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SHERWOOD SUBINTERVAL OF THE MISSION CANYON FORMATION
IN
CENTRAL WESTERN NORTH DAKOTA

by

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REPORT OF INVESTIGATION 97

NORTH DAKOTA GEOLOGICAL SURVEY

John P. Bluemle, State Geologist

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1895 - North Dakota Geological Survey's Centennial Year - 1995

The North Dakota Geological Survey was created by an act of the North Dakota Legislature in 1895, six years after statehood. The Geological Survey was directed to make a

> *... complete account of the mineral kingdom ... including the number, order, dip and magnitude of the several geological strata, their richness in ores, coals, clays, peats, salines and mineral water, marls, cements, building stones and other useful materials, the value of said substances for economic purposes, and their accessibility.*

Such studies continue, but over the years the Geological Survey's mission has grown and is now three-fold: to investigate the geology of North Dakota; to administer regulatory programs and act in an advisory capacity to other state agencies; and to provide public service and information to the people of North Dakota.

The Geological Survey serves as the primary source of geological information in the State. A large amount of geological information can be obtained from NDGS publications; comprehensive collections of cores, samples, and fossils; oil and gas records; coal and subsurface mineral records; and through our affiliate office of the nationwide Earth Science Information Center.

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ABSTRACT

The Mississippian Sherwood subinterval in central-western North Dakota ranges from sabkha anhydrites, through shallow shelf carbonates, to open marine limestones. Deposition was strongly affected by tectonic movement of two Precambrian basement blocks and their mutual boundary along a well developed trough in northern Dunn County. Slow, steady subsidence, or loading, of one block caused a regressive depositional pattern and porosity development in lime mudstones. Intermittant movement on the other block allowed the development of porous grainstone shoals adjacent to a shoreline controlled by basement lineaments. The study area spans the junction of these two dominant Sherwood depositional patterns of the southern and eastern flanks of the Williston Basin.

INTRODUCTION

The Mississippian Madison Group has long been a favorite and highly rewarding target for oil explorationists on the eastern flank of the Williston Basin in North Dakota. In recent years exploration has successfully extended production south and westward ever closer to the large Madison fields (e.g. Little Knife, Big Stick) on the southern basin flank. This study covers the convergence of the two areas in northern Dunn, western McLean, southeastern Mountrail, and southwestern Ward Counties (Fig. 1). It is stratigraphically limited to the Sherwood subinterval of the Mission Canyon Formation (Fig. 2) within the Madison Group.

The Sherwood subinterval is one of the best oil producing Madison units on the eastern flank of the Williston Basin. It has also yielded much of the production from Little Knife, Big Stick, Elkhorn Ranch, and other Mission Canyon pools (Petty, 1988) on the southern flank in Billings and McKenzie Counties. The eastern production, which extends north from the study area into Saskatchewan, is from reservoirs developed adjacent to the Sherwood paleoshoreline or nearby offshore small shoals.

Sherwood Field, located on the Renville County and Saskatchewan border, was discovered in 1958 and has produced over 29.5 million barrels of oil. When production in remaining Sherwood subinterval oil fields (those 17 that are probably economic) on the basin's east flank in North Dakota is added, total Sherwood oil production there exceeds 57 million barrels. Current data are not available for the additional Canadian production, which would certainly add considerably to the total.

A record of slow, steady development, centered in Renville and Ward Counties, followed the original Sherwood Field discovery. By 1970 Sherwood production had been extended to Lone Tree, South Field. Another 15 years passed until Wabek Field was discovered in 1985. During development of Wabek, a downdip pool in the overlying Bluell subinterval was discovered (Plaza Field) in 1989. The success at Wabek, where ultimate reserves are estimated at 6 to 8 million barrels (Sperr, et al., 1993), encouraged strong exploration activity that resulted in extension of Sherwood shoreline production into McLean County at Lucky Mound (Fisher and Hendricks, 1991) and Centennial Fields in 1990. Each author discussed the interrelationship of depositional environments, diagenesis, regional and local structural elements, and reservoir characteristics in exploring for new Sherwood fields.

The following discussion addresses the broader aspects of deposition and structure by illustrating their interdependence in defining potential trends or local areas for petroleum exploration.

DISCUSSION

Though the Sherwood subinterval is the focus of this study, it is just one of a series of similar cycles long recognized in the Williston Basin. Harris, et al. (1966) first subdivided the Upper Mission Canyon Formation into a series of "beds", each representing a regressive pattern beginning with an argillaceous marker unit and ending with an anhydrite (or equivalent carbonate) unit. Voldseth (1986, 1987), working in the same area of north-central North Dakota, added the Dale unit as a partial equivalent of the State A marker and the Coteau as a subjacent unit. He called them intervals, but current usage (Burke, 1991) places them as subintervals of the Frobisher-Alida interval (Fig. 2).

The Coteau and Dale, as defined by Voldseth, are limestones, and he illustrated both units as Mission Canyon lateral facies equivalents of Lower Charles evaporites (1987, fig. 5b). As limestone lithostromes their recognition becomes difficult in much of the Williston Basin, including the present study area. The Dale here can be recognized in some wells at best as an argillaceous carbonate bed a few feet thick. The Coteau equivalent is the highest of the anhydrite beds which characterize the Bluell. Neither one can be considered an equivalent of any Lower Charles

