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AN OVERVIEW OF DOLPHIN FIELD, DIVIDE COUNTY, NORTH DAKOTA

by

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INTRODUCTION

Dolphin Field is located in Divide County, northwestern North Dakota approximately six miles west of the Nesson Anticline (T161N, R95W) (fig. 1). The field produces from two zones, the Middle Devonian Dawson Bay Formation and the Upper Devonian Souris River Formation (fig. 2). To date, the only other fields that have produced from the Middle Devonian Dawson Bay Formation in North Dakota are Temple (Tps158 to 159, Rs95 to 96, Williams County) and Marmon (T157, R100, Williams County). Dolphin Field is of interest because of the high initial potentials and good cumulative production seen from a poorly known pay zone. Dolphin Field also contains the first Souris River production off the Nesson Anticline (Montana Oil Journal, 1987) and, from DST data, it appears that at least one well may be capable of production from the Mississippian Ratcliffe and Devonian Duperow Formations. This paper focuses on the Dawson Bay Formation in Dolphin Field.

REGIONAL GEOLOGY

Dean (1982, figs. 2, 3), who mapped the thickness and porosity of the Dawson Bay Formation in northwestern North Dakota, showed contours trending northwest-southeast. However, from this study, it appears that isopach contours trend more north-south in the vicinity of Dolphin Field (fig. 3). Trends of porosity development are sub-parallel to the isopach trends (fig. 4). An isopach thin extending from the Nesson Anticline across Temple Field to the Dolphin Field area was interpreted to be a paleohigh by Dean. Temple and Dolphin Fields are located where a porosity lens crosses both the paleohigh (isopach thin) and a present-day high (fig. 5).

HISTORY

Dolphin Field was discovered in November, 1986 when Raymond T. Duncan drilled the #1 Bakken test in the NE¼NW¼sec 32, T161N, R95W. The well was drilled to a total depth of 10,065 feet in the Silurian Interlake Formation. A DST over the interval 9,970-10,051 feet flowed gas to surface in 19 minutes and fluids to surface in 102 minutes. A fluid column of 3,356 feet was reversed out and was comprised of 2,000 feet (28.4 bbls) of highly gas-cut oil with a trace of mud and 1,356 feet (14.74 bbls) of highly gas-cut salt water. Oil gravity was 45.8 degrees and the GOR was 1675.5:1. The well was initially perforated from 10,002 to 10,008 feet with 4 JSPF, swabbed with 500 gallons of 15 percent HCL, and completed flowing 1,559 BO + 2,000 mcf + 11.7 BWPD through a 20/64" choke. The flowing tubing pressure was 1,900 PSI. The well was later perforated between 10,008 and 10,038 feet with no change in flow rate.

The first offset well, the #1 Bernice, in the NW¼SW¼ of section 29, was completed flowing 955 BO + 1,300 mcf + 0 BWPD from perforations between 9,926 and 9,978 feet through a 14/64" choke with 2,190 PSI flowing tubing pressure. Another well, the #1 Osborne, located in the NW¼SE¼sec 30, T161N, R95W, averaged 495 BOPD in its first two months of production. Since the discovery, a total of nine locations have been staked or drilled in the field (fig. 4). The field is now believed to encompass approximately 1,920 acres in parts of sections 19, 20, 29, 30, 31, and 32 of T161N, R95W and sections 1 and 2 of T160N, R96W.

LITHOLOGY

Pound (1985) described five lithofacies in the Dawson Bay (table 1)

TABLE 1. LITHOFACIES AND DEPOSITIONAL ENVIRONMENTS OF THE DAWSON BAY FORMATION, MODIFIED FROM POUND (1985).

NORTH DAKOTA DAWSON BAY FORMATION LITHOFACIES	ROCK NAME	DEPOSITIONAL STRUCTURES, ALLOCHEMS, AND PHYSICAL CHARACTER	FAUNA AND FLORA	ENVIRONMENT OF DEPOSITION
F	MUDSTONE (TOP) CRYPTALGAL BOUNDSTONE (LOCALLY ANHYDRITIC) LOCAL INTRACLAST WACKESTONE NEAR BASE	OXIDIZED AND CRENULATED LAMINAE; FENESTRAE; DESSICATION CRACKS; RIPPLE LAMINAE; SCOUR SURFACES; FRAGMENTAL FOSSILIFEROUS LAMINAE; BURROWS; PELOIDS; INTRACLASTS; ARGILLACEOUS; TRACE QUARTZ SILT; COLOR-MOTTLING INCLUDING LOCAL PSEUDOBURROWS	CRYPTALGAL LAMINATIONS (BLUE-GREEN ALGAE) LOCALLY, POORLY FOSSILIFEROUS NEAR TOP AND BASE	SHALLOW EPEIRIC SEA SHORELINE
E	MUDSTONE (TOP) RARE, LOCAL, INTRACLAST WACKESTONE AND PACKSTONE	FENESTRAE; BURROW-MOTTLING; BITUMENS; PELOIDS; INTRACLASTS; PYRITE; ARGILLACEOUS; TRACE QUARTZ SILT; COLOR-MOTTLING	POORLY FOSSILIFEROUS (TOP) GASTROPODS; OSTRACODS; AND LOCAL BLUE-GREEN ALGAE	RESTRICTED SHALLOW EPEIRIC SEA
D	MUDSTONE AND WACKESTONE LOCAL PELOIDAL PACKSTONE	FENESTRAE; BURROW-MOTTLING; BORINGS; COLOR-MOTTLING; PELOIDS; INTRACLASTS; RIPPLE LAMINAE; LOCAL DESSICATION CRACKS; ARGILLACEOUS	GASTROPODS; OSTRACODS; BRACHIOPODS; ECHINODERMS; CORALS; BLUE-GREEN ALGAE; CALCISPHERES; TRILOBITES; and AMPHIPORA	VERY SHALLOW EPEIRIC SEA
C	INTERBEDDED WACKESTONE, PACKSTONE, MUDSTONE, AND BOUNDSTONE	INTRACLASTS; RARE PELOIDS; LOCAL OXIDIZED SURFACES; TYPE I, SUTURE SEAM STYLOLITES HARDGROUNDS AND ARGILLACEOUS NEAR BASE	CYLINDRICAL, SUBSPHERICAL, AND TABULAR STROMATOPOROIDS; CORALS; BRACHIOPODS; BLUE-GREEN ALGAE; BRYOZOANS; ECHINODERMS; GASTROPODS; OSTRACODS; CEPHALOPODS; TRILOBITES; AND CALCISPHERES	STROMATOP-OROID BIOSTROMES AND LOCAL BIOHERMS
B	WACKESTONE AND MUDSTONE OCCASIONAL GRAINSTONE	HARDGROUNDS, ARGILLACEOUS OCCASIONAL LAG DEPOSIT RARE, LOCAL, QUARTZ SILT AND LAMINATIONS NEAR BASE	BRACHIOPODS; ECHINODERMS; CORALS; BRYOZOANS; OSTRACODS; RED ALGAE (?); TRILOBITES; AND CALCISPHERES	SHALLOW EPEIRIC SEA

