

North Dakota Geological Survey

# The Potash Members of the Prairie Formation in North Dakota

By  
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NORTH DAKOTA GEOLOGICAL SURVEY  
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## **ABSTRACT**

New data on the stratigraphy of the Prairie Formation potash deposits was generated from 545 geophysical well logs in northwestern North Dakota. Descriptions and isopachs are presented for six potash-containing members (in ascending stratigraphic order: the Esterhazy, White Bear, Belle Plaine, Patience Lake, Mountrail and White Lake Members).

The combined gross thicknesses of the Esterhazy and White Bear Members exceeds 40 ft (12 m) in wells along the Nesson Anticline in western Burke and Mountrail, and eastern Divide and Williams counties, reaching a maximum of 43 ft (13 m) gross thickness. Net thickness is greatest in western Burke County with a maximum net thickness of 29 ft (8.8 m).

The combined gross thickness of the Belle Plaine and Patience Lake Members exceeds 40 ft (12m) in wells near and east of the Nesson Anticline, however these areas correspond with declining Belle Plaine accumulation and a thickening of the halite interbed separating the two members. Net thickness is greatest in western and central Divide County and reaches a maximum of 26 ft (7.9 m) in northwest Divide County.

The Mountrail Member overlies the Patience Lake Member by an average of 93 ft (28 m). It reaches a maximum thickness of 12 ft (3.7 m), with thickest deposits occurring in central Mountrail, eastern Williams, and southern Divide counties.

A previously unidentified potash layer of limited extent and thickness overlies the Mountrail Member by an average of 46 ft (14 m). It reaches a maximum thickness of six feet, with deposits primarily occurring in north-central Mountrail County. This layer has been named the White Lake Member.

Quantitative log evaluation utilizing gamma ray, caliper, neutron density, and sonic travel time data was performed on a recent potash exploration well to estimate concentrations of sylvite and carnallite in the potash layers. Results are compared to laboratory derived concentrations from the well. Quantitative log evaluation may be useful in planning an exploration program. Log analysis indicates that carnallite is present in the White Bear Member throughout most of Burke County, and is also present in the Patience Lake Member in western Burke County.

## **INTRODUCTION**

This report updates a previous report of the North Dakota potash deposits of the Devonian-age Prairie Formation by Anderson and Swinehart (1979) and includes an update of the stratigraphy of the Esterhazy, White Bear, Belle Plaine, Patience Lake, Mountrail, and White Lake potash-containing members. Anderson and Swinehart described the North Dakota potash deposits, which are extensions of the rich deposits mined in Saskatchewan, as a resource of 50 billion tons underlying an area of 11,000 square miles (28,500 km<sup>2</sup>) in northwestern North Dakota. Since the publication of the Anderson and Swinehart report, many additional oil and gas wells and a new potash exploration well have been drilled into the Prairie Formation.

Previous descriptions of the Esterhazy Member in North Dakota included both the Esterhazy and White Bear Members. This report includes a section on the gross and net thickness of the two members combined, which provides greater continuity with the original report.

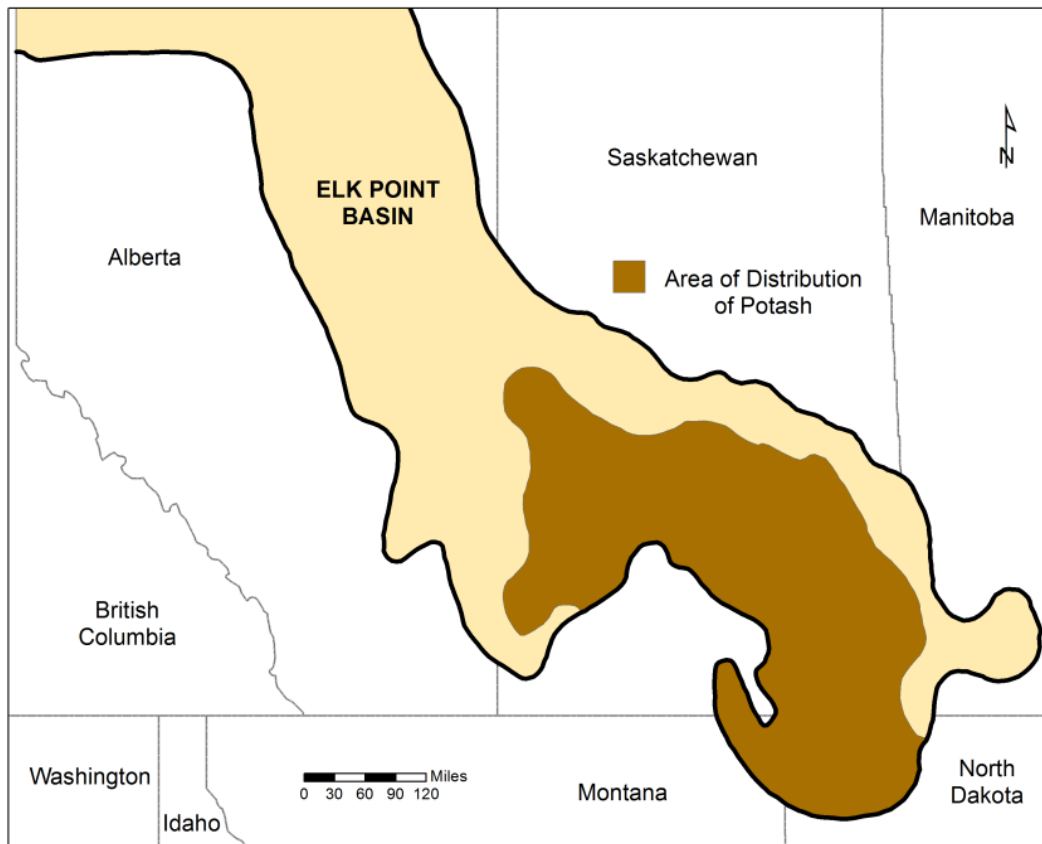
Similarly, previous descriptions of the Belle Plaine Member in North Dakota included deposits of the Patience Lake Member. A section on the combined gross and net thicknesses of Belle Plaine and Patience Lake Members is also included.

Potash production in North Dakota will require solution-mining methods owing to the depths of the deposits, which exceed 5,600 ft (1,700 m). Conventional shaft-mining for potash is generally not considered beyond a depth of 3,500 ft (1,065 m).

## **GEOLOGIC HISTORY OF POTASH UNITS**

During deposition of the Winnipegosis Formation in the early Devonian, the development of a reef complex restricted the flow of open ocean waters in the southern Northwest Territories of Canada to the northwest-southeast trending Elk Point Basin (fig. 1). Two structural divides in the northwestern and central portions of the Elk Point Basin formed three sub-basins. These divides further restricted water from passing into the southernmost sub-basin, an area which included parts of Saskatchewan, southeastern Manitoba, northwestern North Dakota, and northeastern Montana. As a result, inflowing water was at times likely concentrated in potassium as it reached the Saskatchewan sub-basin (Holter, 1969; Garrett, 1996; Yang et al, 2009; Murphy, 2011).

The Prairie Formation deposits in North Dakota conformably overlie the Winnipegosis Formation. Potash beds are present throughout most of the salt basin, but are sometimes absent over pinnacle reefs (Oglesby, 1987) or in areas subjected to erosion or dissolution. The typical progression of evaporite deposition from brines of the Elk Point Basin consists of gypsum or anhydrite followed by halite, sylvite, and finally carnallite, though introduction of fresh waters into the system could reverse the sequence and result in alternating beds of halite and potassium salts.



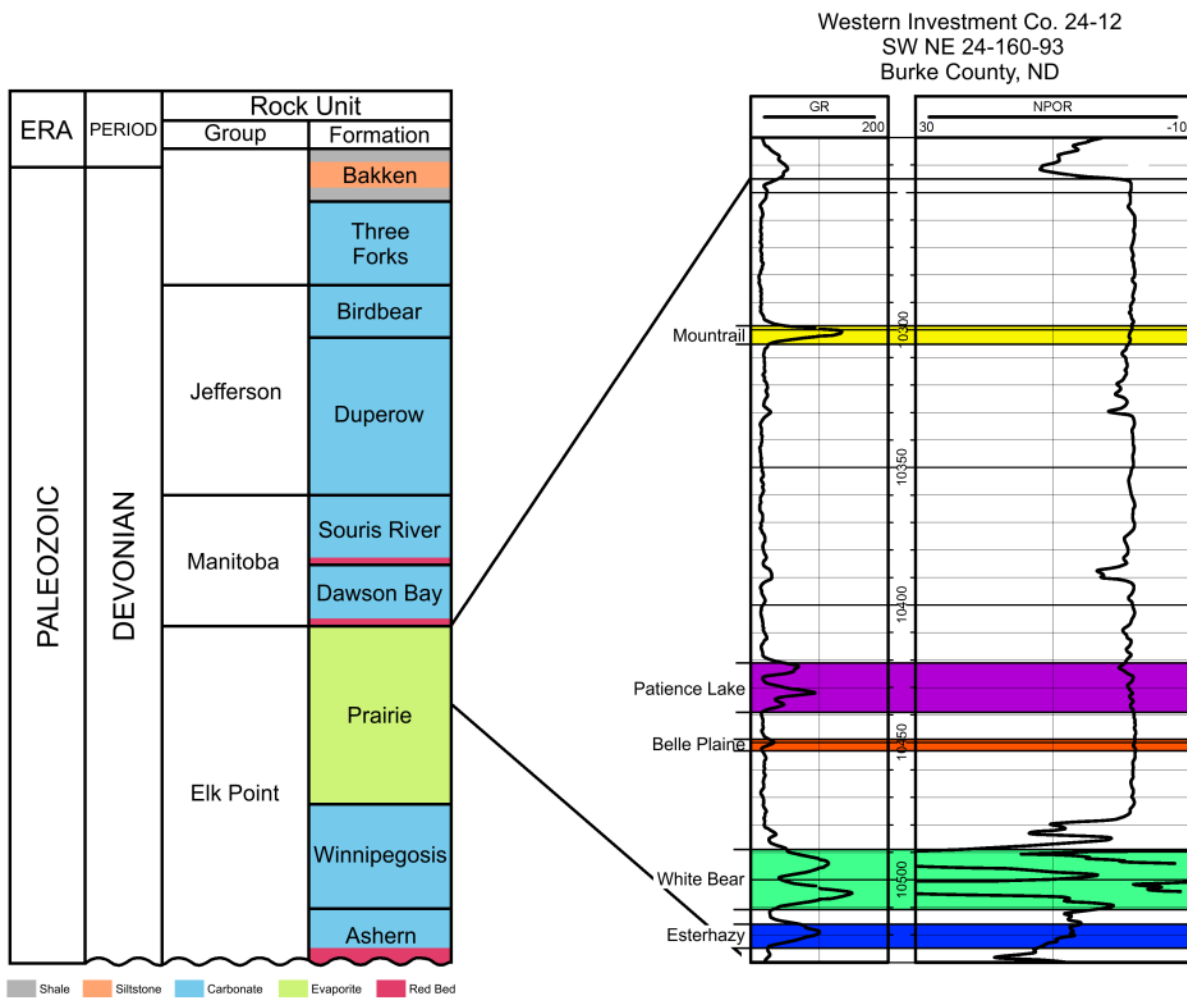
**Figure 1.** Devonian Elk Point Basin (modified from Holter, 1969)

The salts of the Prairie Formation in North Dakota are conformably overlain by the carbonates of the Dawson Bay Formation. The Second Red bed, a clay-rich zone at the base of the Dawson Bay Formation, may have helped preserve the Prairie Formation salt deposits from greater dissolution from the seawater (Anderson and Swinehart, 1979) (fig. 2). Localized thickening of the Second Red bed or other overlying formations is observed where dissolution of the underlying evaporites formed paleolows (Heck and Burke, 1991).

## **METHODS**

The study area encompasses the limits of the Prairie Formation salt deposits located in northwestern North Dakota. Wireline logs from 545 borings, primarily from oil and gas exploration, were examined.

Potash-bearing beds were identified on gamma ray logs. Potash salts contain the element potassium, the radioactive isotope of which ( $^{40}\text{K}$ ) releases gamma radiation during the process of decay. This is recorded on the gamma log as a deflection to the right from the baseline level (fig. 2). The amplitude of the deflection is dependent on the concentration of the potash salts and other factors, and can exceed the scale of the log track.



**Figure 2.** Devonian stratigraphy of the Williston Basin, U.S.A. with a log section including the potash zones of the Prairie Formation in the Western Investment Company No. 24-12 well in Burke County, North Dakota. The gamma log is present on a scale of 0-200 API units in the left column of log section.

Other useful logs for distinguishing potash containing zones include caliper, sonic, and density logs. Potash salt is dissolved more readily by the drilling fluid, which is often saturated with sodium chloride (halite), resulting a widening of the borehole in potash zones. Concentrated potash salts have lower densities than halite, and also tend to have higher sonic transit times or erratic sonic recordings, possibly due to washout of the potash salts during drilling (Elowski, 1980).

Potash members were correlated to the extent they were observed throughout the Williston Basin region of North Dakota and to potash intervals previously mapped in southeastern Saskatchewan. Thickness was measured from the gamma ray curve trough at the base of each member and upward to the peak of its highest layer of potash mineralization. Recorded thicknesses may differ from actual minable thickness due to a sometimes gradual increase or decrease in potash mineralization.



Because of the relative proximity of the Esterhazy and White Bear Members, and the Belle Plaine and Patience Lake Members, isopachs of the two groupings were created representing combined gross thickness and net thickness. Net thickness was measured by subtracting the thickness of halite or clay interbeds within the gross thickness interval, leaving only the potash.

### **Maximum gamma ray measurements**

The maximum gamma ray recordings for potash members of each well are presented in isopach maps to illustrate the observed ranges of potassium concentrations. No corrections were made to the gamma ray measurements to account for the drilling mud weight or borehole size, which may result in a decreased measurement when a heavy drilling mud is used or as the borehole widens. It should also be noted that the gamma ray tracks in some wells logs were cut off at 120 or 200 API units. In these cases the maximum gamma ray measurement was understated.

Formation and member tops picked for the control wells are provided in the appendix. The appendix also includes identifiers, location, elevation, Prairie Formation thickness, member thicknesses, and member maximum gamma ray count information for each control well.

### **Map production**

All isopach and gamma ray maps were based on well-control data only. The maps were generated using PETRA [ver. 3.7.1] geological software. Isopach maps were generated using a grid size of 415 rows and 553 columns. A grid size of 369 rows and 484 columns was used for gamma ray maps. The contour lines are computer-generated and had minimal adjustments made by the author.

## **DETAILED STRATIGRAPHY**

The Prairie Formation salt deposits are located at depths ranging from approximately 5,600 ft (1,700 m) below the surface in northwestern Bottineau County to greater than 12,500 ft (3,800 m) in southern McKenzie County and northwestern Dunn County (fig. 3). The thickness of the Prairie Formation generally follows the development of the Williston Basin, with thickest salt accumulations near the center of the basin along the eastern flank of the Nesson Anticline. The maximum salt thickness observed in North Dakota exceeds 650 ft (200 m) in southern Burke County. Deposits gradually thin outward to a feather's edge at approximately 5-20 miles (8-32 km) from the southern boundary of the Prairie evaporites and at the solution edge at the eastern boundary.

There are six potash-containing members of the Prairie Formation in North Dakota. The following descriptions begin with the lowest stratigraphically, and progress upward through the formation.

