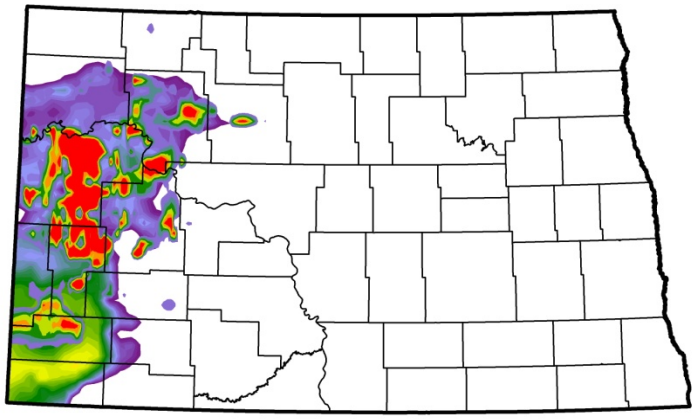
North Dakota Geological Survey

Salts as Candidates for Air Storage in the Williston Basin, ND

By

Stephan H. Nordeng



GEOLOGIC INVESTIGATION NO. 78
NORTH DAKOTA GEOLOGICAL SURVEY
Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources
2009

This paper addresses the recent interest in using salt deposits in North Dakota as storage facilities for compressed air. Of particular interest are the shallowest salts found in Jurassic, Triassic and Permian aged rocks in the Williston Basin (see Fig. 1 & 2). The Pine salt in the Spearfish Formation and the "A" salt in the Opeche Formation are the thickest and most widespread of these salts and therefore the most likely candidates for these type of ventures. These salts lie at a minimum depth of between 6500 and 7000 feet along a line that runs north-northeast to south-southwest from eastern Mountrail County through eastern Dunn County.

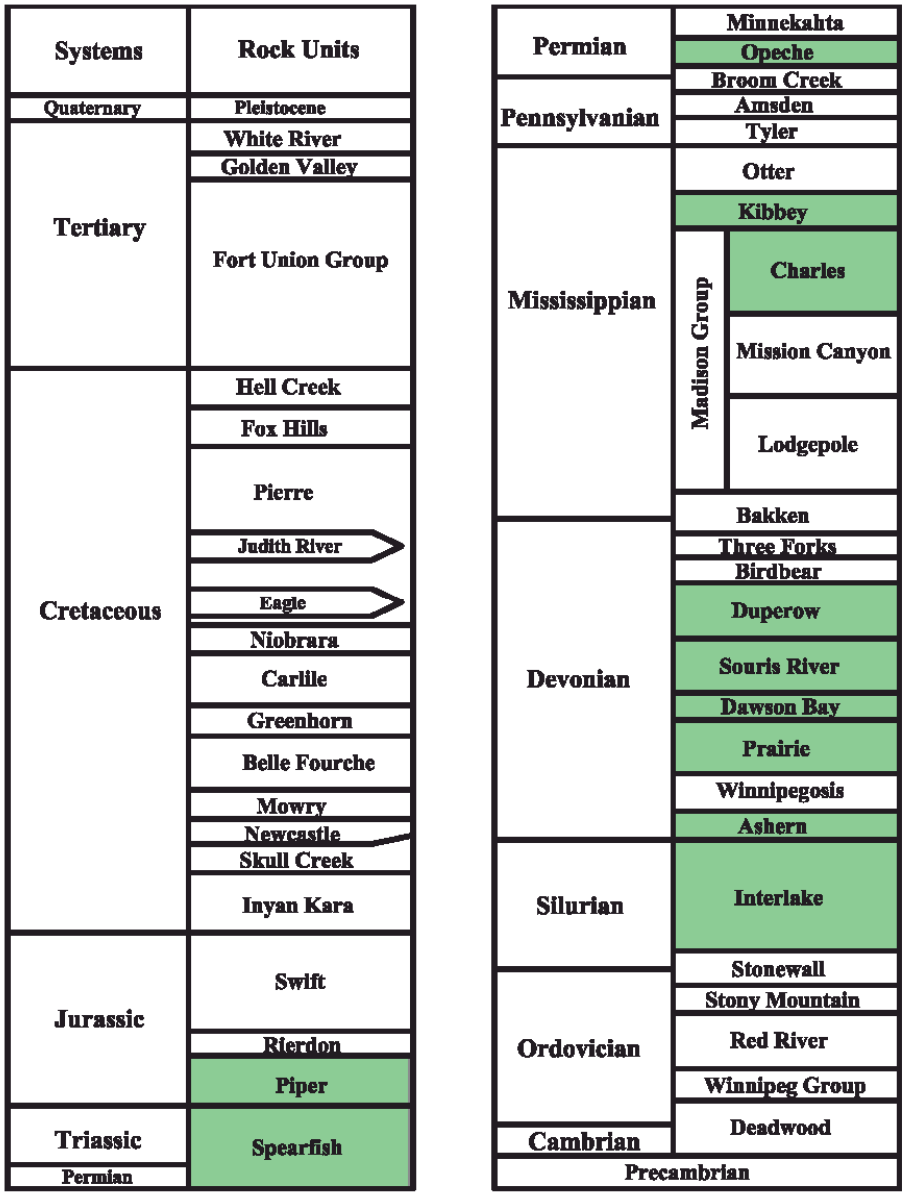


Figure 1. Stratigraphic column of North Dakota. Shaded formations contain salts. (from LeFever and LeFever, 2005)

Geologic Period	*Formation*	*Member*	*Maximum Thickness (ft)*
Jurassic	Swift		
	Rierdon		
	Piper	Dunham salt	189
Triassic	Spearfish	Saude	
		Pine salt	249
		Belfield	
Permian	Minnekahta		
	Opeche	"A" salt	229
		"B" salt	57
Pennsylvanian	Broom Creek		

Figure 2. Stratigraphic nomenclature and maximum thickness for the uppermost salt deposits in the Williston Basin of North Dakota (modified from LeFever and LeFever, 2005).