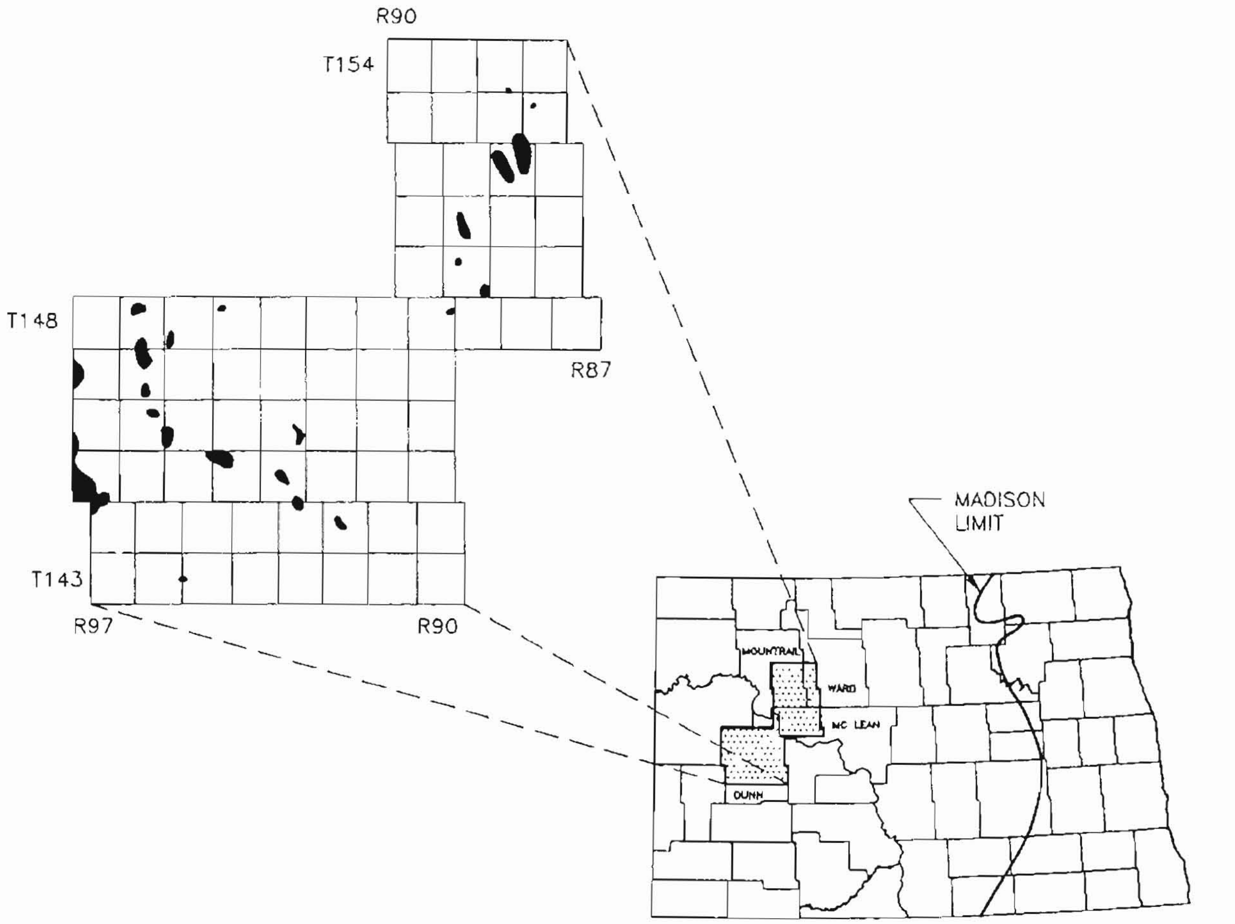

Figure 1. Location map of the study area within North Dakota. Dark areas represent producing oil fields.

unit.

The subintervals that Harris named in 1966 are recognizable here and their relationship to each other is shown in Figure 3. However, only those units from the State A marker to the Mohall have been utilized in this work. A shortage of subsurface information precludes evaluating the influence of lower subintervals on the overall Sherwood deposition.

Depositional Patterns

The Sherwood subinterval lithostratigraphy changes facies from supratidal anhydrites to lagoonal dolomites, lime mudstones, local grainstones, and finally, open shelf limestones. There are many similarities with modern analogs, though none make a perfect model. The extent of the Sherwood anhydrite facies is typical of a coastal sabkha as described by Kinsman (1969) in the Persian Gulf. The sabkha of Abu Dhabi, which is similar to the Sherwood in breadth and uniform thickness, was explained by Butler (1969) as caused by prograding rather than downwarping or sea level rise. However, for at least part of Sherwood time, the sabkha progradation and step-like thickening beginning at the strand line was halted in the area covered by Plate 1. In northwestern Dunn County, a very slow, steady, gradual downwarp of a broad, shallow shelf is suggested by the widely spaced isopachs on Plate

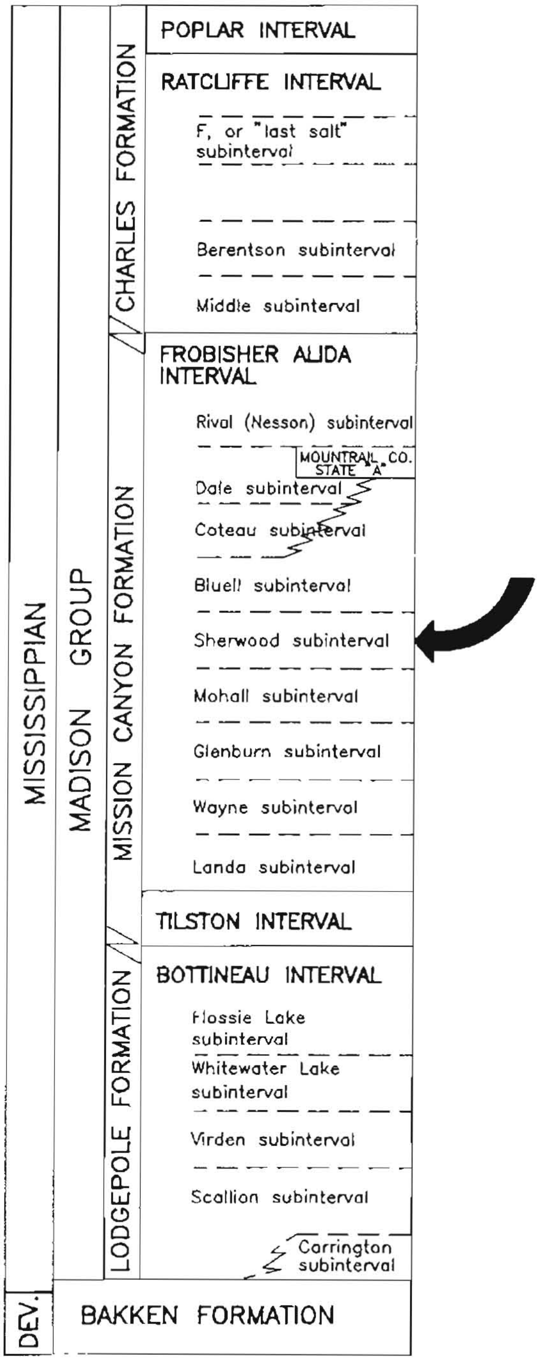

Figure 2. Stratigraphic units of the Madison Group in North Dakota (after Burke, 1991).

2, with seaward advancement of the sabkha and development of wide sabkha islands perhaps similar to those of Abu Dhabi (Butler, et al., 1982). The islands are separated from the coast by lagoonal areas with lime muds and pellets. Another modern sedimentologic comparison may be the islands in Florida Bay, which contain thin layers of lime packstones and grainstones, and supratidal algal mats (Enos and Perkins, 1979). Near Lake Ilo, Werner, and Killdeer Fields similar situations may have prevailed which could have lagoonal environments and localized porous grainstone shoals.

Shoreline depositional patterns for the Sherwood subinterval have been described by Lindsay and Roth (1982) for Little Knife Field, Hendricks, et al. (1987) for Renville County, Petty (1988) for the Billings Nose-Rough Rider area, and Sperr, et al. (1993) for Wabek Field. These examples, with their many similarities, serve well as stratigraphic models for Mississippian time, but they also have clear differences as well. Those parameters which influence the differences can provide keys to understanding trends and changes in depositional environments, and some of them are addressed in this study.

A general depositional pattern for the eastern flank of the Williston basin was described by Hendricks, et al. (1987). They established four regional trends parallel to the Sherwood depositional strike: (1) anhydrite and dolomite of hypersaline lagoons and sabkhas; (2) carbonate mudstones of restricted lagoons; (3) shallow, restricted shelf with island shoals and porous grainstones; (4) open shelf limestones. The transition from the first trend to the second can be used to map the average shoreline position through Sherwood time, and it also has been aligned with structural lineaments (Sperr, et al., 1993).

The eastern flank Sherwood depositional pattern can be extended south through most of this study area to the vicinity of Werner Field. An extensive sabkha is shown on the isopach maps (Plates 1, 2) east and south of the average Sherwood shoreline position. Neutron-density well logs have been utilized to map areas of anhydrite.

