PERMIAN TO JURASSIC REDBEDS OF THE WILLISTON BASIN

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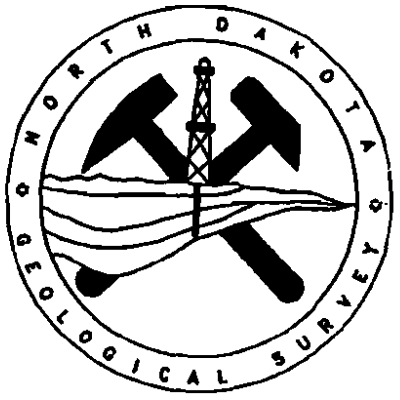

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ABSTRACT

Redbeds of Permian to Jurassic age are present in outcrops in the Black Hills of South Dakota. Redbeds, which have been referred to as Jurassic in age, are present in outcrops in southern Manitoba. In the subsurface, equivalent strata are referred to as the Spearfish Formation of Triassic or Permo-Triassic age in North Dakota and the lower Watrous or Amaranth Formations of Jura-Triassic or Jurassic age in Saskatchewan and Manitoba. Paleontological data are lacking for age resolution. A careful examination of physical evidence from the subsurface indicates that previously unrecognized regional unconformities occur within the clastic redbeds. Areal distribution patterns of these lithogenetic units favor the Jurassic age assignment for a part of the Lower Watrous and Amaranth Formations.

The Spearfish Formation, as originally defined, includes redbeds, which have been correlated with strata from Permian to Jurassic age in eastern Wyoming, although these beds were originally generally assigned a Triassic age. The Spearfish Formation will retain its greatest utility in the subsurface if it is restricted to strata of Permian to Triassic age. Redefinition of the Belfield and Pine units would avoid the introduction of new names and, by applying them to the two lithogenetic units within the Spearfish, would more accurately portray the depositional history of these strata. Similarly a redefinition of the Saude, closely resembling the original definition, would preserve the utility of that term.

INTRODUCTION

Since the earliest days of exploration in the Williston Basin the age and correlation of redbeds has been controversial. Zieglar (1956, p. 170) noted at the First Williston Basin Symposium that "on the basis of stratigraphic position and gross lithology the pre-Piper, post-Minnekahta redbeds in the subsurface of the Williston Basin are considered by many American geologists to be correlative with the Spearfish Formation of Permo-Triassic age. On the other hand, Canadian workers believe that the pre-Piper redbeds in Manitoba and Saskatchewan are lower middle or lower Jurassic in age." The strata referred to as Lower Amaranth in Manitoba or Lower Watrous in Saskatchewan are physically equivalent to strata referred to as Saude or Spearfish in North Dakota. No paleontological evidence has been found to reconcile the differing age interpretations, so conclusive resolution of this question is not yet possible. However, a careful examination of physical evidence provided by Dual Laterologs suggests a most likely solution.

Nearly all exploration wells penetrate the complete Mesozoic section so wells with Dual Laterologs were randomly selected at one or two per township in areas of active exploration. All available logs were used in less active areas. This density is sufficient to provide a regional pattern for most of the strata. The halites have erratic patterns in some areas due to solution so details of presence or absence of halite cannot be shown in all areas on these maps.

PREVIOUS WORK

South Dakota

The term Spearfish Formation was introduced by Darton (1899, p. 387) to refer to redbeds present between the Minnekahta Limestone (Permian) and the Sundance Formation (Jurassic) in the northern Black Hills, South Dakota. The name is derived from the town of Spearfish, but no type section was designated. Lacking paleontological evidence a Triassic (?) age assignment was given on the basis of stratigraphic position. A portion of the strata referred to as Spearfish in the outcrops of the Black Hills has been correlated with Gypsum Spring (Jurassic) strata of Wyoming (Imlay, 1947, p. 237). The Minnekahta Limestone and overlying redbeds of the Spearfish Formation of South Dakota have been shown as correlative with the Goose Egg Formation of Permo-Triassic age of Wyoming (Rascoe, 1972, p. 160).

Manitoba

Seager and others (1942, p. 1415) introduced the term Amaranth Formation for redbeds and evaporites which he referred to as Devonian. Stott (1955, p. 7) defined the term Amaranth Formation as redbeds, evaporites, and carbonates of Jurassic or older age overlying Paleozoic strata in Manitoba. Stott divided the Amaranth into an upper carbonate

and evaporite member of Jurassic age and a lower, unfossiliferous redbed member, which was also assigned a Jurassic age. The Lower Amaranth was further subdivided (Barchyn, 1982, p. 5) into an upper shaly unit and a lower sandy unit. He agreed with the Jurassic age assignment of the entire Amaranth based on a conformable relationship of the Upper and Lower Members of the Amaranth Formation. Barchyn (1982, p. 107) suggested variable depositional conditions for the lower sandy sequence whereas the consistency of log characteristics of the upper shaly sequence was regarded as evidence for more stable conditions in a marine-associated environment. Husain (1991, p. 152) referred to the Lower Amaranth as Jura-Triassic while noting a lack of paleontological evidence for an age assignment.

Saskatchewan

Milner and Thomas (1954, p. 255) introduced the term Watrous Formation to refer to Jurassic redbeds together with carbonates and evaporites overlying Paleozoic strata in Saskatchewan (= Amaranth of Manitoba). Francis (1957, p. 376) referred to the lower portion of Watrous strata as the Jura-Triassic redbeds while noting that the contact with the overlying non-clastics member of the Watrous was gradational. Carlson (1968, p. 1978) referred to the Lower Watrous as "equivalent to the Triassic Spearfish southward where the Jurassic-Triassic boundary is undisputed. Because it has been established that the Spearfish is of Late Permian and Early Triassic age . . ." (Presumably referring to the South Dakota-Wyoming correlations). Christopher (1982, p. 85-87) reviewed the age questions and equated the Lower Watrous of Saskatchewan to the Upper Spearfish floored by the Pine Salt in North Dakota (Saude of current usage). He noted that this interpretation suggests an early Triassic age for the lower Watrous and implies an unconformity and a hiatus spanning Middle Triassic and Early Jurassic between the Lower and Upper Watrous. However, on his stratigraphic cross section (1982, fig. 5, p. 87) Christopher places an unconformity at the base of the Watrous, but does not separate the Lower and Upper Watrous with an unconformity. Kreis (1991, p. 167) considered the Lower Watrous as largely Early Triassic based on stratigraphic considerations "with an undefined portion of the uppermost part possibly being Early to Middle Jurassic."

North Dakota

Laird (1951) referred to the redbeds and evaporites overlying the Permian Minnekahta Limestone as the Spearfish Formation of Triassic age. Zieglar (1956, p. 177) proposed a revision, restricting Spearfish to a portion of those strata and introduced the terms Pine Salt, Saude Formation and Dunham Salt (fig. 1) for the rest of these strata. He recognized a pre-Jurassic regional unconformity, which he considered as coincident with the base of the Pine Salt.

Dow (1967, p. 14) introduced the currently accepted nomenclature for these redbeds and evaporites in North Dakota (fig. 1). He recognized the Dunham Salt as a facies of the Poe evaporite member of the Piper Formation so he transferred the Dunham Salt to the Jurassic Piper Formation. He redefined the Saude to include the "G marker bed" and the clastics between the "G marker bed" and the main halite bed, which he then referred to as the Pine Salt. He introduced the term Belfield Member for the clastics between the Minnekahta Limestone and Pine Salt. He used the terms Belfield, Pine, and Saude as members of the Spearfish Formation. He assigned a Permo-Jurassic age to these strata as he did not recognize any unconformity within the redbeds and evaporites. He used Saude and Spearfish synonomously in the area north and east of the limit of Pine Salt.

Rascoe (1972, p. 148) accepted a disconformity at the base of the Pine Salt, but considered it to be an intra-Guadalupe disconformity. He placed the pre-Jurassic unconformity at the base of the Poe or Dunham evaporites.

The Williston Basin nomenclature chart (Bluemle, et al., 1981) places the Triassic-Permian boundary at the top of the Pine Salt with a conformable relationship between the Spearfish and Minnekahta Formations. The North Dakota Stratigraphic Column (Bluemle, et al., 1986) has the Saude, Pine, and Belfield as members of the Spearfish Formation, and assigns a Permo-Triassic age to these strata. They recognize a pre-Jurassic unconformity, which they place at the base of the Dunham or Poe Members of the Jurassic Piper Formation.