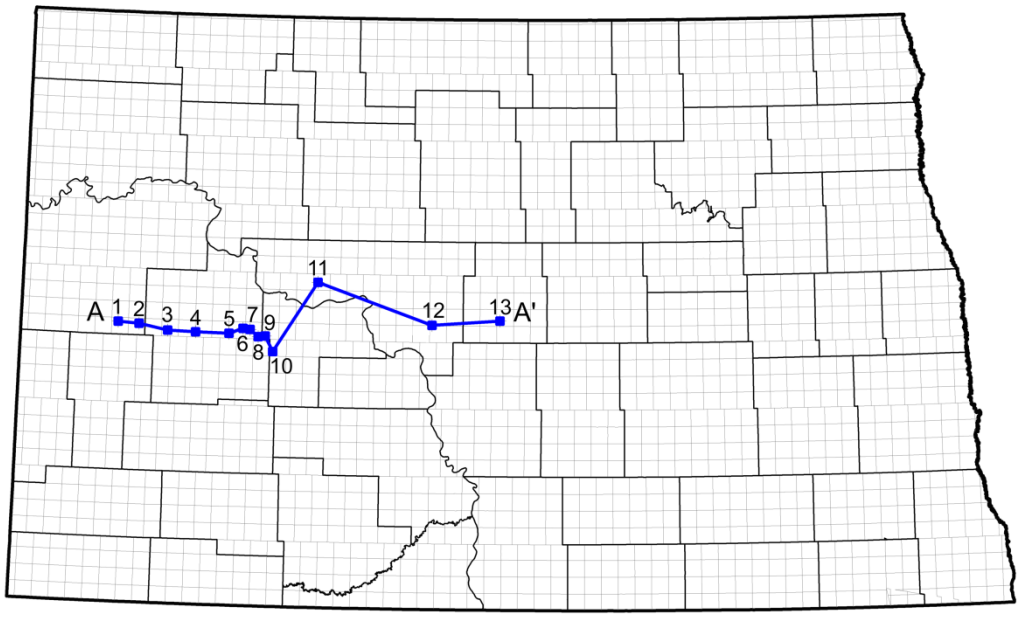


Figure 3. Map of North Dakota showing the locations of the wells used to construct the cross section in Fig. 4. The gray square near location 12 is Township 145 North, Range 81 West .

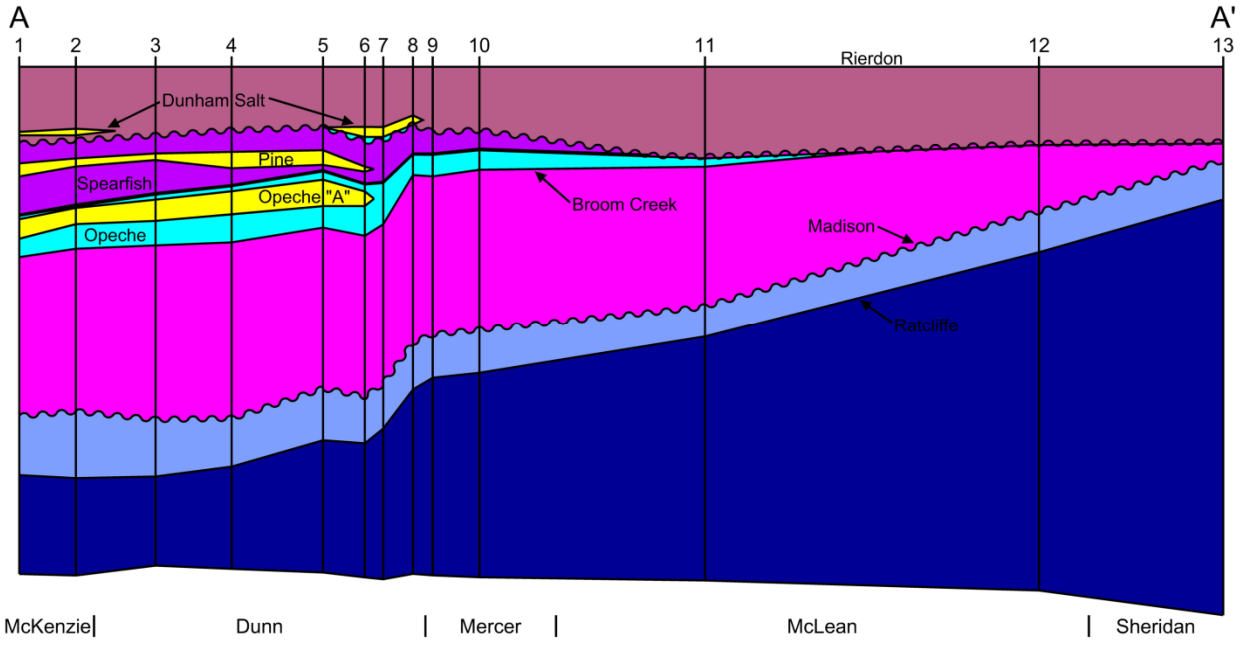


Figure 4. A west to east cross section from McKenzie County to Sheridan County, North Dakota showing the pinchout of the Opeche “A”, Pine and Dunham salts near the border between Dunn and Mercer Counties.