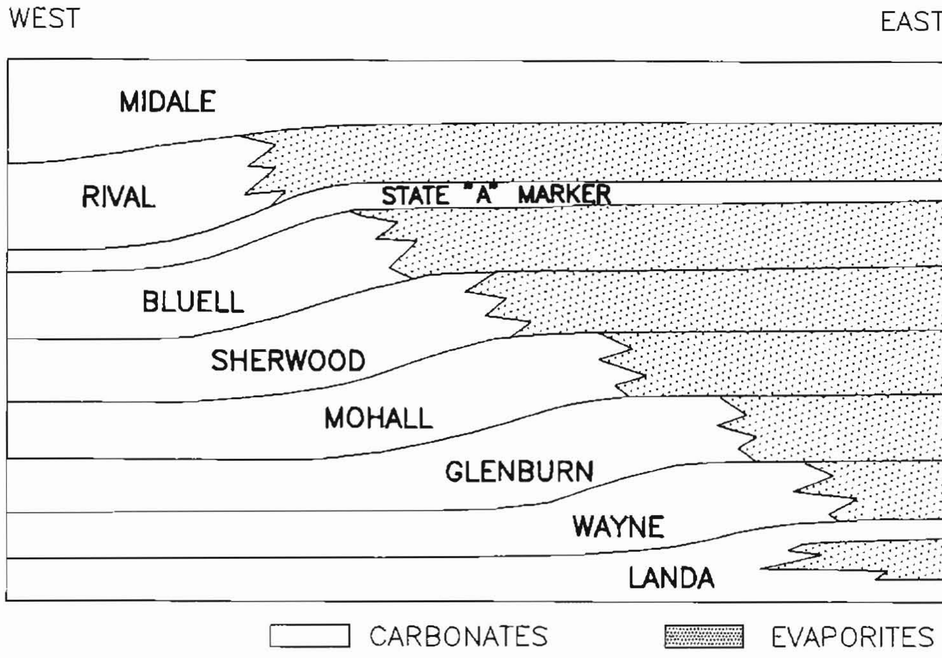

Figure 3. Generalized Mission Canyon stratigraphy in North Dakota (after Hendricks, 1988).

Where a mixture of anhydrite and carbonate mudstone is indicated by the logs, an average of 20% anhydrite in the total subinterval has been used to represent the approximate shoreline position for the entire Sherwood time. To the west a very shallow, restricted shelf, as indicated by the isopach contour pattern, extends seaward up to three miles and contains local lagoon and shoal areas. The shoals, similar to those at Wabek and Lucky Mound Fields, are potential reservoirs. Beyond the shelf is a distinct slope for two to three miles and then a trough, represented by thicknesses exceeding 76 feet on Plate 1 and 72 feet in northeastern Dunn County (Plate 2).

Also in Dunn County, there is a large area where salt was deposited in middle Sherwood time, extending across all of T144N-R91W and beyond (Plate 2). Total salt deposition never exceeded 17 feet in thickness, and was interrupted several times by thin layers of anhydrite. The extent of the salt is fairly well established except southward where few wells have been drilled. Sherwood salt has also been locally recognized in other areas on the eastern flank of the basin (LeFever, et al., 1989, 1991).

West of the salt area Sherwood stratigraphic patterns reflect response to a different, more stable depositional environment. For the southern flank of the basin, including northwestern Dunn County, Petty (1988) recognized six depositional facies: (1) coastal sabkha with anhydrite and carbonate mudstones; (2) restricted, shallow lagoons of burrowed mudstone-wackestone; (3) barrier bars and island shoals of either peloidal-pisolitic grainstone or peloidal-oolitic-skeletal grainstone, which are tightly cemented and form updip stratigraphic seals for dolomites of succeeding facies; (4) restricted shelf burrowed mudstones with porous dolomites; (5) open marine burrowed skeletal wackestones or packstones, also with dolomitization; (6) open marine shoals with skeletal lime grainstones, that occur infrequently. These facies were established for the entire Frobisher-Alida interval, suggesting a long standing quiescence and uniformity of overall conditions in this part of North Dakota in

Middle Mississippian time.

The transition between the two major depositional patterns occurs in Dunn County in the vicinity of Lake Ilo and Werner Fields. Contour patterns on Plate 2 indicate a strong embayment southeast of Lake Ilo during Sherwood time, with the area of salt occurrence representing the distal end. The northwest-southeast linearity to the embayment suggests a tectonic influence similar, but on a larger scale, to that discussed by Sperr, et al. (1993) for Wabek Field.

Structure

Throughout the Williston Basin the recognition of lineaments and related Precambrian basement structural blocks, and their influence on Phanerozoic stratigraphy has been discussed by several authors, including Thomas (1974), Brown (1978), and Shurr (1979, 1982). The pattern of the isopachs on Plates 1 and 2, the track of the average Sherwood shoreline position, and structural elements described at Wabek Field all suggest that larger scale tectonic elements are an important controlling factor in Sherwood depositional patterns.

Earlier, Laird (1964) mapped a series of northwest-trending structures through northern Dunn County, on a line from Bismarck to Williston. Gerhard, et al. (1982) mapped a southeast extension of the Antelope Field anticline as the Bismarck-Williston Trend (also referred to as a zone, or lineament). Even though their illustrations of the trend are limited to very generalized maps, it appears to extend along a line approximating the orientation of the Missouri River, S45E between Dunn and McLean Counties (Fig. 4). The effect of the Bismarck Trend is first evident on the Ordovician Winnipeg Formation as shown by the isopach maps of Anderson (1982), and it continued to influence deposition throughout the Paleozoic. As late as Pennsylvanian time the Desmoinesian Lineament, a parallel feature to the northeast, defined the boundary of deposition in western North Dakota (Maughan and Perry, 1986). Within the study area, Sperr, et al. (1993) utilized geophysical evidence to demonstrate the local position of Precambrian basement linear structures with respect to grainstone shoals formed during Sherwood subinterval deposition at Wabek Field.

Along the eastern flank of the Williston Basin the effects of certain basement lineament features can be interpreted from the pattern of the Sherwood shoreline as outlined by Hendricks, et al. (1987). At the international border the shoreline is first aligned northeast-southwest then turns sharply to a northwest-southeast direction, and back again to repeat in a step-like manner from Renville to McLean Counties. Structural noses parallel the first direction, plunging southwest into the basin (LeFever and Anderson, 1986; Hendricks, et al., 1987). Within the study area these features begin to plunge in a more westerly direction in McLean County (Plate 3), and in northern Dunn County the plunge is northwestward (Plate 4).

On Plate 4 a strong, northwest plunging, structural nose extends from Halliday Field to Killdeer Field where it begins to merge with north-south elements of the Little Knife and Nesson Anticlines. An adjacent syncline, north of Lake Ilo Field, aligns closely with the Sherwood embayment discussed above, and parallels the Bismarck-Williston Trend. Normal faults, striking northwest, have been recognized on proprietary petroleum industry seismic data in the vicinity of the several oil fields along the structural nose, which suggests repeated uplift through Paleozoic time. The same area on the isopach map (Plate 2) shows a thin Sherwood subinterval with linear areas of thickening on both sides. The complex of structural elements are informally termed the Killdeer Trough on Figure 4. Further work on tectonic and depositional history of this part of the Williston Basin is ongoing to substantiate the full extent of the trough.