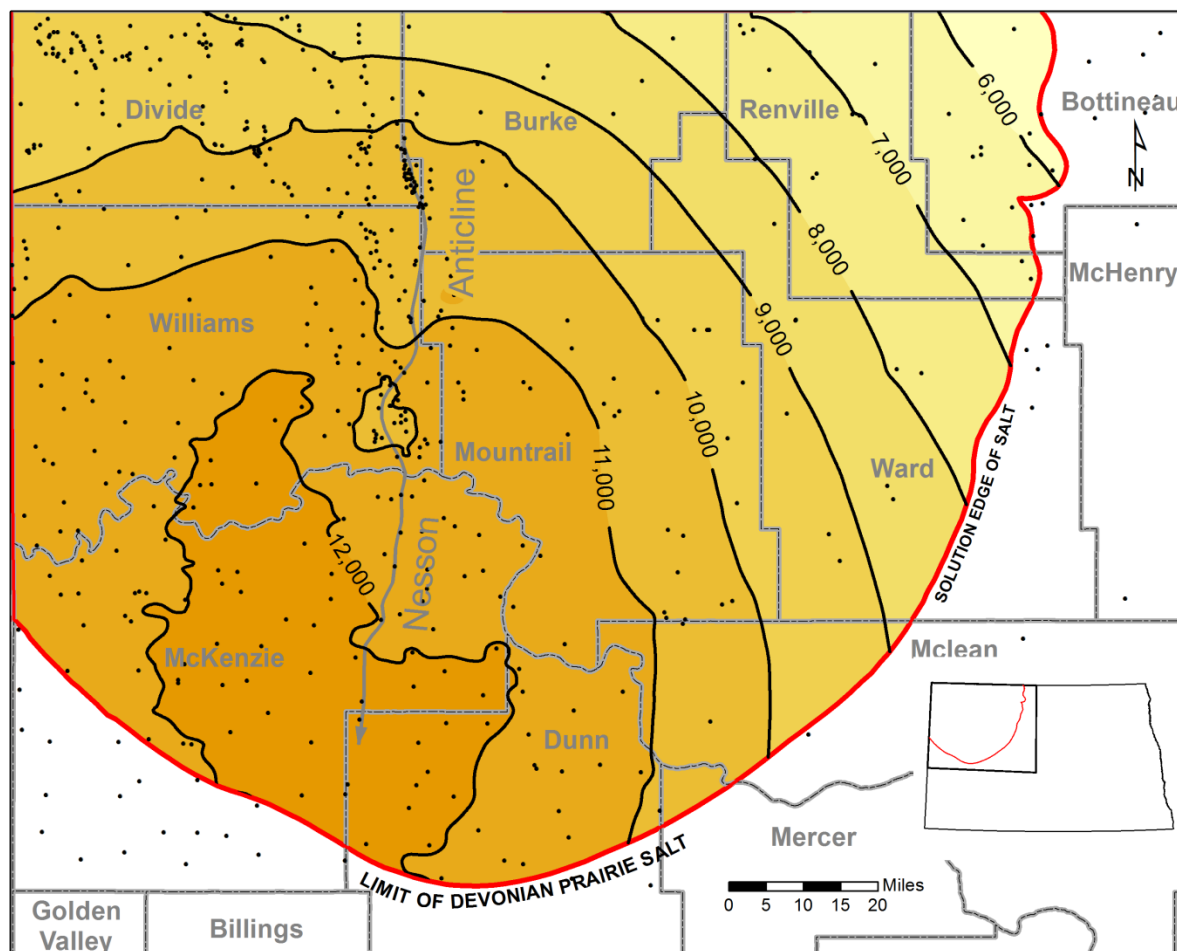


Figure 3. Depth from surface (in feet) to top of the Prairie Formation in North Dakota.

### Esterhazy Member

The Esterhazy Member is the lowermost potash-rich interval of the Prairie Formation. The Esterhazy Member was identified in 253 wells. Its occurrence in North Dakota is most frequently observed as one potash bed, but it also can appear as two or more beds with interbeds of halite or clay. The Esterhazy Member is absent in large portions of Divide and Williams counties and from northeast Mountrail County through much of Renville and northwestern Bottineau counties. The Esterhazy Member reaches a maximum gross thickness of 16 ft (4.9 m) with the thickest areas of deposits occurring in southwestern Divide, northwestern and southeastern Williams, northeastern McKenzie, and southern Mountrail counties (fig. 4). The depths to the Esterhazy Member range from 6,004 to 12,674 ft (1,830 to 3,863 m).

Gamma ray measurements are depicted in figure 5. Gamma ray recordings were off the scale of the graph (200 API units) in 13 wells located in eastern McKenzie, northern Dunn, central Divide, and southeastern Mountrail counties.

### **White Bear Member**

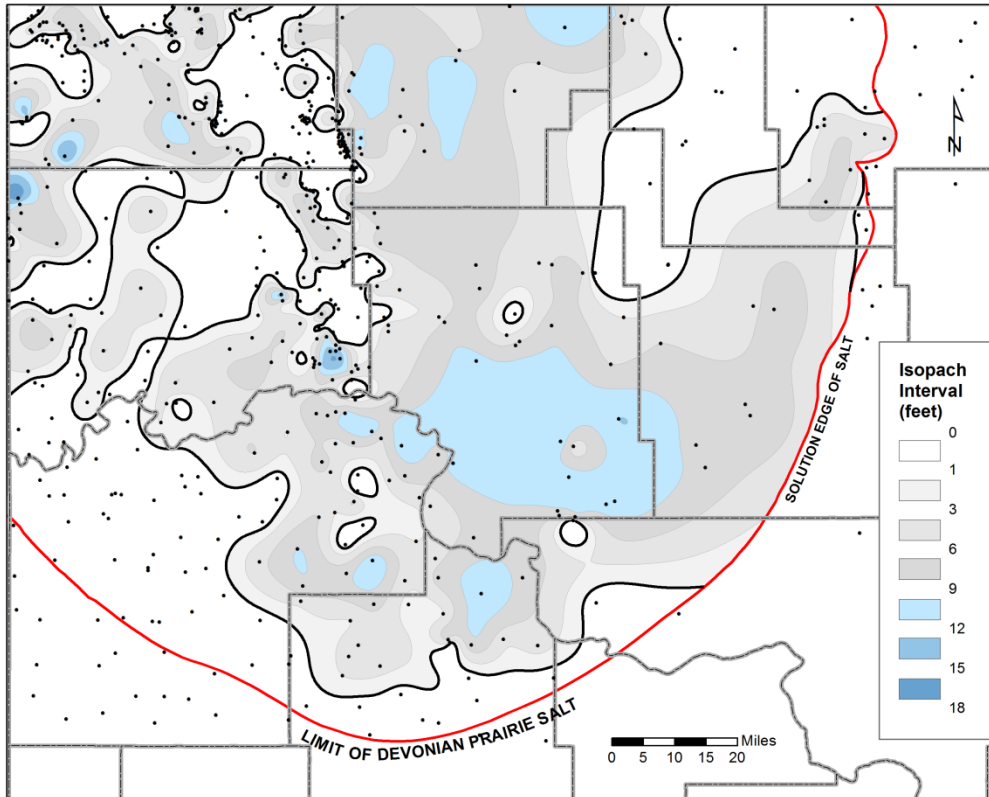
The White Bear Member overlies the Esterhazy Member by an average of 9 ft (2.7 m), and an observed range of 2 to 32 ft (0.6 to 9.8 m). The White Bear Member was not previously identified in North Dakota but was lumped into the Esterhazy Member. In this study, it was traced from Saskatchewan into North Dakota and identified in 421 wells. The White Bear Member is observed between the depths of 10,077 ft (3,071 m) and 10,100 ft (3,078 m) in the Aalund No. 4-35 well located in NW¼NW¼, sec. 35, T 162 N., R 99 W., Divide County (fig. 6). It commonly appears as two or three potash-rich beds, separated by interbeds of halite or clay. The White Bear Member is the most expansive of the potash-containing members in North Dakota, extending southwestwards from the salt solution edge in western Bottineau County into northeastern Dunn County and northern McKenzie County. It is absent in portions of eastern Divide County, mainly along the Nesson Anticline trend, as well as in parts of northern Williams, northwestern Ward, northeastern Renville, and western Bottineau counties. The White Bear Member reaches a maximum thickness of 29 ft (8.8 m) with thickest accumulations located east of the Nesson Anticline near the western borders of Burke and Mountrail counties. Thick deposits are also observed in northwestern and southern Williams County, and southwestern Divide County (fig 7). Depths to the White Bear Member range from 5,636 to 12,579 ft (1,718 to 3,834 m).

Gamma ray measurement are depicted in figure 8. Gamma ray recordings were off the scale of the graph (200 API units) in 82 wells.

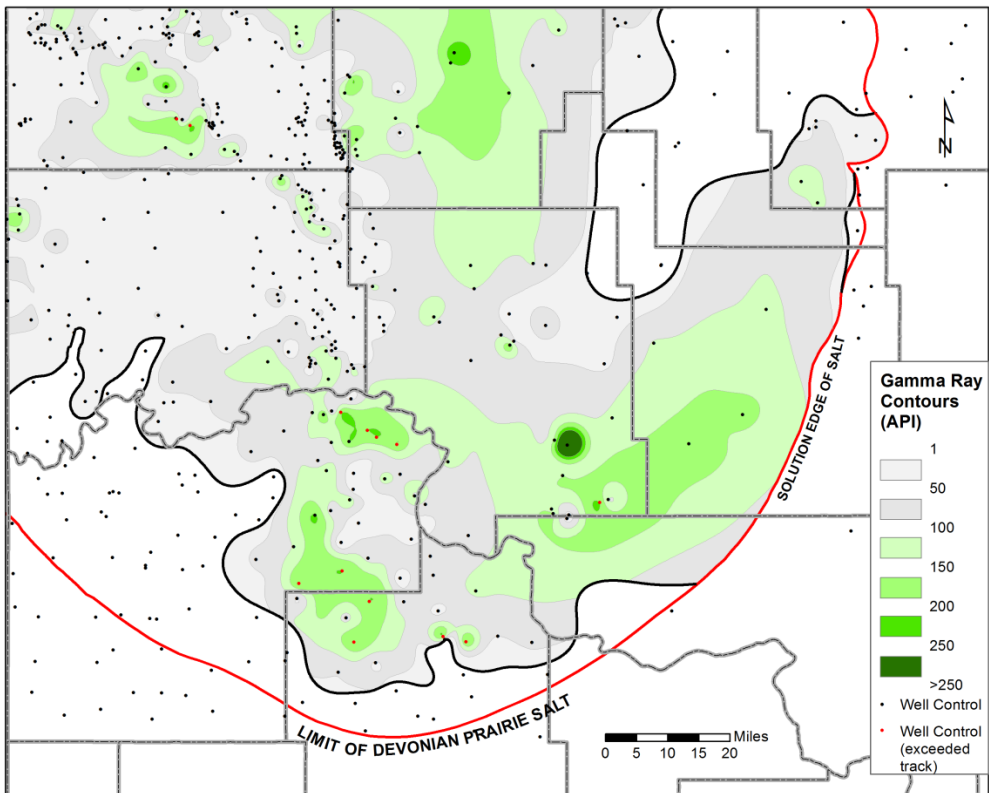
### **Belle Plaine Member**

Of the four potash beds identified in Canada, the Belle Plaine Member is the least extensive both in area and thickness in North Dakota. Deposits are largely limited to Divide, Burke, and northwestern Williams counties, though sporadic zones are also present in McKenzie, Mountrail, and Renville counties. The Belle Plaine Member was identified in 185 wells. The Belle Plaine Member overlies the White Bear Member by an average of 29 ft (8.8 m), and by an observed range of 14 to 43 ft (4.3 to 13 m). It generally appears as one or two potash-rich beds separated by a halite interbed. It reaches a maximum thickness of 18 ft (5.5 m) in northwestern Divide County (fig. 9). The depth to the Belle Plaine Member ranges from 7,131 to 12,544 ft (2,174 to 3,823 m).

Gamma ray counts are depicted in figure 10. The gamma ray did not exceed the scale of the graph within the Belle Plaine Member on any of the logs.



**Figure 4.** Isopach map of the Esterhazy Member of the Prairie Formation in North Dakota. Black dots are control wells.



**Figure 5.** Gamma ray map of the Esterhazy Member of the Prairie Formation in North Dakota. Black dots are control wells. Red dots indicate control wells where the gamma count was beyond the scale of the log. Gamma-ray measurements were not corrected for boring size or mud weight.

Aalund No. 4-35  
 NW NW 35-162-99  
 Divide County, ND

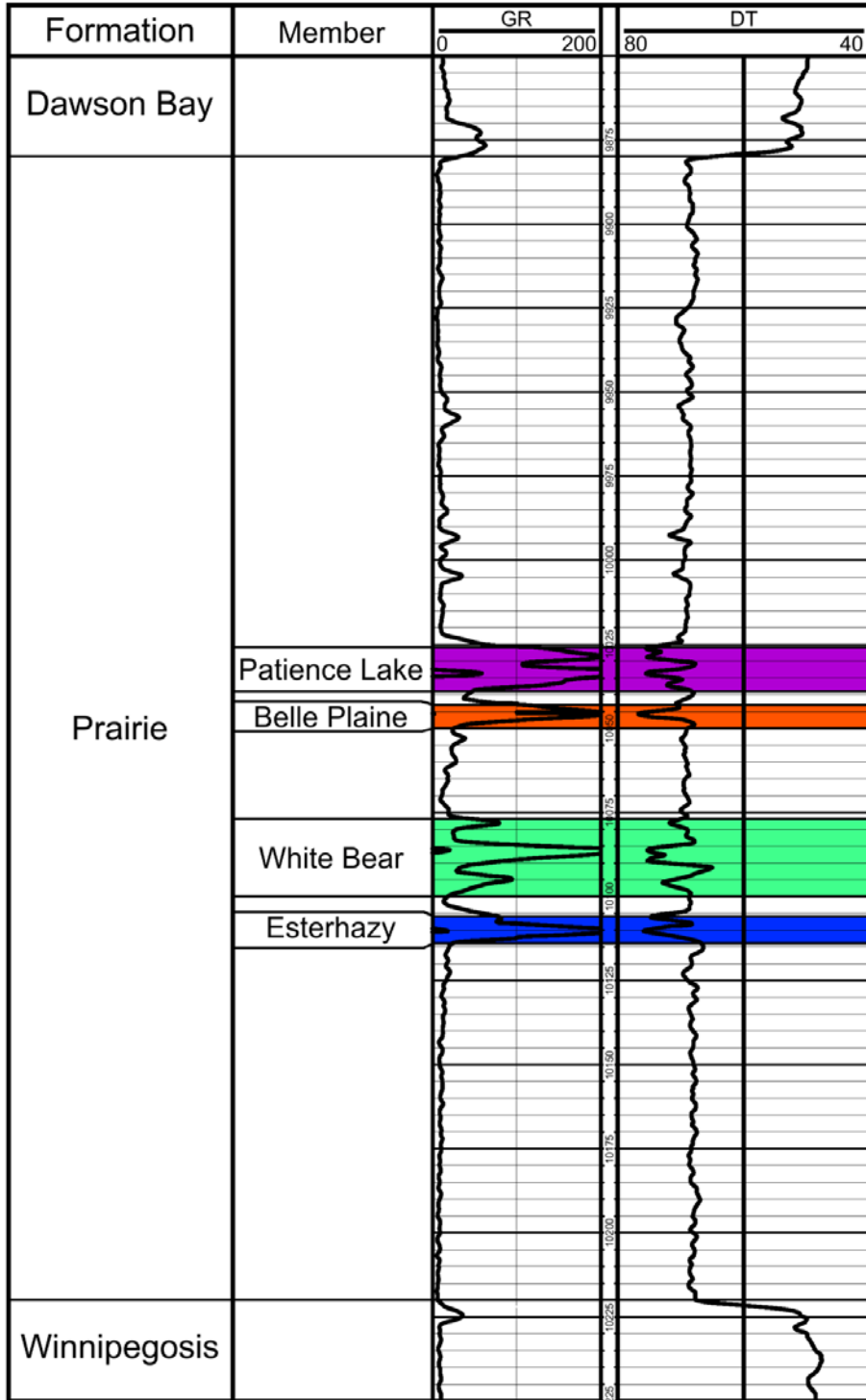
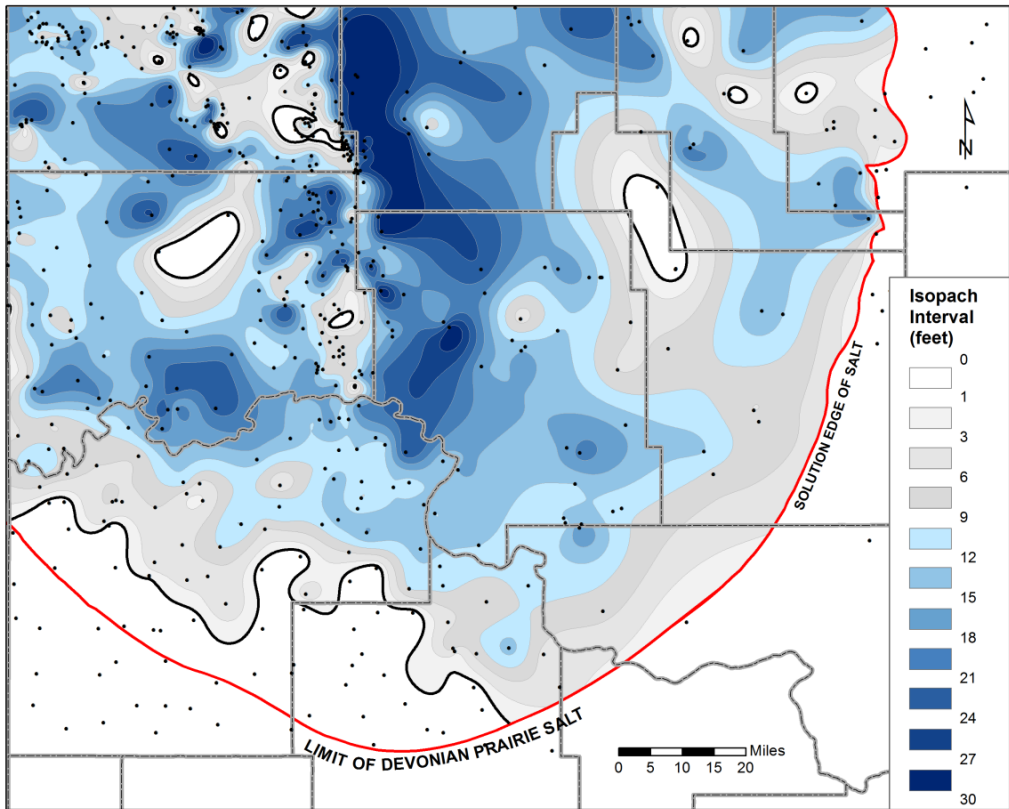
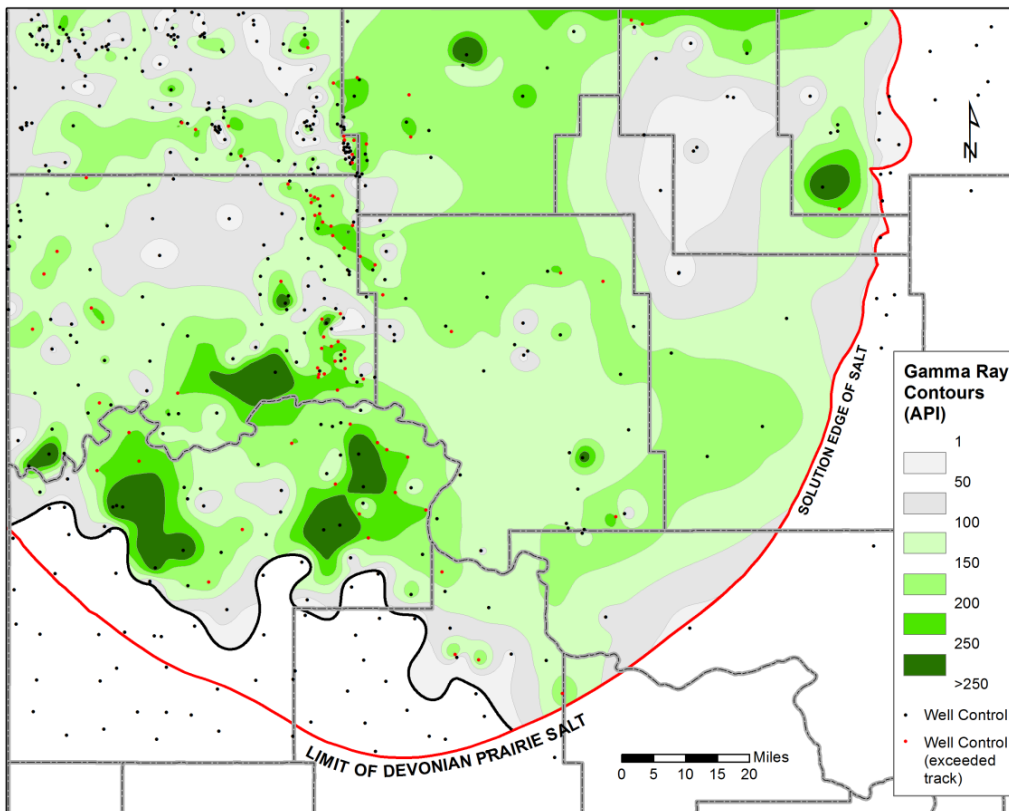


