NEWBURG - SOUTH WESTHOPE OIL FIELDS, NORTH DAKOTA

by

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Newburg–South Westhope Oil Fields, North Dakota[1]

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Abstract The Newburg and South Westhope oil fields, located in Bottineau County, North Dakota, in the northeastern part of the Williston basin, are excellent examples of stratigraphic traps, although structural elements are involved in trapping of the accumulations. The oil is produced from two adjacent zones separated by a major unconformity, and they are considered to be a common reservoir. The productive units are the "Ratcliffe" interval of the Mississippian Charles Formation and the Saude Member of the Triassic Spearfish Formation. Post-Paleozoic migration of the oil is indicated because, even though the "Ratcliffe" was exposed to considerable erosion, it is productive at the unconformity.

Introduction

The Newburg and South Westhope oil fields are located in T161–162N, R79–80W, Bottineau County, north-central North Dakota, in the northeastern part of the Williston basin (Fig. 1). This sedimentary basin covers approximately 150,000 sq mi (390,000 sq km) in North Dakota, South Dakota, and Montana, and in the provinces of Manitoba and Saskatchewan, Canada. It contains up to 15,000 ft (4,920 m) of sedimentary rock ranging in age from Cambrian through Tertiary (Link, 1958, p. 6).

History

Newburg Field

The discovery well for the Newburg field was the Amerada Petroleum Corp. No. 1 Beauchamp (SE¼ SW¼, Sec. 21, T161N, R79W), completed July 10, 1955, with an initial daily production of 73 bbl of 35.8° API oil and 26 bbl of water (Folsom *et al.*, 1958, p. 15) from a basal sandstone in the Triassic Spearfish Formation at 3,507 ft (1,070 m) and the "Ratcliffe" interval of the Mississippian Charles Formation. For 25 months this well remained the lone producer in the field; in September 1957, Amerada completed the No. 1 L. D. Henry 1.25 mi (2 km) north of the discovery, at 3,406 ft (1,040 m). Initial production was 121 bbl/day from the Spearfish-Charles. Net "pay" thickness in the field is 17.8 ft (5.4 m). Development drilling followed rapidly and, as of January 1, 1970, 112 producing wells had been drilled. By February 16, 1967, 24 of these wells had been converted to injection wells.

The field since has been unitized and is operated by the Amerada-Hess Petroleum Corporation. Pressure maintenance was begun in February 1967. Total production from the field to July 1, 1970, has been 9,581,577 bbl of oil; remaining reserves are estimated to be 4.4 million bbl.

South Westhope Field

The discovery well in the South Westhope field, the Cardinal Petroleum Company No. 1 Russell R. Smith (SW¼ SW¼, Sec. 14, T162N, R80W), was completed January 28, 1957, with an initial daily production of 25 bbl of oil and 5 bbl of water. The production is from the Spearfish-Charles; net "pay" thickness in the field is 15.5 ft (4.7 m). Ultimately, 61 producing wells were drilled in the field; 49 are now pumping, 5 are plugged and abandoned, 1 is used for salt-water disposal, and 6 are shut in. Total production from the field to July 1, 1970, has been 5,415,686 bbl of oil; remaining reserves are estimated to be 8.2 million bbl.

Stratigraphy

General

The oil in the Newburg and South Westhope fields is produced from two adjacent zones separated by a major unconformity; the producing zones are considered to be a common reservoir. The two units are the "Ratcliffe" interval of the Mississippian Charles Formation of the Madison Group and the overlying Saude Member of the Triassic Spearfish Formation.