that represent an overall shallowing-upward sequence from shallow epeiric sea to shoreline environments. A core cut in the Duncan #1 Bernice well fits Pound's model of a shoaling-upward sequence from subtidal carbonates to a supratidal anhydrite (fig. 6). The lower part of the core consists of dark-brown-black, pervasively dolomitized, thick-bedded, skeletal wacke-packstones interbedded with thin mudstones (lithofacies C and D of Pound). These grade upward through dark brown-black, thin-bedded, dolomitized skeletal, peloidal wacke-mudstones (lithofacies E and F) into laminated anhydrite (fig. 7A, 7B, 7C).

POROSITY

The types of porosity most commonly seen in the Duncan core are moldic, intercrystalline, and vuggy. Molds vary in size from less than 1 mm to greater than 2 cm. With the exception of stromatoporoids, most skeletal allochems have been dissolved leaving only molds as a record of their presence (fig. 7A). Large vugs that can exceed 7 cm in their long dimension are present (fig. 7D). Small vugs (less than 5 mm) are more common, especially in the finer grained fabrics. Growth of authigenic dolomite has reduced the porosity (Thomas and Powell, 1980) as has salt plugging (fig. 7A). Core analysis (table 2) shows that porosities are usually low, with the maximum reported being 14 percent, but permeabilities are good in the more porous zones (Core Laboratories, 1987). Fractures are present in the core but these are frequently filled by either dolomite or anhydrite cements.

TRAP

The trapping mechanism at Dolphin Field is an updip pinch-out of porosity like the trap at Temple Field (Dean, 1982). The trap becomes apparent when net porosity is mapped (fig. 4). Porosity decreases updip from the #1 Bernice well, with 34 feet of greater than 6 percent porosity, to only 7 feet in the Ashland Oil #1-29 Fenster (fig. 8). Another well, the Duncan #1 Rivers, has no porosity greater than 5 percent and a crossover effect due to salt can be seen on the neutron-density log (fig. 9). (Dean, 1982) noted a similar effect at Temple Field. Even though the limits of the field are not yet defined, it appears that the reservoir trends northwest-southeast, subparallel to the porosity trends shown by Dean (1982, fig. 3). Based on the available well control, no structural closure is apparent within the field (fig. 5). However, structure has apparently been enhanced by differential salt dissolution. Several areas of thin salt can be seen on an isopach map of the Prairie salt (fig. 10). At least some of the dissolution occurred during latest Souris River and middle Duperow time as these sections are thickened in some wells with thin salt.

Dissolution of pore-filling salt in the Dawson Bay, which may have occurred during dissolution of the Prairie Evaporites, enhanced porosity. As an exploration model, the most likely targets lie where the updip edges of porosity zones cross structural highs (Dean, 1982). Traps may be enhanced in areas of salt dissolution.

RESERVES

The original oil in place can be approximated from the formula:

(7758)X(Porosity)X(Thickness)
X(Area)X(1-Sw)/Boi.

Recoverable reserves can be approximated by the formula:

(7758)X(Porosity)X(Thickness)
X(Area)X(1-Sw)X(RF)/Boi where:

TABLE 2. CORE ANALYSIS FROM CORE LABORATORIES, INC.