Figure 6. Log section of the Aalund No. 4-35 well, Divide County, showing potash members of the Prairie Formation in North Dakota.



**Figure 7.** Isopach map of the White Bear Member of the Prairie Formation in North Dakota.



**Figure 8.** Gamma ray map of the White Bear Member of the Prairie Formation in North Dakota.

## **Patience Lake Member**

The Patience Lake Member was not previously identified in North Dakota but was lumped into the Belle Plaine Member. In this study, it was traced from Saskatchewan into North Dakota and identified in 381 wells. The Patience Lake Member is observed between the depths of 10,026 ft (3,056 m) and 10,050 ft (3,063 m) in the Aalund No. 4-35 well (fig. 6). It occurs as one or more potash-rich beds separated by interbeds of halite or clay. Clay seams appear to be more prevalent in and above the Patience Lake Member than they are elsewhere in the Prairie Formation. Where the Belle Plaine Member is present, the Patience Lake Member overlies it by an average of 11 ft (3.4 m), and by an observed range of 2 to 29 ft (0.6 to 8.8 m). The Patience Lake Member overlies the White Bear Member by an average of 45 ft (13 m). It is absent in parts of Divide County and along the Nesson Anticline and also in pockets near its depositional edge in Renville and McKenzie counties. The Patience Lake Member reaches a maximum thickness of 27 ft (8.2 m) in northern Williams County, with thick accumulations also occurring in eastern Divide, western and central Burke, and central Mountrail counties (fig. 11). Depths range from 6,622 to 12,505 ft (2,018 to 3,812 m)

Gamma ray measurements are depicted in figure 12. Gamma ray recordings went off the scale of the graph (200 API units) in 32 wells located in central and southeastern Divide, eastern Williams, and northeastern Mountrail counties.

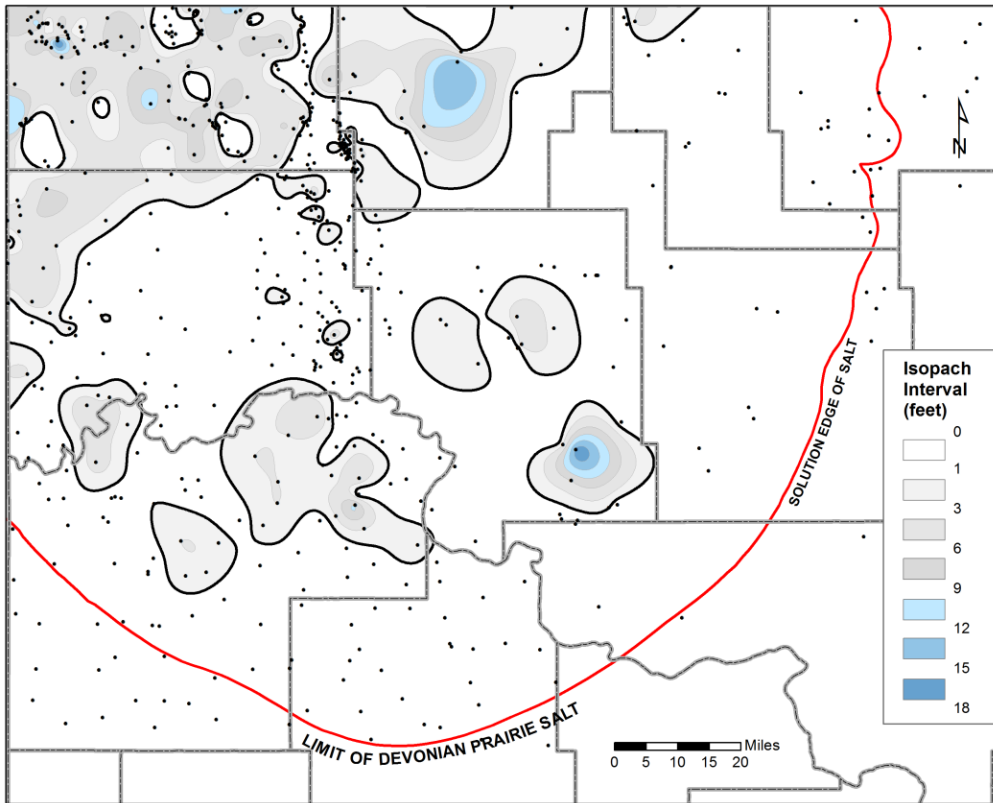
## **Mountrail Member**

The Mountrail Member overlies the Patience Lake Member by an average of 93 ft (28 m), and by an observed range of 68 to 143 ft (21 to 44 m). The Mountrail Member was recognized in 169 wells. It is limited in areal extent and does not extend into Canada. The Mountrail Member reaches a maximum thickness of 12 ft (3.7 m), with thickest deposits occurring in central Mountrail, eastern Williams, and southern Divide counties (fig. 13). The Mountrail Member ranges from 6 to 106 ft (1.8 to 32 m) below the top of the Prairie Formation. The depths to the Mountrail Member range from 9,198 ft (2,804 m) in northwestern Divide to 12,353 ft (3,765 m) in southeastern Williams County. Its economic potential is limited by its vertical separation from the lower potash members (fig 2).

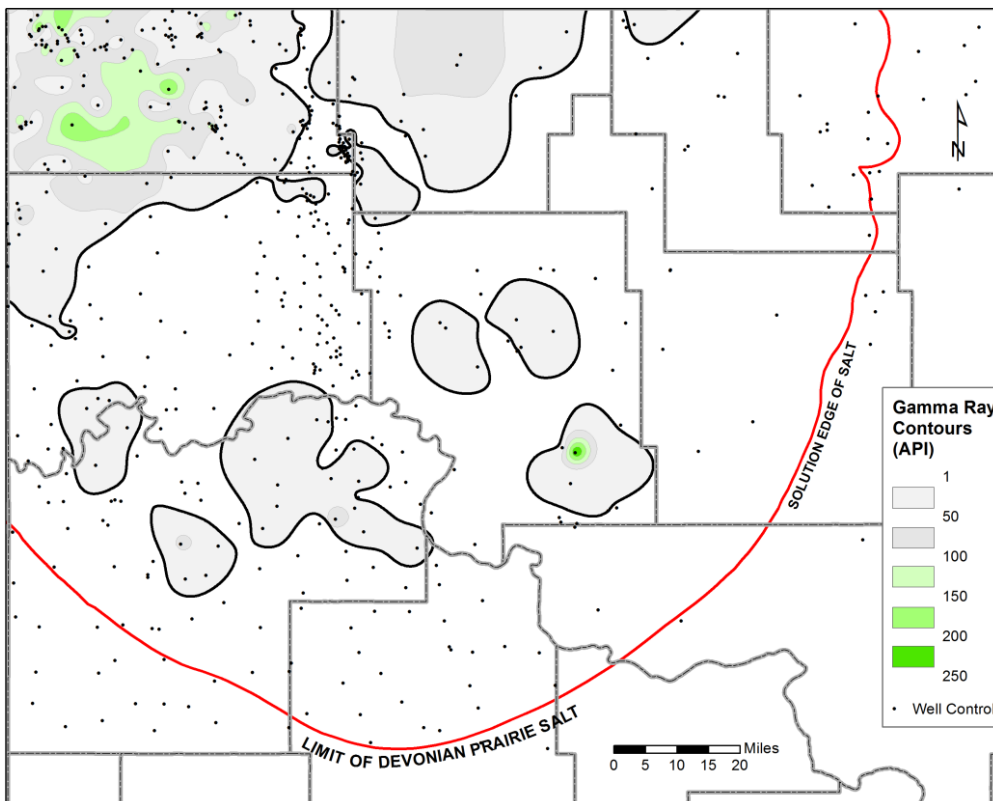
Gamma ray measurements are depicted in figure 14. Gamma ray counts exceeded the track of the graph (200 API units) in 15 wells located in eastern Williams, central Mountrail, northeastern McKenzie, and southern Williams counties.

## **White Lake Member**

A previously unknown potash layer was identified in 9 wells located in northeastern Williams and northern Mountrail counties (fig. 15). This layer is given the name White Lake Member and is established for the potash bed between depths of 10,618 ft (3,236 m) and 10,624 ft (3,238 m) in the Laredo No. 26-1 well located in SW $\frac{1}{4}$ NE $\frac{1}{4}$ , sec. 26, T. 156 N., R. 91 W., Mountrail County (fig. 16). The layer overlies the Mountrail Member by an average of 46 ft (14 m), and a range of 31 to 90 ft (9 to 27 m). The maximum thickness observed is 6 ft (1.8 m). Because of its limited extent and thickness, isolation from other potash beds, and moderate to low gamma ray signature, it is not expected to be economically important.