The "Ratcliffe" interval has been subdivided into several units of which one, the "Midale subinterval," is well recognized because it is the reservoir in the Midale field, Saskatchewan (Parker, 1956; Fuller, 1956), as well as in several fields in eastern Montana and southern Canada. The "Midale" forms the base of the "Ratcliffe," and over it are the informally designated units making up the remainder of the "Ratcliffe" in the Newburg and South West-

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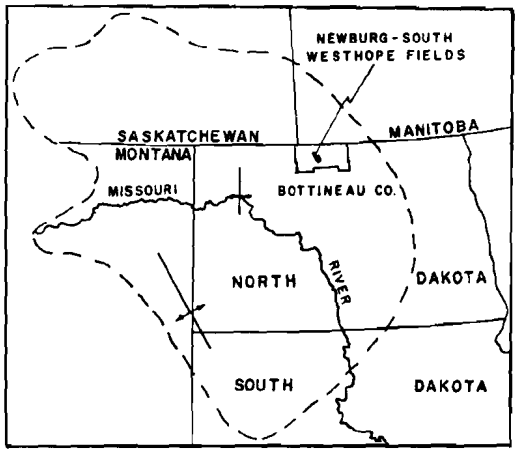


FIG. 1—Map showing Williston basin and location of Newburg–South Westhope fields.

hope fields. They are, in ascending order: "Midale Anhydrite," "Lower Berentson," "Upper Berentson," and "Berentson Anhydrite." This subdivision is illustrated in Figure 2.

The Triassic Spearfish Formation was described in detail by Dow (1967, p. 10–13), who subdivided it into several members of which only the Saude is present at Newburg–South Westhope fields. A typical log of the Spearfish Formation is indicated in Figure 2.

"Frobisher-Alida" Interval

The Mississippian "Frobisher-Alida" interval directly underlies the "Midale" part of the "Ratcliffe" interval in the field areas. This unit is predominantly a carbonate and evaporite sequence, and evaporites (principally anhydrite) are predominant in the upper part.

"Ratcliffe" Interval

In the Newburg–South Westhope area, all of the "Ratcliffe" units were truncated successively from west to east by post-Mississippian erosion. A short distance east of the fields, the entire "Ratcliffe" section has been eroded and the overlying Spearfish lies unconformably on the "Frobisher-Alida" beds (Fig. 3).

Figure 4 is a structural map of the post-Mississippian unconformity in the field areas, where it is of "Ratcliffe" age.

Lithologically, the "Ratcliffe" is composed predominantly of carbonate rocks and anhydrites which appear to be cyclic in origin. The cyclic nature of the beds provides some excellent markers for subsurface mapping. A typical log showing the main units of the "Ratcliffe" is shown in Figure 2.

"Midale Subinterval"—The "Midale" in this area is 35–40 ft (10–12 m) thick. Harrison and Larson (1958) described the unit as being "cream to buff, micro-granular to oolitic and calcarenitic limestone." They further stated that "It has poor to fair scattered inter-granular and pin point vugular porosity and generally shows slight oil staining."

Overlying the "Midale" are the informally designated units composing the rest of the "Ratcliffe" interval.

"Midale Anhydrite"—This unit consists of approximately 30 ft (10 m) of dense dolomitic anhydrite ranging in color from gray to pink.

"Berentson Zone"—This zone is generally subdivided into two units—the "Lower Berentson" and the "Upper Berentson." The "Lower Berentson" has a thickness of 28–30 ft (8.5–9 m) and is composed of two lithologic units, a basal limestone and an upper anhydrite. The limestone unit, according to Harrison and Larson (1958), is "consistently 8 feet thick throughout the field [Newburg] . . . and provides a good structural marker." They described the unit as being "thinly bedded brown, gray, and lavender, very argillaceous, sandy textured, micro-granular limestone containing scattered and insignificant oil shows." The overlying anhydrite unit has a thickness of about 20 ft (6 m) and is composed of gray to pink dolomitic anhydrite.

Directly overlying the anhydrite of the "Lower Berentson" is the productive zone of the "Ratcliffe" in the Newburg and South Westhope fields, the "Upper Berentson." Harrison and Larson (1958) described the lithology of this unit as being "predominantly a buff to brown, calcarenitic, fragmental, and medium-granular limestone showing fair to good pin point to small vugular porosity and some intergranular porosity. Fossils and oolites are common."