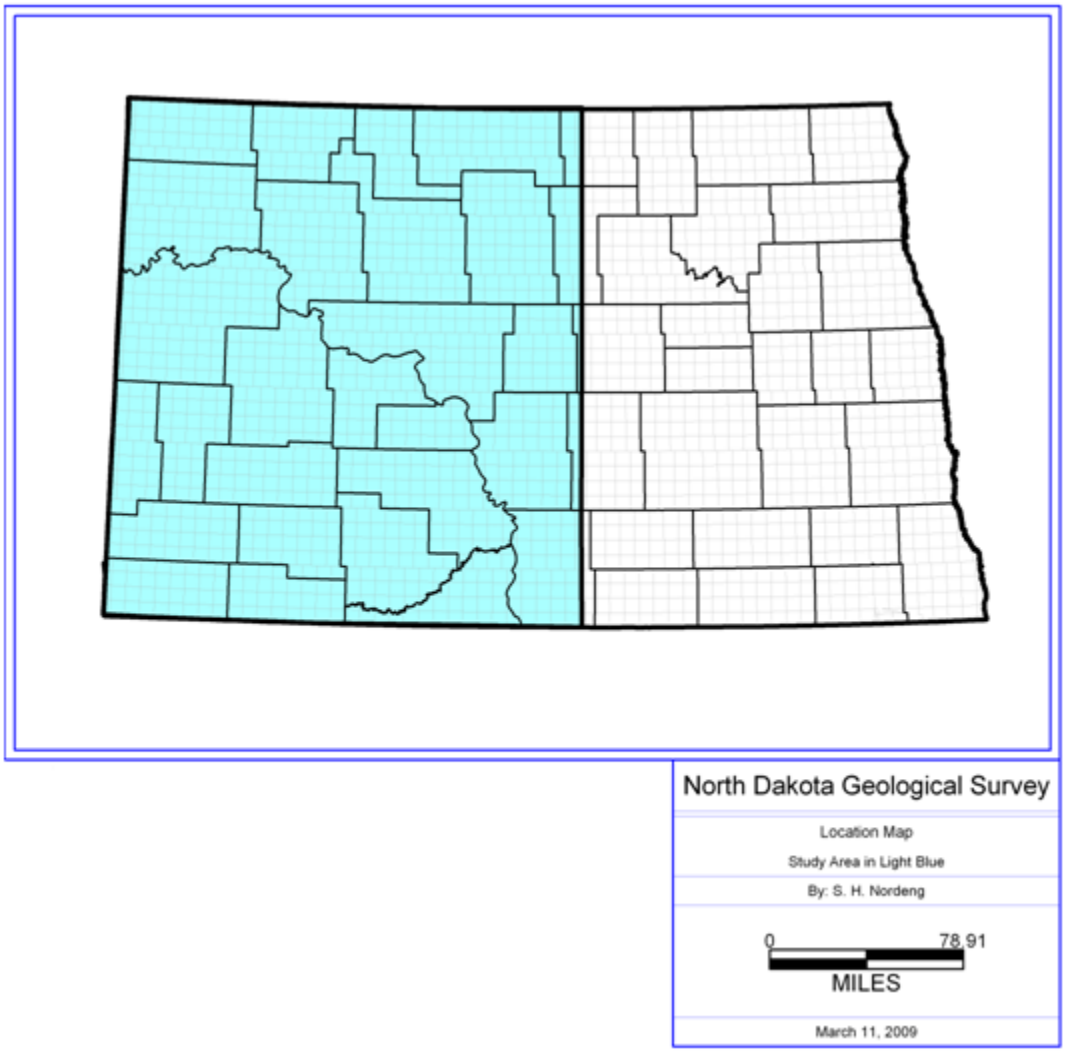


Figure 5. Location map in which the area detailed in the maps that follow are shaded in blue. The gray shaded square in southern McLean County is Township 145 North, Range 81 West.

Piper Formation

The Piper Formation consists of an interbedded sequence of marine limestone and shale. Piper deposition started with a thin, 10 ft (3 m) thick, bed of shale, informally referred to as the Poe marker. This shale horizon is overlain by the Dunham salt. The Dunham extends over most of western North Dakota with a few isolated lenses outside of the main salt body. It reaches a maximum thickness of 189 ft (57.6 m).

The Dunham salt consists predominantly of halite with some interbeds of reddish brown mudstone and anhydrite. The Dunham also followed patterns similar to the Spearfish and was probably deposited during a minor restrictive phase in a transgression (from Lefever and Lefever, 2005).

