth:**
 - 244-ft
(74.4m)



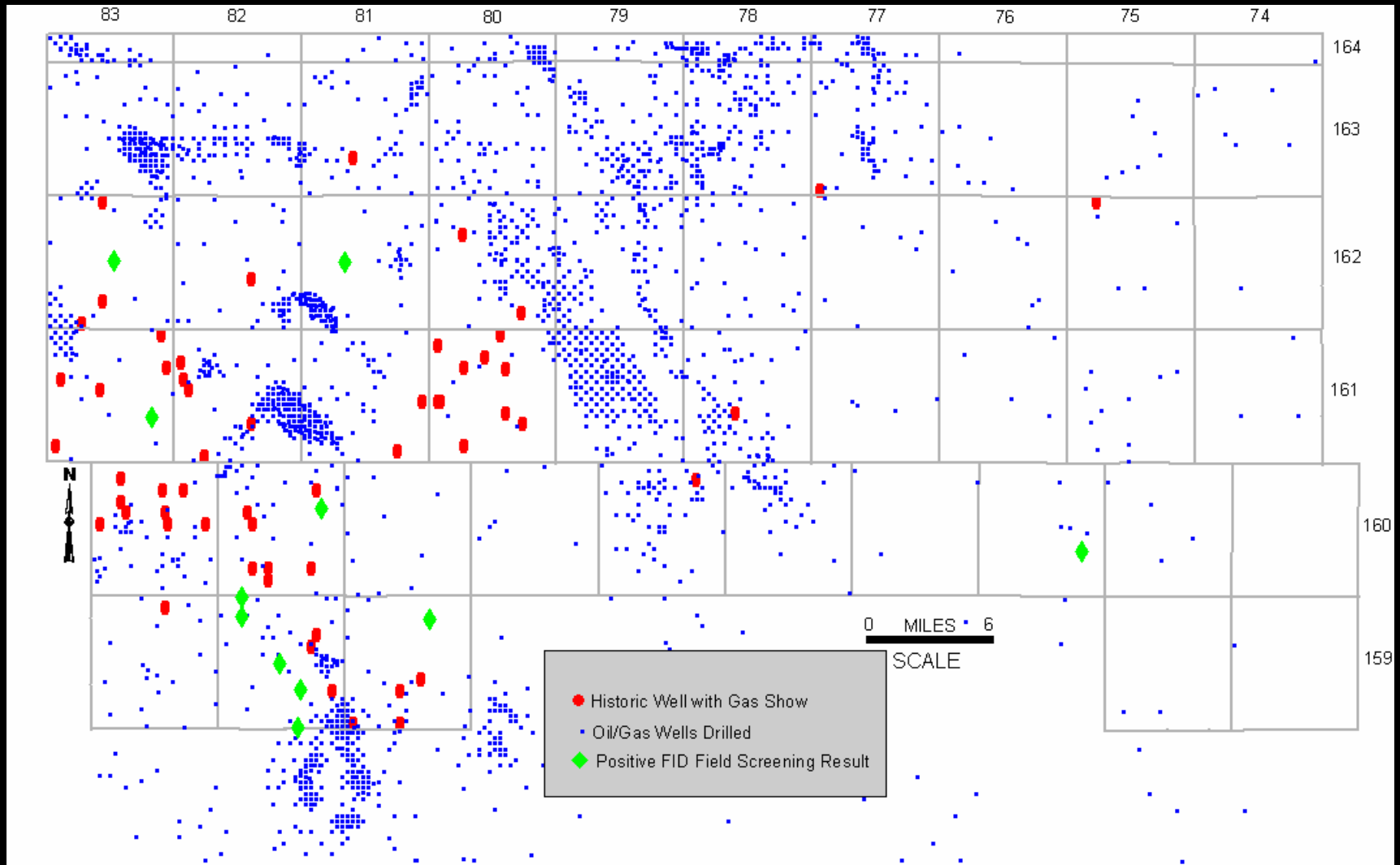
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Relationship of Recent Reconnaissance Field Screening Results to Historic Shallow Wells with Gas Shows and Oil/Gas Wells Drilled in Bottineau County



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Summary and Conclusions

- A positive correlation exists between areas of relatively low sulfate concentrations in the range of 0-500 mg/L and moderate bicarbonate concentrations in the range of 400-1000 mg/L to areas that contain both historic and recent shallow natural gas occurrences in shallow groundwater wells.
- Further, the occurrence and distribution of sulfate and bicarbonate concentrations can be used to indicate areas favorable for methane generation and occurrence as evidenced by historic and recent shallow gas field screening data.



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