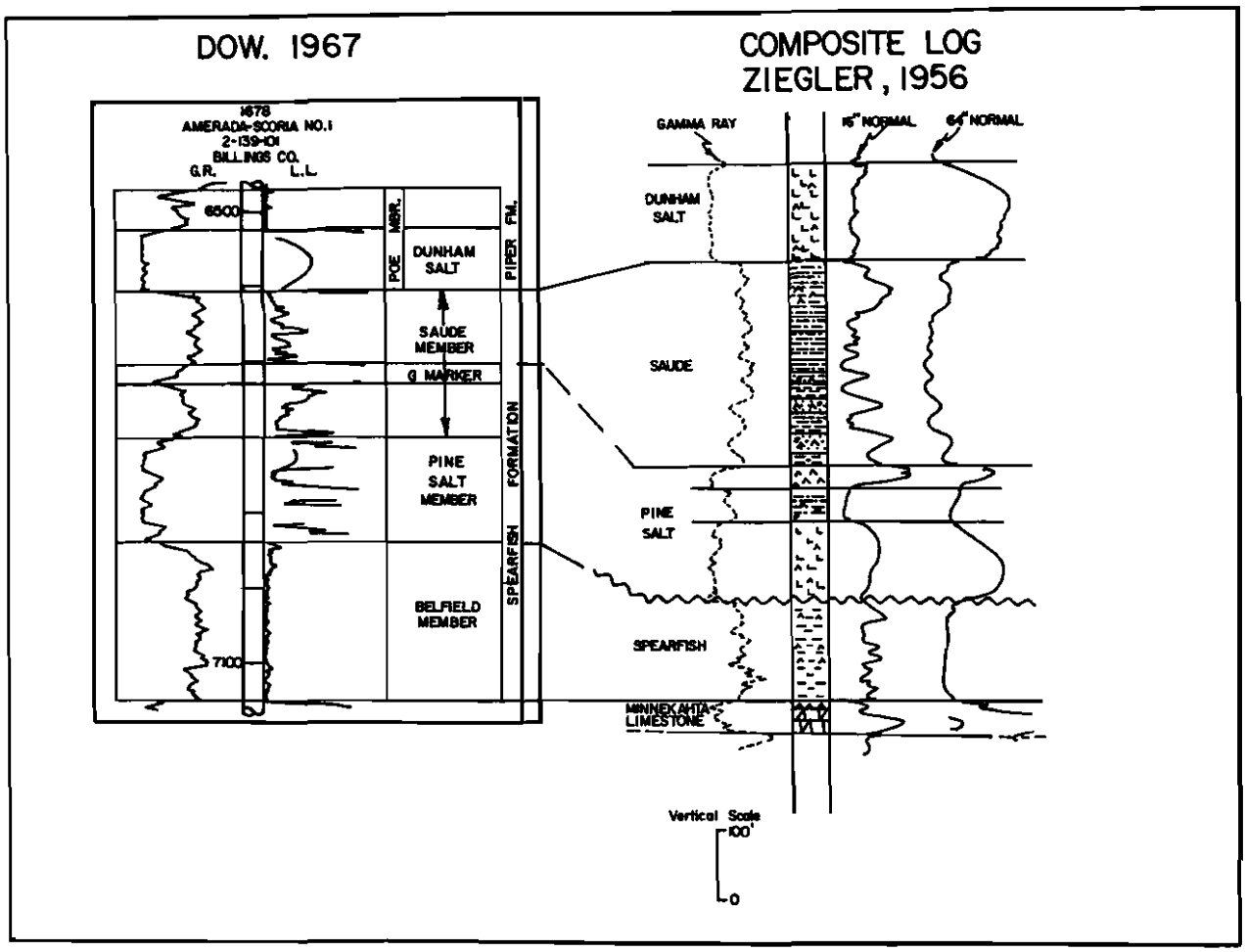


Figure 1. Typical log characteristics and stratigraphic nomenclature of redbed strata.

NEW INTERPRETATIONS

Three episodes of halite deposition have occurred in the Williston Basin from the Permian through Jurassic time span. The halites and the Minnekahta Limestone are distinctive lithologies that have been used to divide these strata into stratigraphic units. These recognized subdivisions have provided useful mapping units where the halites are present. However, these units are not lithogenetic units, their use tends to mask the geologic history, and the clastics of the Belfield and Saude units have been combined as Saude in areas to the north and east of the limit of the halite.

Careful examination of Dual Laterologs indicates that previous interpretations have either misplaced (Zieglar, 1956; Rascoe, 1972; Bluemle, et al., 1981, 1986), or ignored (Dow, 1967), unconformities present within the strata currently referred to as the Spearfish Formation in North Dakota. The unconformities, rather than being at the base of the halites, are within the clastics currently referred to as the Belfield and Saude Members of the Spearfish Formation. Recognition of these unconformities shows that the Dunham and "P" (Pine) salts, like the Opeche Salt, are part of depositional episodes which begin and end with clastics. The areal extent of the "G Salt" and the presence of clastics between the "G Salt" and the underlying halite clearly indicate that they are part of the same depositional episode. Referring to the main halite bed as the "P Salt" eliminates duplication of the term Pine.

I would propose that the terms Saude, Pine, and Belfield should be redefined to reflect lithogenetic units. The Saude and Belfield should be

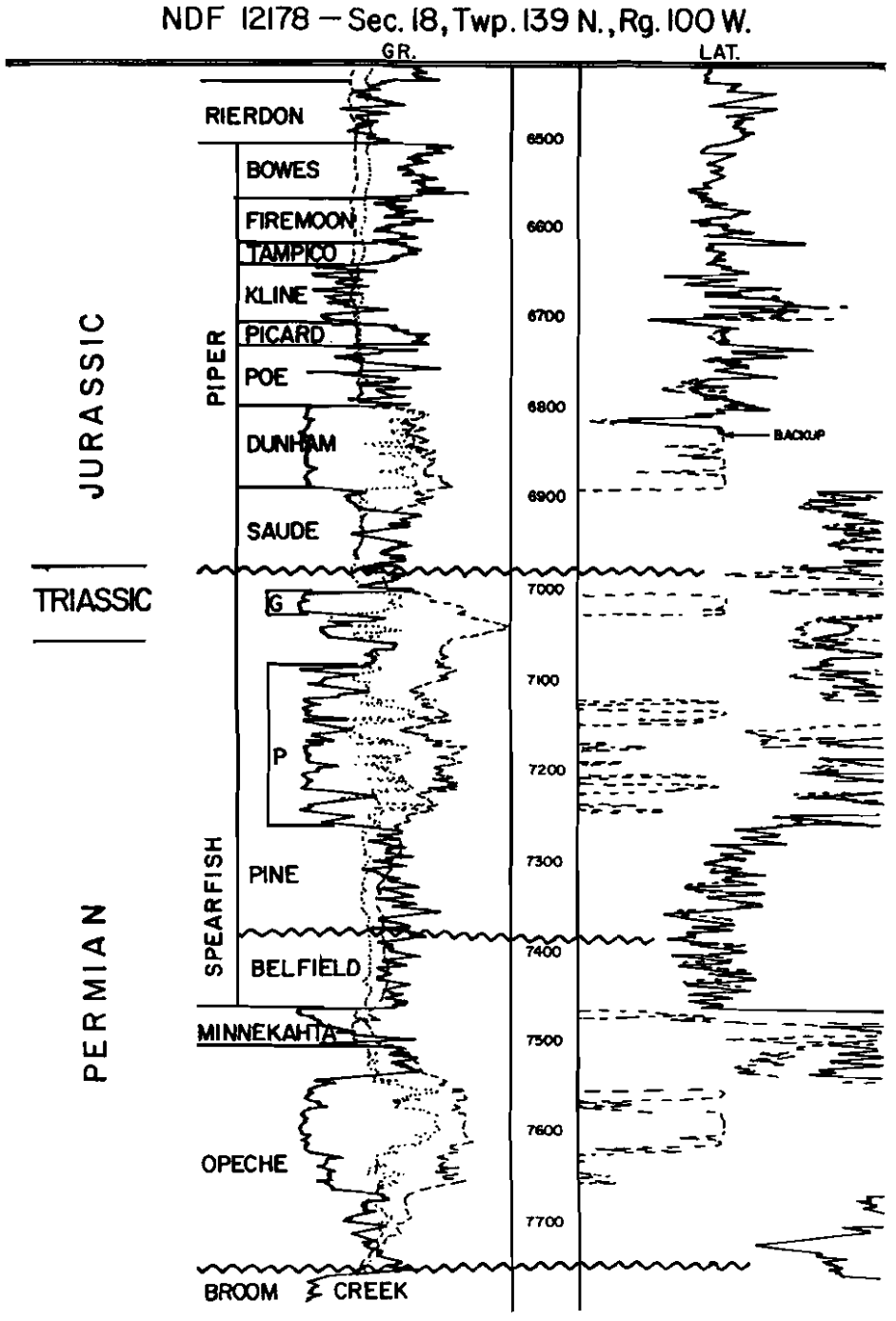


Figure 2. Typical log characteristics and revised stratigraphic nomenclature for Jurassic to Permian redbed strata.

restricted to portions of the strata currently referred to these units with the remaining portions added to the Pine. I would use Belfield and Pine as members of the Spearfish Formation of Permo-Triassic age. I would transfer the Saude as a member to the Piper Formation of Jurassic age (fig. 2).

STRATIGRAPHIC REVIEW

Permian

Deposition of the Opeche Formation began with red clastics followed by halite in the central basin area and then red clastics before deposition of the Minnekahta Limestone. Current extent of the halite (fig. 3) indicates depositional thicknesses have been preserved except for the southeast margin through Stark and Dunn Counties where rapid thinning from 100 feet to absent indicates a solutional margin. Depositional thicknesses of the Opeche Formation are preserved where the Minnekahta Formation is present (fig. 4). Similarly, depositional thicknesses of the Minnekahta Formation have been preserved where the Belfield Member of the Spearfish Formation is present (fig. 5).

Two distinct laterolog characteristics (see cross sections A-A' and B-B', plates 1 and 2) are present within the clastics between the Minnekahta Limestone and the halite referred to as the Pine Salt. I believe this marks an unconformity and I believe that the term Belfield will retain its utility if it is redefined as the clastics between the Minnekahta Limestone and the unconformity. It is recognized by higher resistivity readings on the laterolog. The overall distribution of the redefined Belfield Member with its zero edge closely parallel to the 35-foot contour of the Minnekahta Limestone and the rapid thinning from 50 feet to a zero edge to the north and east indicate erosional limits for the Belfield Member in those areas (fig. 6).

The Opeche and Minnekahta have always been assigned a Permian age. The Pine Salt has been correlated as Permian (Rascoe, 1972, Bluemle, et al., 1981) which then requires that the Belfield Member, as redefined, be assigned a Permian age.

Permo-Triassic

The term Pine would have its greatest utility if it were redefined similar to its original definition to include halites and associated clastics. Deposition would then begin with the clastics between the Belfield Member and the "P Salt" continuing through the "G Salt" and concluding with clastics above the "G Salt" (see cross sections A-A' and B-B', plate 1).

The "G Salt" (fig. 7) appears to have depositional thicknesses preserved. The "P Salt" (fig. 8) also has depositional thicknesses preserved in most areas. The eastern margin of the "P Salt" is likely a solution margin and there are some areas, particularly along the Nesson Anticline, where solution may have altered thicknesses. The preservation of depositional thicknesses of these halites in most areas indicates that clastic deposition must have succeeded evaporite deposition before any erosional episode.