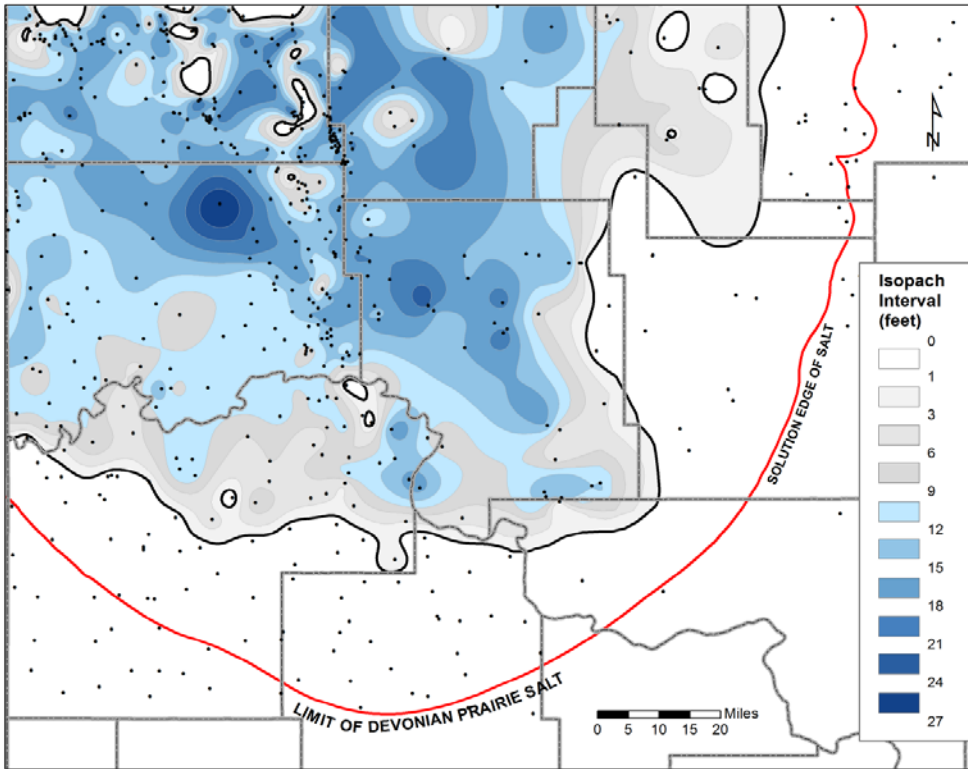


**Figure 9.**  
Isopach map of the Belle Plaine Member of the Prairie Formation in North Dakota.

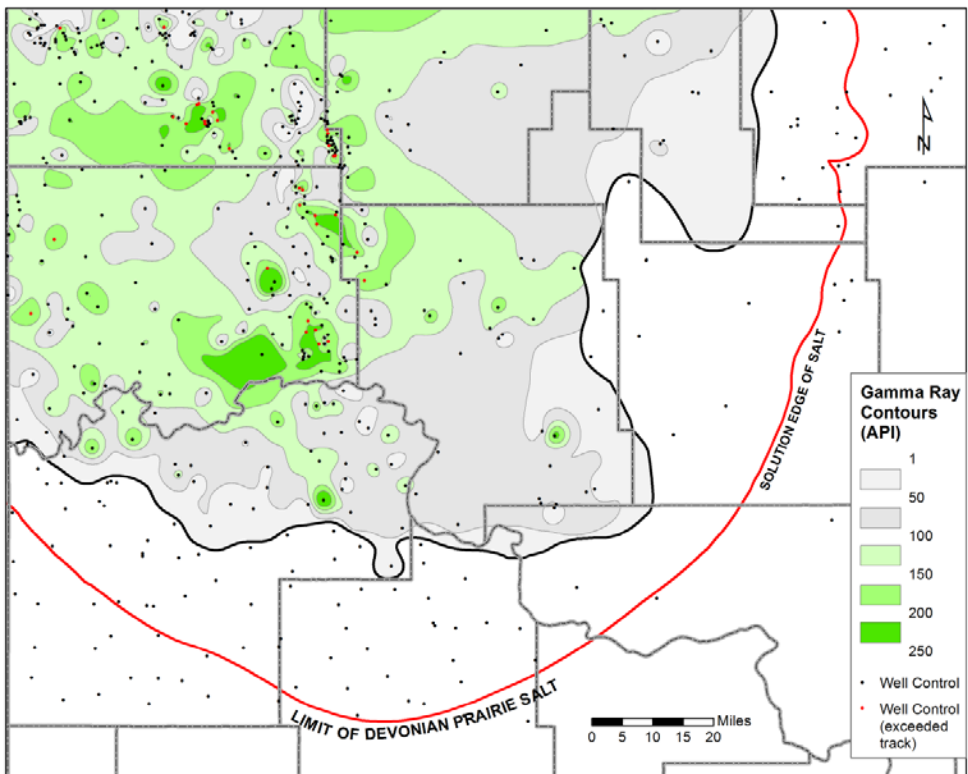


**Figure 10.**  
Gamma ray map of the Belle Plaine Member of the Prairie Formation in North Dakota.

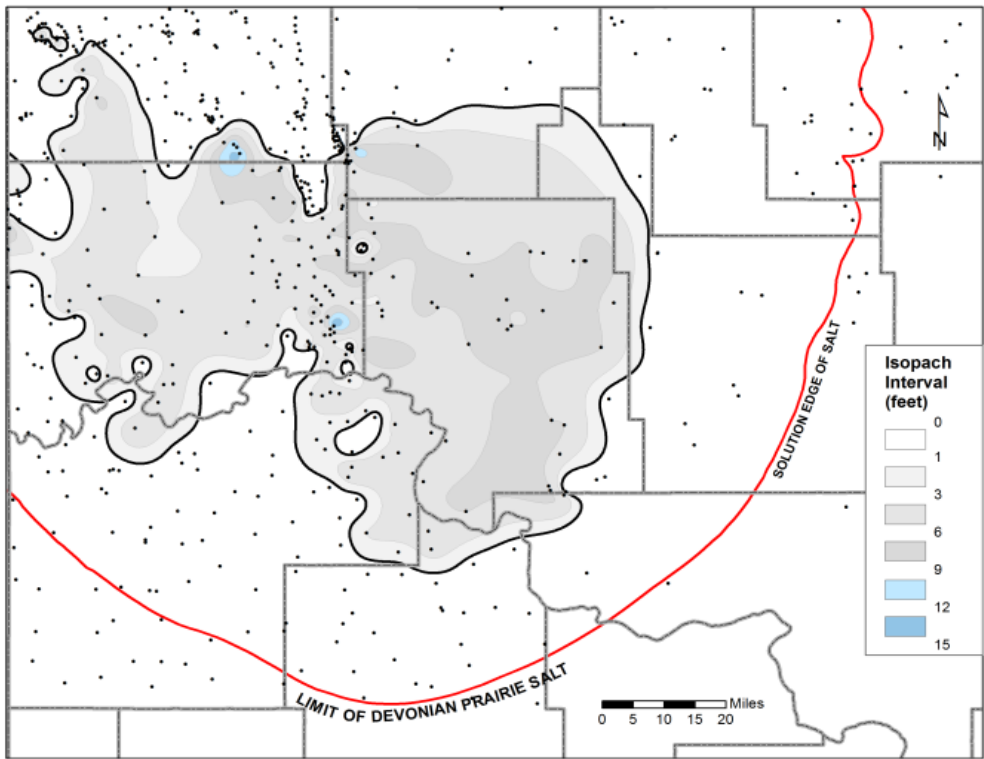




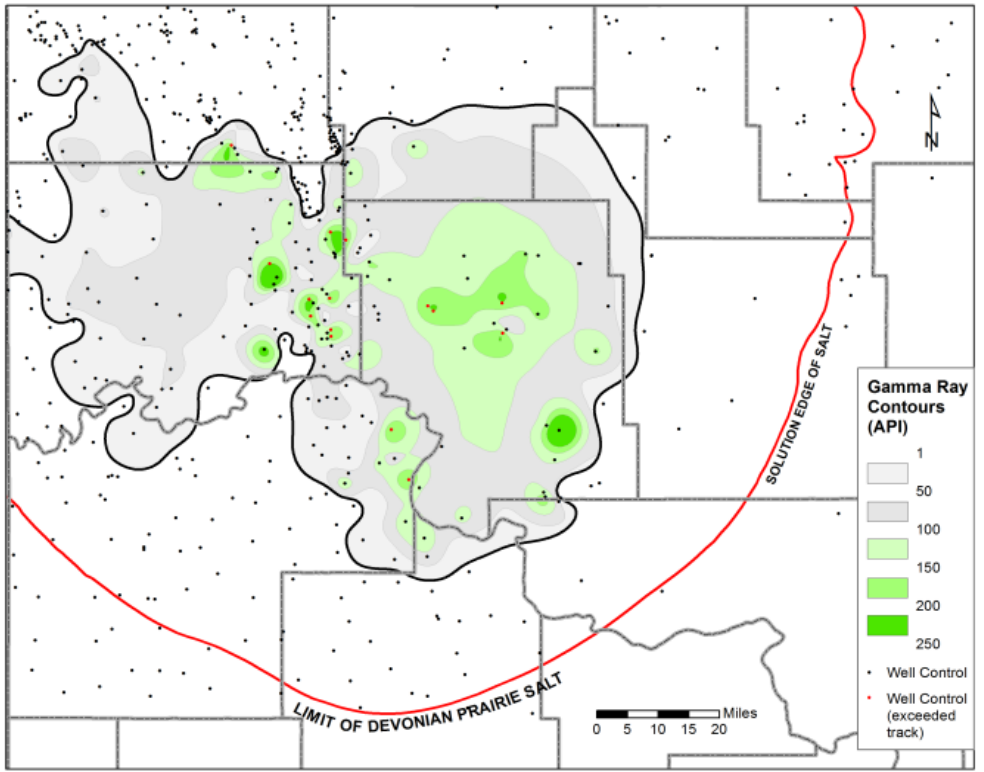
**Figure 11.** Isopach map of the Patience Lake Member of the Prairie Formation in North Dakota.



**Figure 12.** Gamma ray map of the Patience Lake Member of the Prairie Formation in North Dakota.



**Figure 13.** Isopach map of the Mountrail Member of the Prairie Formation in North Dakota.



**Figure 14.** Gamma ray map of the Mountrail Member of the Prairie Formation in North Dakota.

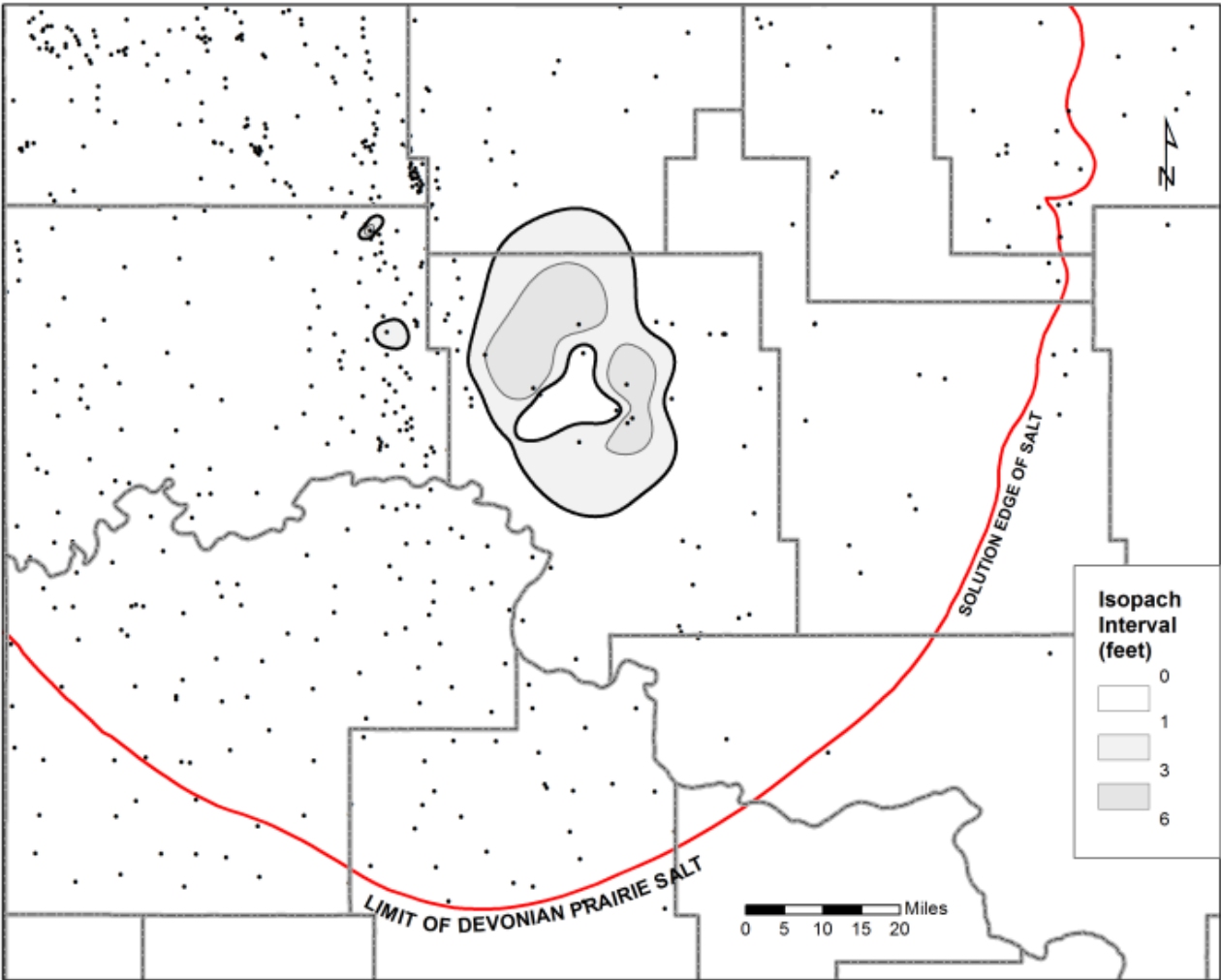
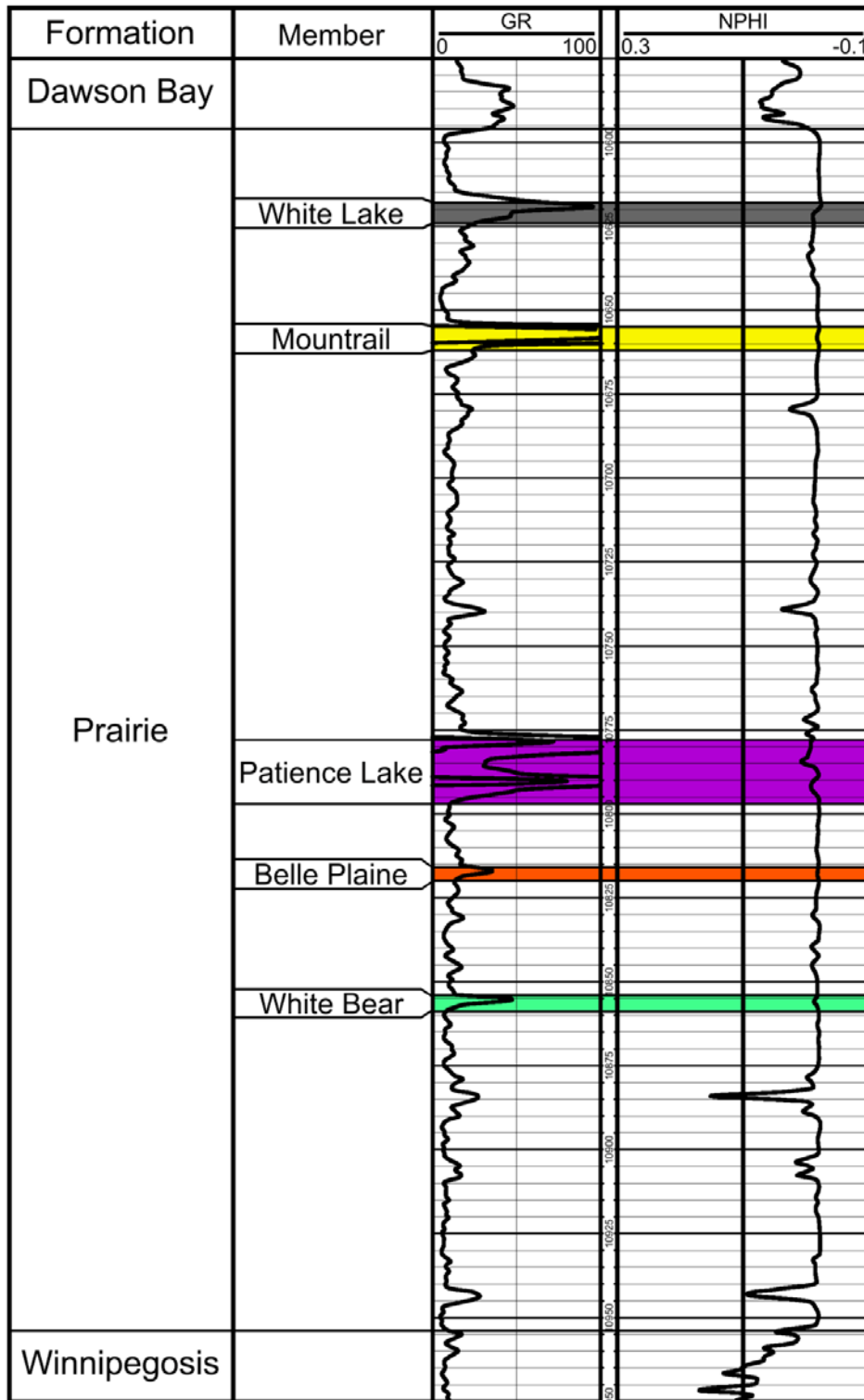


Figure 15. Isopach map of the White Lake Member of the Prairie Formation in North Dakota.