RAYMOND T. DUNCAN
NO. 1 BERNICE
WILDCAT
DIVIDE COUNTY, NORTH DAKOTA

DATE : 1-11-87
FORMATION : DAWSON BAY
DRLG. FLUID: SALT GEL NO OIL
LOCATION : NW SW SEC 29 T161 R95W

FILE NO. : 38050-3799
ANALYSIS : HKF, CLG
ELEVATION: 2309 KB
WILLISTON, NORTH DAKOTA

CONVENTIONAL BOYLE'S LAW ANALYSIS

SAMPLE NUMBER	DEPTH	PERM Ka MAXIMUM	POR. He	FLUID OIL	SATS. WTR	GRAIN DEN	DESCRIPTION
	9911.0-9938.0		CORE NO. 1 DAWSON BAY FM.				
			1-11-87 CUT 27' REC.27'				
	9911.0-17.0						AHHY NO ANALYSIS
1	9917.0-18.0	8.70*	1.8	11.3	22.6	2.85	DOL V/FN XLN-SUC SCAT VUGS
2	9918.0-19.0	0.01	0.8	0.0	73.0	2.82	DOL V/FN XLN SALT XLS
3	9919.0-20.0	0.09	6.9	11.8	19.7	2.79	DOL MED XLN SCAT VUGS
4	9920.0-21.0	100.	12.9	9.8	58.6	2.79	DOL FN XLN SCAT VUGS
5	9921.0-22.0	30.	6.0	12.2	31.4	2.83	DOL FN-MED XLN PP VUGS SALT XLS
6	9922.0-23.0	3.60	11.5	0.0	14.8	2.83	DOL FN-MED XLN SCAT SALT XLS
7	9923.0-24.0	0.01	0.7	0.0	65.0	2.82	DOL V/FN XLN-V/FN SUC SCAT VUGS W/SALT
8	9924.0-25.0	0.13	4.6	34.6	23.1	2.82	DOL V/FN-FN XLN SCAT VUGS SALT XLS
9	9925.0-26.0	0.01	2.8	20.1	16.1	2.85	DOL VN-MED XLN SALT XLS
10	9926.0-27.0	0.01	4.5	15.1	58.4	2.84	DOL FN-MED XLN VUGS W/SALT XLS
11	9927.0-28.0	0.01	2.8	16.4	52.3	2.83	DOL FN-MED XLN
12	9928.0-29.0	15.	10.0	10.3	25.8	2.85	DOL FN-MED XLN VUGS W/SALT XLS
13	9929.0-30.0	2.10	6.1	16.1	17.9	2.85	DOL FN-MED XLN VUGS W/SALT XLS
14	9930.0-31.0	0.01	0.6	0.0	68.1	2.80	DOL V/FN XLN VUGS W/SALT XLS
15	9931.0-32.0	0.02	0.5	10.6	63.5	2.82	DOL FN-MED XLN SCAT VUGS W/SALT XLS
16	9932.0-33.0	0.01	0.5	9.8	19.6	2.79	DOL FN-MED XLN SALT XLS
17	9933.0-34.0	0.04	3.2	33.0	42.4	2.85	DOL V/FN XLN SCAT VUGS W/SALT XLS
18	9934.0-35.0	12.	5.9	19.9	23.9	2.85	DOL V/FN XLN SCAT VUGS W/SALT XLS
19	9935.0-36.0	0.01	3.5	10.3	24.1	2.84	DOL MED XLN SALT XLS
20	9936.0-37.0	116.	14.0	10.5	42.1	2.84	DOL V/FN XLN SCAT VUGS W/SALT XLS
21	9937.0-38.0	0.06	5.1	11.9	19.0	2.85	DOL MED XLN SCAT VUGS W/SALT XLS

*DENOTES FRACTURED PERM SAMPLE

Average Porosity = 7½%
Thickness of Pay = 25 feet
Area (acres) = 1,920
Water Saturation (Sw) = 20%
Recovery Factor (RF) = 20%
and Shrinkage Factor (Boi) = 1.9

Using these numbers the original oil in place is approximately 11,750,000 STB of which approximately 2,350,000 STB are recoverable during primary production. Through July, 1987 the field has produced more than 569,000 BO and 800 MMCF. Most of the data for reserve calculations are from data supplied by Dolphin field interest owners during case no. 4352 before the North Dakota Industrial Commission.

SUMMARY

Since its discovery in 1986 Dolphin Field has produced more than 569,000 barrels of oil from the Middle Devonian Dawson Bay Formation, a relatively new producing horizon in North Dakota. Wells in the field have both high initial potentials and good cumulative production, and rapid payouts can be expected. The field produces from a stratigraphic trap located along a structural nose. Similar traps may be found by drilling the updip edges of structurally high porosity thicks.

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Fischer, D. W., and Bluemle, J. P., 1986, Oil Exploration and Development in the North Dakota Williston Basin: 1984-1985 Update, North Dakota Geological Survey Miscellaneous Series 67, 40 p.

Pound, W. R., 1985, The Geology and Hydrocarbon Potential of the Dawson Bay Carbonate Unit (Middle Devonian), Williston Basin, North Dakota, University of North Dakota M.S. thesis, 320 p.

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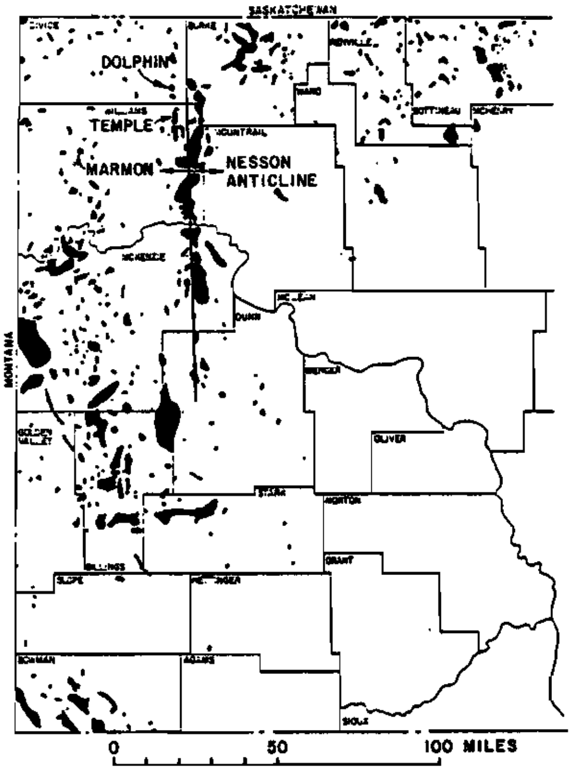


Figure 1. Index map of western North Dakota with oil fields located. Modified from Fischer and Bluemle (1986).