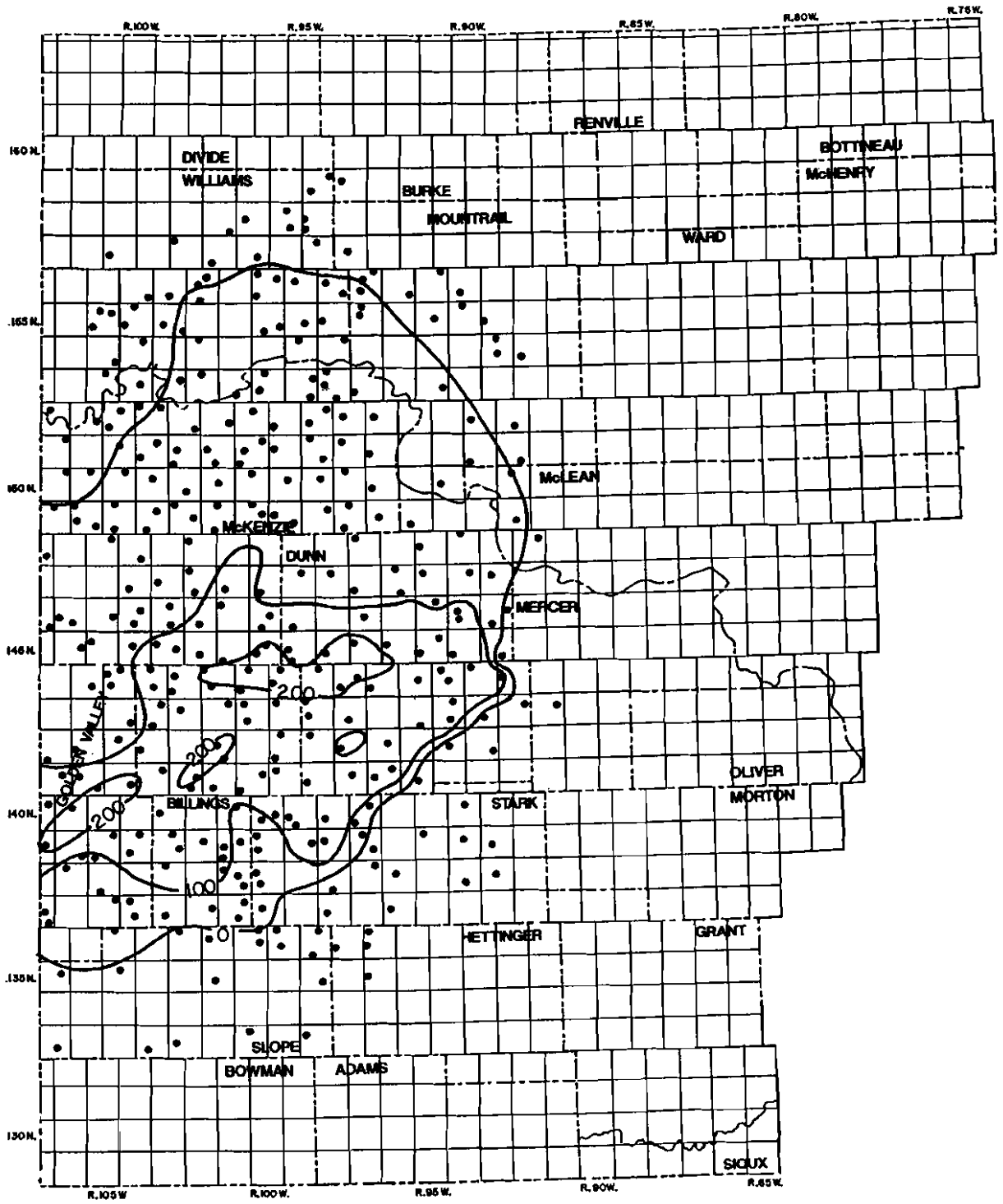
The red clastics between the Belfield Member and the "P Salt" are approximately the same thickness as the Pine clastics to the east of the limit of the "P Salt" in southwestern North Dakota. If we accept the Permian age ascribed to the Pine Salt (Rascoe, 1972), then these clastics must also be of Permian age.

The area of greatest thickness of the Pine Member (fig. 9) is in the area where the "G Salt" is present and in the area of maximum thickness of the "P Salt." In those areas, clastics are relatively thin in the upper portion of the Pine Member. Proceeding northward, as the "P Salt" thins, the clastics below the "P Salt" thin while the clastics overlying the "P Salt" thicken (plate 1). Assuming a facies relationship between the evaporites and the clastics, this would imply a Permian age for most of the Pine clastics where halite is absent.

The "G Salt" has been correlated with the Little Medicine Tongue of the Goose Egg Formation of Wyoming which is considered to be Triassic in age. This correlation would imply a Triassic age for the overlying clastics and a Permo-Triassic age assignment for the redefined Pine Member (fig. 2).

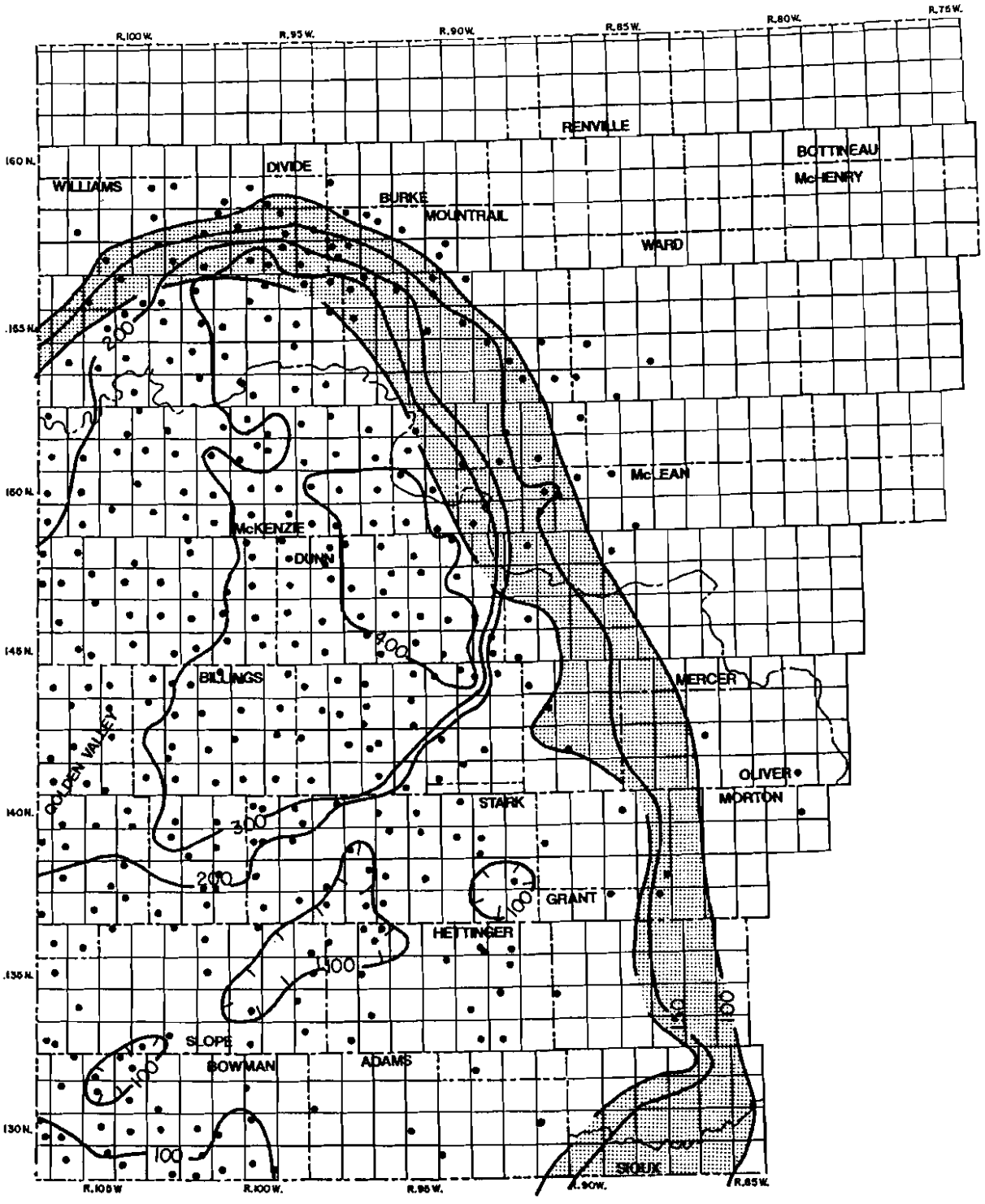
Jurassic

The Rierdon and Piper Formations are of unquestioned Jurassic age and have depositional thicknesses preserved in most areas of western North Dakota. The Piper Formation, as currently recognized in North Dakota, is equivalent to the Nesson Formation as defined by Nordquist (1955) plus the Dunham Salt. Nordquist (1955) defined six members and these members are recognizable in the central basin area, but facies changes make it difficult to trace the units south and eastward. Current Montana usage is to restrict the term



Contour Interval 100 feet

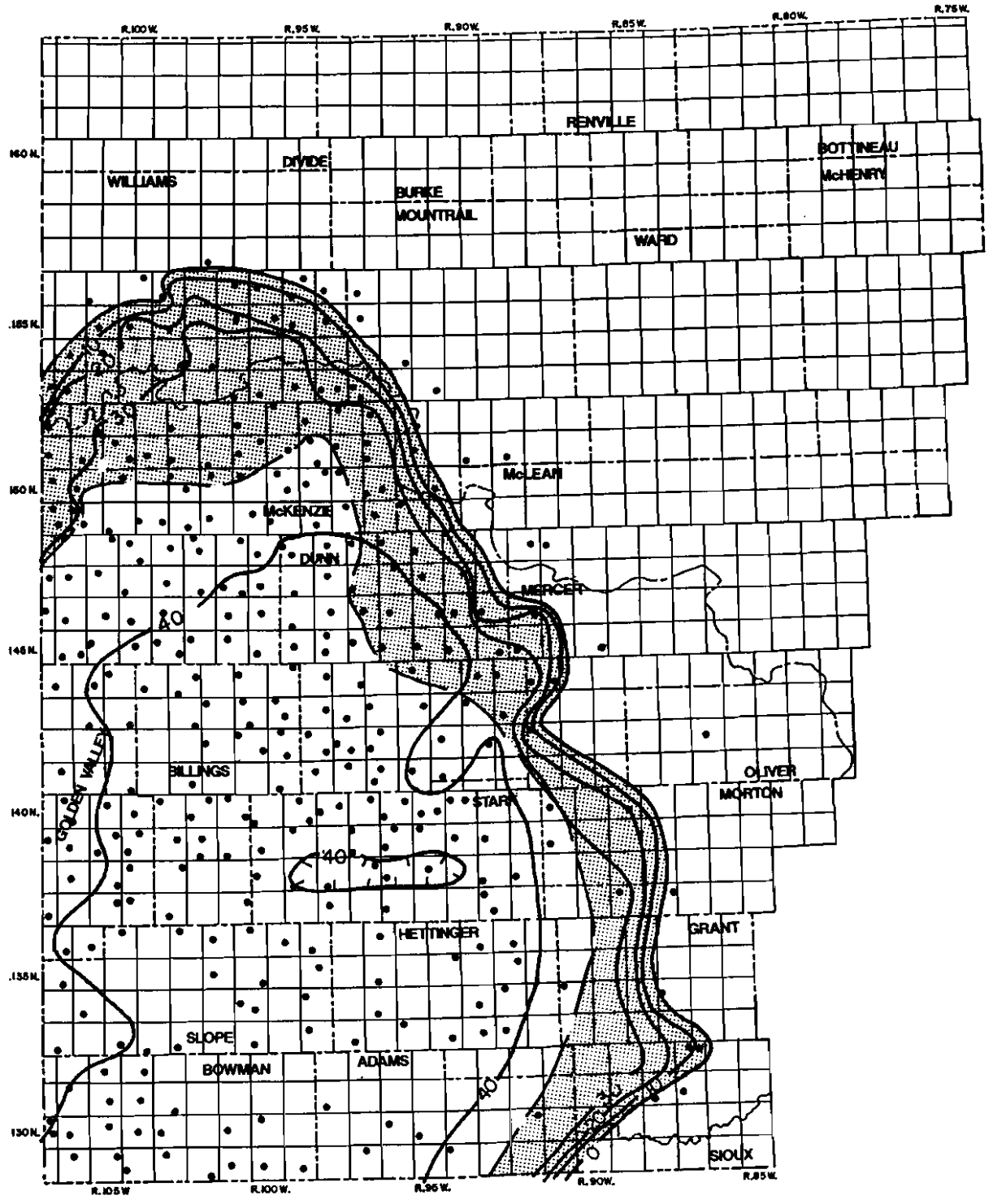
Figure 3. Isopach map of the Opeche Salt.