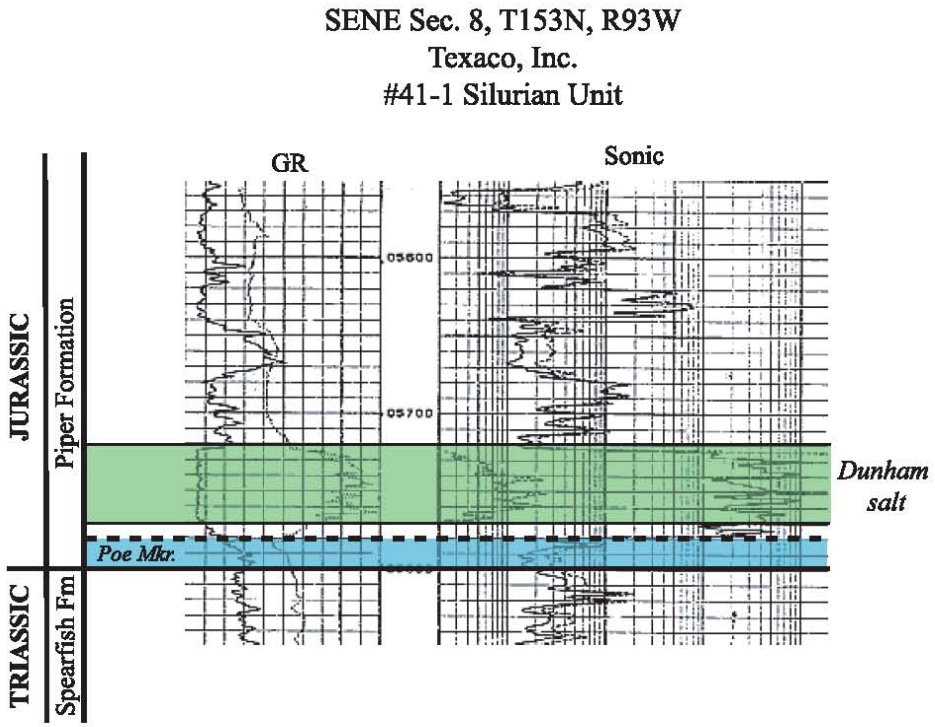


Figure 6. Gamma ray and sonic logs run through the Jurassic Piper Formation that illustrates the log response from the Dunham salt (from LeFever and LeFever, 2005).

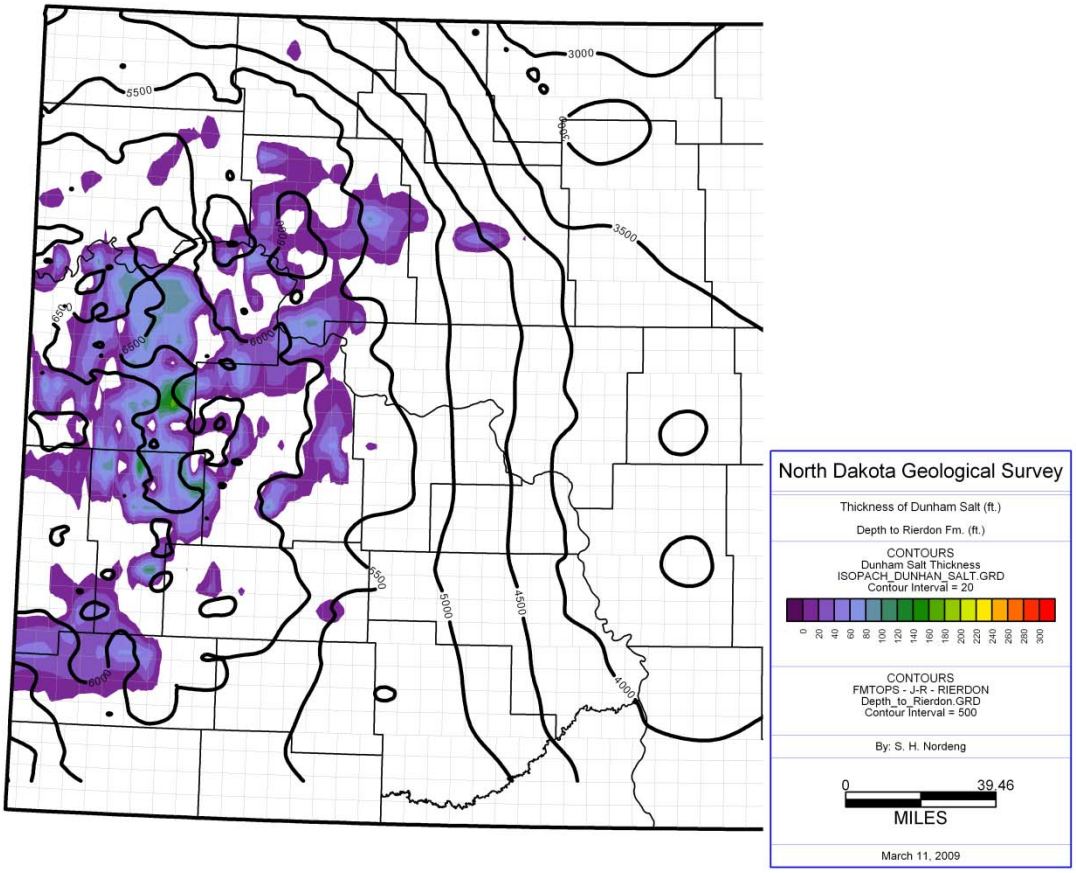


Figure 7. Shaded contours represent the thickness in feet of the Dunham salt within the Jurassic Piper Formation. The contour lines represent the approximate depth in feet to the top of the overlying Rierdon Formation.