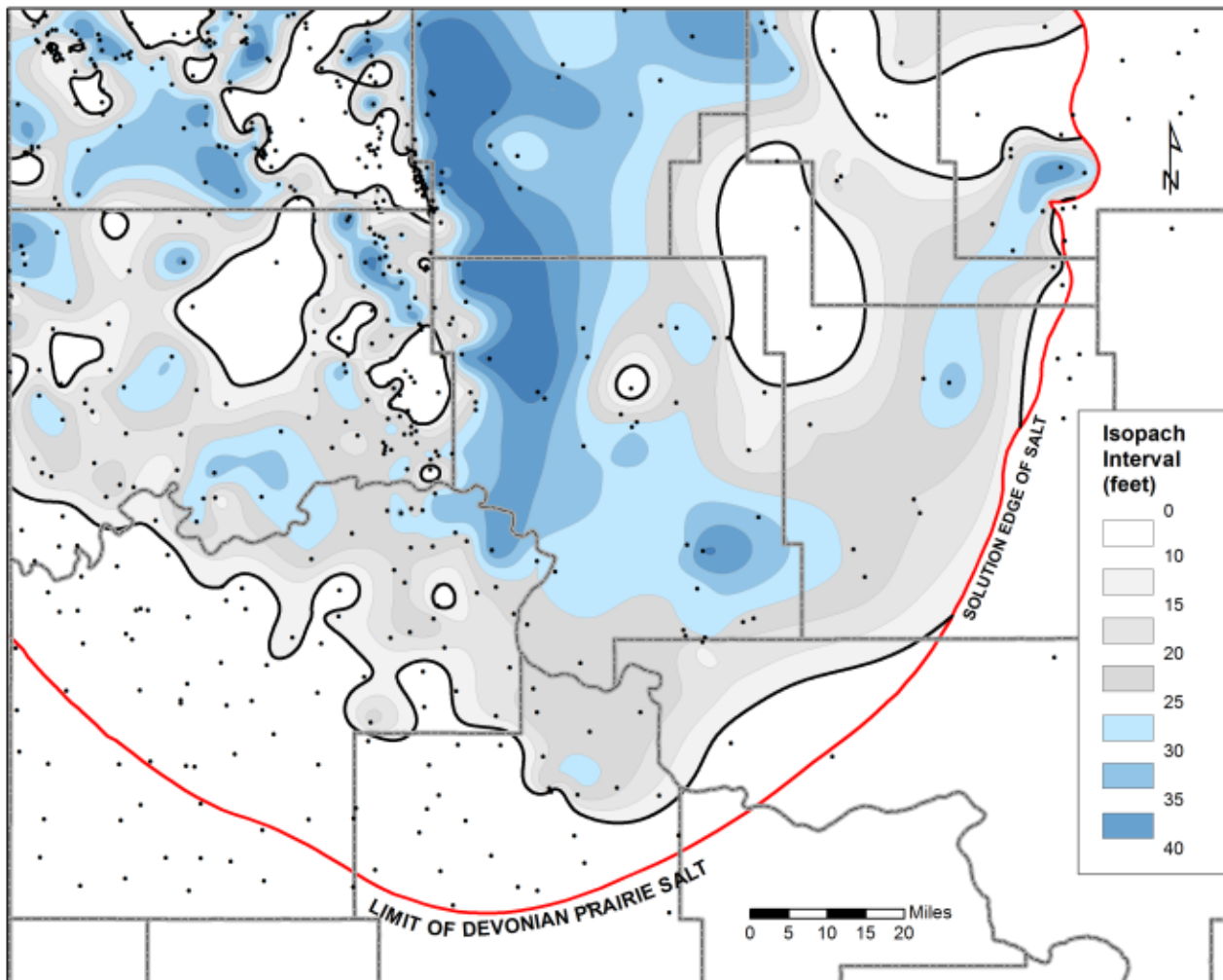
Laredo No. 26-1  
 SW NE 26-156-91  
 Mountrail County, ND



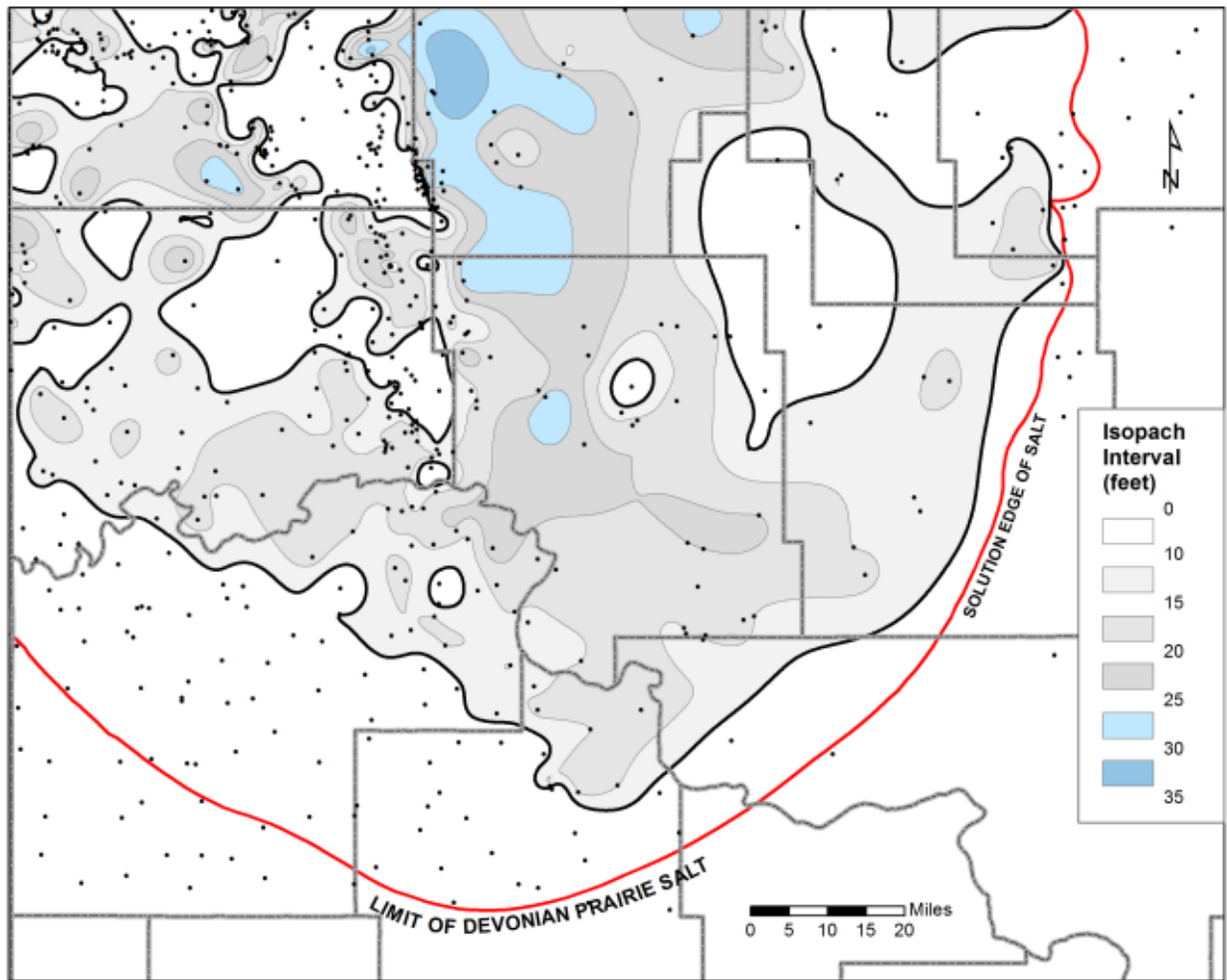
**Figure 16.** Log section of the Laredo No. 26-1 well, Mountrail County, showing potash members of the Prairie Formation in North Dakota.

## GROSS & NET THICKNESSES OF ADJACENT LAYERS

The cumulative gross thickness of Esterhazy and White Bear Members exceeds 40 ft (12 m) in wells along the Nesson Anticline in western Burke and Mountrail and eastern Divide and Williams counties, reaching a gross thickness maximum of 43 ft (13 m) (fig 17). The maximum observed cumulative net thickness of the Esterhazy and White Bear Members is 29 ft (8.8 m) with the thickest net accumulations concentrated in western Burke County. Net accumulations over 25 ft (7.6 m) in thickness are also observed in south-central Divide, northeastern Burke, and northwestern Mountrail counties (fig. 18).

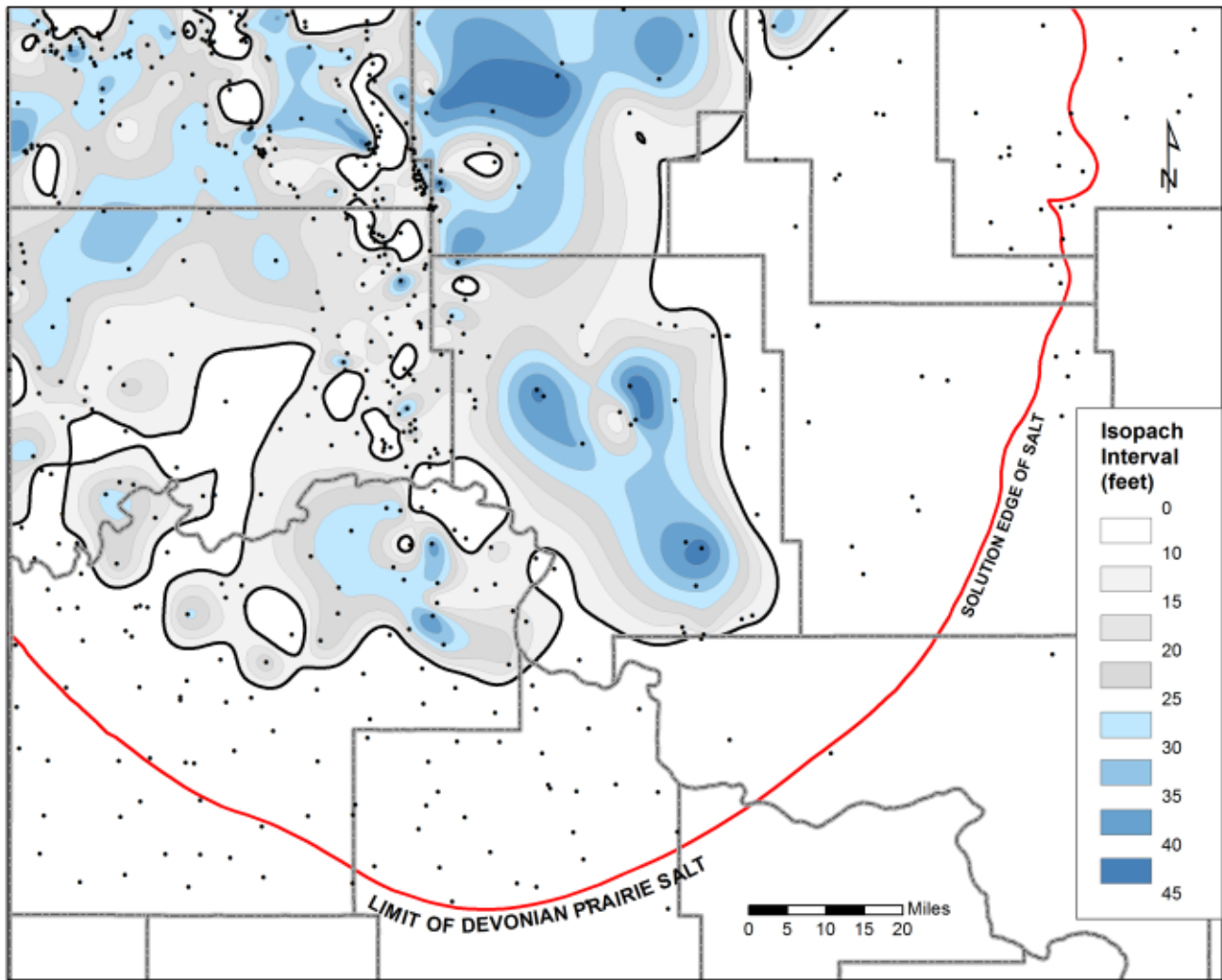


**Figure 17.** Isopach map of the gross combined thickness of the Esterhazy and White Bear Members of the Prairie Formation in North Dakota.

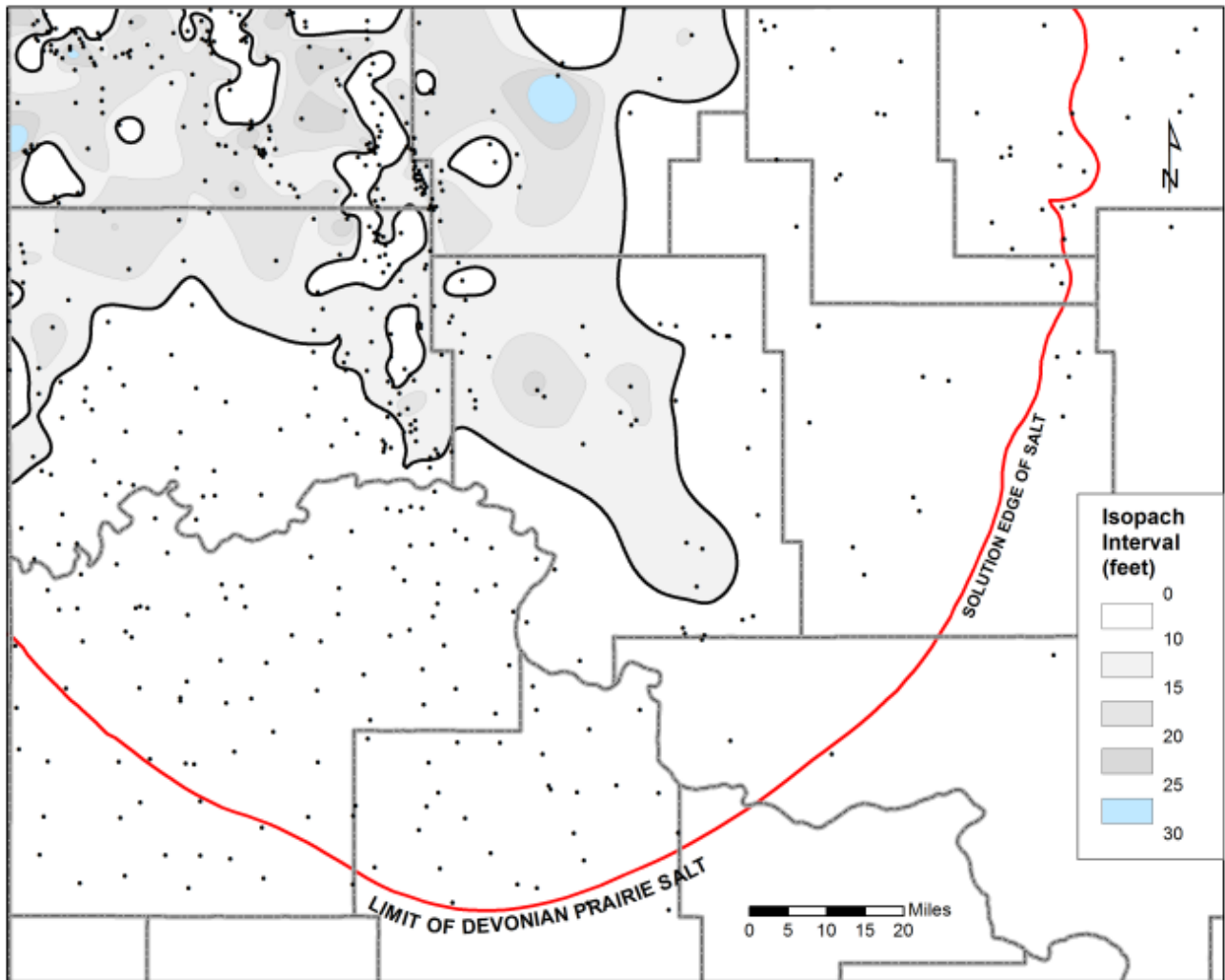


**Figure 18.** Isopach map of the net combined thickness of the Esterhazy and White Bear Members of the Prairie Formation in North Dakota.

The observed cumulative gross thickness of Belle Plaine and Patience Lake Members exceeds 40 ft (12 m) in nine wells located in eastern Divide, central and western Burke, northeastern Williams, and central Mountrail counties (fig. 19). However, these areas generally are along or east of the Nesson Anticline where the halite interbed separating Belle Plaine from the Patience Lake thickens. The Belle Plaine Member is sporadic, thin, and has low gamma ray measurements in these regions. The maximum observed cumulative net thickness of Belle Plaine and Patience Lake Members is 26 ft (7.9 m) in northwestern Divide County with thick net accumulations occurring locally in western and central Divide and western Burke counties. (fig. 20).



**Figure 19.** Isopach map of the gross combined thickness of the Belle Plaine and Patience Lake Members of the Prairie Formation in North Dakota.