In contrast to Dunn County, a comparison of Plates 3 and 4 shows much less correlation between Sherwood structure and thickness northeast of the Bismarck-Williston Trend except on a detailed scale. From Plate 1 the effect of linear Precambrian basement structures is indicated by the directional changes of the Sherwood shoreline. Larger, northwest-oriented paleo-

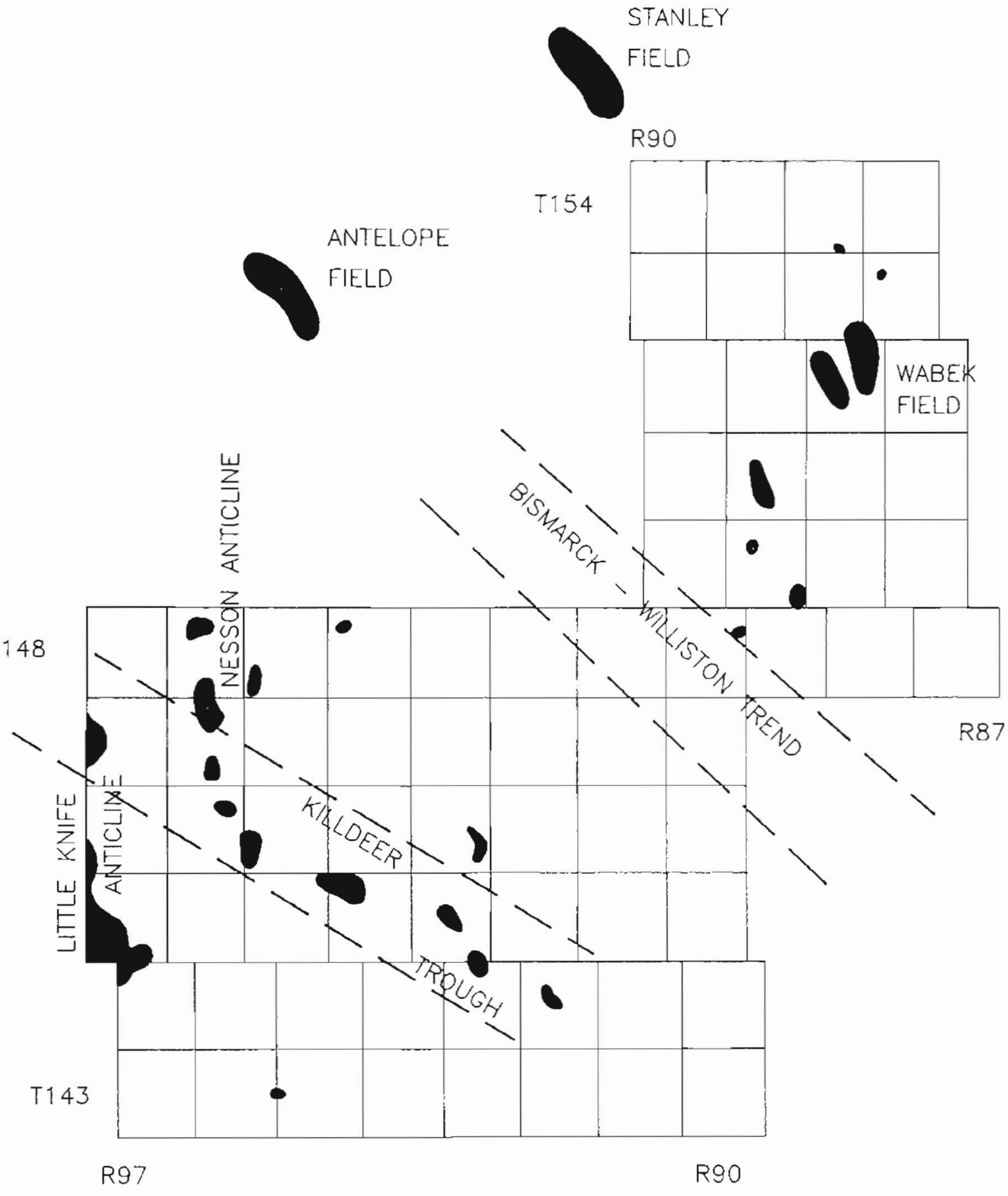

Figure 4. Primary structural elements in northern Dunn and southwestern McLean Counties. Black areas represent oil fields.

structures show up only as isopach thins and adjacent thicks (= embayments) normal to the northeast-southwest striking shoreline and offshore trough.

The study area is thus divided into two major tectonic blocks whose mutual boundary follows approximately along the Killdeer Trough in north-central Dunn County. East and northeast of there structural movements formed a pattern consistent with the eastern flank of the Williston Basin, and could have been a primary cause of the multiple orderly regressive cycles (= subintervals) during Upper Mission Canyon time. To the west tectonic movement was similar to that of the southern flank of the basin, with more stability and slower regression of the seas during deposition of the Mission Canyon Formation.

The result was differing depositional patterns during Sherwood time and subsequently differing reservoir parameters for trapping of hydrocarbons. Although local sedimentologic environments to the west appear inconsistent, the very slow subsidence there created good potential for influx of magnesium and dolomitization of shallow shelf lime muds in a manner similar to that described by Petty (1988) for the Billings Nose. In contrast, the eastern flank patterns contain porous grainstone shoals allied with the shoreline position for individual subinterval cycles. An example is Wabek Field , and the relationship there between Precambrian basement structures and Sherwood deposition mentioned above.

A review of Plates 1-4 provides a good comparison of Sherwood structure and deposition. Though paleostructure may be masked, the isopach maps give an indication of what may have been the scene in Mississippian time. Structurally the Killdeer Trough is easily recognized, but the Bismarck-Williston Trend is not evident. However, Plate 1 shows an area of thin deposition northwest of Lucky Mound Field that aligns with the average Sherwood shoreline and suggests a possible Precambrian basement lineament that would parallel the Bismarck-Williston Trend. Likewise, a northwest-trending thin Sherwood area extends from Wabek Field to Stanley Field (see Fig. 4 for location), and may represent yet another, deeper structural element that influenced depositional patterns of the Sherwood subinterval.

Porosity

The differing depositional patterns and associated elements of the foregoing discussion have resulted in two separate basic environments in which porosity developed. West of the Killdeer Trough porosity in the Sherwood subinterval has formed through dolomitization of shallow shelf lime mudstones, packstones, and wackestones. On the eastern flank of the basin porosity typically developed by dolomitization of lime grainstones and wackestones on nearshore shoals, or in adjacent dolomudstones.

Plates 5 and 6 show distribution of Sherwood porosity measured by net feet of average values of 10% or more from neutron-density log cross plots. Though some bias is inevitable due to well distribution, there is a correlation of porosity with the shoreline position on Plate 5. Better porosity favors the shallow, nearshore shelf and shoal grainstones adjacent to the average shoreline position in Mountrail and McLean Counties. A second, northwest trend from Wabek Field is recognizable as well. Since this trend is offshore, but still associated with Sherwood thinning, it may represent shoals or proximity to island sabkhas.

In northern Dunn County porosity is best developed around Little Knife and nearby fields where the Sherwood restricted shelf lithologies are thicker (Lindsay and Roth, 1982). Dolomitization of this facies produced widespread porosity unrelated to the coastal anhydrites of the sabkha. Rather, the dolomites change either to facies 3 grainstones (in Petty's facies listed above), or dolomitic lime mudstones. Where porosity does form adjacent to the sabkha it is in scattered, localized pods along the transition between the two major depositional patterns and thence eastward. The pods correlate with isopach thins similar to the northeastern part of the study area.

