OIL FIELD DATA

Field and Pool: WOODNORTH

Location: Twp(s) 8 Rge(s) 27 WP M

DISCOVERY DETAILS

Method:

Well: Name: BA CDN. SUP. WOODNORTH 3-33-8-27

Completed: APRIL, 1954 OPEN HOLE

Perforated: NO

Treatment: NO

Initial Potential:

GEOLOGY

Producing Zone(s): LODGE POLE (ONLY MEMBER UNKNOWN)

Other Shows:

Trap type: COMB.

Lithology: LIMESTONE (CRINOIDAL)

Maximum Reservoir Thickness: 15'

Regional Setting:

Deepest Formation Penetrated:

DEVELOPMENT DATA

Total Wells: Completed Oil: 16 Gas Dry and Abandoned: 3 D&A 8 ABD P

Producing Oil: 7 Suspended oil:

Injection or Disposal: Water: 2 Gas:

Well Spacing: 40 Acres Pattern:

Logging Practice:

Completion Practice: OPEN HOLE. ACID TREATMENT

RESERVOIR DATA

Type of Drive: WATER

Estimated Oil in Place: 3.2 MM S.T. bbls(bbls/acre-foot)

Estimated Recoverable Oil: 800 M S.T. bbls(")

Oil Zone Thickness: Maximum: 15' Average: 8.3

Gas Zone Thickness: Maximum:

Porosity: 8.6 % Permeability: md

Area: 800 acres

Oil characteristics: Gravity: 0.857 °API 33.6 Sulphur: 1.02 %

Pour Point: -50°F Initial Solution GOR Base:

Pressure Maintenance or Secondary Recovery:

PRODUCTION

MPR. 45 BOPD

Economic Allowance: present Operating:

Market Outlet (pipeline): CROMER P.L.

Bibliographical references.

THE BRITISH AMERICAN OIL COMPANY LIMITED
PRODUCTION AND PIPELINE DEPARTMENT
RESERVOIR ENGINEERING SECTION

WOODNORTH FIELD
RESERVOIR STUDY

by

R. K. CRAIG
JOHN NIKOLAYCHUK

REGINA, SASKATCHEWAN, CANADA

September 5, 1958

WOODNORTH FIELD RESERVOIR STUDY

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PURPOSE

This study reviews the history, geology and reservoir mechanics of the Woodnorth Field and estimates the total anticipated recovery from the pool.

SUMMARY AND CONCLUSIONS

The Woodnorth Field is located 11 miles southwest of the town of Virden, Manitoba. Oil is produced from the Lodgepole formation of Mississippian age in this and eight similar pools of varying size in the immediate area.

The reservoir is a structural trap and contains highly undersaturated oil under a strong bottom water drive.

The pool contains 8,196 acre feet and is 985 acres in areal extent. The wells initially averaged 8.32 feet in net pay thickness in which the porosity averages 8.58%.

The oil-water interface has risen an estimated 14 feet since discovery with the production of 567,000 barrels of oil, 49 MMCF of gas and 302,000 barrels of water. Water production has necessitated the abandonment of progressively higher wells until at present only nine wells are produced.

It is estimated that an additional 191,000 barrels of oil will be recovered for a cumulative total of 758,000 barrels which represents a recovery of 24.49% of the oil in place.

The relatively low recovery is attributed to the highly fractured nature of the reservoir and its active water drive. Producing drawdowns are insufficient to void the less permeable matrix porosity prior to influx of the aquifer.

The existing M.P.R. of 45 barrels per well per day has not resulted in premature water breakthrough in any well and consequently appears to be an efficient withdrawal rate.

DISCUSSION

INTRODUCTION

The Woodnorth Field is situated 14 miles east of the Manitoba - Saskatchewan border and 47 miles north of the international boundary. Its location with respect to other fields in this area is shown on Figure 1.

The Field was discovered with the completion of B. A.-Canadian Superior Woodnorth 3-33-8-27-WPM on April 21, 1954, which was drilled to test a seismic high. Development then continued on 40-acre spacing with a total of twenty wells being drilled. Sixteen were completed as oil wells, three abandoned as dry holes and the remaining well was suspended immediately after completion when it flowed 90 per cent water. One of the dry holes, B.A.-Union Woodnorth 9-28A was subsequently completed for salt water disposal in the Devonian formation. Seven of the original sixteen producers were suspended prior to March, 1958.