"Berentson Anhydrite"—In the farther downdip parts of the fields the "Upper Berentson" is separated from the overlying Spearfish by as much as 42 ft (13 m) of the upper part of the "Ratcliffe" (Harrison and Flood, 1956). This section includes the "Berentson Anhydrite," approximately 12–18 ft (4–6 m) thick. In the highest parts of the field, this upper section of the "Ratcliffe" (including the "Berentson Anhydrite") has been truncated, allowing communication between the "Upper Berentson" and the overlying Spearfish reservoirs.

In much of the area covered by the two

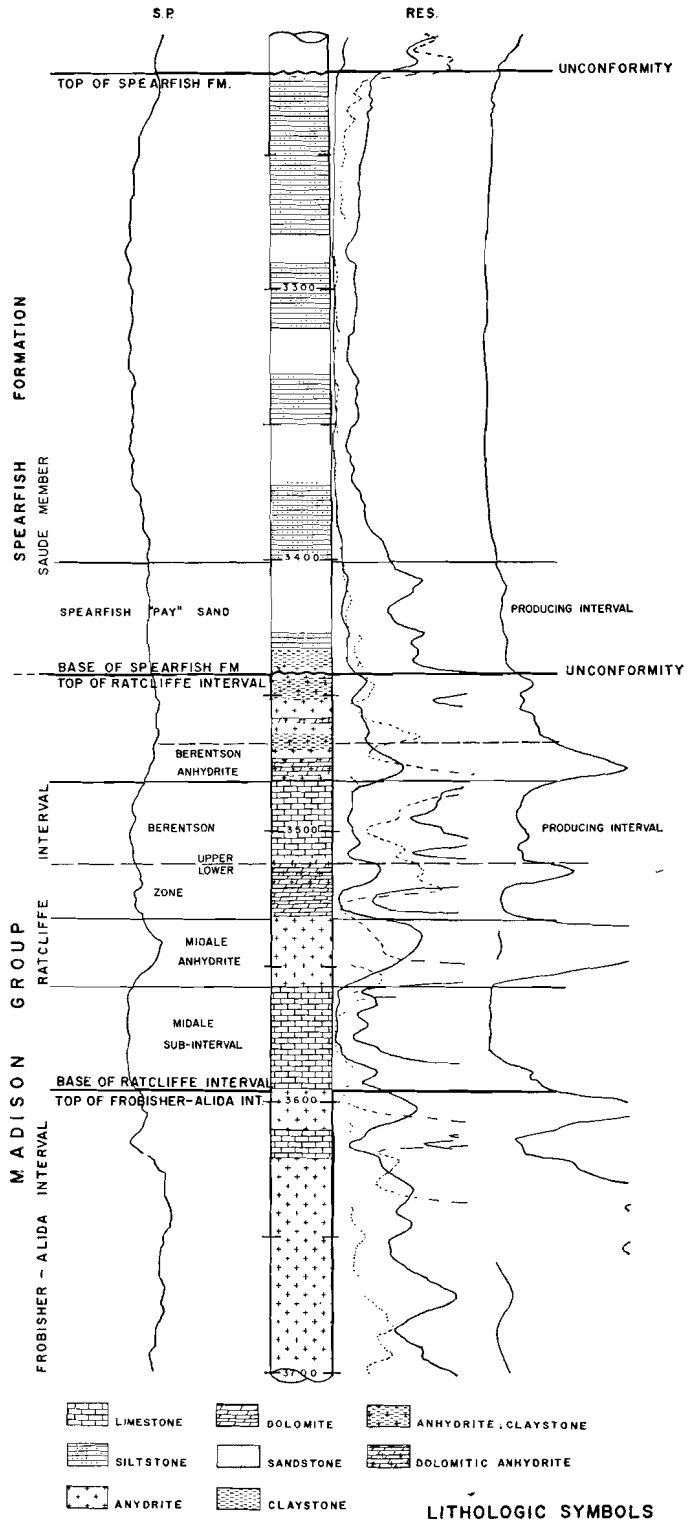


FIG. 2—Type log of Newburg–South Westhope oil fields: Amerada Petroleum Corporation No. 1 Beauchamp, SE¼ SW¼, Sec. 21, T161N, R79W.