Cross Sections

A series of cross sections (Plate 7) illustrates the changing depositional patterns normal to the shoreline and between the two tectonic blocks. The sections are stratigraphic, with the reference datum at the top of the Sherwood marker. The superjacent Bluell subinterval is included to show the general variation of that unit in relation to the Sherwood.

Section A-A' shows the characteristic transition pattern for the eastern flank of the basin in the northeastern portion of the study area. The Luff K-35 Nielson well has a thicker Sherwood section composed of limestones deposited in an open marine slope environment. Shoreward from there is a narrow shelf leading to the northeast-southwest shoreline. A shallow platform adjoining the shoreline, which is necessary for development of packstone and grainstone shoals, is generally lacking here. A poorly developed shoal does occur in upper Sherwood beds at Spring Valley Field, which lies directly adjacent to the shoreline. Porosity there is predictably low in an environment dominated by lagoonal mudstones and anhydrite precipitation. Throughout the study area wells drilled along a northeast striking shoreline have often tested only small amounts of oil with considerable water, indicative of marginal porosity in poorly developed shoals.

In contrast, section B-B' illustrates the pattern for a northwest-southeast striking shoreline with a broader shallow shelf. At Plaza Field thick, tight limestones formed on a slope environment, while updip to the east a shoal facies was deposited on the shelf at Wabek Field. The transition from shoal to lagoon is seen on the log of the Home Petroleum Lynne 32-2 which shows more dolomite and even some anhydrite. The Duncan Oil Tvedt 1-32 shows the rapid change (less than one mile) to an intertidal environment with tight carbonate mudstones, increased anhydrite and a thinner total Sherwood section. Cross section B-B' typifies the general eastern flank depositional pattern described by Hendricks, et al. (1987).

On section C-C' two aspects of Sherwood deposition are illustrated. The section includes the coastal sabkha on the east and the transition to island sabkhas, and north of Lake Ilo Field it crosses the probable boundary of the two tectonic blocks. A continual northwesterly regression of the Sherwood sea is apparent here, with a concomitant encroachment of sabkha evaporites from middle to upper Sherwood time. Associated tectonism might be slow subsidence of the western block with little interruption. In contrast, the Wabek Field area had more static, or slightly oscillatory, nearshore conditions that produced two porosity zones, both of which are recognizable in several of the field wells. In that situation, tectonic subsidence may have been slowed to allow a renewal of shoal growth.

At Werner Field an island sabkha probably formed, separated from the coastal sabkha by a lagoon with lime mudstones, represented by the section in the Tenneco Schettler 1-20 well. South of that well shoals may have developed on a narrow shelf adjacent to an embayment (see Plate 2). With encroaching evaporites from the east, potential reservoir facies would likely have both vertical and lateral anhydrite seals.

West of Werner Field, C-C' cuts across another island sabkha with anhydrite in the middle Sherwood. Again, west of Killdeer Field a similar situation prevailed and the Amoco Fischer 1-A well has a considerable thickness of anhydrite only three miles southeast of open marine limestone in the HNG Murphy 14-1, which suggests a very narrow shelf in that area. An alternative viewpoint would allow these to be areas of subaqueous, rather than sabkha anhydrite. However, lacking well core information about the anhydrite, the alternative interpretation is less consistent with the overall deposition and structural history of the area.

Another view of the same depositional model is represented by section D-D'. In northwestern Dunn County the sabkha encroached from south to north during upper Sherwood time. The lime mudstones of a lagoon are present in the Cities Service State B-1 well, nearly five miles north of Murphy Creek Field where anhydrites and mudstones intermix. This suggests a very gradual facies change unlike that which occurs on the eastern flank of the basin. In addition, the isopach map (Plate 2) does not indicate presence of a consistent shallow shelf and accompanying slope. Consequently the average shoreline position is more difficult to define in this area. Sherwood deposition, then, represents a slow, continual, northward regression with irregular local facies variations. In that environment porous shoals are lacking and reservoirs occur in the dolomitized mudstones on the widespread shelf of Petty's (1988) model.

CONCLUSIONS

The study area can be separated into two parts, with the depositional history of each being affected by a major Precambrian basement structural block. The boundary between the blocks forms part of the Killdeer Trough, recognized by a series of northwest-southeast aligned structural elements. The eastern block was periodically active during Mississippian time, with repeated times of minor subsidence, reflected in the stratigraphic facies relationships. In contrast, the western block subsided very slowly and steadily, resulting in irregular local facies patterns. At the mutual block boundary narrow, linear, well-defined anticlines and synclines developed, with associated normal faulting. It is possible that all of the structural movement is the result of sediment loading. However, since the two blocks and their mutual boundary responded differently to the same amount of sediment loading on basement crustal material, it is concluded that Sherwood deposition was significantly affected by tectonic activity in this portion of the Williston Basin.

Each of the two general depositional patterns that corresponds to a structural block has facies representing a lateral transition from sabkha anhydrites to open marine limestones. The eastern basin flank pattern shows evidence of periodicity between stratigraphy and structure, and an average Sherwood shoreline position that corresponds to Precambrian basement linear structural features. At least locally, the adjacent restricted shelf area has been similarly related, at Wabek Field (Sperr, et al., 1993). The western block depositional pattern is one of slow, continuous subsidence and gradual northerly regression as anhydrites overstep the carbonates. Associated with northwest-trending basement linear structures are shallow shelf deposits and island sabkhas, which change quickly to thicker carbonates in narrow adjacent troughs.

Porous grainstone shoals develop on northwest oriented shorelines of the eastern flank depositional pattern. They form in restricted shallow shelf areas with lagoonal mudstones separating them from the sabkha. The western part of the area (Dunn County) is representative of the southern Williston Basin depositional pattern described by Petty (1988), in which porosity forms from dolomitization of the lime mudstones. Grainstone shoals are nonporous and irregularly distributed, as are all facies here. However, the pattern of the western block may have larger areas of porosity development and subsequently larger fields.

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PLATE 1

SHERWOOD ISOPACH
AND SHORELINE
McLean and Mountrail Co.'s

Contour Interval 4'

<20% >20% Anhydrite = 20%
(Average Shoreline Position)

