

The Wiley Field: A Mission Canyon Depositional Model with No Topographic Barrier

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The Wiley field is located in Bottineau County, North Dakota, and is one of several fields that produce oil from Mississippian Mission Canyon Formation carbonates along the northeastern margin of the Williston Basin. Oil produced from Wiley field is trapped primarily by the updip facies change from porous carbonates of the Mission Canyon Formation to impermeable evaporites of the Charles Formation. In plane view, the contact between carbonates and evaporites (primarily anhydrite) in this portion of the Williston Basin forms a digitate pattern (Obelenus, 1985, p.131-137).

A standard depositional model for fields producing from the Mission Canyon Formation along the northeastern margin of the Williston Basin consists of a carbonate topographic barrier, shoreward of which evaporites were deposited. This standard model concludes that oil production comes from porous carbonates associated with depositional topographic highs, and trapped by updip (shoreward) evaporites (Elliot, 1982, p.131; Hendricks, et al., 1987, p.226).

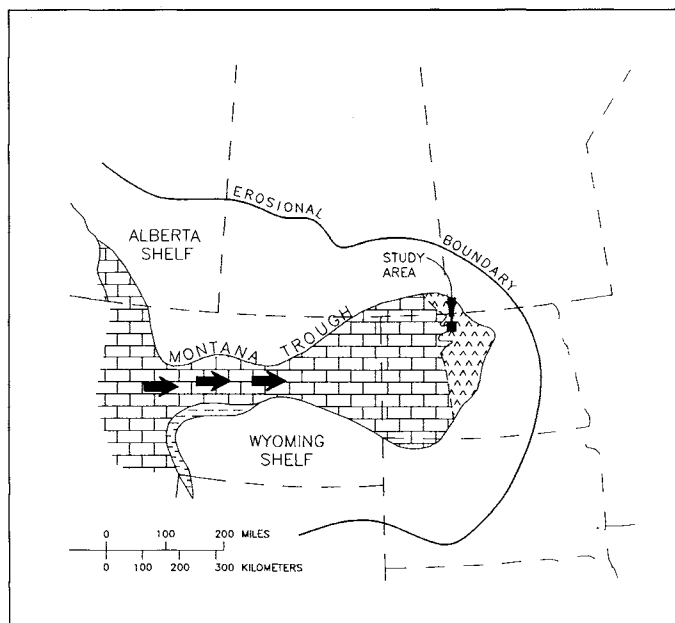


Figure 1. An illustration showing the probable configuration of the Williston Basin and its primary inlet/outlet (Montana Trough) during Upper Kaskaskia Sequence deposition. Also shown is the location of the study area and its position relative to the carbonate-sulfate transition zone, its position within the Williston Basin, and its position relative to the primary inlet/outlet. Arrows indicate the primary direction of seawater flow into the Williston Basin to replace that lost from the basin by evaporation. Modified from Gerhard, et al., (1982).

However, detailed examination of cores and electric logs from Wiley field provides evidence that little or no topographic relief was present in the transition zone between areas of carbonate and evaporite precipitation during deposition. Rather, the data support a model that suggests that the change from carbonate to evaporite precipitation was due primarily to the evolution of increasingly saline waters along established linear flow paths; i.e., chemical rather than topographic controls.

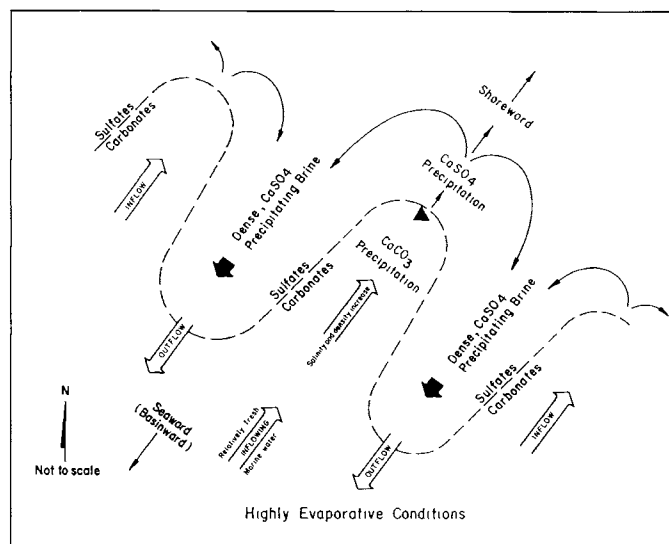


Figure 2. A schematic, plane-view diagram illustrating the formation of a digitate, carbonate/sulfate contact by the pattern of movement of marine waters that are continuously evaporating, and becoming progressively more saline along their path of flow. The relative position of the Wiley field in this setting is indicated by the solid triangle (Luther, 1988a, p. 149).