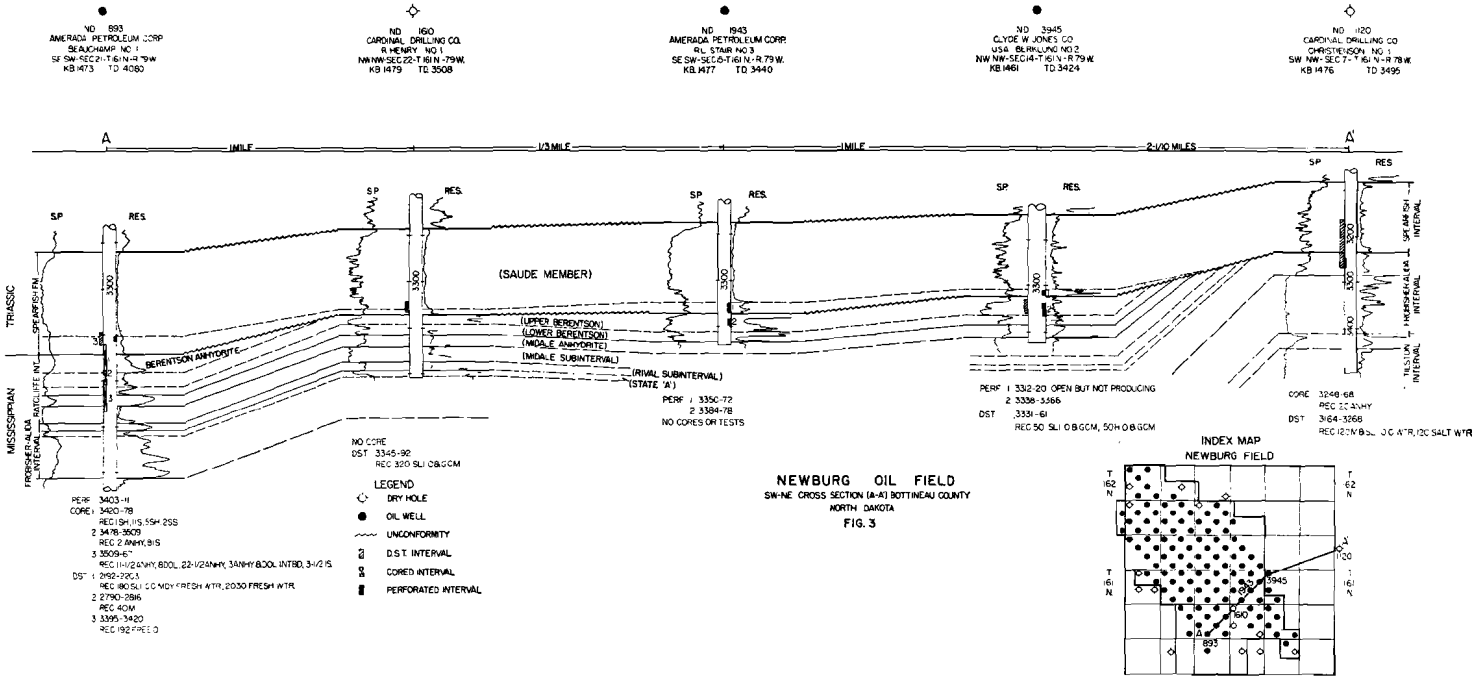