Scale: 1:8000

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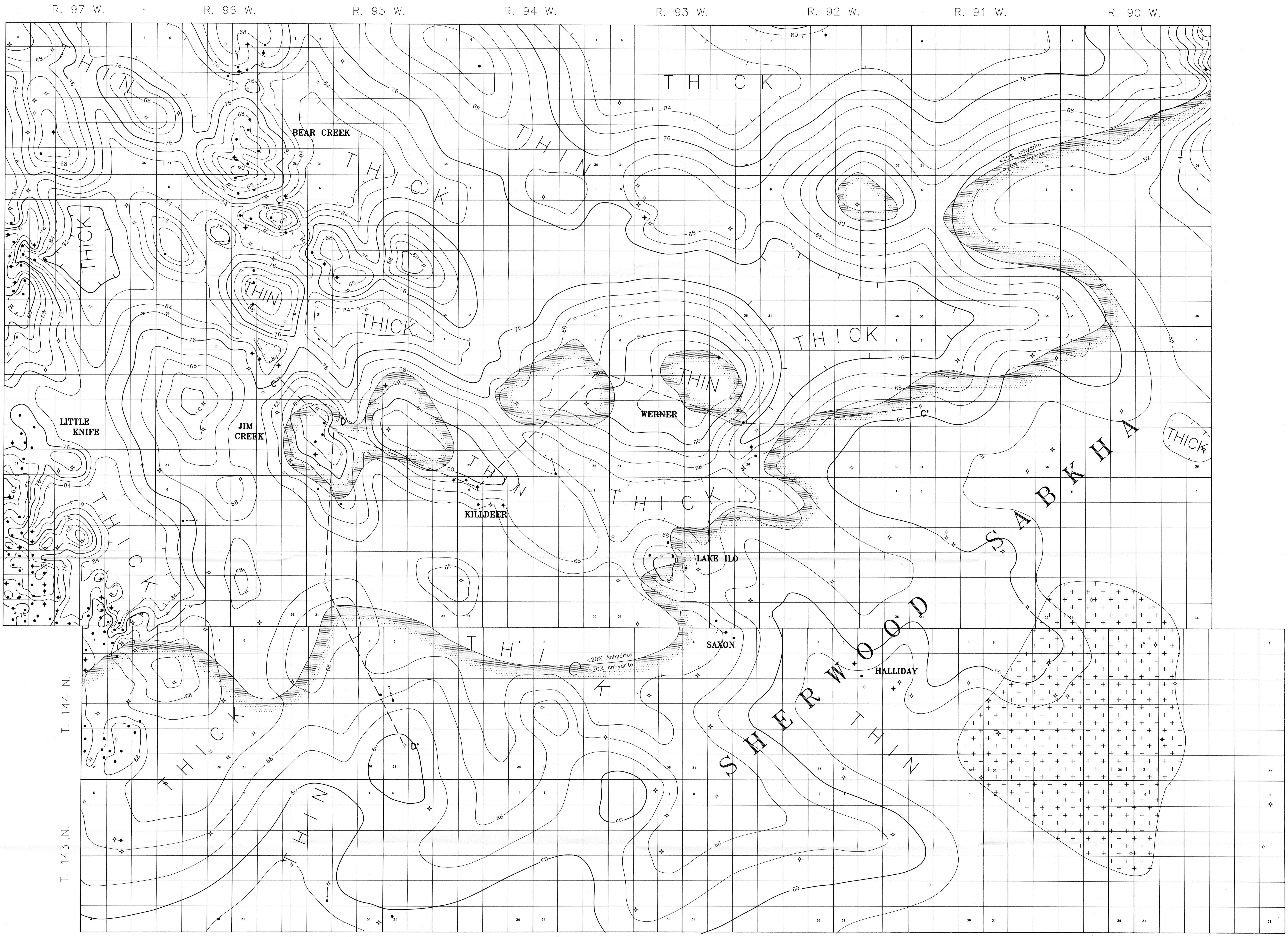

PLATE 2

SHERWOOD ISOPACH AND SHORELINE Dunn County

C.I. = 4'

<20% / >20% Anhydrite = 20% (Average Shoreline Position)

Salt

Scale: 1:8000

NORTH DAKOTA GEOLOGICAL SURVEY
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PLATE 3

SHERWOOD STRUCTURE
McLean and Mountrail Co.'s

Contour Interval 50' (25' in fields)

<20% ▨ >20% Anhydrite = 20%
(Average Shoreline Position)

Scale: 1:8000

NORTH DAKOTA GEOLOGICAL SURVEY
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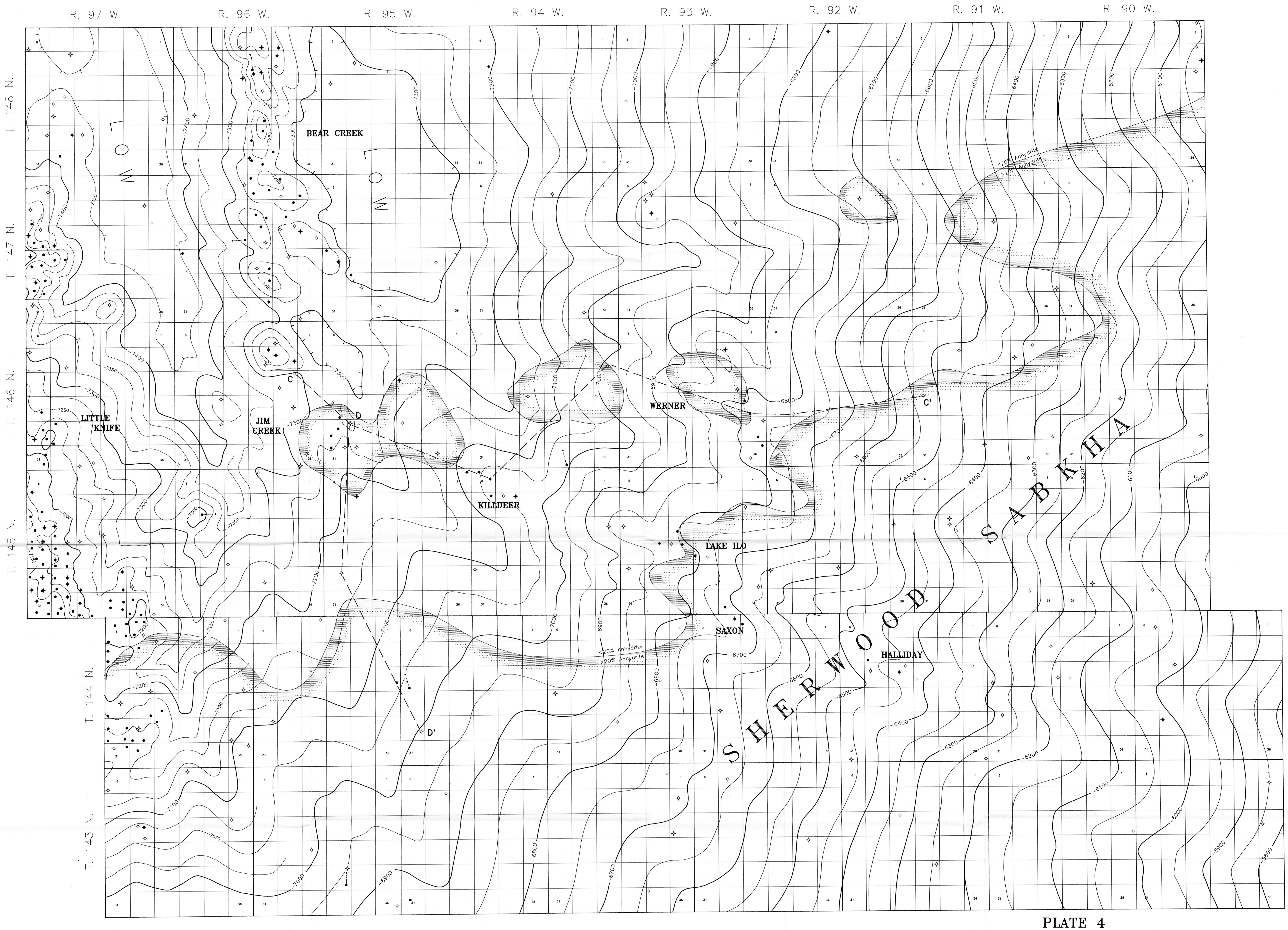