Contour Interval 100 feet

Limit of Minnekahta ———

Figure 4. Isopach map of the Opeche Formation.



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Limit of Belfield ———

Figure 5. Isopach map of the Minnekahta Formation.

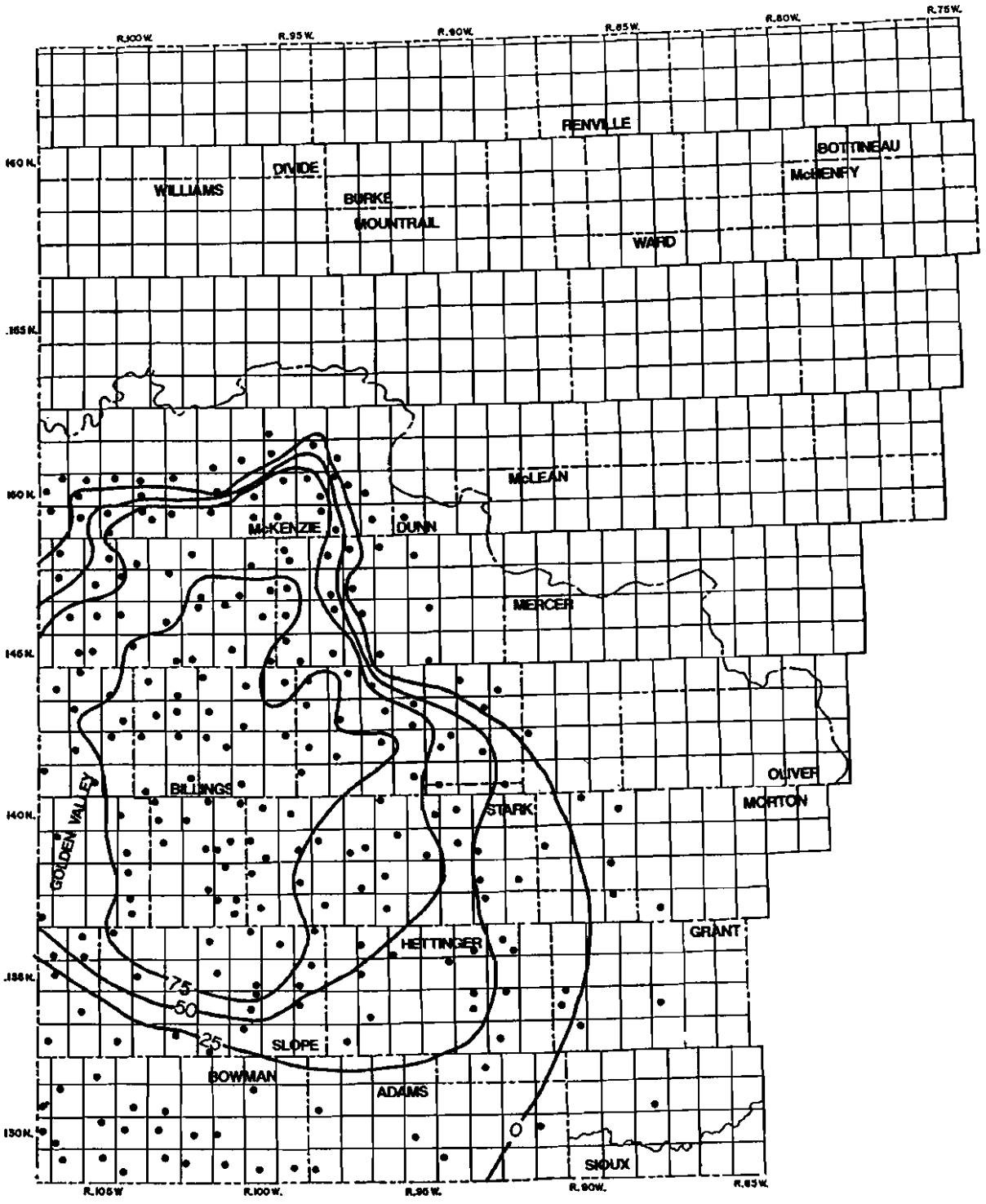

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Figure 6. Isopach map of Belfield Member of the Spearfish Formation.

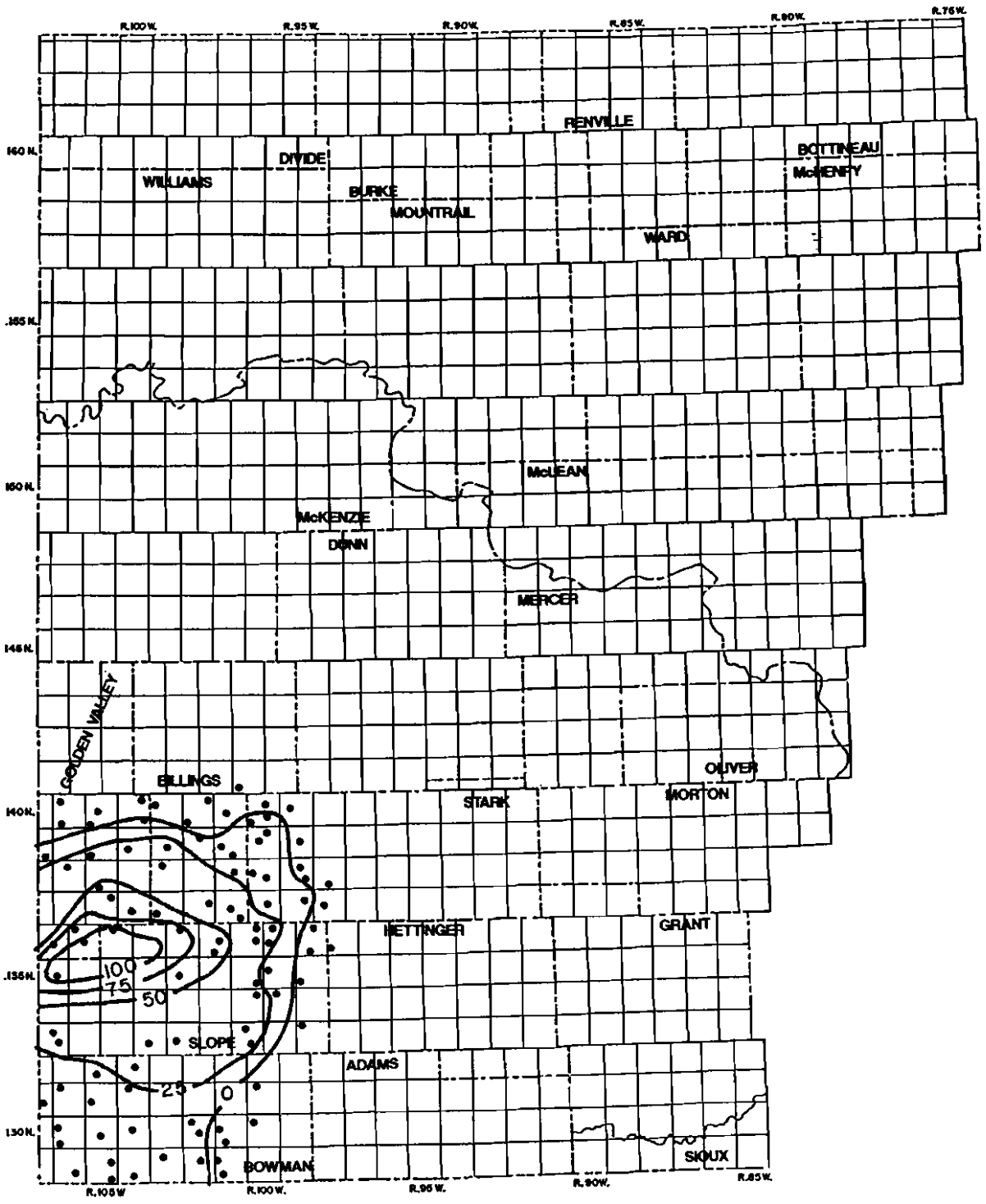

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Figure 7. Isopach map of "G" Salt.