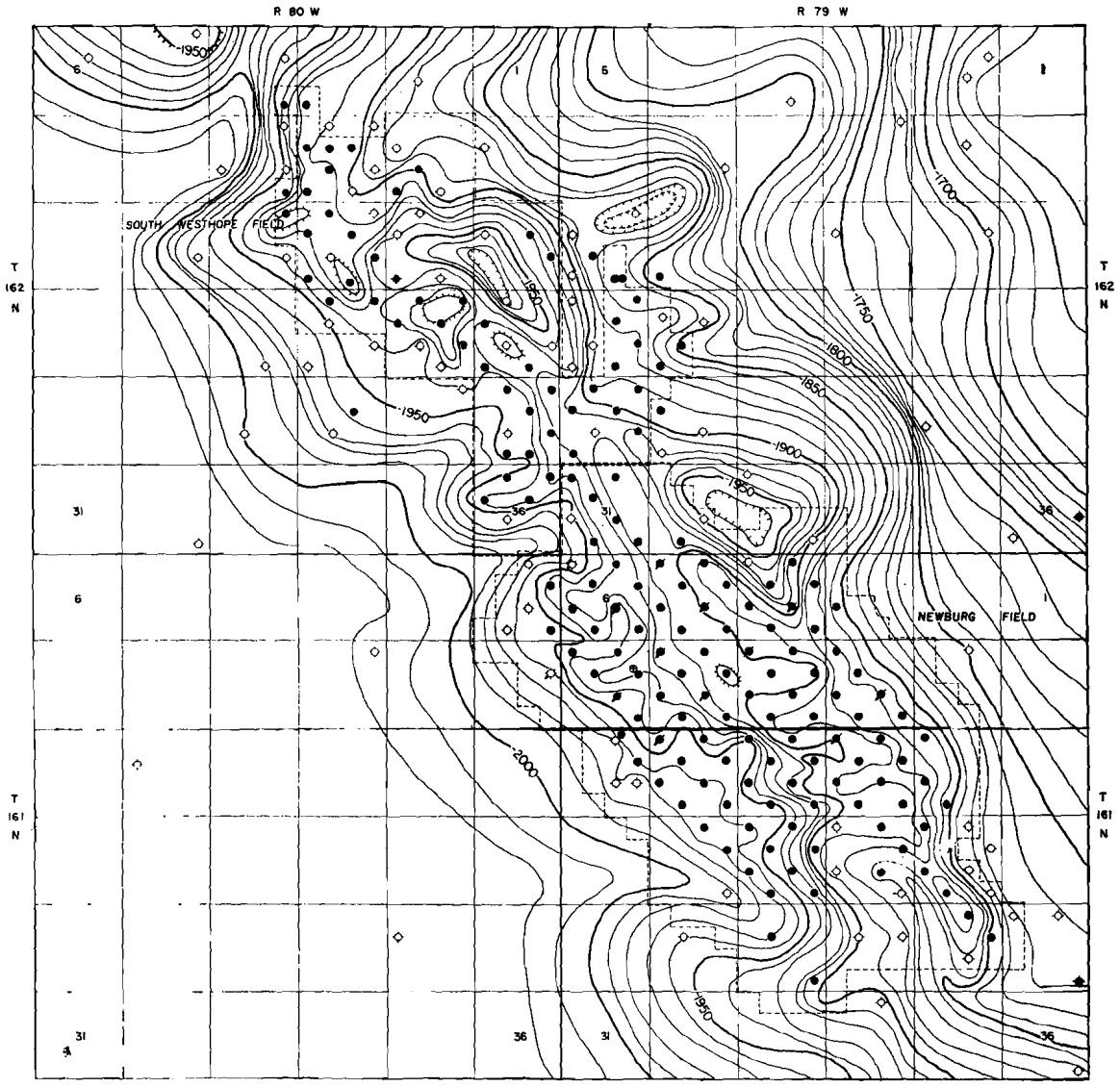