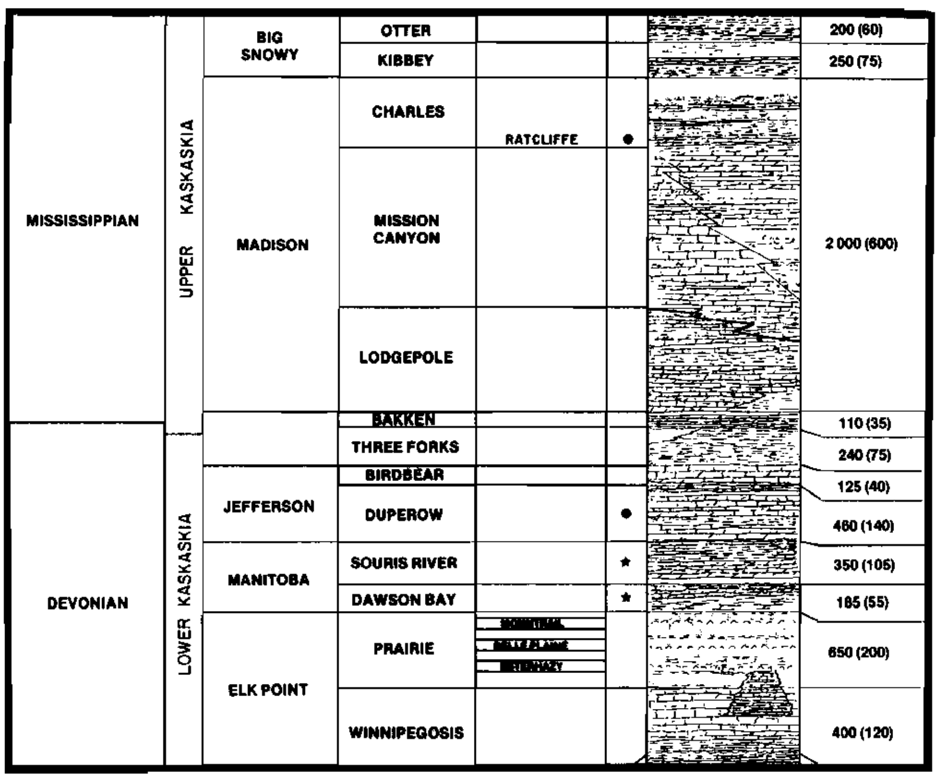


Figure 2. Stratigraphic section of Kaskaskia rocks. Producing formations are indicated by a ★ and shows by a ● . Modified from Bluemle et al (1986).

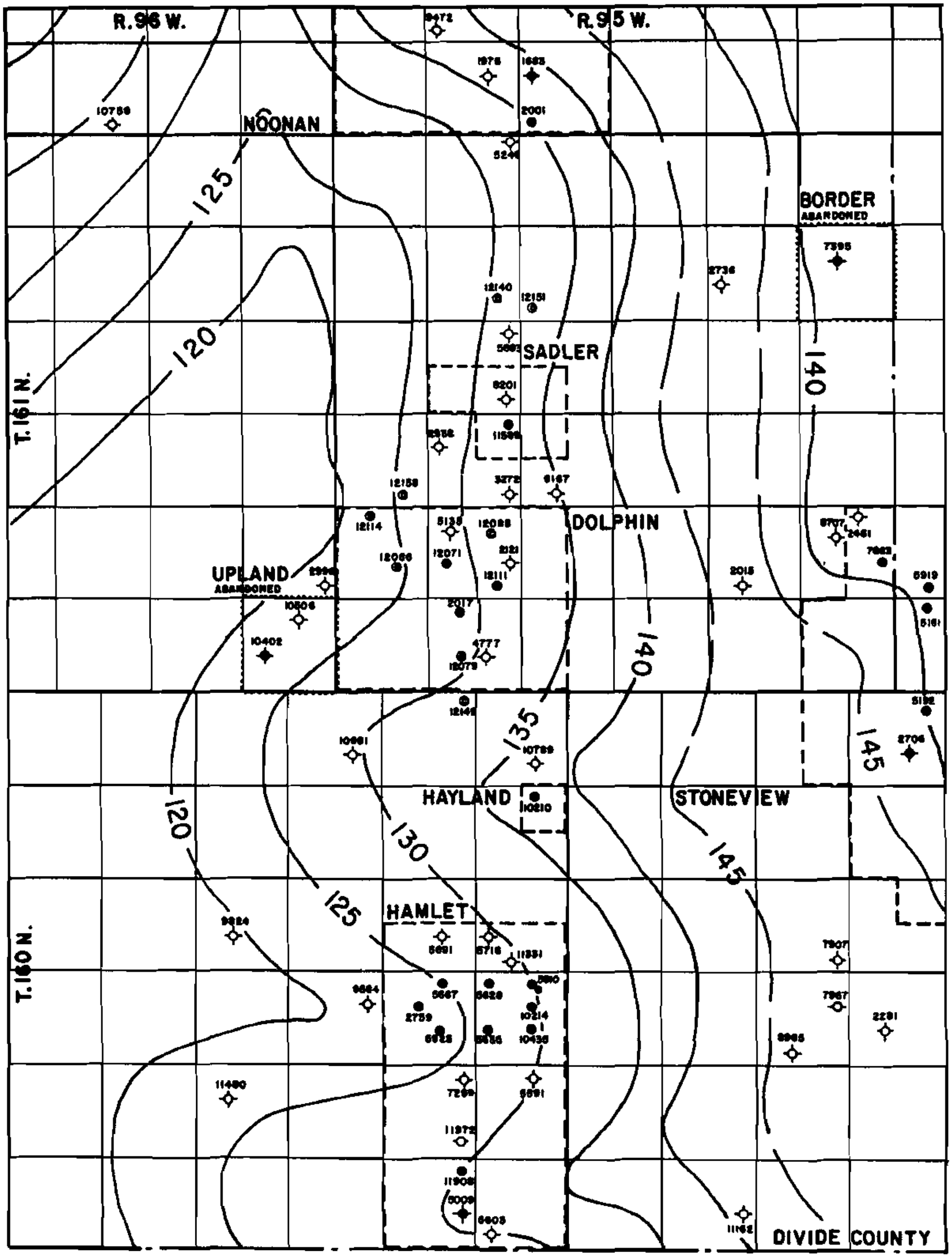


Figure 3. Isopach map of the Dawson Bay Formation, southeastern Divide County, North Dakota. Contour interval = 5 feet.