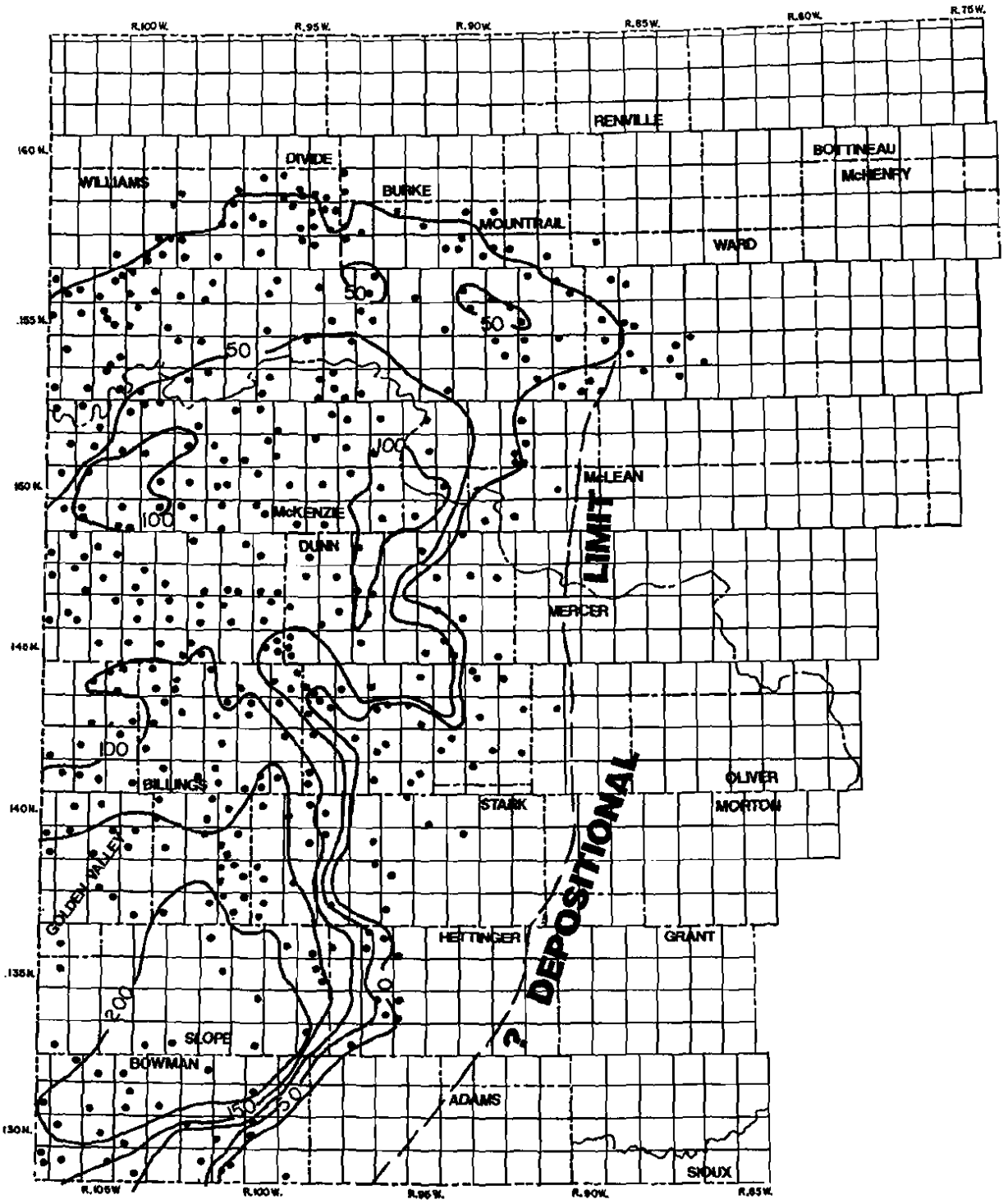

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Figure 8. Isopach map of "P" Salt.

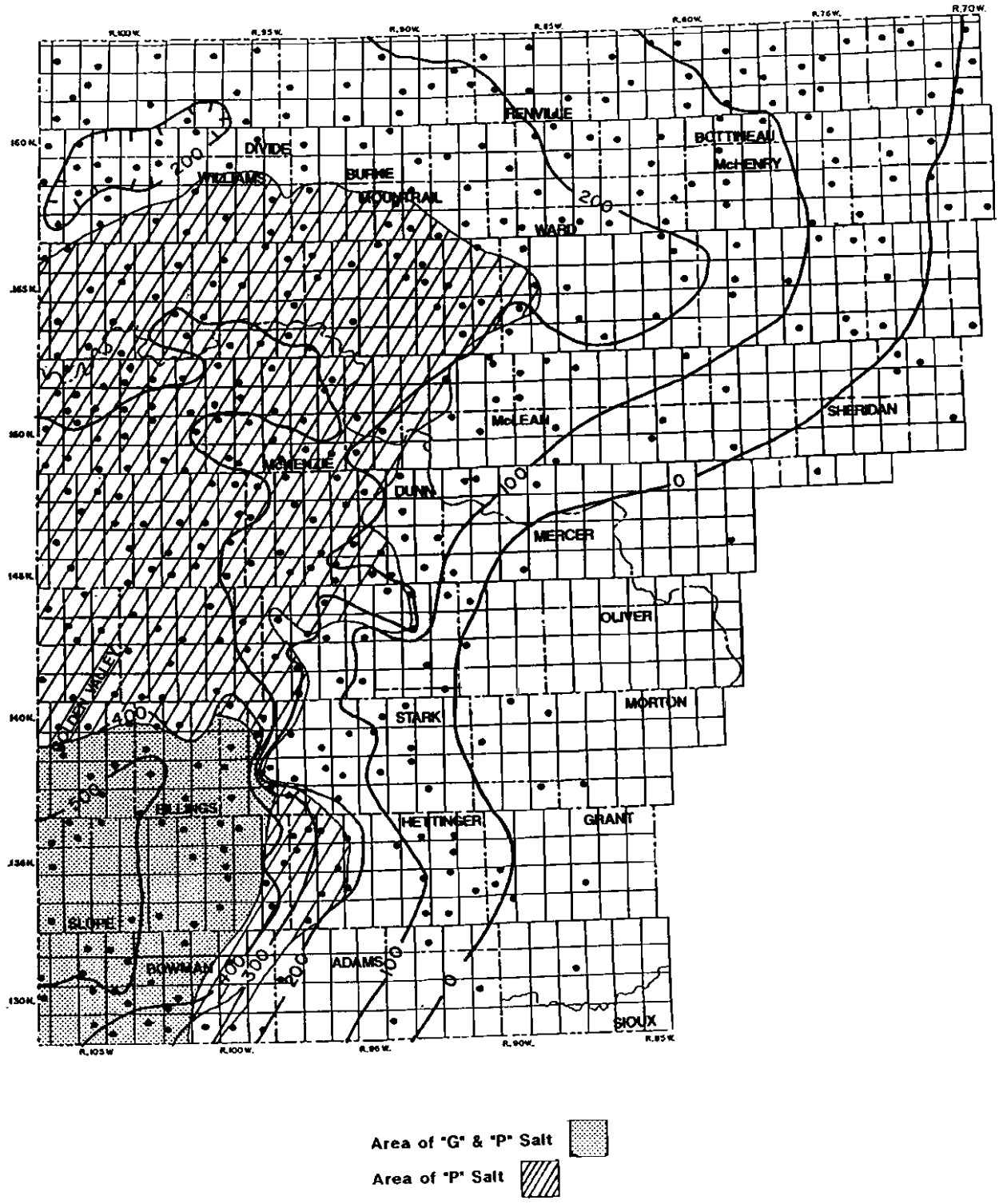


Figure 9. Isopach map of Pine Member of the Spearfish Formation.

Nesson Formation to the Kline, Picard and Poe Members with the upper members transferred to the Piper Formation. The lower Piper, as currently defined in North Dakota, is a redbed and evaporite depositional episode which includes the Picard Shale, Poe Evaporite, and Dunham Salt. The upper Piper consists of a normal marine depositional sequence of shales and limestones of the Bowes, Firemoon, Tampico, and Kline Members. The top of the Rierdon Shale and the top of the Picard Shale provide two consistent picks to provide the normal marine Jurassic regional depositional pattern. It shows a gradual northwest to southeast thinning of these strata from nearly 500 feet in northwestern North Dakota to less than 200 feet at the South Dakota border (fig. 10).