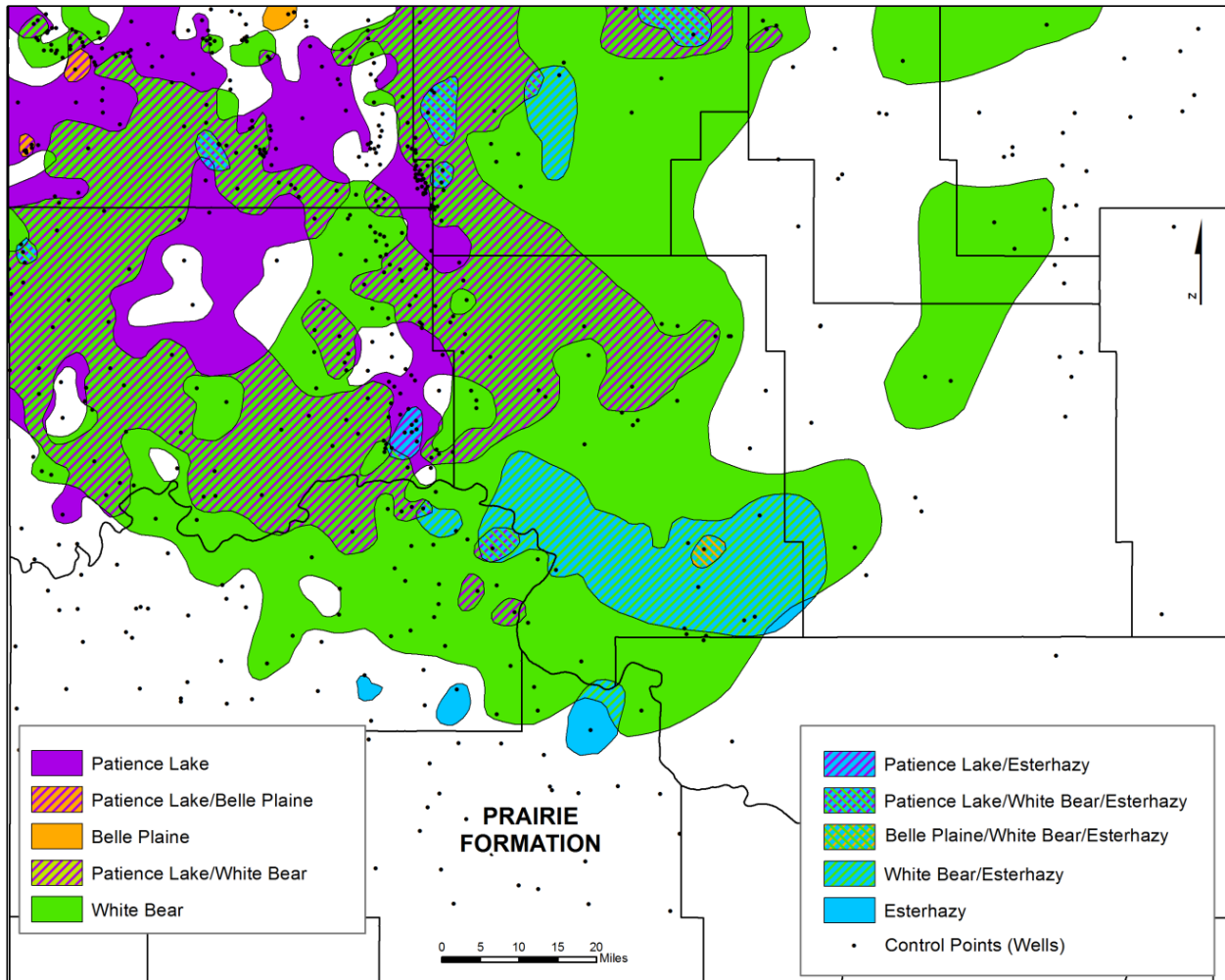


**Figure 20.** Isopach map of the net combined thickness of the Belle Plaine and Patience Lake Members of the Prairie Formation in North Dakota.



## COMPOSITE MAP

A composite map depicting areas where the Esterhazy, White Bear, Belle Plaine, and Patience Lake Members each attain thicknesses greater than 9 ft (2.7 m) and gamma ray counts greater than 100 GAPI at some point of the thickness interval is presented in figure 21. The lines are hand drawn interpretations based on figures 4, 5, and 7 through 12.



**Figure 21.** Composite map representing areas where individual potash members are 9 ft (2.7 m) or greater in thickness and record a gamma ray count of 100 GAPI or greater.

## STRATIGRAPHIC POSITION OF POTASH ON GAMMA LOGS

West of the Nesson Anticline in Divide County, the potash members straddle the mid-point of the Prairie Formation, with the Patience Lake/Belle Plaine Members above and the White Bear/Esterhazy Members below. Approximately 40-50 ft (12-15 m) of halite separates the Belle Plaine Member from the White Bear Member in this area. East of the Nesson Anticline the Prairie Formation thickens and the potash layers become positioned higher in the Prairie Formation as the distance from the anticline increases (figs. 22 & 23).

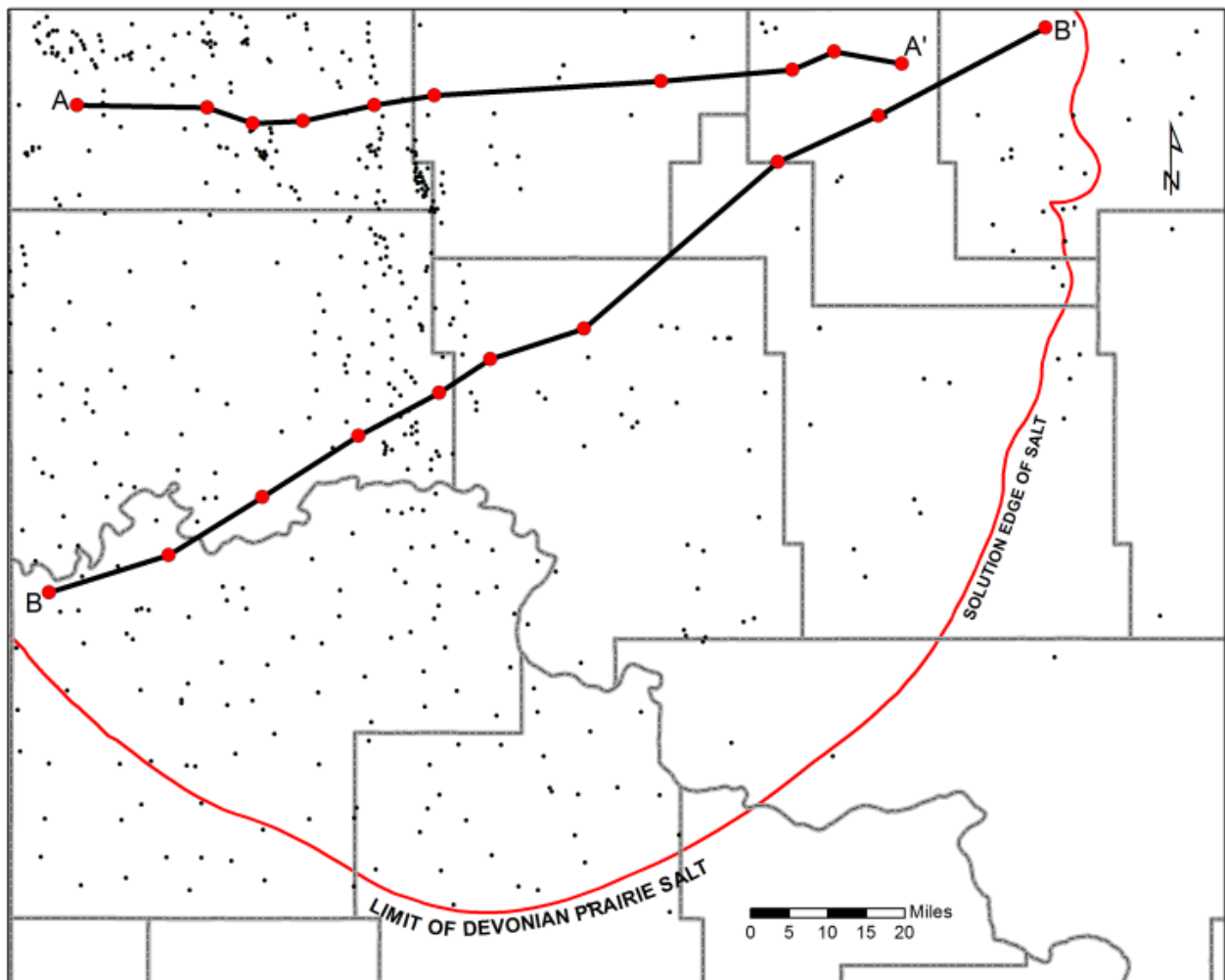
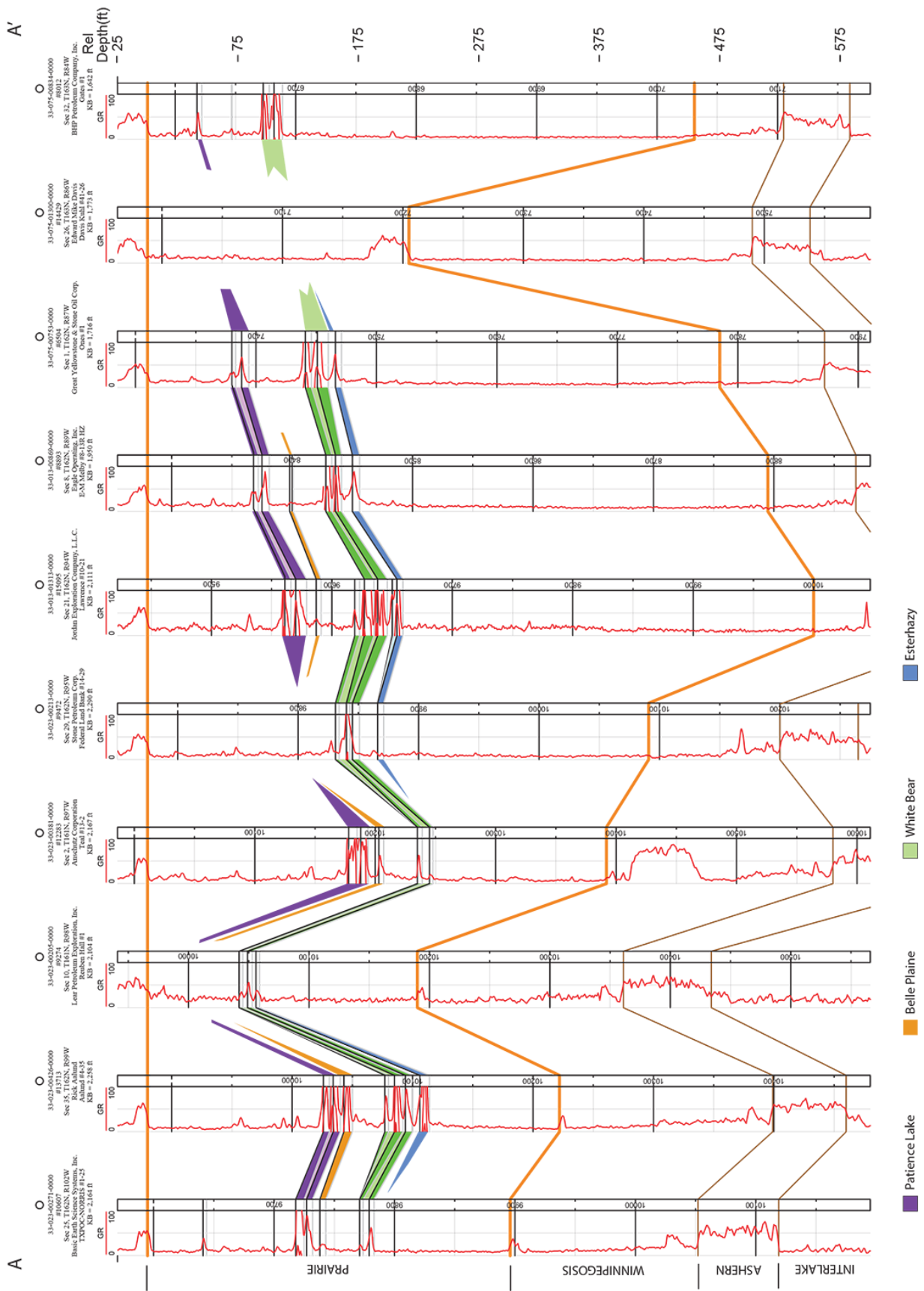
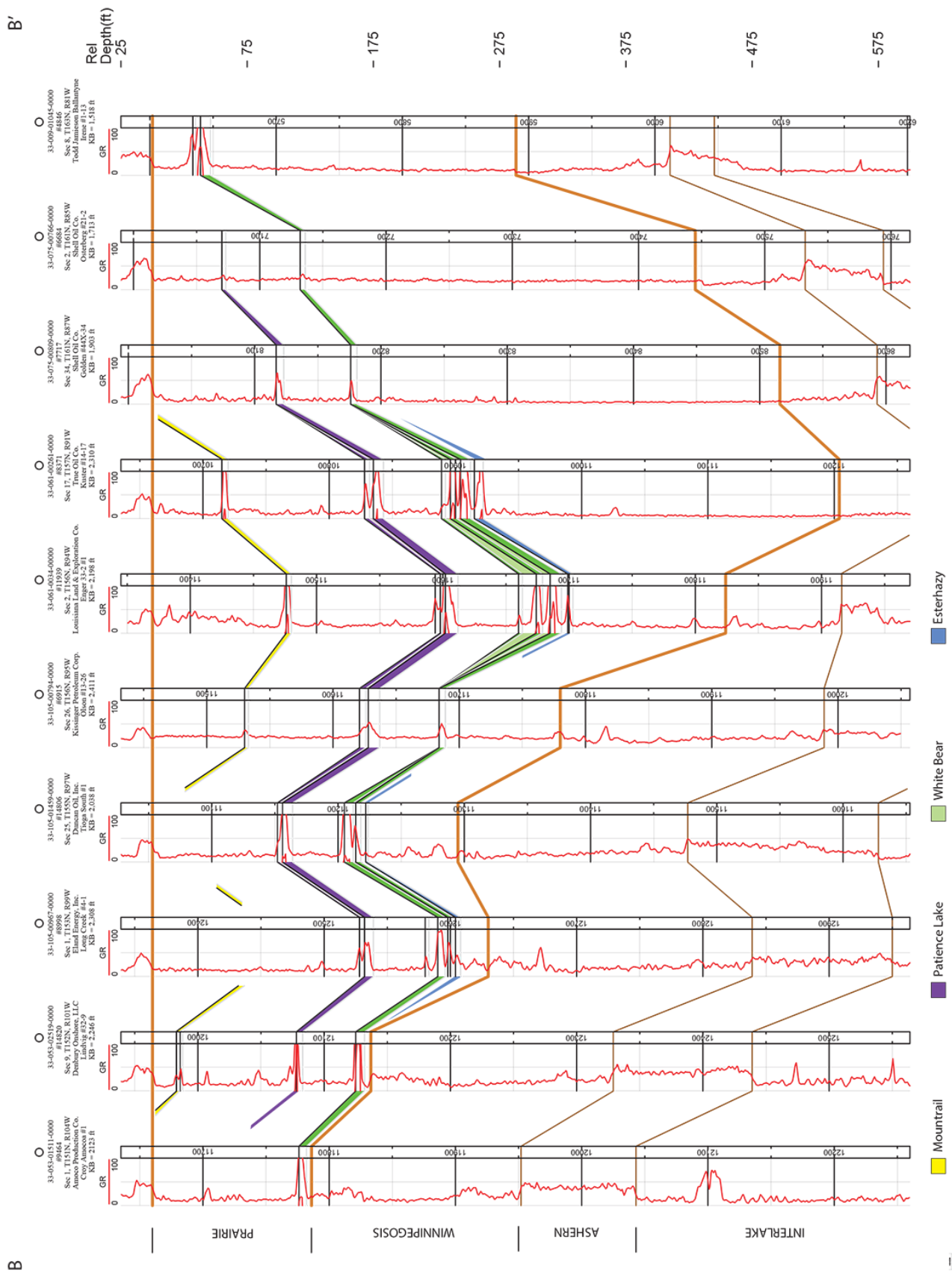


Figure 22. Study area showing the locations of cross-sections.

In northwestern McKenzie County, the White Bear Member is located near the bottom of the salt section. Potash layers progress upward through the salt section in a northeasterly direction, with the White Bear Member approaching the top of the Prairie Formation in northwestern Bottineau County (fig. 24).



**Figure 23.** West-east schematic cross-section A-A'. Note two wells (33-023-00205-0000 and 33-075-01300-0000) where the Prairie Formation salts are thinned, possibly due to partial salt dissolution or non-deposition. Location of the cross-section is shown in figure 22.



**Figure 24.** Southwest-northeast cross-section B-B'. Note offlap of potash members (White Bear to Mountrail) in both the southwestern and northeastern ends of the cross-section. Location of the cross-section is shown in figure 22.

Southeast of the Nesson Anticline, the Patience Lake, Belle Plaine, White Bear, and Esterhazy Members go from being centrally situated within the salt section to gradually lower in the section as it thins out toward the southeastern corner of Mountrail County. Throughout much of McKenzie County, the Esterhazy and White Bear Members occur near the base of the Prairie Formation. Figures 2, 6, 16 and 25 through 27 illustrate selected log sections through the potash layers of the Prairie Formation.