FIG. 3—SW-NE cross section *A-A'*, Newburg oil field.



NEWBURG - SOUTH WESTHOPE OIL FIELDS

BOTTINEAU COUNTY, STATE OF NORTH DAKOTA

T. 161-162 N. R. 79-80 W.

SCALE 1 INCH = 2000 FT

1 MILE

STRUCTURE CONTOUR MAP CONSTRUCTED ON TOP OF THE POST MISSISSIPPIAN UNCONFORMITY

CONTOUR INTERVAL 10 FT.

- OIL WELL
- DRY HOLE
- FLUID INJECTION WELL
- ABANDONED LOCATION
- NON COMMERCIAL PRODUCER
- FIELD OUTLINE
- 1-36 SECTION NUMBERS
- SALT WATER DISPOSAL WELL
- STRUCTURE CONTOUR LINES
- STRUCTURALLY LOW AREA
- STRUCTURALLY HIGH AREA

FIG. 4—Structure contour map of post-Mississippian unconformity surface, Newburg–South Westhope oil fields.

fields, the "Upper Berentson" has been truncated (at least in part) by pre-Mesozoic erosion. In the South Westhope field, this unit was affected to a somewhat greater degree by pre-Mesozoic erosion and, in a few places, has been entirely removed. The overlying Triassic Spearfish, therefore, lies unconformably on the "Upper Berentson" in much of the area. Thus, oil that is thought to have come from the "Upper Berentson" migrates vertically into the basal sandstone of the Spearfish.

Spearfish Formation

Saude Member—Unconformably overlying the "Ratcliffe" (particularly the "Upper Berentson" part) in the Newburg and South Westhope fields is the Saude Member of the Triassic Spearfish Formation. The Saude provides both a reservoir rock and a cap rock for the Newburg and South Westhope accumulations. Thickness of the unit ranges from 180 to 220 ft (55–67 m). The Saude is a redbed section composed predominantly of shale, silty shale, siltstone, and very fine- and fine-grained sandstone but including some thin beds of anhydrite. The dominant color is reddish, ranging from brick red and reddish orange-brown, to reddish brown, with some gray and gray-green siltstone and shale and gray to white very fine-grained sandstone.

Forming the base of the Saude, and locally known as the "Spearfish pay" in the field areas, is a sandstone section. This section is composed of approximately 40 ft (12 m) of fine-grained quartzose sandstone which is interbedded with reddish shales and greenish-gray siltstone. Figure 5 is an isopach map of the sandstone.

Overlying the sandstone and providing a vertical seal for it is a 20–25-ft (6–8 m) unit of impermeable red shale, reddish-brown to gray siltstone, and tightly cemented sandstone. This section also contains either anhydrite inclusions or thin-bedded anhydrites.

Overlying this impermeable unit is a unit locally known as the "water sand." This water-bearing sandstone forms the base of a 100-ft (31 m) section of very fine-grained sandstone, siltstone, and shale. Overlying this sequence and underlying the Jurassic Piper Formation is a 50–60-ft (15–18 m) thickness of brick red to reddish-brown shale with interbedded brick red siltstone in the lower half (Harrison and Larson, 1958).

Structure

Even though the Newburg and South Westhope fields display almost textbook examples of stratigraphic trapping, the accumulations are, in part, structurally controlled. The fields are situated on the eastern flank of a generally north-south-trending syncline (Fig. 6).

The presence of this syncline is perhaps the most important single factor in the accumulation of oil in the Newburg–South Westhope area. As is indicated on the Madison subcrop map (Fig. 6), the strike of the beds is generally northwest-southeast, and, had it not been for the syncline, post-Mississippian erosion would have removed the "Ratcliffe" interval from the area of the fields.

The syncline is thought to have been formed as a result of solution of salt of the Devonian Prairie Formation accompanied by subsidence of the overlying strata. Although the major solution in this area predated deposition of the "Ratcliffe," later subsidence and adjustment probably caused further sinking of the sediments in this area, thereby allowing preservation of much of the "Ratcliffe" section during post-Mississippian erosion.

From maps constructed during the course of this study, but not included in this paper, it appears that the field areas were affected also by minor differential subsidence and adjustment. In the Newburg field, topographic lows and highs in the "Ratcliffe" are reflected by "thicks" and "thins," respectively, in the overlying Spearfish. Conversely, in the South Westhope field, the "Ratcliffe" topographic lows and highs are mirrored in the Spearfish. In addition, the "Ratcliffe" apparently was eroded more deeply in the South Westhope field than in the Newburg field. Thus, it is concluded that the Newburg field area underwent some minor subsidence and readjustment prior to Spearfish deposition, whereas, in the South Westhope field area, minor subsidence and readjustment occurred after Spearfish deposition.