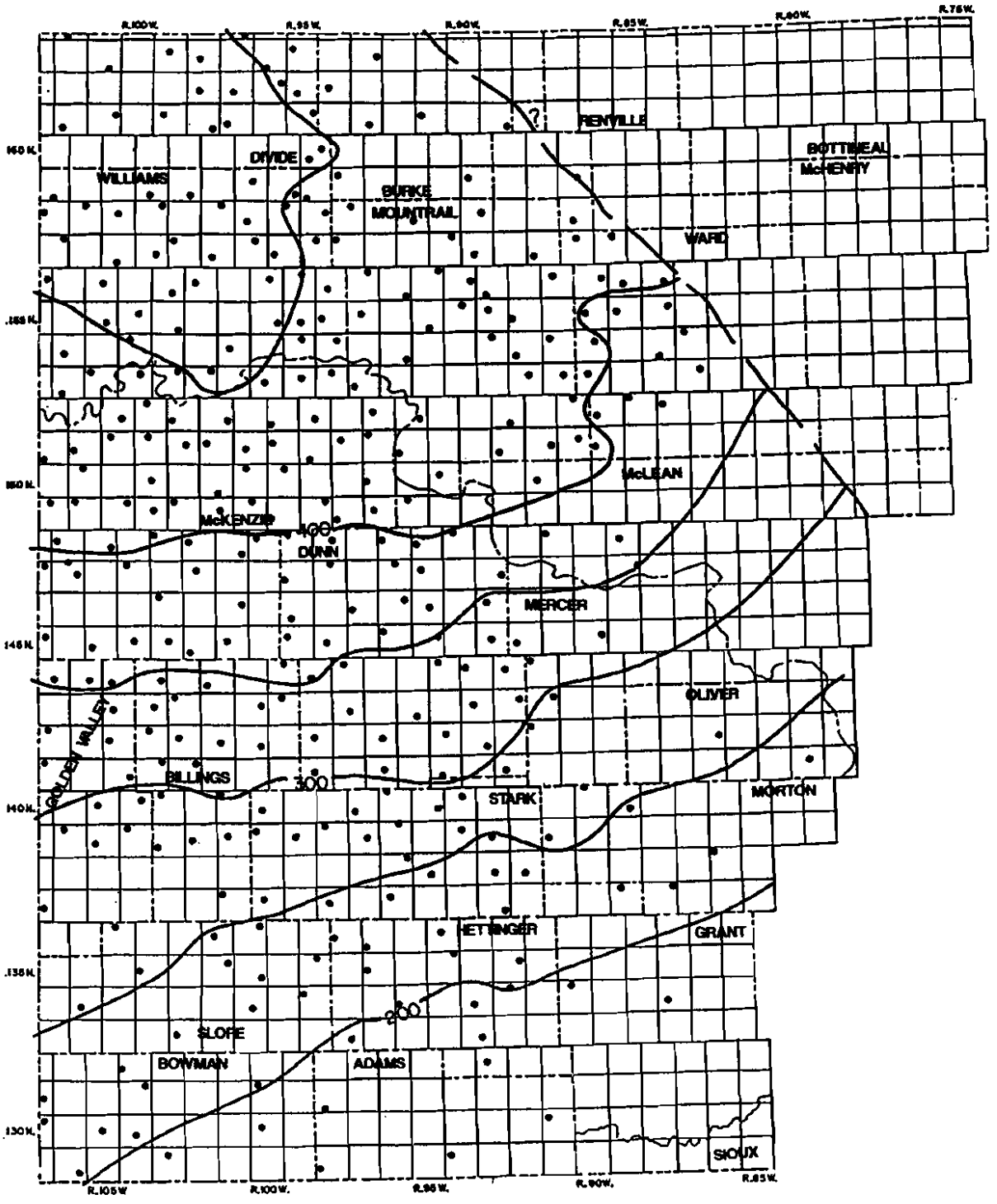
Zieglar introduced the term Saude to refer to clastics between the Dunham and Pine Salts assuming a Jurassic age for both salts. Subsequent interpretations have agreed with the Jurassic age of the Dunham Salt, but the clastics have generally been regarded as Triassic in age in North Dakota. The term Saude is derived from the Phillips Petroleum Company - Olivia Saude No. 1 well (NW SE 19-158-74) where salts are absent and redbeds lie unconformabiy on the Tilston Interval of the Madison Formation (Mississippian). Presumably the name was chosen because of the cored interval in that well (fig. 11) although Zieglar did not designate this as the type section. Zieglar used a composite log from an area of the basin where all the salts are present to define the Saude (fig. 1). Dow used a well in the same area to redefine the Saude and then designated the interval between 6290 feet and 6610 feet in the Amerada Petroleum Corporation - Pederson, Cater No. 1 well (NE SW 21-158-95) as a type section (fig. 12). Presumably he chose that well because he wanted to redefine the Saude as the interval between the Poe Evaporite and the "P" rather than the "G" salt (fig. 1). As thus defined, the Saude was considered to be Triassic since the top of the Permian was placed at the top of the "P" (Pine) Salt. Dow described the upper 60 feet, based on cuttings, as moderate reddish brown, slightly calcareous, silty shale. The remainder of the Saude was described as moderate reddish orange siltstone, sandy in part, with rounded, frosted sand grains. Dow (1967, p. 19) thought it probable that the Jurassic-Triassic boundary was in the upper part of the Saude. Zieglar placed the Jurassic unconformity at the base of the Pine Salt so he considered the Saude to be Jurassic in age.

I would redefine the Saude Member of the Piper Formation as the interval from 2802 to 2848 feet in the Phillips Petroleum Company - O. Saude No. 1 well (fig. 13). This interval is equivalent to an upper portion of Dow's type section, the interval from 6290 to 6405 feet in the Amerada Petroleum Corporation - Pederson, Cater No. 1 well (fig. 12). As thus defined, the Saude is generally less than 100 feet thick, but extends south and east of the limit of the Pine Member of the Spearfish Formation and represents the initial Jurassic deposition in the Williston Basin (fig. 13).

The Dunham Salt (fig. 14) is limited to the central basin area and has an erratic distribution due to dissolution in many areas. One of these areas has been demonstrated as Post-Piper dissolution (Dow, 1967, pl. 17), but no attempt has been made to document time of dissolution in other areas. Where depositional thicknesses of the Dunham Salt are present the Dunham Salt thickens with compensated thinning of Poe anhydrites (plate 2) This demonstrates the facies relationship of the evaporites and accounts for the Jurassic age assignment for this salt.

Unconformities

The subtle lithologic changes within the redbeds make recognition of unconformities difficult, but log characteristics on Dual Laterologs (plates 1-2) are consistent with regional unconformities within the redbeds. Recognition of the unconformity between the Belfield and Pine Members of the Spearfish Formation is aided by the areal extent of the higher resistivity redbeds to the areal extent of the underlying Minnekahta Limestone. Recognition of the unconformity between the Saude and Pine redbeds is more tenuous, but utilizes a combination of the gamma ray and resistivity characteristics. There is also generally a higher resistivity below this unconformity and the gamma ray characteristics are consistent with the generally noted more shaly lithology of strata immediately below the Poe (or Amaranth) Evaporites. Placement of pre- "P" (Pine) and pre-Dunham unconformities within the red clastics provides a more logical depositional sequence than initial thick salt deposition.



Contour Interval 50 feet

Limit of Picard Shale — — —

Figure 10. Isopach map of Reirdon Formation and Bowes through Kline Members of the Piper Formation.

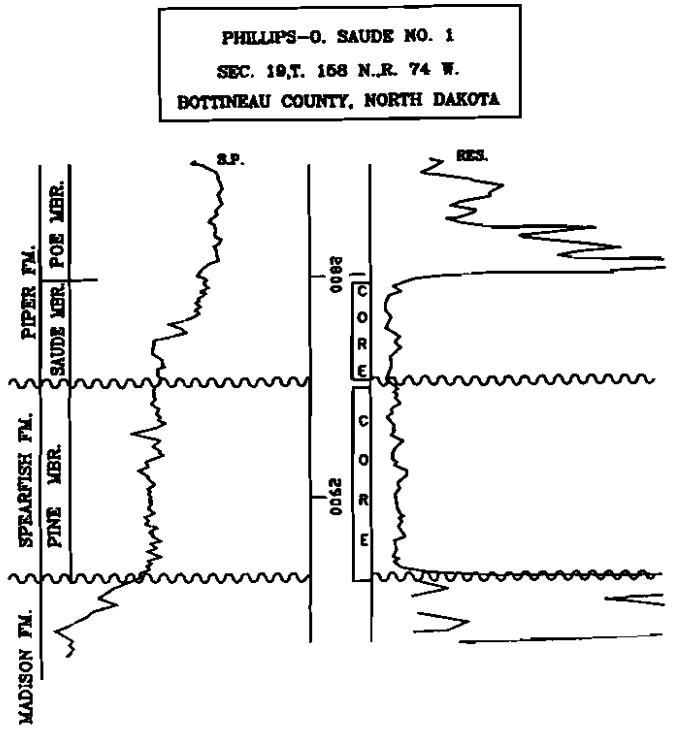


Figure 11. Log of Phillips Petroleum Corp. - O. Saude No. 1 well (NW SE 19-158-74) with revised definition of Saude Member of Piper Formation.