Cumulative production to March 31, 1958, was 566,934 barrels of oil, 301,713 barrels of water and 49,323 M.C.F. of gas. Gas production is not metered in the Woodnorth Field, consequently, gas production figures were obtained by applying the solution gas-oil ratio to the cumulative oil production. A graphical history of the pool showing pressure, production and well count is included as Figure 2, and tabulated in Appendix III.

Subsequent to the Woodnorth discovery, development of the Daly Field extended production along strike towards the Woodnorth Field. The closest production in Daly is three miles northwest.

GEOLOGY

The southwest corner of Manitoba is underlain by a wedge of Mississippian rocks that form part of the northeastern shelf of the Williston basin. The Lodgepole - the producing formation - and the underlying Bakken are the only Mississippian formations present in the Woodnorth, Daly and Virden areas.

The Lodgepole is conformably underlain by the Bakken formation and in the Woodnorth area is unconformably overlain by the basal Red Beds of the Jurassic Watrous formation. The formation is approximately 330 feet thick in the Woodnorth area and consists mostly of limestone with cherty and argillaceous intervals. Below the unconformity at the top of the Lodgepole a zone of varying thickness has been altered by dolomitization and extensive introduction of anhydrite.

During development of the Daly and Virden field areas, stratigraphic subdivisions of the Lodgepole were defined and named in each area by field personnel. The stratigraphic sections in the two areas are quite different (e.g. well-defined oolites in the Virden area, none at Daly) indicating different depositional environments. The lithological units can generally be identified throughout their respective field areas. However, they generally cannot be recognized in wells a short distance from the fields, owing to abrupt facies changes and the lenticular nature of some of the units. Time equivalence of the strata in the two areas has not been established.

Figure 3 (enclosed in pocket at back of report) illustrates radioactive logs from typical Woodnorth and Daly Field wells showing the correlation of Field nomenclature with two recent geologic nomenclatures.

In the Daly Field, the Lodgepole subdivisions can generally be identified in cores, whereas, in the Woodnorth Field, the Daly subdivisions or their equivalents cannot be easily recognized.

A generalized description of the Lodgepole section in the Woodnorth Field, from top to bottom, is as follows:

Altered zone (15' - 55' thick): finely interbanded dolomite and bluish grey anhydrite, with scattered very thin maroon to greenish grey shale bands. The dolomite is pinkish brown to brown, cryptocrystalline, anhydritic, slightly argillaceous.

Altered zone to "Daly shaly zone" equivalent (85' - 125' thick): limestone, grey, brown, mauve and pink, microcrystalline to cryptocrystalline, moderately argillaceous with occasional siliceous bands and shale partings, and minor anhydrite blebs in the upper part. Bands of crinoidal fragmental limestone are more frequent near the "Cruickshank crinoidal" equivalent at the base of the interval. The pay section is about one-third down this interval, at the top of a zone of open vertical fractures (Woodnorth fracture zone). Vertical fractures in the top third of this interval and in the altered zone are infilled with anhydrite.

"Daly shaly zone" equivalent (100' thick): limestone, pink to white, microcrystalline, less argillaceous than in the Daly field.

Unnamed basal unit (90' thick): limestone, pink to white, microcrystalline with abundant cream lithographic chert nodules.

Within the section lying between the altered zone and the Daly shaly zone equivalent lies a marker exhibiting marked low resistivity on electric logs. This zone has been named the "Woodnorth Marker". This marker is easily recognizable in the northern and central parts of the field but not readily identifiable in flank wells on the southern part of the field. The marker can not be related definitely to lithology in that it is not apparent in cores. The marker may occur either above or below the fractured zone.

STRUCTURE:

Figure 4 shows contours on the Lodgepole Formation. Figure 5 is a map showing contours on the top of the Fracture Zone. The flanks of the Mississippian topographic feature depicted by the top of the Lodgepole dip more steeply than the structural feature illustrated by the Fracture zone. In Figure 6, (enclosed in pocket at back of report) seven east-west cross sections are shown which illustrate the structural configuration of pertinent features in relation to the sea level datum. In Figure 5, estimated oil-water interfaces are shown as of discovery and as of February 1958. The location of interfaces is discussed in a later section.

RESERVOIR CHARACTERISTICS:

Porosity and permeability of the Woodnorth Lodgepole reservoir are largely secondary in origin, the result of vertical fracturing of the limestone. Many of the fractures have been enlarged by solution effects of circulating waters; in some cases sizeable cavities have resulted. The vuggy porosity of the Woodnorth reservoir, unusual in Manitoba Lodgepole fields, is closely associated with the fractures.