Conclusions

The Newburg and South Westhope fields are excellent examples of secondary stratigraphic traps. The traps resulted from a combination of geologic processes. The "Ratcliffe" interval, which contains the Mississippian "pay" section in the fields, was deposited under somewhat restrictive conditions which continued throughout deposition of the rest of the Madison Group. However, after deposition of the "Ratcliffe," the area began sinking, probably as a result of later subsidence and readjustment which followed the initial subsidence and adjustment resulting from solution of the salt in the Devonian Prairie Formation. This sinking resulted in

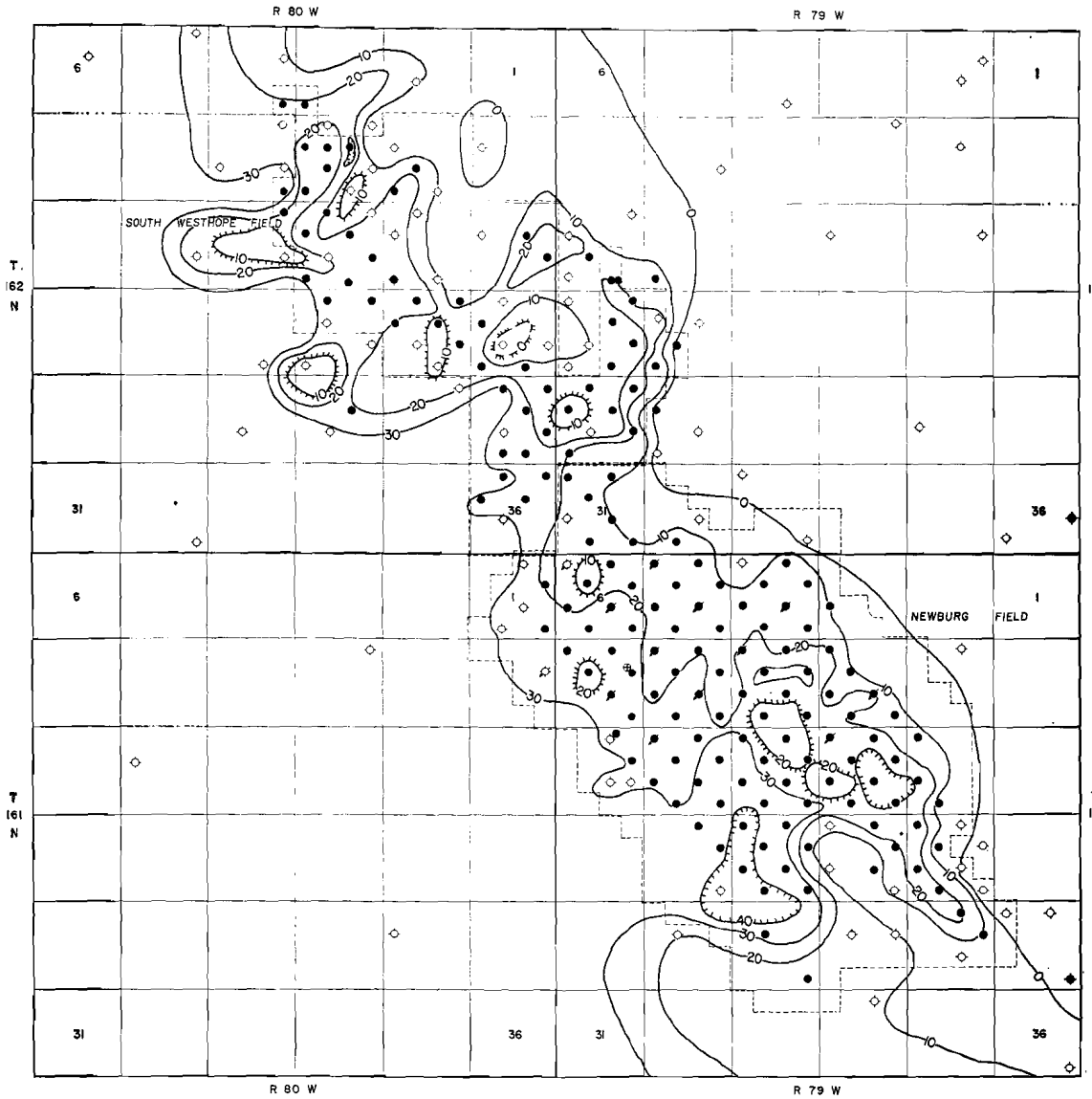


FIG. 5—Isopach map of Triassic Spearfish "pay" interval, Newburg–South Westhope fields.