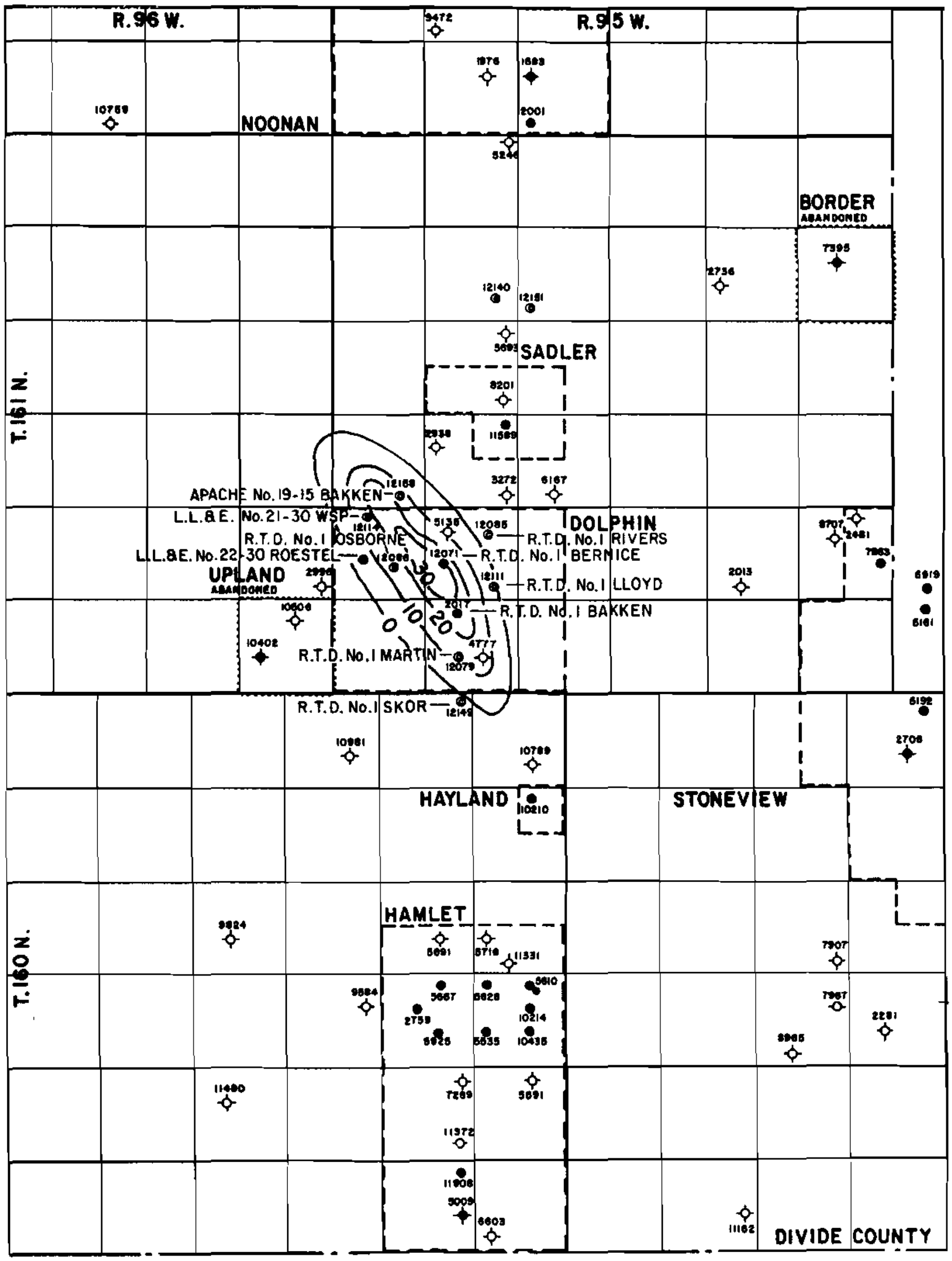


Figure 4. Net feet of greater than 6% crossplot porosity, Dolphin field, Divide County, North Dakota. Also shown are the names and locations of field tests. Contour interval = 10 feet.