Blue Rock No. 29-18  
 NE SW 29-161-101  
 Divide County, ND

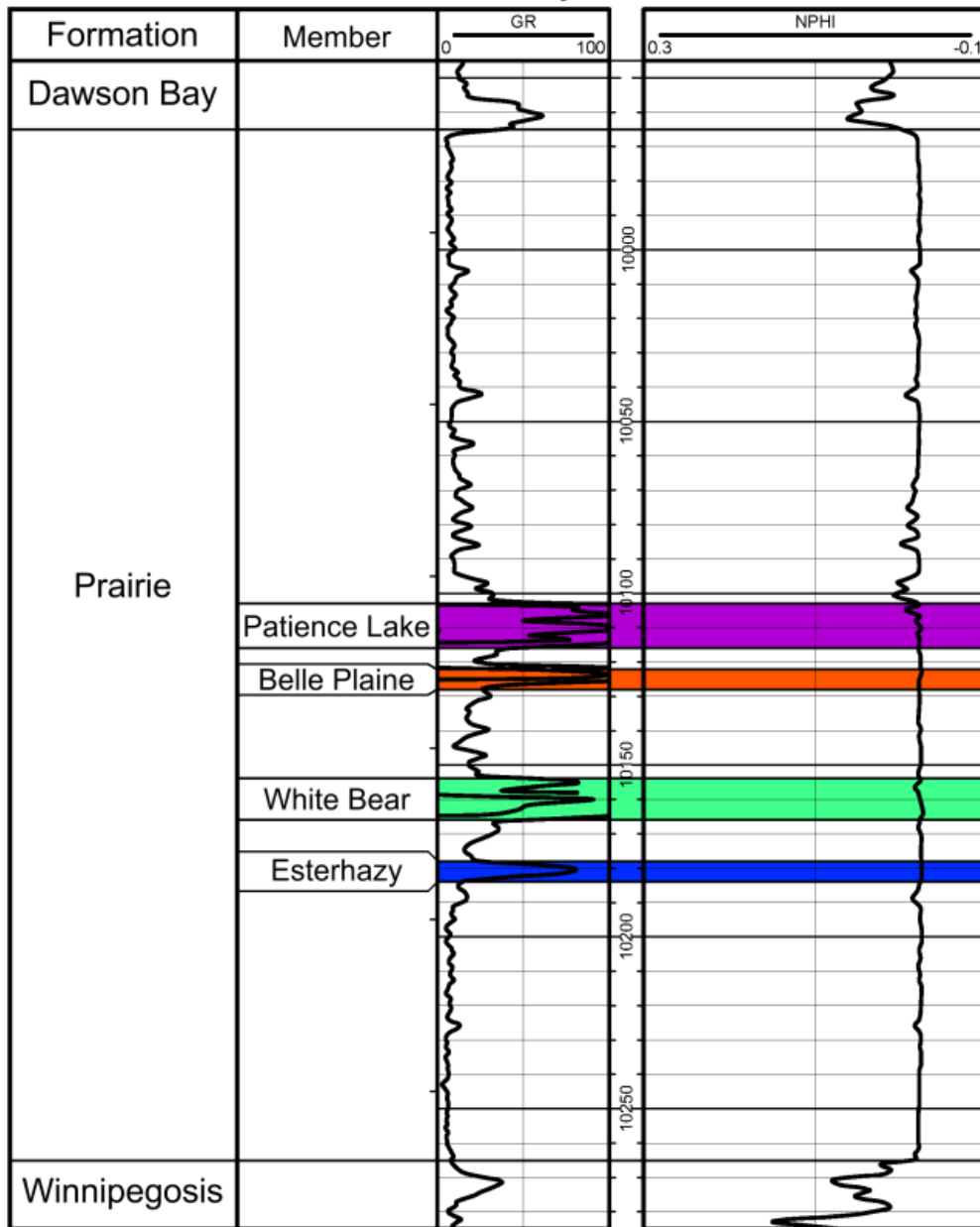


Figure 25. Log section of the Blue Rock No. 29-18 well, Divide County, showing the Prairie Formation.

Dakota Salts Eby-1  
 SE SE 31-163-91  
 Burke County, ND

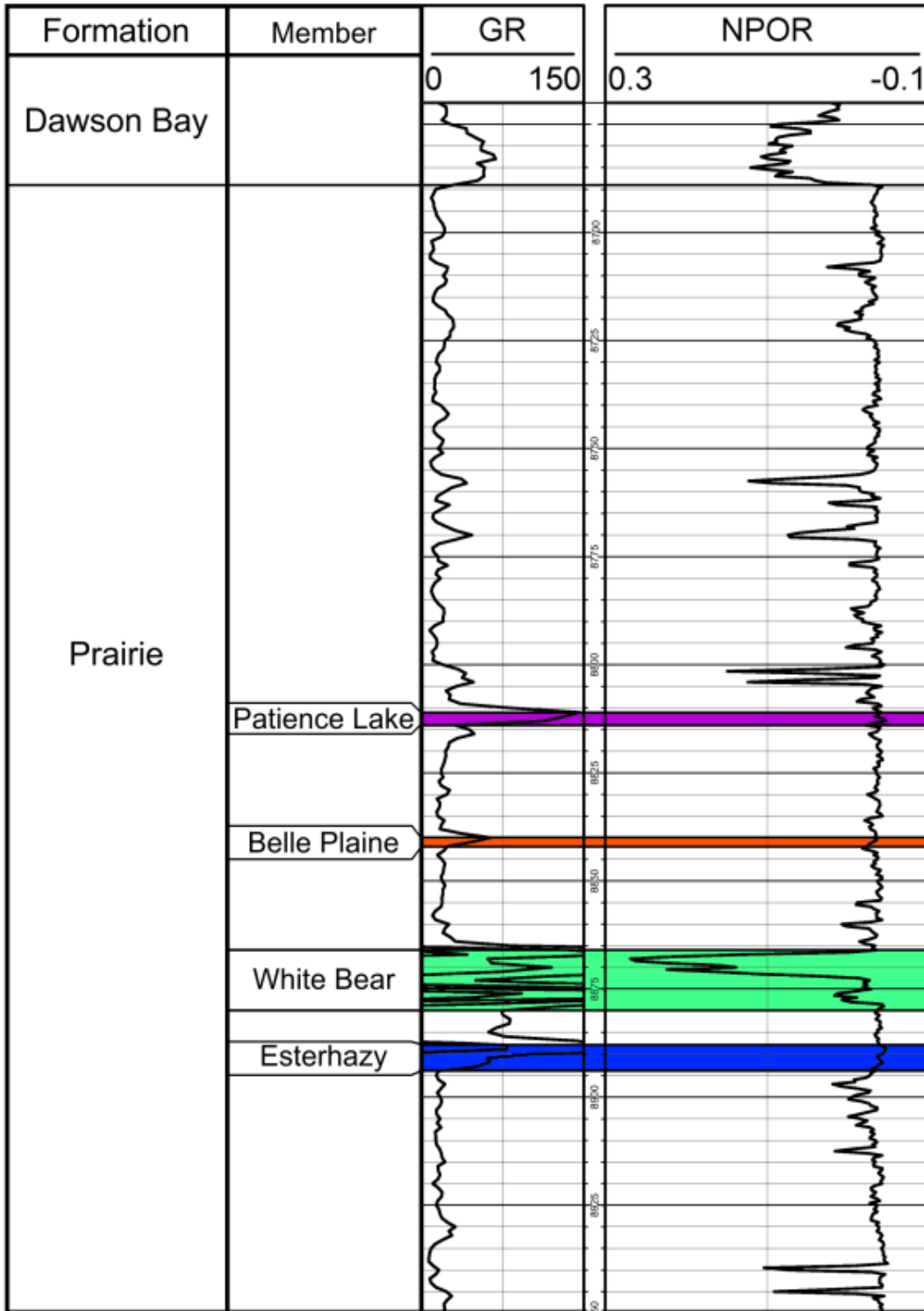
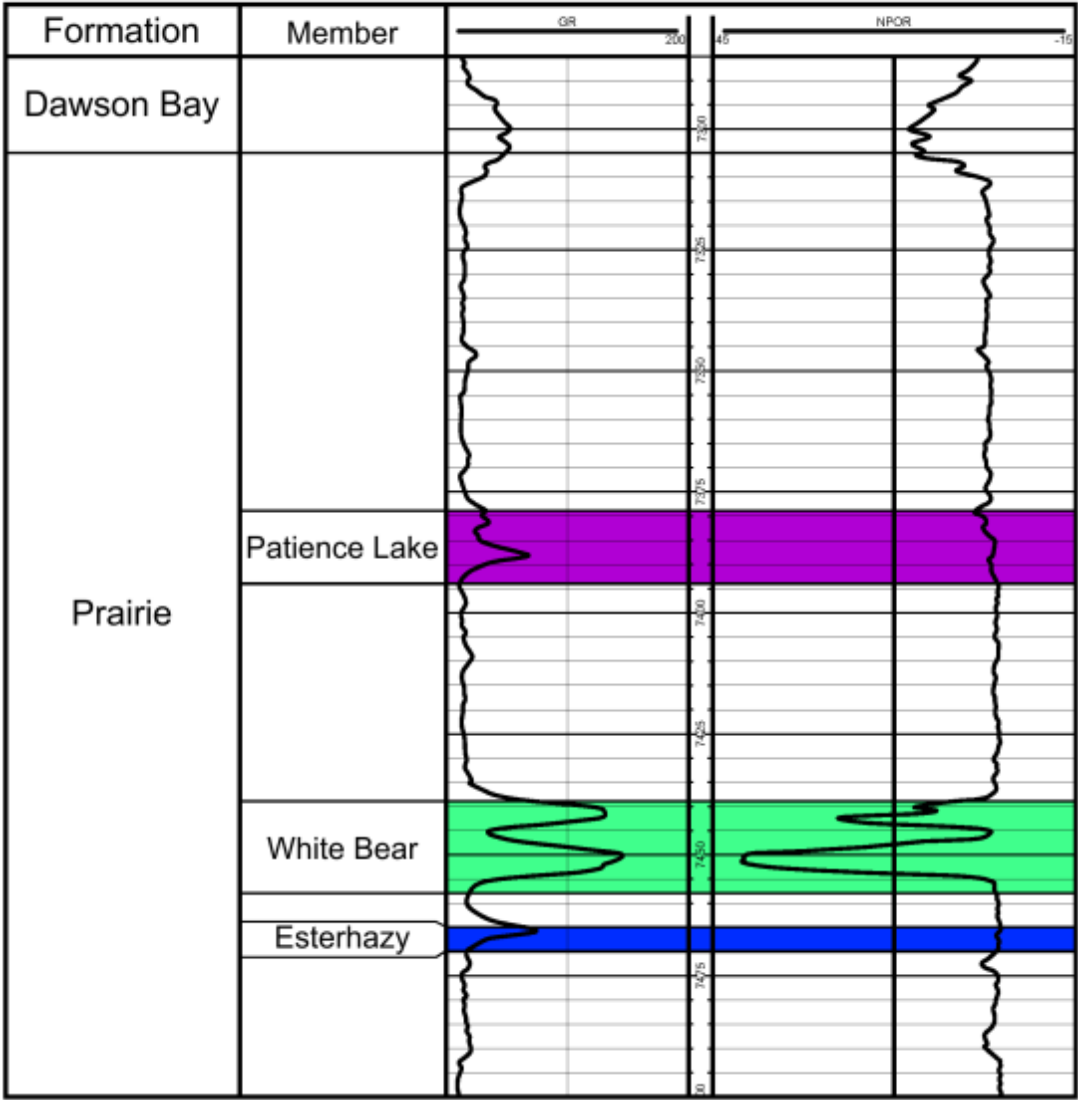


Figure 26. Log section of the Dakota Salts Eby-1 well, Burke County, showing the potash members of the Prairie Formation.

Great Yellowstone & Stone Oil Corp. Ones #1  
 SW NE 1-162-87  
 Renville County, ND



**Figure 27.** Log section of the Great Yellowstone & Stone Oil Corp. Ones #1 well, Renville County, showing the potash members of the Prairie Formation.

**MINERALOGY OF THE POTASH DEPOSITS**

The lack of significant coring and sampling activity through the Prairie Formation means there is limited mineralogical data for the Prairie Formation from North Dakota deposits. However, available data indicates the North Dakota deposits consists primarily of halite (NaCl) and the potassium containing salts, sylvite (KCl) and carnallite (KMgCl<sub>3</sub>·6H<sub>2</sub>O) along with insoluble material consisting of mainly of clay, but also possibly anhydrite and dolomite. This is consistent with the more widely studied Canadian equivalent Prairie Evaporite and is also supported by core analysis reports from the Dakota Salts Eby-1

and Kalium Chemical Ltd Ewing #3-3 potash exploration wells. Common in these reports are descriptions of coarse beds of halite, clear to buff and having a range of colors including white, yellow, orange, brown, and green; sometimes with clay-filled fractures and occasional blebs of sylvite. Potash intervals include medium coarse to fine sylvinitic with brick-red skins and green clay flakes; and carnallite ranging from massive to coarse or very coarse and present in violet, red, orange, and copper coloring. Occurring intermittently throughout the halite and potash beds are bands of clay, typically 0.1-0.3 ft (0.3-0.9 m) thick, but occasionally exceeding one foot (0.3 m) in thickness. The prevalence of clay increases above the Patience Lake Member throughout much of the study area. Two clay seams occurring between the Patience Lake and Mountrail Members appear to be sufficiently distinctive and widespread as to be useful as marker beds.

While the lack of core and sample data through the potash-containing beds limits the amount of available mineralogical data, estimates which may provide useful information for the planning of an exploration program can be made from widely available geophysical log data. The recent potash exploration test well in north-central Burke County, Dakota Salts Eby-1, has provided data from which estimates of the concentrations of carnallite and sylvite may be determined.

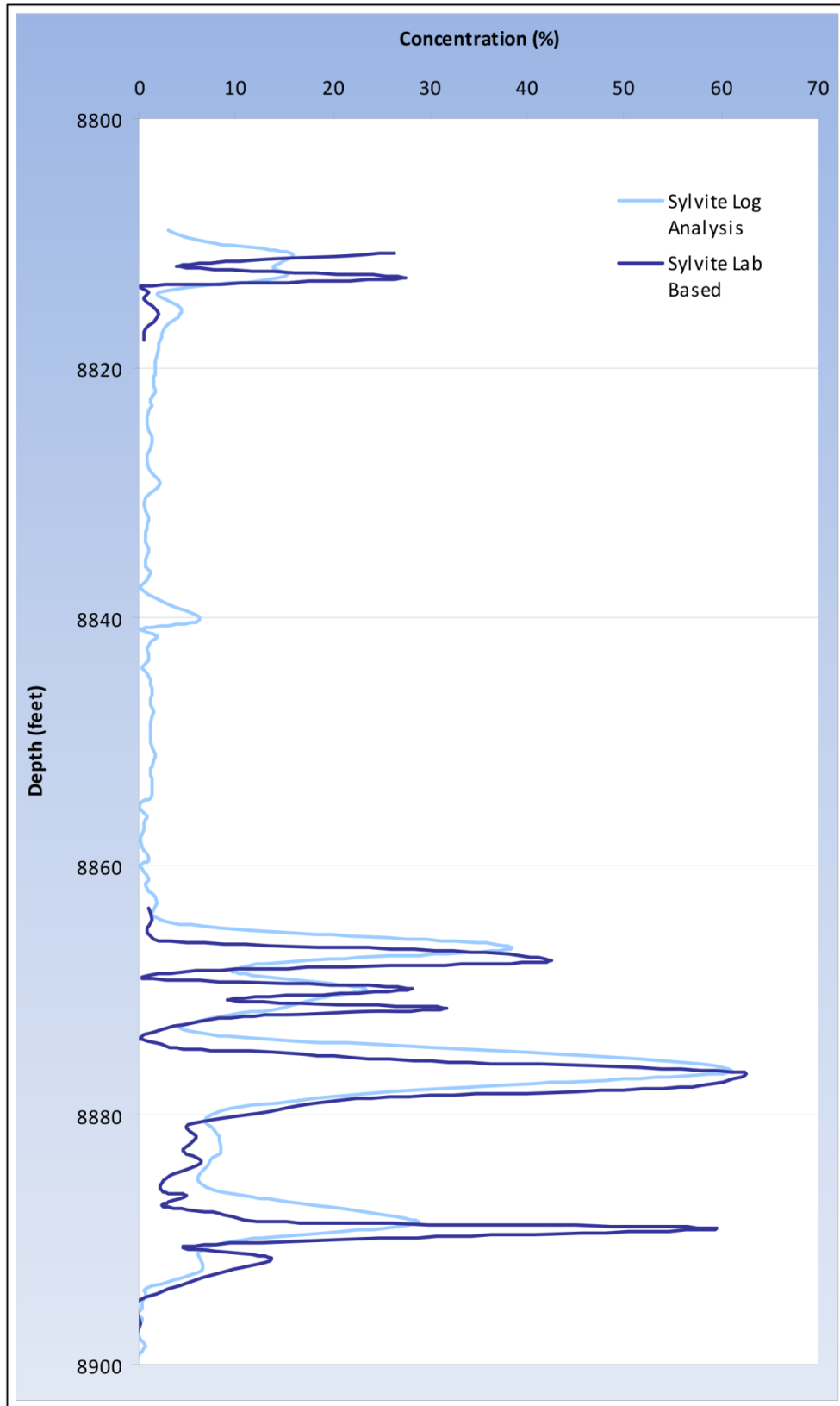
Quantitative log evaluation was performed using the method described in Crain and Anderson (1966) and Crain (2014), which utilizes the gamma ray log with a correction for borehole size and drilling mud weight, the neutron density log, and borehole compensated sonic log. Log data was entered into a spreadsheet at half-foot intervals and evaluated for concentrations of halite, sylvite, carnallite, and insoluble material. An adjustment to all neutron log measurements was made to best fit the log-derived carnallite concentrations to laboratory measurements. The sylvite and carnallite calculations, based on the log analysis, were plotted over the corresponding laboratory-derived measurements (figs. 28 and 29).