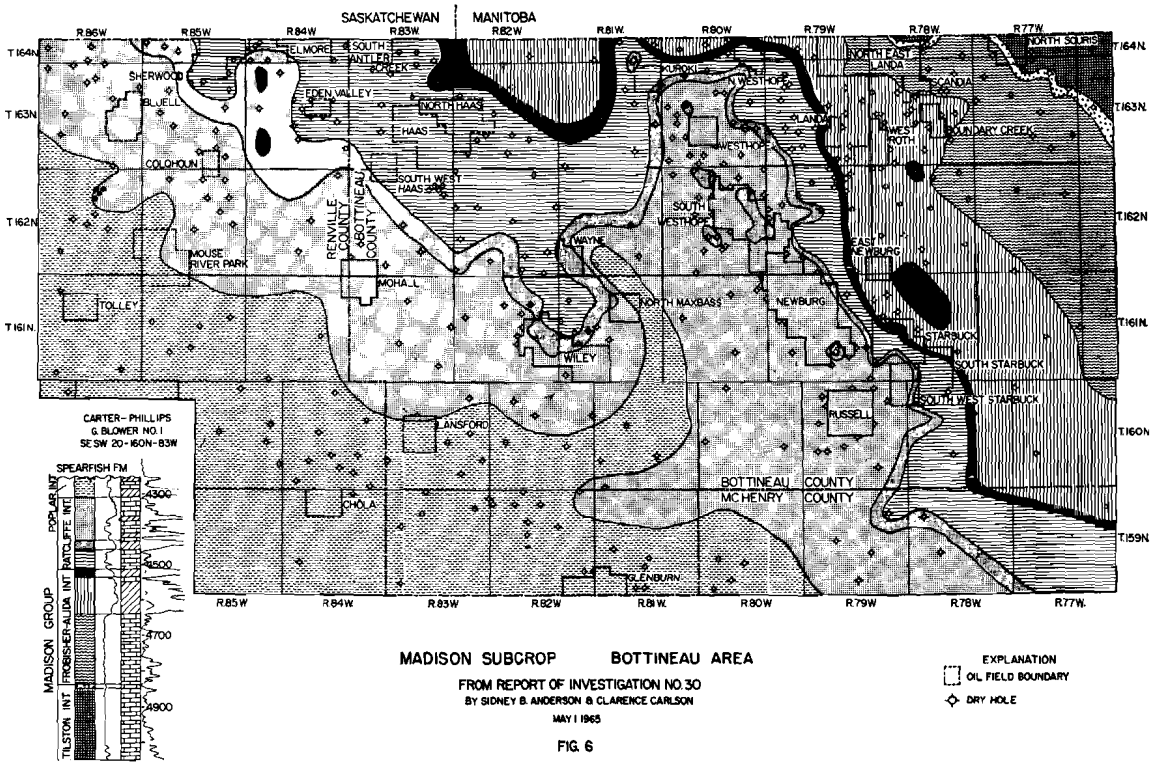


FIG. 6—Madison subcrop, Bottineau area (from Anderson and Carlson, 1965).

the development of the synclinal area shown in Figure 6. Following the withdrawal of the Mississippian sea and prior to deposition of the Saude Member of the Triassic Spearfish Formation, the area underwent extensive erosion. The Mississippian reservoir rocks were preserved because the area of the fields was lowered structurally.

With the advance of the Triassic seas, Spearfish sediments were deposited on the truncated "Ratcliffe" strata, in particular the "Upper Berentson." Initial Spearfish deposition provided the sandstone reservoir which forms the basal Triassic unit in the fields.

Even though the Madison rocks ("Ratcliffe") were exposed to weathering for a long time, oil now is being produced from these rocks at the unconformity, thus indicating post-Paleozoic migration.

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