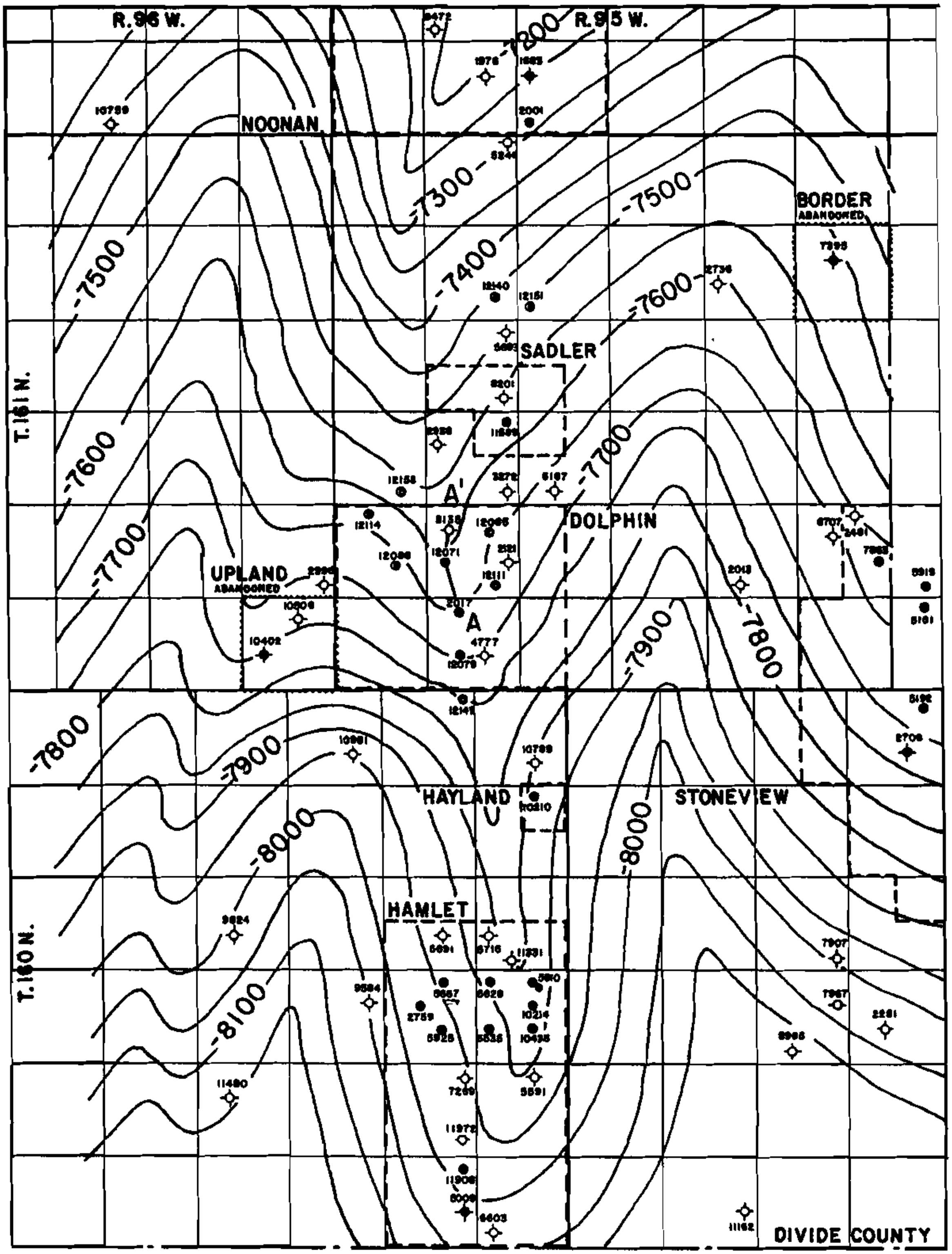


Figure 5. Structure contour map on the top of the Dawson Bay formation, southeastern Divide County, North Dakota. Contour interval = 50 feet.

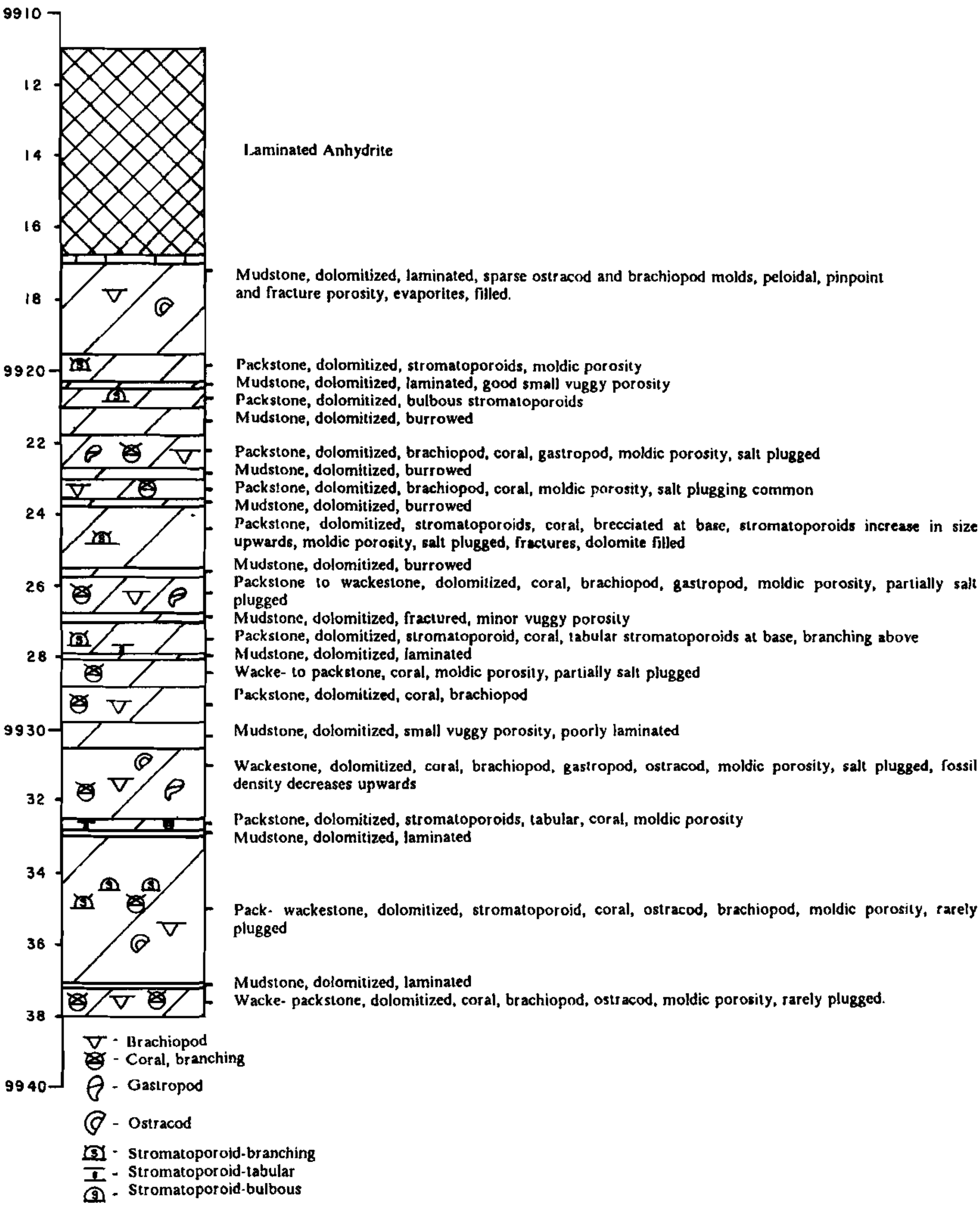
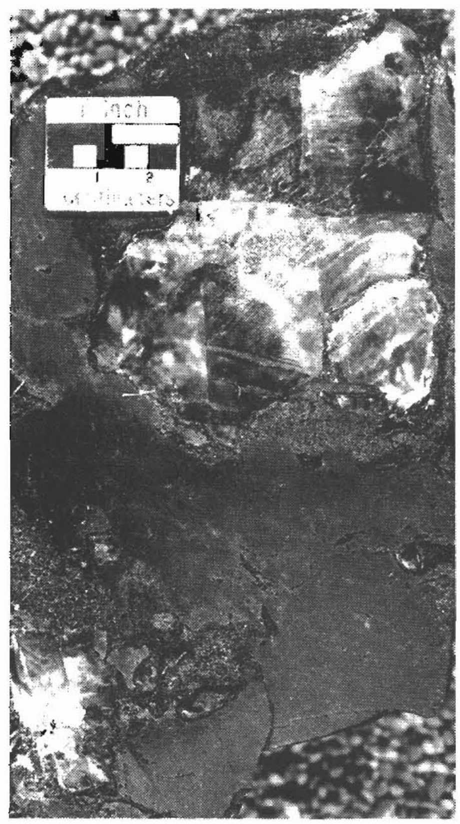


Figure 6. General description of core from Duncan #1 Bernice, sec29, T161N, R95W, Divide County, North Dakota.