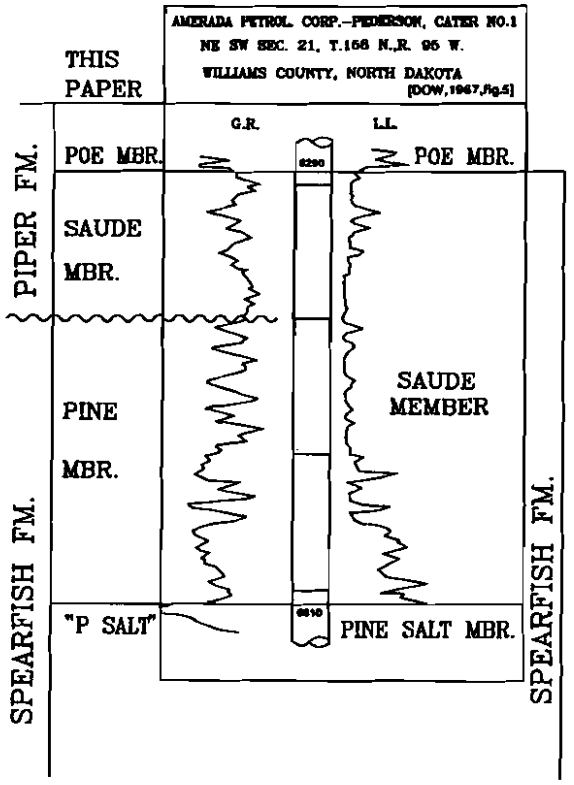
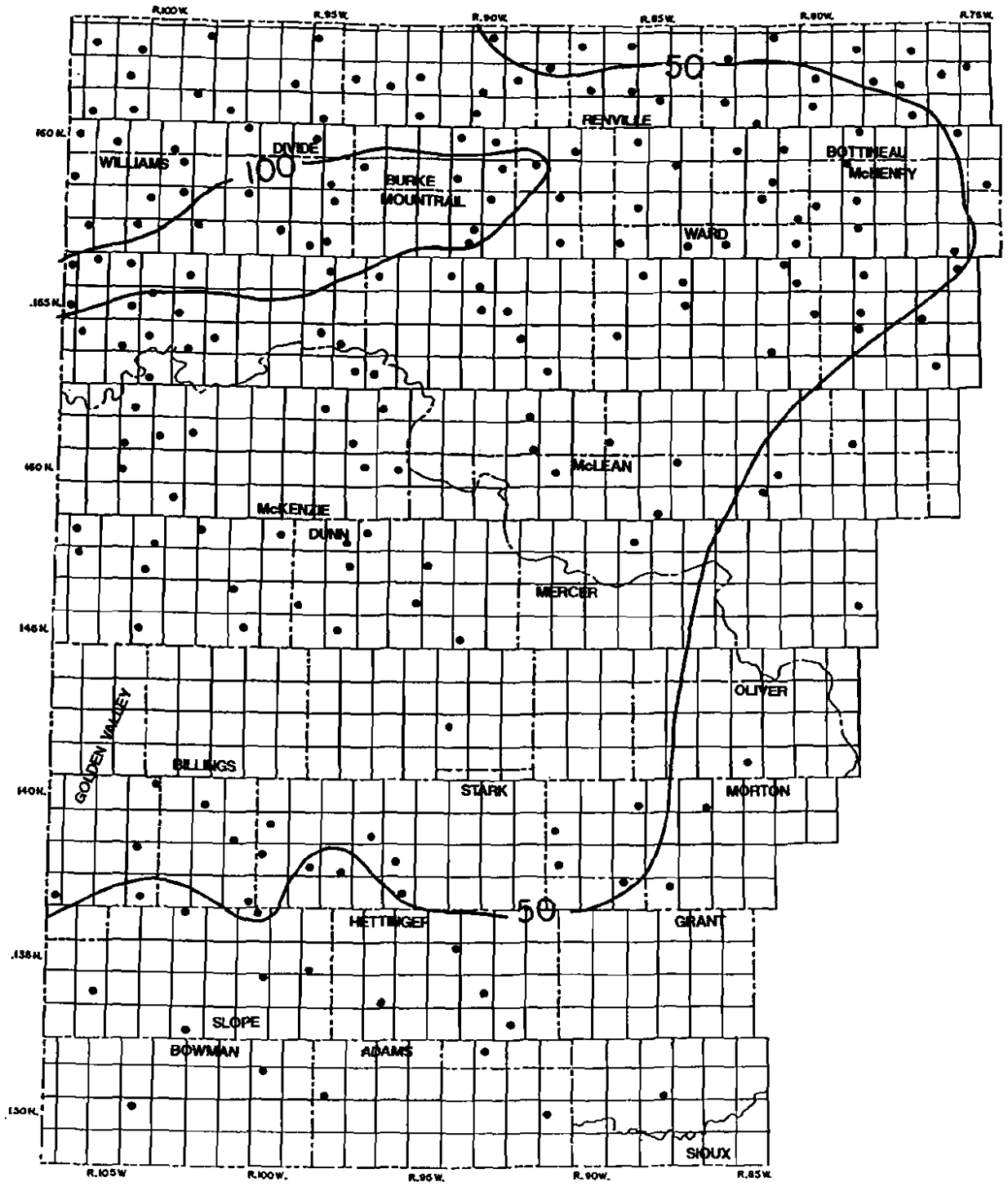
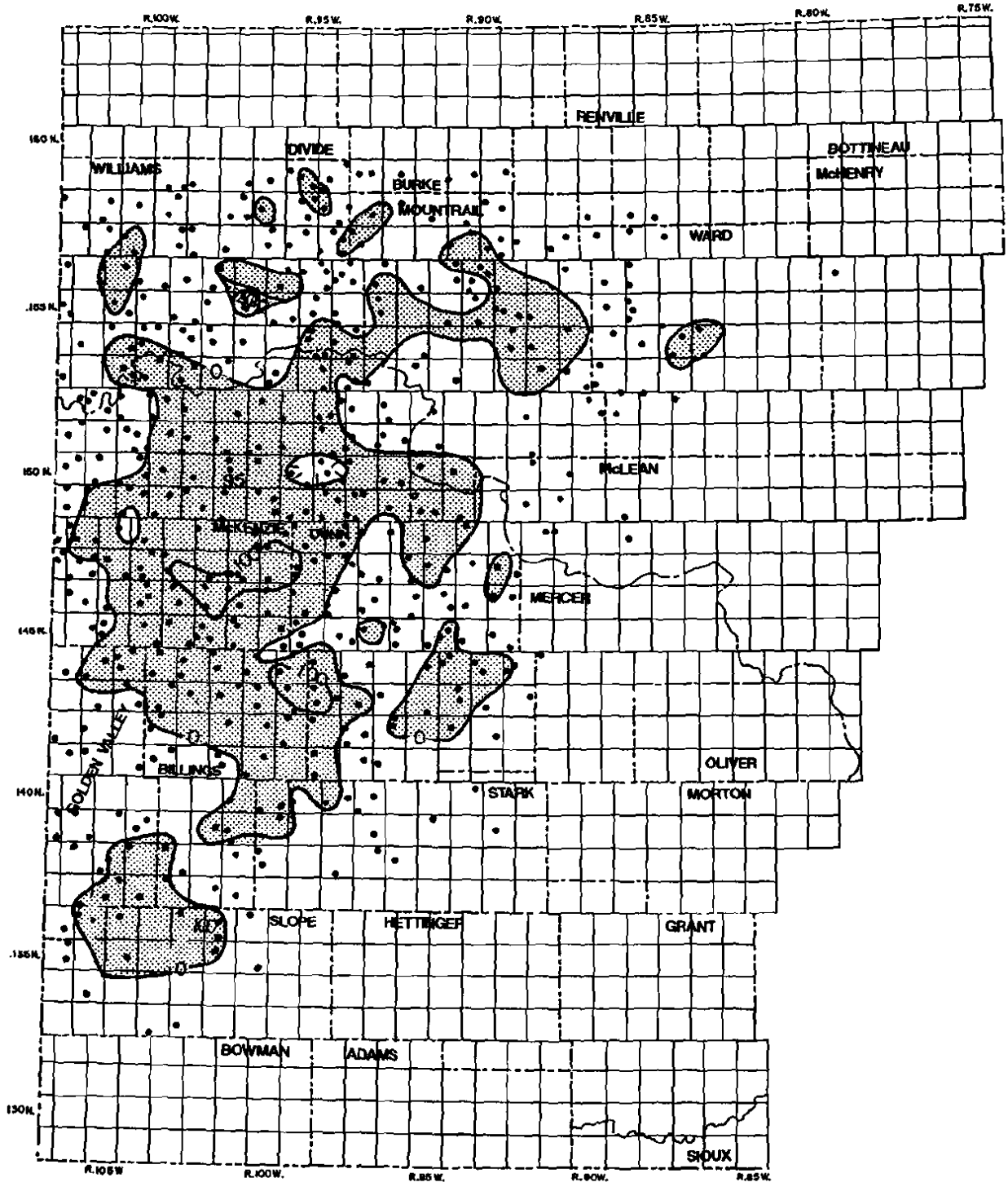


Figure 12. Log of Amerada Petroleum Corp. - Pederson, Cater No. 1 well (NE SW 21-158-95) showing revised definition of Saude Member of Piper Formation.



Contour interval 50 feet

Figure 13. Isopach map of Saude Member, Piper Formation.



Contour interval 100 feet

Figure 14. Isopach map of Dunham Salt, Piper Formation.

The unconformity between the Opeche Formation or older Paleozoic strata and overlying redbeds has been referred to as a pre-Mesozoic event (Anderson, 1974). The nature of the contact in southeastern Saskatchewan, southwestern Manitoba, and north-central North Dakota is one of essentially unweathered Mississippian carbonates with only minor secondary anhydrite in areas where the overlying redbeds are referred to as the Pine Member. This is in sharp contrast to south-central North Dakota where a karst topography has developed to a depth of 130 feet in the Herman Hanson - Welder No. 1 well (NE NW 20-133-72; Carlson, 1958) where red shales of the Saude Member of the Piper Formation overlie Mississippian carbonates (fig. 15). This indicates a significant age difference in different areas for the unconformity between redbeds and Paleozoic strata in North Dakota. I would submit that the elusive pre-Middle Jurassic unconformity is at the horizon which I have designated as the pre-Saude unconformity.

Global sea level lowstands of Early Pennsylvanian, Mid-Leonardian and Sinemurian age with associated unconformities fit nicely with unconformities at the base of the Tyler, Opeche, and Piper (Saude Member) Formations. The unconformity at the base of the Pine, if associated with the relative sea level fall at the base of the Middle Triassic would indicate a Triassic age for the Pine Member. Preservation of depositional thicknesses of the Pine halites below the unconformity associated with the Early Jurassic sea level lowstand would seem more likely if the Pine were deposited during the Triassic relative sea level rise than during the Permian. However, if the Wyoming correlations are correct, the pre-Pine unconformity is a mid-Guadalupian (Permian) event.

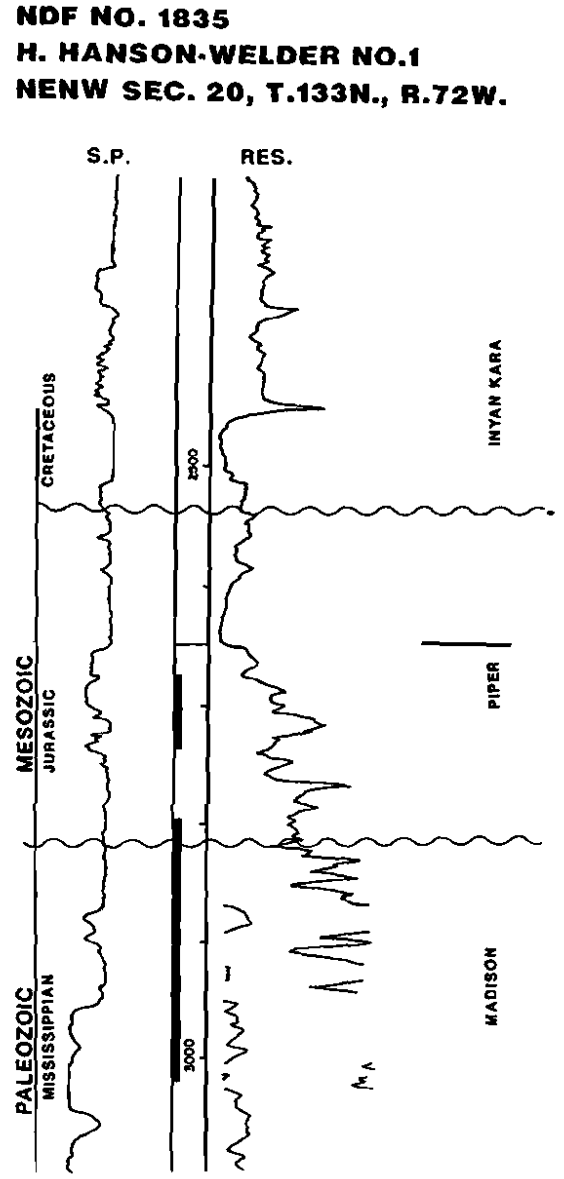


Figure 15. Log characteristics of Jurassic and Mississippian strata in the Herman Hanson - Welder No. 1 well (NE NW 20-133-72) in Logan County.

CONCLUSIONS

The Spearfish Formation, as currently defined in North Dakota, is generally consistent with type Spearfish, i.e., it contains strata of probable Permian to Jurassic age. However, common usage, and quite likely the original intent was to restrict Spearfish to the pre-Jurassic strata. A formation should be a lithogenetic unit; as such the Belfield and Pine might be referred to as formations, but they are equivalent to the Permo-Triassic portion of the type Spearfish so I would recommend that they be regarded as members of the Spearfish Formation.