Where lab values exceed those from log analysis, the discrepancy may be due to a sample collected from a thin layer with higher radioactivity than the salt layers above and below it. The gamma ray logging tool is unable to isolate thin layers of high radioactivity and as a result, the recorded measurement at any point represents an average of a two- to three-foot interval. Thus, thin layers with high radioactivity become slightly widened and reduced in amplitude in the gamma ray measurements that are used in the log analysis calculations.

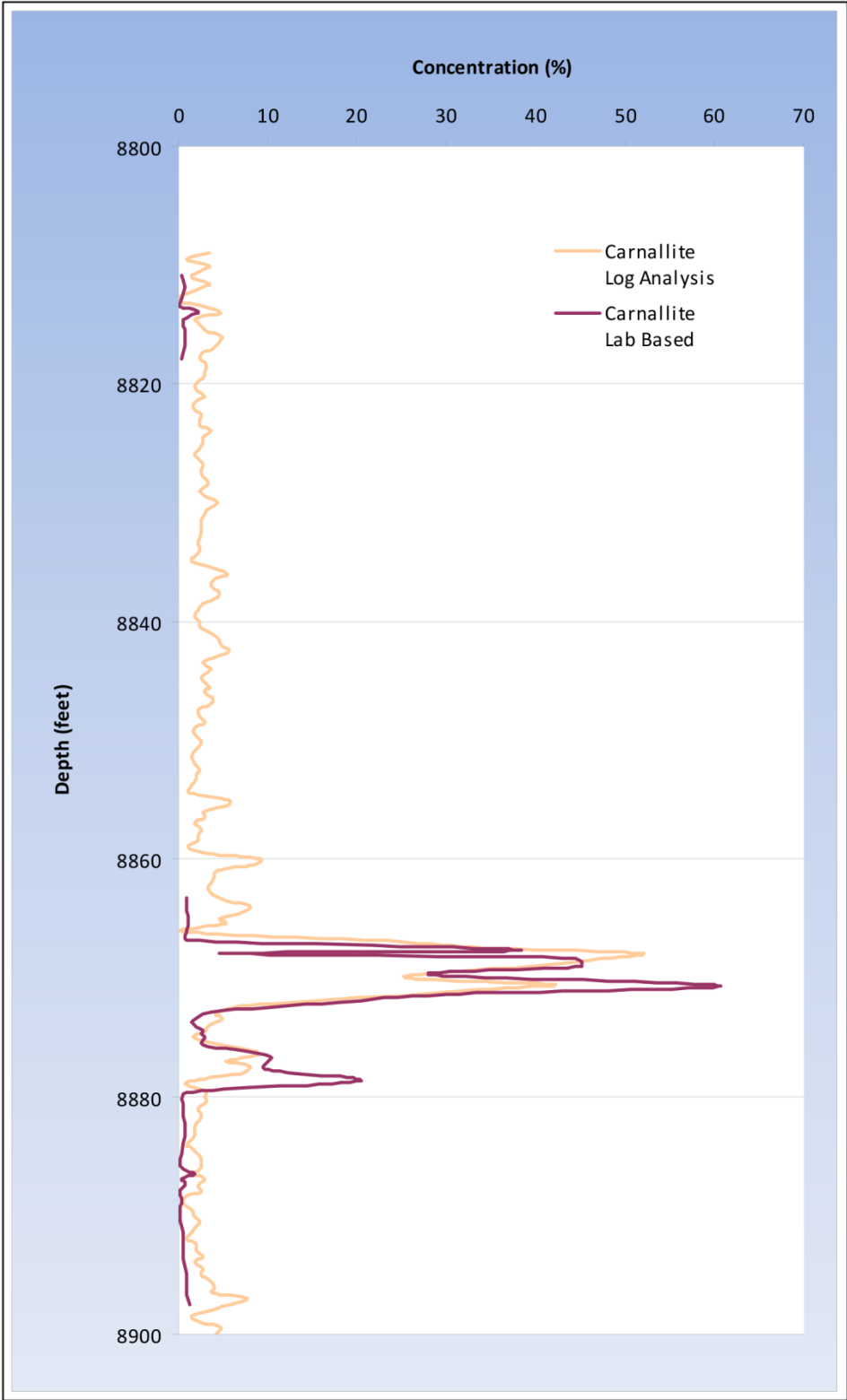
Neutron logs indicate that carnallite is likely present throughout most of Burke County. Carnallite appears to be most prevalent in the White Bear Member, but is also present in the Patience Lake Member near the western border of the county.

In her report on potash deposits in Saskatchewan, Fuzesy (1982) notes "where a member is enriched in carnallite its thickness is about 30 per cent greater than average." There is some indication that this localized thickening due to carnallite also occurs in North Dakota. Additional log evaluation studies are being conducted to estimate total potassium oxide ( $K_2O$ ) concentrations as well as the percent values of sylvite and carnallite in the potash zones throughout the basin.





**Figure 28.** Comparison of quantitative log analysis-derived sylvite concentrations to laboratory derived concentrations from the Dakota Salts Eby-1 well in Burke County.



**Figure 29.** Comparison of quantitative log analysis-derived carnallite concentrations to laboratory derived concentrations from the Dakota Salts Eby-1 well in Burke County.

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UW/VAP	WELL NAME	WELL NO	SURFACE ELEVATION	NS	FRASURE	WELL R	MH T-A	R-C	P-L	P-A	B-P	W-B	W-B-A	W-C	W-D	W-E	W-F	W-G	W-H	W-I	W-J	W-K	W-L	W-M	W-N	W-O	W-P	W-Q	W-R	W-S	W-T	W-U	W-V	W-W	W-X	W-Y	W-Z	A1	A2	A3	A4	A5	A6	A7	A8	A9	A0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B0	C1	C2	C3	C4	C5	C6	C7	C8	C9	D1	D2	D3	D4	D5	D6	D7	D8	D9	E1	E2	E3	E4	E5	E6	E7	E8	E9	F1	F2	F3	F4	F5	F6	F7	F8	F9	G1	G2	G3	G4	G5	G6	G7	G8	G9	H1	H2	H3	H4	H5	H6	H7	H8	H9	I1	I2	I3	I4	I5	I6	I7	I8	I9	J1	J2	J3	J4	J5	J6	J7	J8	J9	K1	K2	K3	K4	K5	K6	K7	K8	K9	L1	L2	L3	L4	L5	L6	L7	L8	L9	M1	M2	M3	M4	M5	M6	M7	M8	M9	N1	N2	N3	N4	N5	N6	N7	N8	N9	O1	O2	O3	O4	O5	O6	O7	O8	O9	P1	P2	P3	P4	P5	P6	P7	P8	P9	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	R1	R2	R3	R4	R5	R6	R7	R8	R9	S1	S2	S3	S4	S5	S6	S7	S8	S9	T1	T2	T3	T4	T5	T6	T7	T8	T9	U1	U2	U3	U4	U5	U6	U7	U8	U9	V1	V2	V3	V4	V5	V6	V7	V8	V9	W1	W2	W3	W4	W5	W6	W7	W8	W9	X1	X2	X3	X4	X5	X6	X7	X8	X9	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	AA1	AA2	AA3	AA4	AA5	AA6	AA7	AA8	AA9	AB1	AB2	AB3	AB4	AB5	AB6	AB7	AB8	AB9	AC1	AC2	AC3	AC4	AC5	AC6	AC7	AC8	AC9	AD1	AD2	AD3	AD4	AD5	AD6	AD7	AD8	AD9	AE1	AE2	AE3	AE4	AE5	AE6	AE7	AE8	AE9	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AG1	AG2	AG3	AG4	AG5	AG6	AG7	AG8	AG9	AH1	AH2	AH3	AH4	AH5	AH6	AH7	AH8	AH9	AI1	AI2	AI3	AI4	AI5	AI6	AI7	AI8	AI9	AJ1	AJ2	AJ3	AJ4	AJ5	AJ6	AJ7	AJ8	AJ9	AK1	AK2	AK3	AK4	AK5	AK6	AK7	AK8	AK9	AL1	AL2	AL3	AL4	AL5	AL6	AL7	AL8	AL9	AM1	AM2	AM3	AM4	AM5	AM6	AM7	AM8	AM9	AN1	AN2	AN3	AN4	AN5	AN6	AN7	AN8	AN9	AO1	AO2	AO3	AO4	AO5	AO6	AO7	AO8	AO9	AP1	AP2	AP3	AP4	AP5	AP6	AP7	AP8	AP9	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AR1	AR2	AR3	AR4	AR5	AR6	AR7	AR8	AR9	AS1	AS2	AS3	AS4	AS5	AS6	AS7	AS8	AS9	AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AU1	AU2	AU3	AU4	AU5	AU6	AU7	AU8	AU9	AV1	AV2	AV3	AV4	AV5	AV6	AV7	AV8	AV9	AW1	AW2	AW3	AW4	AW5	AW6	AW7	AW8	AW9	AX1	AX2	AX3	AX4	AX5	AX6	AX7	AX8	AX9	AY1	AY2	AY3	AY4	AY5	AY6	AY7	AY8	AY9	AZ1	AZ2	AZ3	AZ4	AZ5	AZ6	AZ7	AZ8	AZ9	BA1	BA2	BA3	BA4	BA5	BA6	BA7	BA8	BA9	BB1	BB2	BB3	BB4	BB5	BB6	BB7	BB8	BB9	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9	BD1	BD2	BD3	BD4	BD5	BD6	BD7	BD8	BD9	BE1	BE2	BE3	BE4	BE5	BE6	BE7	BE8	BE9	BF1	BF2	BF3	BF4	BF5	BF6	BF7	BF8	BF9	BG1	BG2	BG3	BG4	BG5	BG6	BG7	BG8	BG9	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BI1	BI2	BI3	BI4	BI5	BI6	BI7	BI8	BI9	BJ1	BJ2	BJ3	BJ4	BJ5	BJ6	BJ7	BJ8	BJ9	BK1	BK2	BK3	BK4	BK5	BK6	BK7	BK8	BK9	BL1	BL2	BL3	BL4	BL5	BL6	BL7	BL8	BL9	BM1	BM2	BM3	BM4	BM5	BM6	BM7	BM8	BM9	BN1	BN2	BN3	BN4	BN5	BN6	BN7	BN8	BN9	BO1	BO2	BO3	BO4	BO5	BO6	BO7	BO8	BO9	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BQ1	BQ2	BQ3	BQ4	BQ5	BQ6	BQ7	BQ8	BQ9	BR1	BR2	BR3	BR4	BR5	BR6	BR7	BR8	BR9	BS1	BS2	BS3	BS4	BS5	BS6	BS7	BS8	BS9	BT1	BT2	BT3	BT4	BT5	BT6	BT7	BT8	BT9	BU1	BU2	BU3	BU4	BU5	BU6	BU7	BU8	BU9	BV1	BV2	BV3	BV4	BV5	BV6	BV7	BV8	BV9	BW1	BW2	BW3	BW4	BW5	BW6	BW7	BW8	BW9	BX1	BX2	BX3	BX4	BX5	BX6	BX7	BX8	BX9	BY1	BY2	BY3	BY4	BY5	BY6	BY7	BY8	BY9	BZ1	BZ2	BZ3	BZ4	BZ5	BZ6	BZ7	BZ8	BZ9	CA1	CA2	CA3	CA4	CA5	CA6	CA7	CA8	CA9	CB1	CB2	CB3	CB4	CB5	CB6	CB7	CB8	CB9	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CD1	CD2	CD3	CD4	CD5	CD6	CD7	CD8	CD9	CE1	CE2	CE3	CE4	CE5	CE6	CE7	CE8	CE9	CF1	CF2	CF3	CF4	CF5	CF6	CF7	CF8	CF9	CG1	CG2	CG3	CG4	CG5	CG6	CG7	CG8	CG9	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CI1	CI2	CI3	CI4	CI5	CI6	CI7	CI8	CI9	CJ1	CJ2	CJ3	CJ4	CJ5	CJ6	CJ7	CJ8	CJ9	CK1	CK2	CK3	CK4	CK5	CK6	CK7	CK8	CK9	CL1	CL2	CL3	CL4	CL5	CL6	CL7	CL8	CL9	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9	CN1	CN2	CN3	CN4	CN5	CN6	CN7	CN8	CN9	CO1	CO2	CO3	CO4	CO5	CO6	CO7	CO8	CO9	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CQ1	CQ2	CQ3	CQ4	CQ5	CQ6	CQ7	CQ8	CQ9	CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9	CU1	CU2	CU3	CU4	CU5	CU6	CU7	CU8	CU9	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8	CV9	CW1	CW2	CW3	CW4	CW5	CW6	CW7	CW8	CW9	CX1	CX2	CX3	CX4	CX5	CX6	CX7	CX8	CX9	CY1	CY2	CY3	CY4	CY5	CY6	CY7	CY8	CY9	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	DA1	DA2	DA3	DA4	DA5	DA6	DA7	DA8	DA9	DB1	DB2	DB3	DB4	DB5	DB6	DB7	DB8	DB9	DC1	DC2	DC3	DC4	DC5	DC6	DC7	DC8	DC9	DD1	DD2	DD3	DD4	DD5	DD6	DD7	DD8	DD9	DE1	DE2	DE3	DE4	DE5	DE6	DE7	DE8	DE9	DF1	DF2	DF3	DF4	DF5	DF6	DF7	DF8	DF9	DG1	DG2	DG3	DG4	DG5	DG6	DG7	DG8	DG9	DH1	DH2	DH3	DH4	DH5	DH6	DH7	DH8	DH9	DI1	DI2	DI3	DI4	DI5	DI6	DI7	DI8	DI9	DJ1	DJ2	DJ3	DJ4	DJ5	DJ6	DJ7	DJ8	DJ9	DK1	DK2	DK3	DK4	DK5	DK6	DK7	DK8	DK9	DL1	DL2	DL3	DL4	DL5	DL6	DL7	DL8	DL9	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DN1	DN2	DN3	DN4	DN5	DN6	DN7	DN8	DN9	DO1	DO2	DO3	DO4	DO5	DO6	DO7	DO8	DO9	DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	DP9	DQ1	DQ2	DQ3	DQ4	DQ5	DQ6	DQ7	DQ8	DQ9	DR1	DR2	DR3	DR4	DR5	DR6	DR7	DR8	DR9	DS1	DS2	DS3	DS4	DS5	DS6	DS7	DS8	DS9	DT1	DT2	DT3	DT4	DT5	DT6	DT7	DT8	DT9	DU1	DU2	DU3	DU4	DU5	DU6	DU7	DU8	DU9	DV1	DV2	DV3	DV4	DV5	DV6	DV7	DV8	DV9	DW1	DW2	DW3	DW4	DW5	DW6	DW7	DW8	DW9	DX1	DX2	DX3	DX4	DX5	DX6	DX7	DX8	DX9	DY1	DY2	DY3	DY4	DY5	DY6	DY7	DY8	DY9	DZ1	DZ2	DZ3	DZ4	DZ5	DZ6	DZ7	DZ8	DZ9	EA1	EA2	EA3	EA4	EA5	EA6	EA7	EA8	EA9	EB1	EB2	EB3	EB4	EB5	EB6	EB7	EB8
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