PLATE 4

SHERWOOD STRUCTURE
Dunn County

Contour Interval 50' (25' in Fields)

<20% >20% Anhydrite = 20%
(Average Shoreline Position)

Scale: 1:8000

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PLATE 5

SHERWOOD NET POROSITY

McLean and Mountrail Co.'s

Contour Interval 20 0–ft. below 100 & 100 0–ft. above

<20%
>20%
Anhydrite = 20%
(Average Shoreline Position)

Scale: 1:8000

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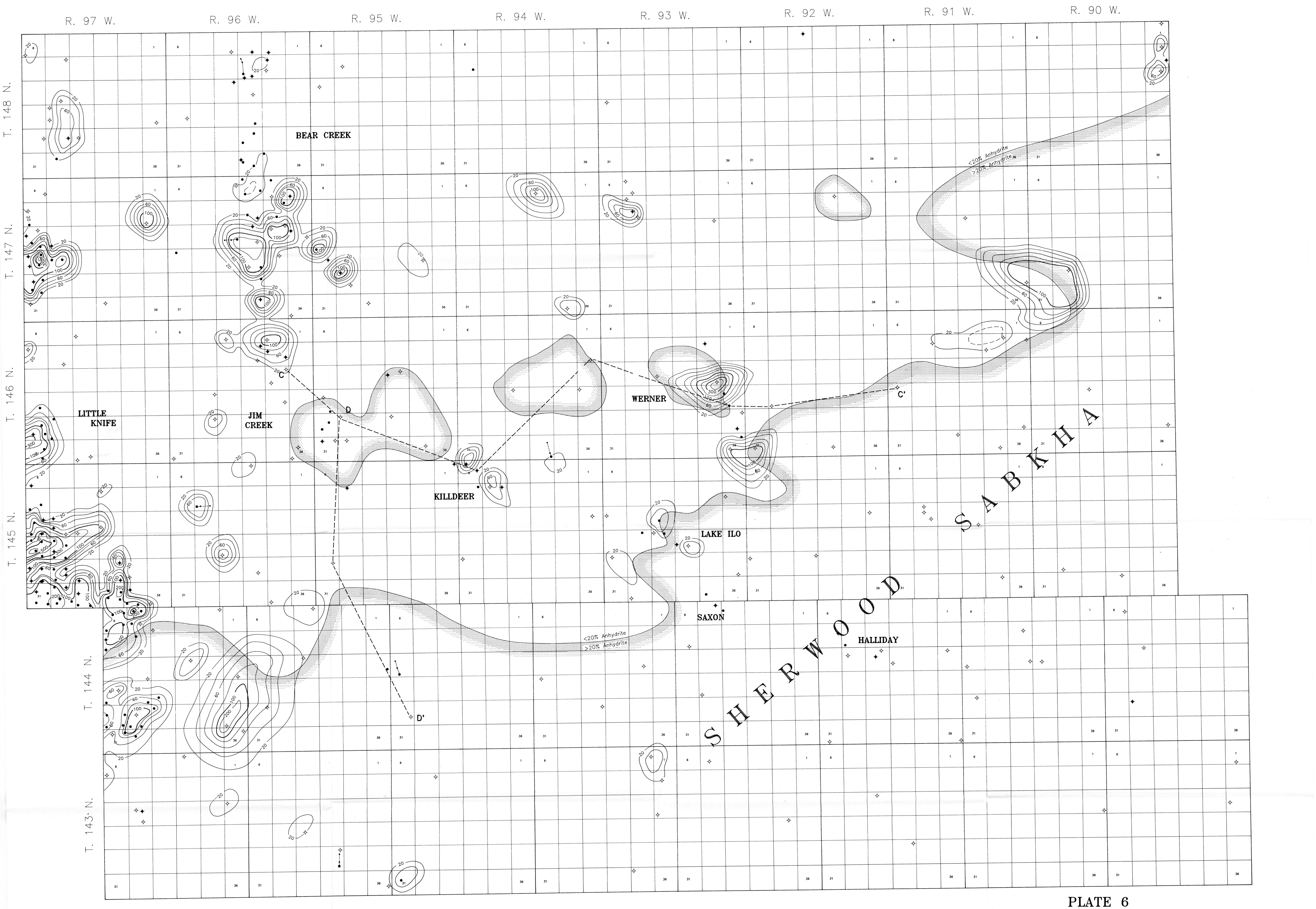

PLATE 6

SHERWOOD NET POROSITY

Dunn County

Contour Interval 20 Ø–ft. below 100 & 100 Ø–ft. above

<20% >20%	Anhydrite = 20% (Average Shoreline Position)