(A) Dolomitized packstone with salt plugging moldic porosity. Core depth 9922.5 feet.

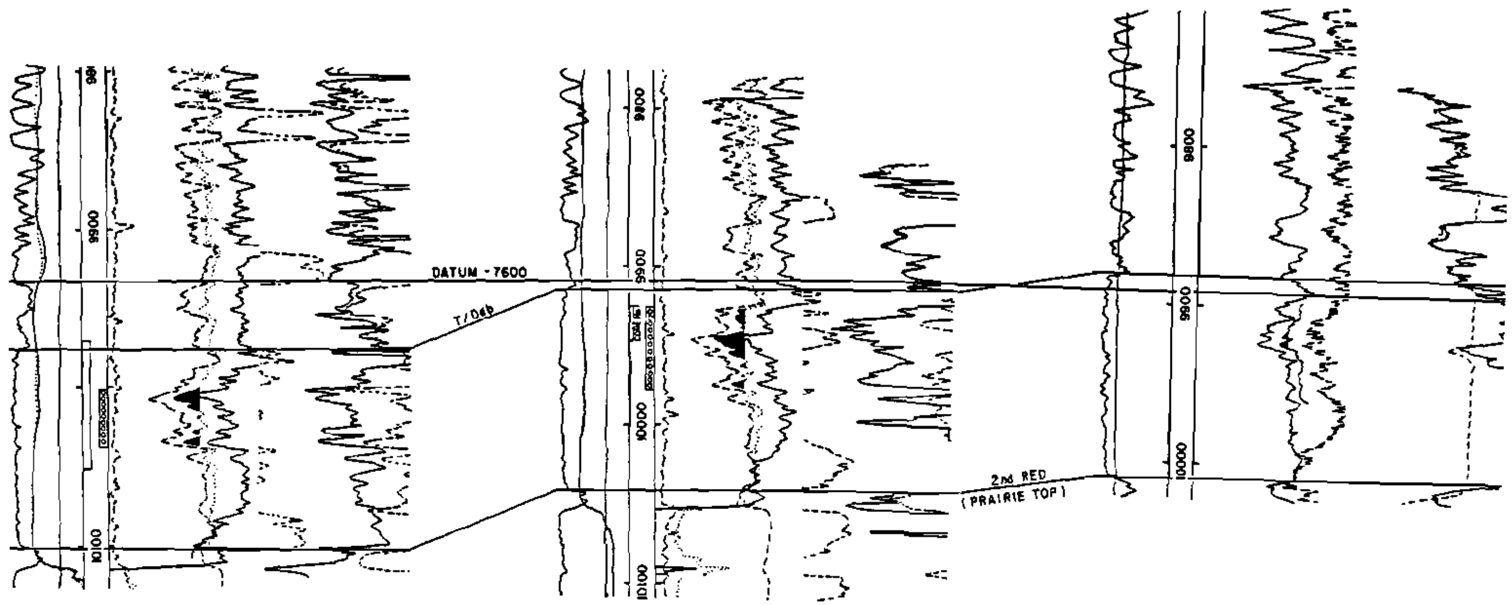
(B) Dolomitized mudstone, laminated at base. Core depth 9923 feet.

(C) Laminated anhydrite. Core depth 9911 feet.



(D) Dolomitized wackestone with large salt filled vug. Core depth 9932 feet.

Figure 7. Core photographs from Duncan #1 Bernice.



DST #4 9970-10051
times 15-60-27-242
PIPE Rec. 2000' HGCO w/tr mud (28.40 bbls)
1356' HGCSW (14.74 bbls)

Sample Chamber Rec.
975 cc oil
425 cc SW
10.21 CFG
@ 1650 PSIG

Pf 10,002-10,008 w/4 JSPF (8-1-86)
IPF 1,559 BO
2,000 MCF
11.7 BWPD
GOR 1300:1
42 API (Corr.)
20/64" Choke
1900 FTP

on 3-30-87
pf 10,022-36
w/4 JSPF
No change in
prod.

perf 9926-78 w/4 JSPF
IPF 955 BO
1,300 MCF
0 BW
GOR 1361:1
45 API (Corr.)
14/64" Choke
2190 FTP

NO CORE
NO TESTS

Figure 8. Structural cross-section across Dolphin field with updip porosity pinch-out shown.