A Permian age assignment for the Belfield Member is consistent with the conformable relationship to the Minnekahta Limestone and the age assignment of the Minnekahta in other areas. The age of the Pine Member is less clear. The "G" salt has been correlated with the Little Medicine Tongue of the Goose Egg Formation of Wyoming

which is regarded as near the base of the Triassic. That interpretation indicates a primarily Permian age for the Pine Member. Physical evidence in the Williston Basin seems more consistent with a Triassic age assignment, but the correlations to strata regarded as Permian in Wyoming is also plausible. Therefore a Permo-Triassic age assignment for the Pine seems appropriate until more definite age criteria are established.

A pre-Middle Jurassic unconformity has been generally recognized, but the physical placement has been controversial. Placement of this unconformity at the base of the redefined Saude is consistent with Canadian observations of a gradational or conformable contact between the redbeds and the overlying Jurassic evaporites and carbonates. Limiting the pre-Middle Jurassic on Paleozoic strata unconformity to the area beyond the limits of the Pine Member of the Spearfish Formation is consistent with the differing weathering characteristics of the Paleozoic carbonates and evaporites in those areas. Placing the pre-Middle Jurassic unconformity within the redbeds in the subsurface is consistent with the relationship in the outcrops in the Black Hills.

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MISCELLANEOUS SERIES 78

PLATE 1

A — A'

NDF NO. 9100
ESTERBY #1-11
BLUEBONNET ENERGY CORP.
NWSW SEC. 11, T. 159 N., R. 100 W.

NDF NO. 11933
ARTHUR SMITH #32-28
DEKALB ENERGY CO.
SWNE SEC. 28, T. 156 N., R. 100 W.
(TIE WELL C-C')

NDF NO. 11455
BROGGER 21-4 #1
LOUISIANA LAND & EXPLOR.
NENW SEC. 4, T. 153 N., R. 99 W.

NDF NO. 9434
SIPE AMOCO UNIT "A" #1-A
AMOCO PRODUCTION CO.
SENW SEC. 9, T. 145 N., R. 99 W.
(TIE WELL B-B')

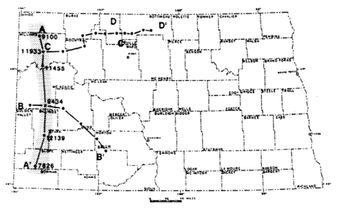
NDF NO. 12179
TRACY MOUNTAIN #16-19
AXEM RESOURCES ,INC.
SESE SEC. 19, T. 139 N., R. 100 W.

NDF NO. 7826
STUBER RANCH #1-17
STAMAN EXPLOR. & PRODUCTION CO.
NENE SEC. 13, T. 133 N., R. 102 W.

G.R. LAT.

RIERDON
BOWES-
FIREMOON-
TAMPICO-
KLINE
PICARD
POE
SAUDE
DUNHAM
PINE
"G"
"P"
BELFIELD
MINNEKAHTA
OPECHE
BROOM CREEK-
AMSDEN
TYLER
OTTER-
KIBBEY SANDSTONE
KIBBEY LIMESTONE

JURASSIC
PERMO-TRIASSIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN



B — B'

NDF NO. 8615
CINNAMON CREEK #17-12
PENNZOIL CO.
SWNW SEC. 17, T. 145 N., R. 102 W.

NDF NO. 9434
SIPE AMOCO UNIT "A" #1-A
AMOCO PRODUCTION CO.
SENW SEC. 9, T. 145 N., R. 99 W.
(TIE WELL A-A')

NDF NO. 9597
HARTMAN #1-27
PUMA PETROLEUM CO.
NWSE SEC. 27, T. 145 N., R. 96 W.

NDF NO. 10606
CONOCO-FRINDLEY 15 #1
CONOCO ,INC.
NWNW SEC. 15, T. 142 N., R. 93 W.

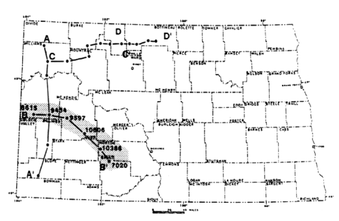
NDF NO. 10386
AMOCO KREIS #1
AMOCO PRODUCTION CO.
NENE SEC. 20, T. 139 N., R. 90 W.

NDF NO. 7020
WILLIAM STECKLER #1
TEXAS PACIFIC OIL CO., INC.
SENE SEC. 5, T. 137 N., R. 88 W.

G.R. LAT.

RIERDON
BOWES-
FIREMOON-
TAMPICO-
KLINE
PICARD
POE
DUNHAM
SAUDE
PINE
BELFIELD
MINNEKAHTA
OPECHE
BROOM CREEK-
AMSDEN
TYLER
OTTER-
KIBBEY SANDSTONE
KIBBEY LIMESTONE

JURASSIC
PERMO-TRIASSIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN



C — C'

NDF NO. 11933
ARTHUR SMITH #32-28
DEKALB ENERGY CO.
SENE SEC. 28, T. 156 N., R. 100 W.
(TIE WELL A-A')

NDF NO. 12305
NELS ANDERSON #1
ORYX EMERGY CO.
NENE SEC. 13, T. 156 N., R.96 W.

NDF NO. 8991
HOWELL #15-44
MARATHON OIL CO.
SESE SEC. 15, T. 157 N., R. 91 W.

NDF NO. 11766
NICKOL #11-91
MERIDIAN OIL CO.
NWNW SEC. 19, T. 159 N., R. 91 W.

NDF NO. 10273
SCHUMACHER #1-2
INEXCO OIL CO.
NWNW SEC. 2, T. 159 N., R. 89 W.

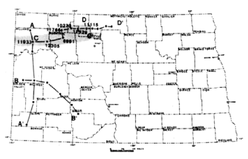
NDF NO. 12529
MILLER "F" #12-13
PG & E RESOURCES CO.
NWSW SEC. 13, T. 159 N., R. 87 W.

NDF NO. 11115
VENDSEL #1-1
ALBRITTON RESOURCES ,INC.
SESW SEC. 1 , T. 159 N., R. 85 W.
(TIE WELL D-D')

GR. LAT.

REIRDON
BOWES-
FIREMOON-
TAMPICO-
KLINE
PICARD
POE
SAUDE
PINE
"P" SALT
OPECHE
AMSDEN
TYLER
OTTER-
KIBBEY
KIBBEY LS
MADISON

JURASSIC
PIPER FM.
PERMO-TRIASSIC
SPEARFISH FM.
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN



D

D'

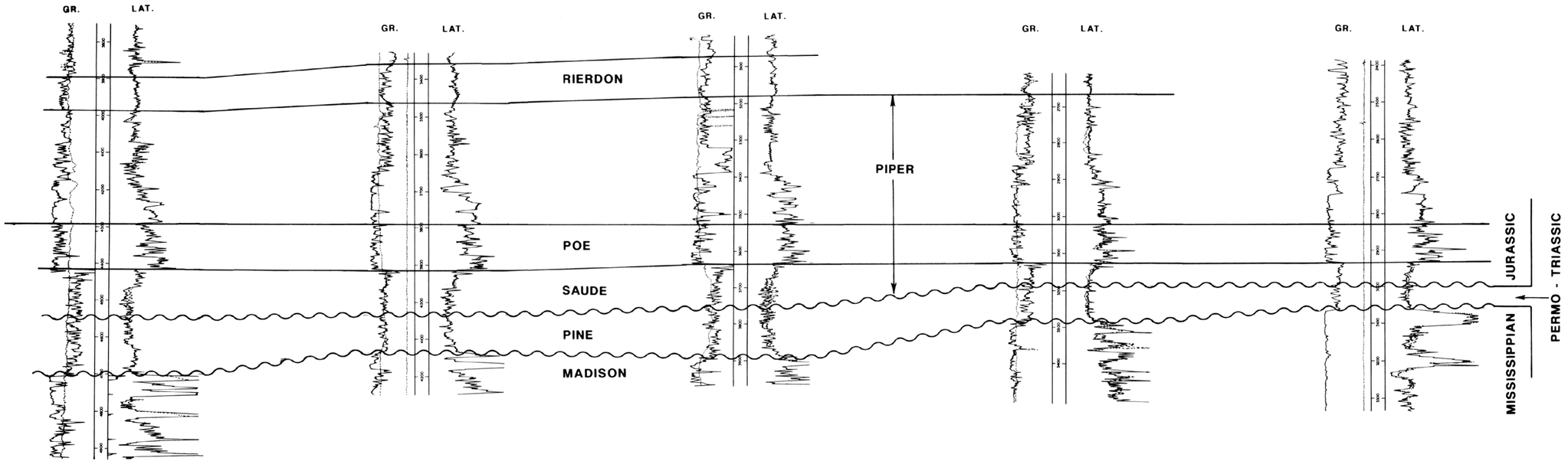
NDF NO. 11115
VENDSEL #1-1
ALBRITTON RESOURCES , INC.
SESW SEC. 1, T. 159 N., R. 85 W.
(TIE WELL C-C')

NDF NO. 11443
ADAMS FEDERAL #12-26
NICOR EXPLORATION
SWNW SEC. 26, T. 160 N., R. 83 W.

NDF NO. 12586
SPEARS 11-19 #1
WACKER OIL, INC.
NWNW SEC. 19, T. 160 N., R. 81 W.

NDF NO. 10163
MYRON SCHEFLO et al #1
DON BILLS & CLINTON ST. CLAIR
NWNE SEC. 13, T. 161 N., R. 79 W.

NDF NO. 9522
BJORNSETH #1
COASTAL OIL & GAS CORP.
SWNW SEC. 21, T. 161 N., R. 77 W.



E

E'

NDF 10513
CHRISTIANSEN-THOMPSON RANCH #1-8
ENSTAR CORP.
NENE SEC. 8,T. 156 N.,R. 76 W.

NDF 8856
WANGLER #1
SOUTH RANCH OIL CO., INC.
NESE SEC. 18,T. 153 N.,R. 73 W.

NDF 11654
MASON #11-24
TRUE OIL CO.
NWNW SEC. 24,T. 149 N.,R. 70 W.

NDF 11599
KRUEGER #42-28
TRUE OIL CO.
SENE SEC. 28,T. 145 N.,R. 70 W.