Spearfish Formation

There are three members of the Spearfish Formation, the lower Belfield, middle Pine Salt, and upper Saude (Dow, 1967). The lower two members are restricted to the central basin area, Montana, South Dakota, and Wyoming. The uppermost member, the Saude, extends northward into Canada. In addition to the middle Pine Salt Member, the Spearfish has two other minor salts present within the Saude Member.

The Pine Salt is the thickest of the three salts and has the greatest areal extent. The Pine reaches a maximum thickness of 249 ft (75.9 m). A persistent marker bed lies approximately 20 ft (6 m) above the Pine salt in Bowman, Slope, and portions of Golden Valley, Billings, Stark, and Hettinger Counties. It is generally an anhydrite and is referred to informally as the G marker bed. Isolated lenses of the G salt occur northeast of the main concentration. The G salt is thinner than the rest of the Spearfish salts, with

a maximum thickness of 205 ft (62.5 m). An unnamed salt overlies the G salt in a very limited area in Slope County, and reaches a maximum thickness of 130 ft (38.6 m) (from LeFever and LeFever, 2005).

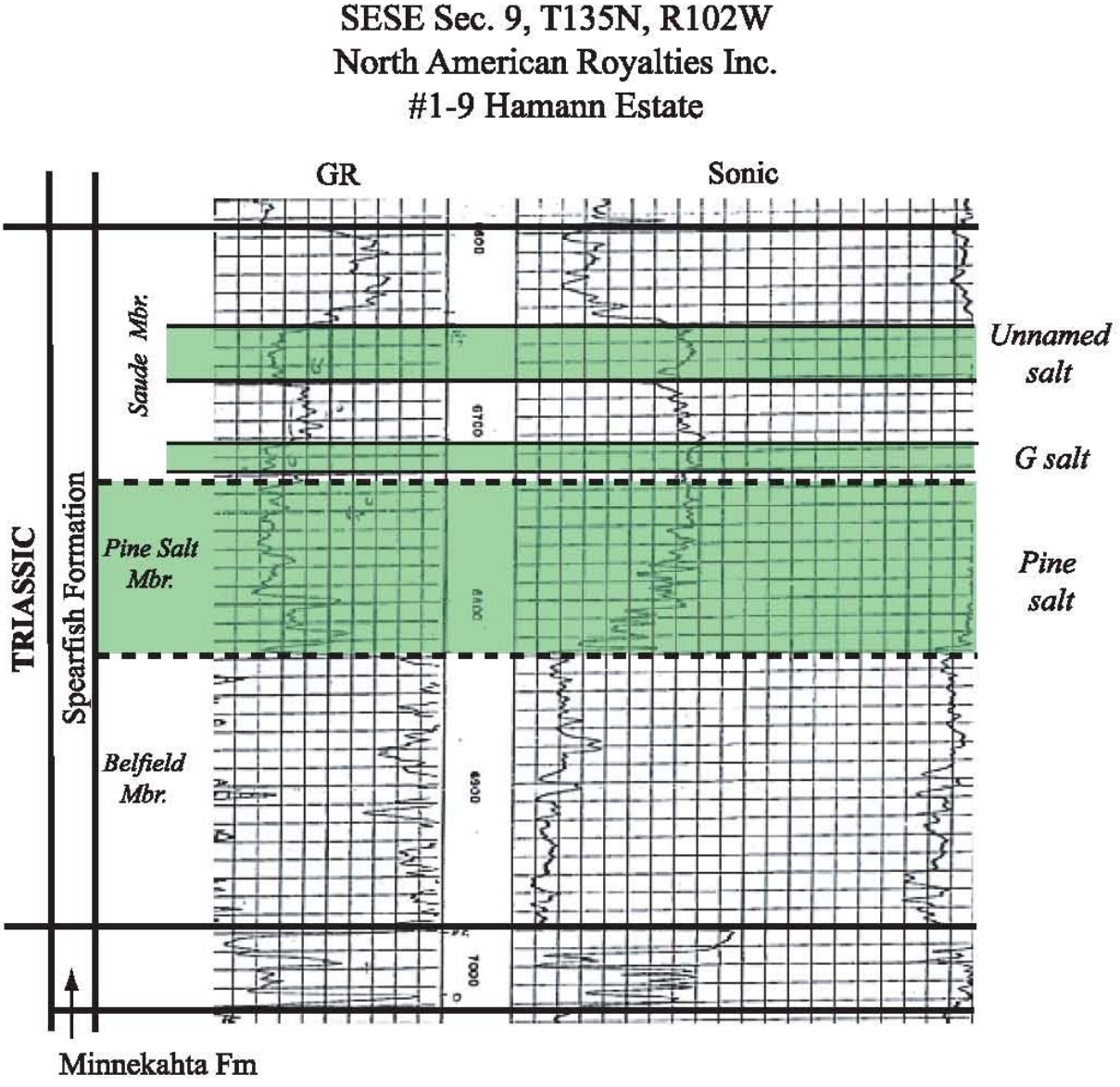


Figure 8. Gamma ray and sonic logs through the Spearfish Formation that includes the Pine salt member (from LeFever and LeFever, 2005).