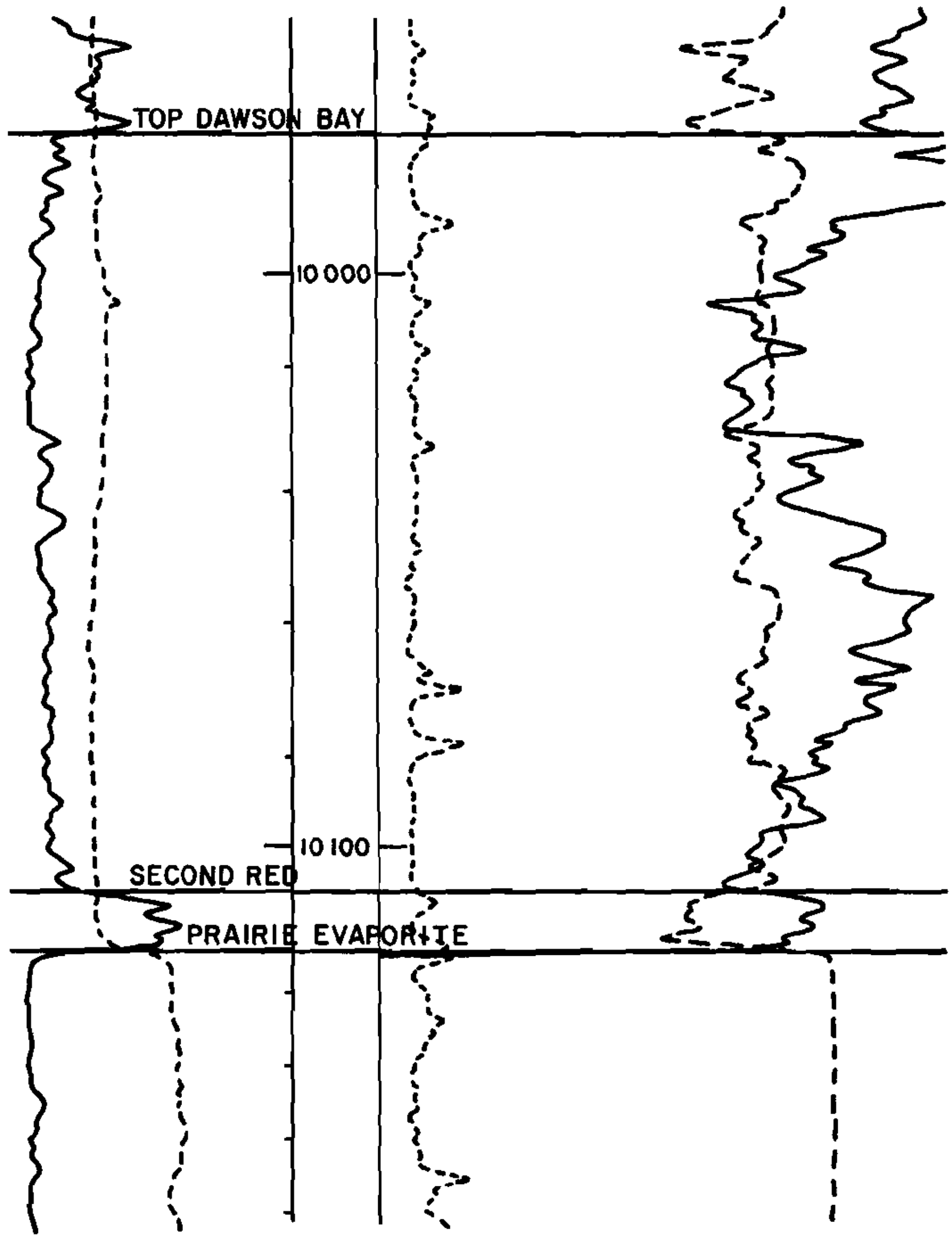


Figure 9. Neutron-density log from the R. T. Duncan #1 Rivers well over the Dawson Bay Formation. Note the cross-over effect between 10,004 and 10,028 feet.

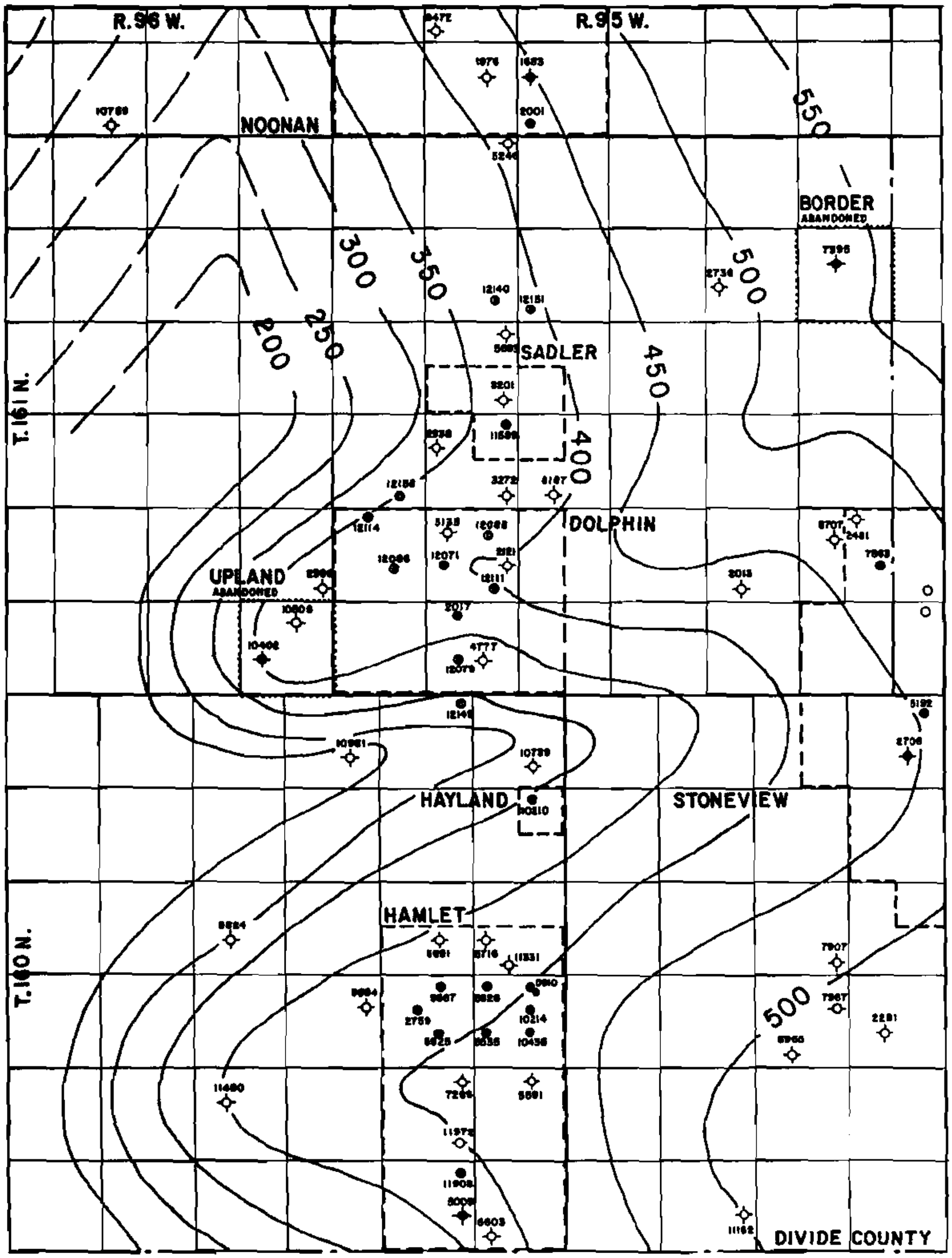


Figure 10. Isopach map of the Prairie salt section near Dolphin field, southeastern Divide County, North Dakota. Contour interval = 50 feet.