Scale: 1:8000

NORTH DAKOTA GEOLOGICAL SURVEY
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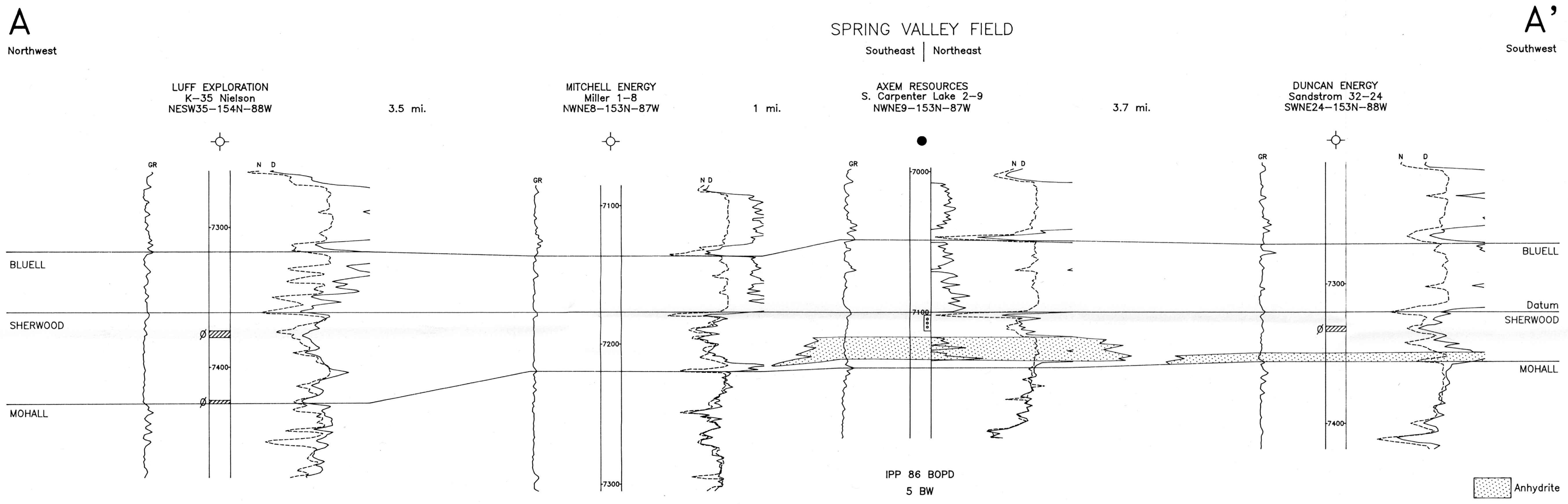
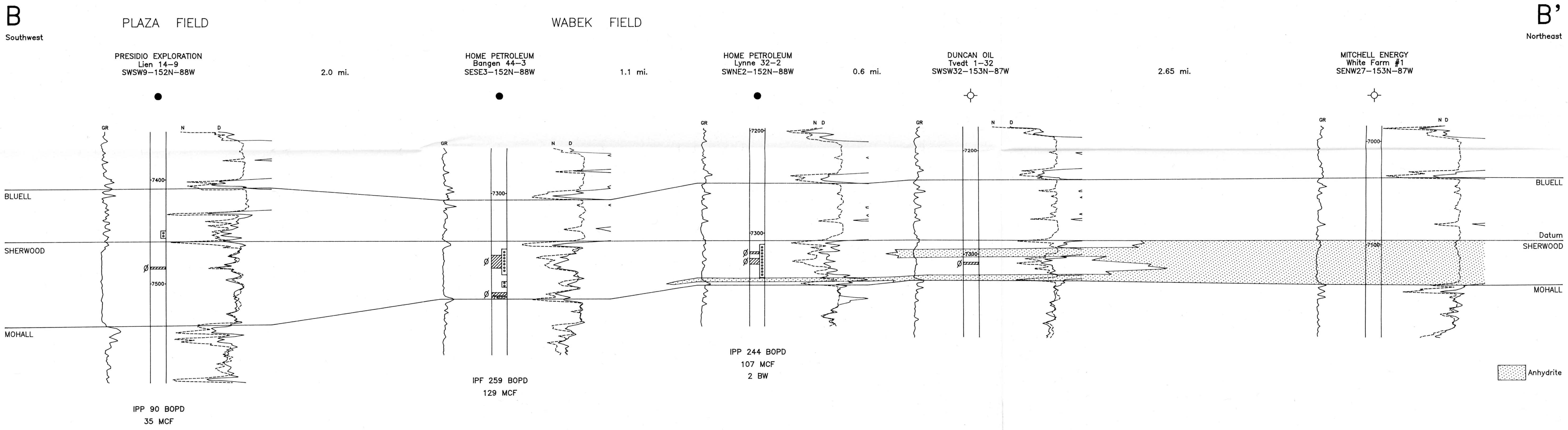
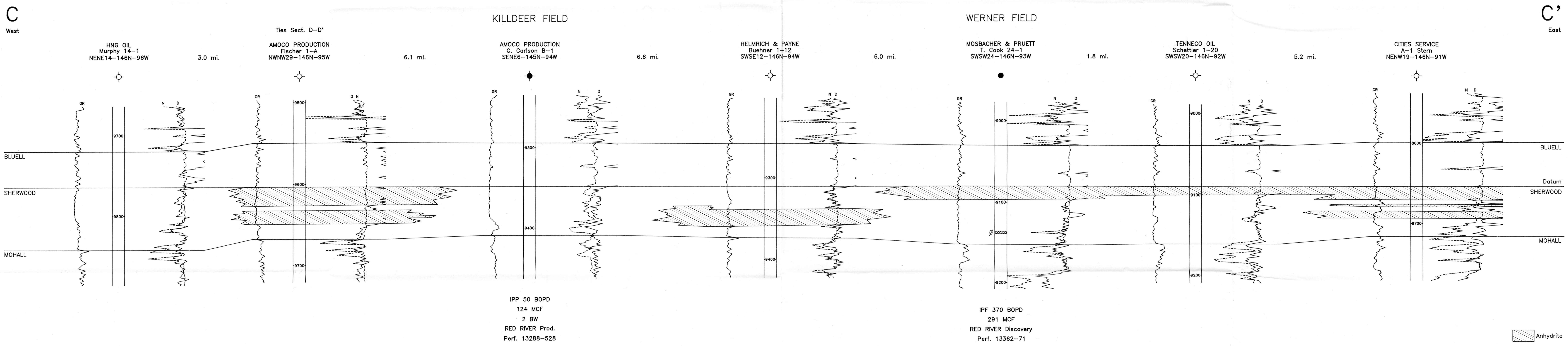
PLATE 7
SHERWOOD CROSS SECTIONS

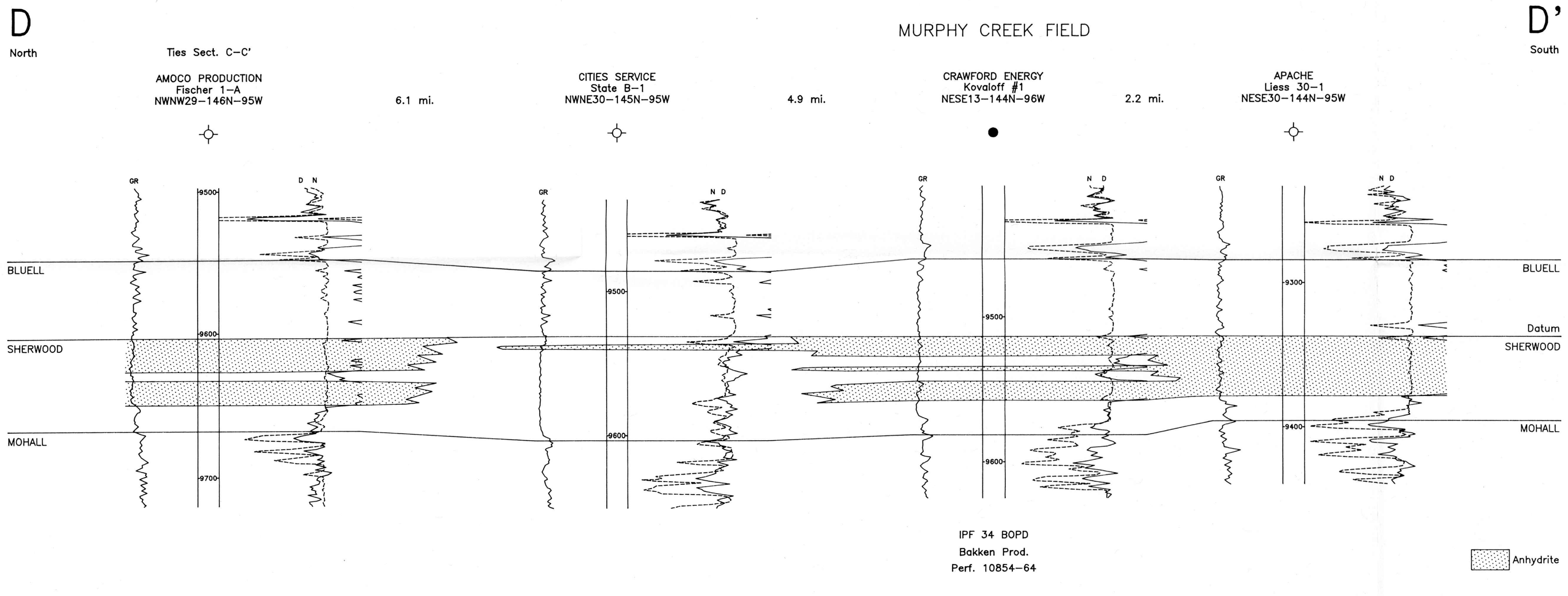
North Dakota Geological Survey

Report of Investigation 97









INDEX MAP OF STUDY AREA