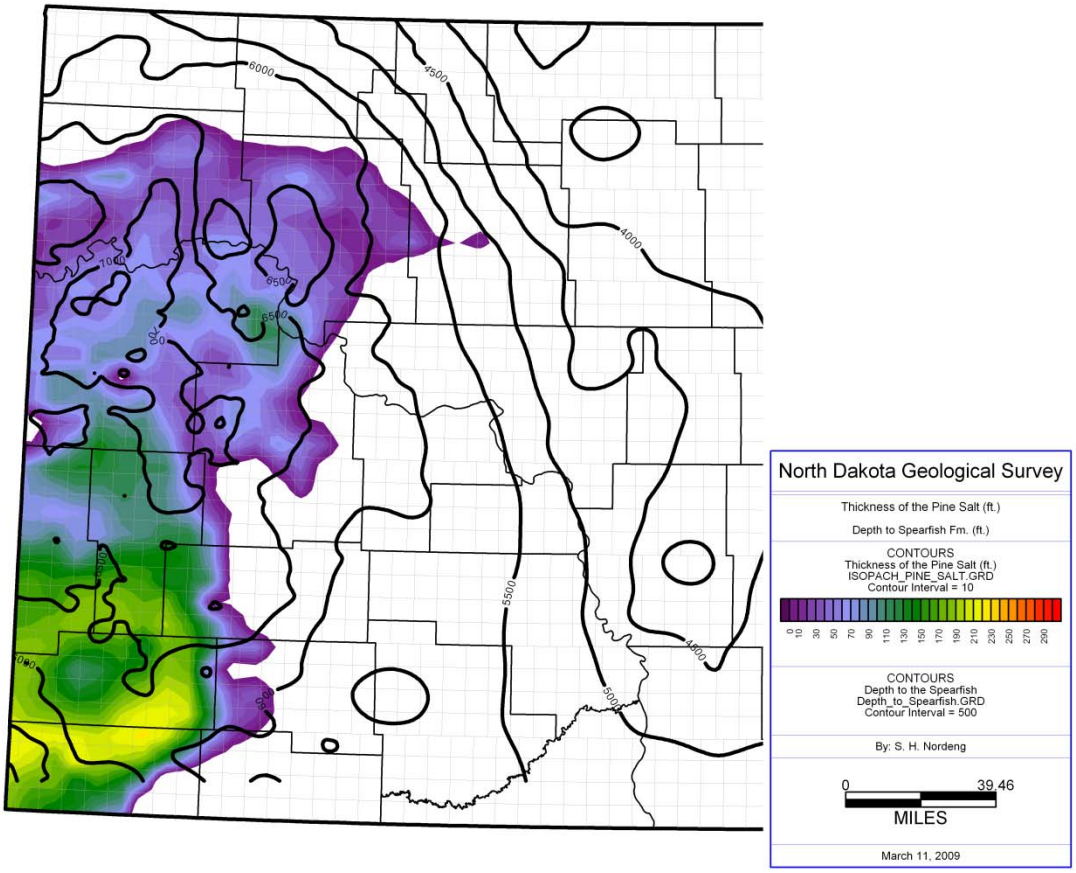


Figure 9. Shaded contours represent the thickness in feet of the Pine Salt found within the Triassic Spearfish Formation. The solid contour lines represent the approximate depth to the top of the Spearfish Formation (ft.).

Opeche Formation

The Opeche Formation consists of evaporites and fine-grained detrital sediments. In the central portion of the basin, these are predominantly halite and red claystones. Towards the margin of the basin anhydrite, gypsum, and dolomite predominate (Maughan, 1966; Bluemle et al., 1986).

Two massive salts referred to as the Opeche A and B can be mapped within the Opeche Formation (Anderson and Hansen, 1957). The upper salt, Opeche A, has a slightly greater areal extent than the lower Opeche B salt. There is a significant difference in thickness; the maximum thickness of the Opeche the Opeche A is 229 ft (69.8 m) whereas the Opeche B is no more than 57 ft (17.4 m) thick.

Benison and Goldstein (2000) argued for a nonmarine origin for the evaporites of the Opeche Formation throughout the Williston Basin, and attributed the salts to deposition in an inland playa-type saline-pan. The basin at the time of Opeche deposition was at the landward end of a long embayment of the Permian sea (Sandberg, 1973). It became more isolated with time, possibly as a result of uplift along the Cedar Creek anticline. This uplift continued to restrict flow from the open sea and increase the salinity within the basin. Salts and clastics were laid down as the seas dried up and streams brought muds in from surrounding areas (from LeFever and LeFever, 2005).