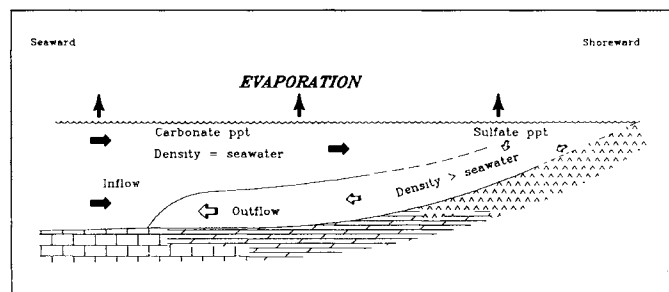


Figure 3. A schematic diagram that illustrates possible fluid movements affecting sedimentation in the study area. Continuous evaporation of marine water in the basin would require the inflow of marine water (solid arrows) to replace that water lost by evaporation. Evaporation of marine waters would lead to precipitation of increasingly soluble minerals along the flow path, and would form dense, concentrated brines that settle to the sea bottom and displace less dense waters (light arrows). Dolomitization and other diagenetic processes might result from this dense, outflowing brine. No scale intended; vertical scale and slope greatly exaggerated. Modified from Sonnenfeld (1984).

The linear flow paths were established due to several factors: the distance from, and flow direction of, "normal" marine water from the Montana Trough to the margins of the basin (Fig. 1) to replace water lost by evaporation and thus maintain a common sealevel; the probable shallow depth of the Williston Basin (Fischer, et al., 1987, p.226); the creation of very saline brines as marine water evaporated while flowing to distant basin margins; the lack of a deep "hole" on the basin margin to hold chloride deposits/brines as indicated by the lack of large halite deposits; the basinward flow of those resulting brines; and the creation of horizontally segregated flow paths caused by the interactions of shallow water depth, friction, and waters of widely different composition/density (normal marine vs. brine) flowing in opposite directions (Fig. 2).

Data from the Wiley field support a model in which an evaporation-driven, stable, linear, seawater flow path, and the precipitation of increasingly soluble minerals along that flow path, are the dominant factors controlling the distribution of minerals and biota in the study area. This model also negates the need for topographic highs to form porous reservoir rocks (Luther, 1988b, p.876) or topographic barriers behind which evaporite precipitation occurred, forming updip reservoir seals.

The distribution of cements and other diagenetic features present in the study area, are consistent with the assumed horizontal salinity gradient created by the increasingly saline seawater/brine flowing across the area. This distribution, in part, supports the concept that most diagenesis occurred near surface. The model also provides a mechanism for diagenetic events (such as dolomitization) basinward of the study area as dense, bottom-hugging brines flowed basinward (Fig. 3), possibly altering exposed sediments.

This model for sedimentation and diagenesis controlled by horizontal salinity gradients may provide an alternative explanation for deposition of Mission Canyon Formation sediments elsewhere along the basin margin and may provide clues for future exploration strategies.

REFERENCES CITED

- Elliot, T. L., 1982, Carbonate facies, depositional cycles and the development of secondary porosity during burial diagenesis, in J. E. Christopher, and J. Kaldi, eds., Fourth International Williston Basin symposium: Saskatchewan Geological Society Special Publication No. 6, p. 131-151.
- Fischer, H. J., M. R. Luther, K. E. Eylands, and C. F. Quinn, 1987, Salinity, oxygenation, and topographic controls on Mississippian subtidal sedimentation in a portion of the Mission Canyon Formation, Williston Basin, North Dakota, in C. G. Carlson, and J. E. Christopher, eds., Fifth International Williston Basin Symposium: Saskatchewan Geological Society Special Publication No. 9, p. 266-267.
- Gerhard, L. C., S. B. Anderson, J. A. Lefever, and C. G. Carlson, 1982, Geological development, origin, and energy mineral resources of Williston Basin, North Dakota: AAPG Bulletin, v. 66, p. 989-1020.
- Hendricks, M. L., B. P. Birge, Jr., and J. D. Eisel, 1987, Habitat of Sherwood oil, Renville County, North Dakota, in C. G. Carlson, and J. E. Christopher, eds., Fifth International Williston Basin Symposium: Saskatchewan Geological Society Special Publication No. 9, p. 226-241.
- Luther, M. R., 1988a, Deposition and diagenesis of a portion of the Frobisher-Alida interval (Mississippian Madison Group), Wiley field, North Dakota: Unpublished Masters Thesis, University of North Dakota, 313 p.
- Luther, M. R. 1988b, Alternative hypothesis for development of vugular porosity in Mission Canyon Formation: AAPG Bulletin, v. 72, p. 876.
- Obelenus, T. J., 1985, Depositional environments and diagenesis of carbonates and associated evaporites, Frobisher-Alida interval, Madison Group (Mississippian), Williston Basin, northwestern North Dakota: Unpublished Masters Thesis, University of North Dakota, 313 p.
- Sonnenfeld, P., 1984, Brines and Evaporites: New York, Academic Press, 613 p.