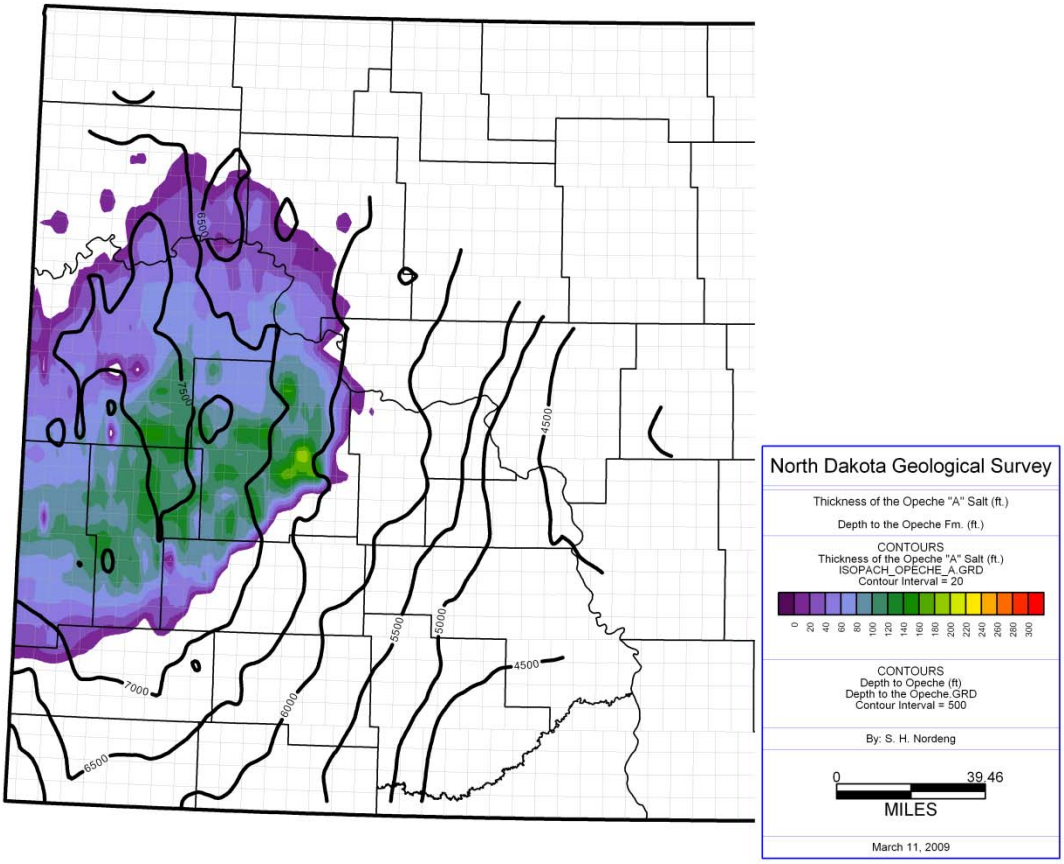


Figure 10. The color filled contours represent the thickness (ft.) of the Permian Opeche “A” Formation. The solid contour lines represent the approximate depth to the top of the Opeche Formation.

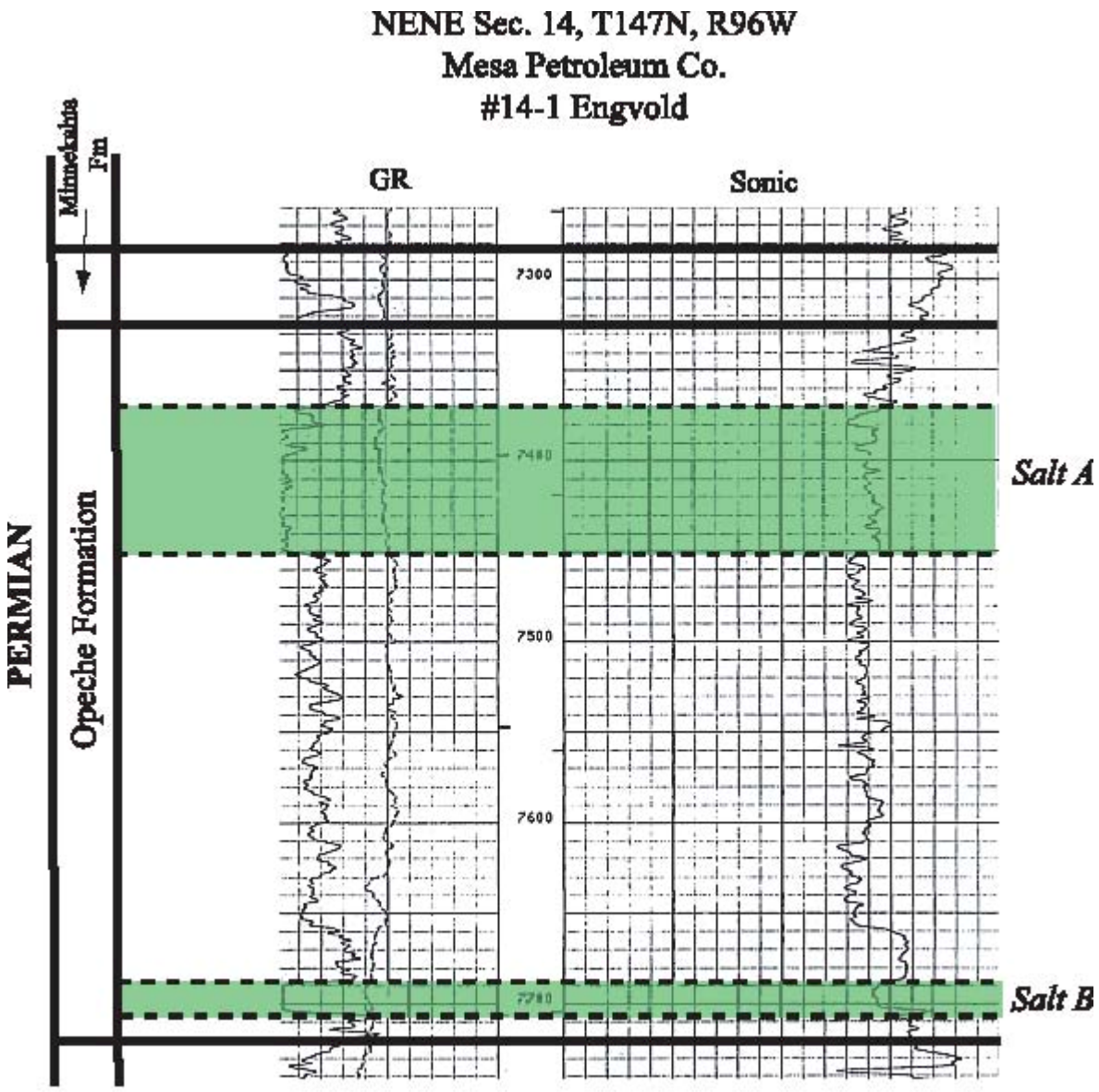


Figure 11. A gamma ray and sonic log run through the Opeche Formation showing the typical log response of the “A” and “B” salts (from LeFever and LeFever, 2005).

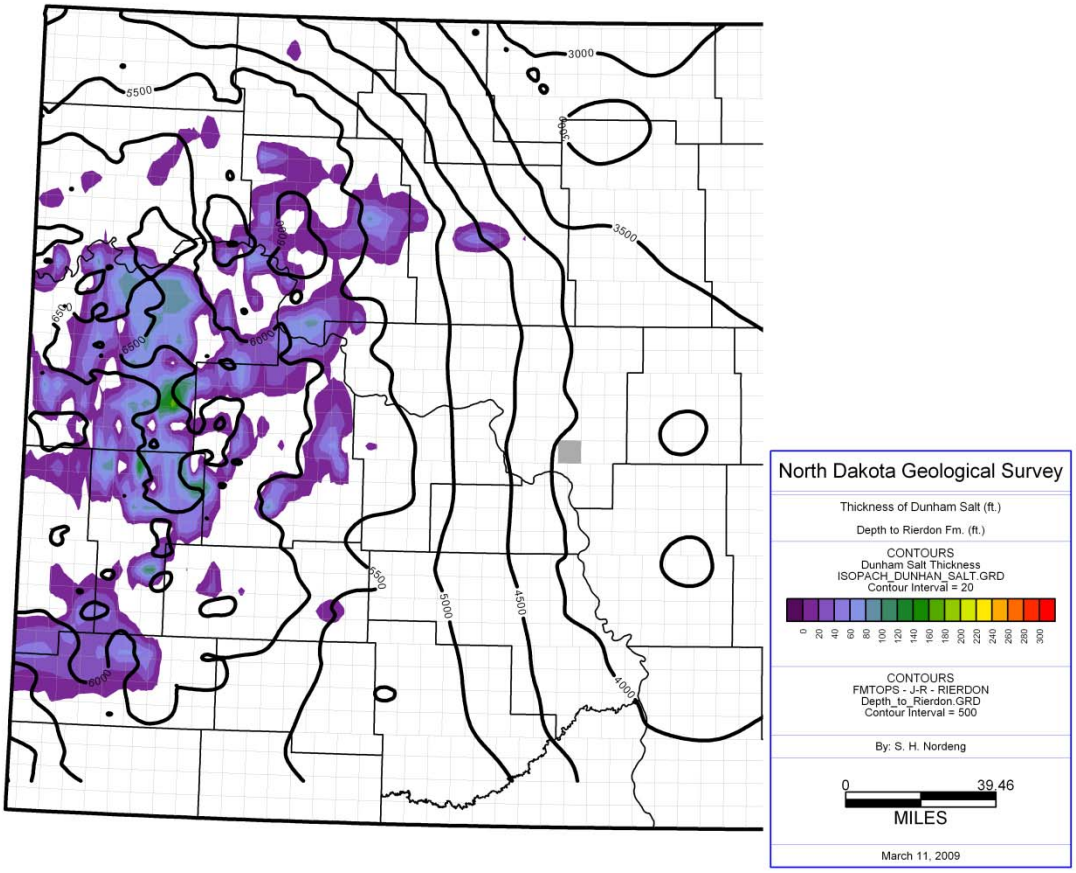


Figure 12. The color filled contours represent the thickness (ft.) of the Permian Opeche “B” Formation. The solid contour lines represent the approximate depth to the top of the Opeche Formation.

References

Anderson, S. B. and Hansen, D. E., 1957, Halite deposits in North Dakota, North Dakota Geological Survey, Report of Investigation No. 28.

Benison, K. C., and Goldstein, R. H., 2000, Sedimentology of ancient saline pans: An example from the Permian Opeche Shale, Williston Basin, North Dakota, U.S.A.: Journal of Sedimentary Research, v. 70, p. 159-169.

Bluemle, J. P., Anderson, S. B., Andrew, J. A., Fischer, D. W., and LeFever, J. A., 1986, North Dakota stratigraphic column: North Dakota Geological Survey Miscellaneous Series 66, 3 sheets.

Dow, W. G., 1967, The Spearfish Formation in the Williston Basin of western North Dakota: North Dakota Geological Survey Bulletin 52, 28 p.

LeFever, J. A., and LeFever, R. D., 2005, Salts in the Williston Basin, North Dakota, North Dakota Geological Survey, Report of Investigations No. 103, North Dakota Geological Survey, Bismarck, North Dakota, 38 pgs.

Sandberg, C. A., 1973, Salt and Potash, *in* Mineral and Water Resources of North Dakota: North Dakota Geological Survey Bulletin 63, p. 151.

Maughan, E. K., 1966, Environment of deposition of Permian salt in the Williston and Alliance basins, *in* J. L. Rau, ed., Second Symposium on Salt: Northern Ohio Geological Society, p. 37-47.