Vertical fractures occur from the top of the Lodgepole to below the pay section. However, the fractures in the altered zone and the upper part of the limestone section are infilled with anhydrite. Open vertical fractures observed in cores vary from less than one inch in length to about twelve feet. Deviation of fracture planes from vertical is generally very small.

The top of the Woodnorth fracture zone is an arbitrary pick and is selected where a marked increase in permeability is evident from core analysis, drill stem test recoveries or core descriptions. In the cores from some wells a few tight vertical fractures, not infilled, are present above the top.

Figure 7 is an isopachous map of the original gross fracture zone pay. These gross pay zones were obtained by subtracting the depth of the top of the zone from the oil water interface.

In this study, pays are assigned only to the Woodnorth fracture zone. Drill stem test and core analysis data for the lodgepole section above the Woodnorth fracture zone suggest that with a few possible exceptions this interval will not yield oil in commercial quantity. The section above the fracture zone may contribute additional pay in B.A.-Union Woodnorth No. 14-28 and California Standard Woodnorth No. 6-28. In this upper zone in the above wells, porosity occurs in bands generally less than two feet thick, separated by thinner non-porous intervals. Evaluation of this zone would probably require fracture treatment as do the poor permeability zones in the Daly Field. The importance of permeability precludes the use of logs for assigning pays to this section in wells where core analysis and drill stem test data are not available.

B.A.-Union Woodnorth No. 13-28, originally completed in the fracture zone, is now producing from an eight foot perforated interval mostly in the altered zone and eleven feet above the top of the fracture zone. The interval was sandfractured with 10,000 pounds of sand and 1,120 gallons of acid. A pressure of 3,500 psi was required to "break" the formation. This completion in an interval with poor porosity and permeability is not considered sufficient to justify assignment of reserves to the Lodgepole section above the fracture zone; on the contrary, the high water production (20-50 per cent) is inconsistent with the elevation of the perforated interval and strongly suggests communication with the fracture zone.

Figure 8 is an isopachous map of the net pay within the fracture zone above the original oil-water interface. Net pays are calculated from core analyses using a permeability cut-off of 0.1 millidarcy and a porosity cut-off of five per cent. For uncored wells net pays were calculated from logs. Where the complete section was not penetrated, estimates were made of the net pay using the factor of 0.65 to discount to net pay. This factor is the average ratio of net to gross pay exhibited by the analysed core.

The field weighted net porosity has been determined from core analysis as 8.58 per cent. It was observed that both porosity and permeability vary widely due to the fracturing prevalent throughout the field and the solution by water which has resulted in the formation of vugs. Permeabilities are generally low, but local fracturing results in streaks of infinite permeability and consequently an average permeability figure cannot be assessed. As previously discussed net pay is defined as that pay exceeding 0.1 millidarcy horizontal permeability.

The average connate water saturation of the area is estimated at 40%. No oil base cores were taken to verify this figure, but it is consistent with water saturation in other pools in the area.

WELL COMPLETION:

Productive intervals of the wells in this area are relatively thin, ranging from three to thirty-seven feet and averaging fifteen feet.

Of the 16 wells completed in this area, four were cased through and perforated while the other 12 were completed open hole. Five of the wells flowed on completion while eleven required small acid treatments to stimulate flow.

Completion details are contained in the Well Data Sheet in Appendix I.

RESERVOIR FLUID DATA:

On July 29, 1954, a reservoir fluid sample was obtained from B.A.-Union Woodnorth 14-28 at a pressure of 1102 psig and a subsea depth of 869 feet. Using a pressure gradient of 0.45 psi/ft. and a subsea datum of 920 feet, the original pressure is calculated to be 1125 psig. Analysis of the sample indicated a saturation pressure of 124 psig at the reservoir temperature of 84°F. The low saturation pressure is indicative of a highly undersaturated reservoir.

The original formation volume factor was determined to be 1.0577 reservoir volumes per stock tank volume, the solution gas-oil ration 87 cubic feet per barrel and the oil viscosity 3.51 centipoises.

Differential liberation of gas in the laboratory to saturation pressure yielded a formation volume factor of 1.064 and a gas-oil ratio of 87 cubic feet per barrel at reservoir temperature. The viscosity of the crude under these conditions was found to be 3.24 centipoises. A plot of the relative oil volume (the volume of reservoir oil at various pressures and reservoir temperatures divided by the volume at 14.4 psig and 60° F.) is shown in Figure 9.

OIL IN PLACE:

Using the reservoir factors and the fluid data from the preceding discussion, the stock tank oil in place as planimetered from Figure 7, an isopachous map of the net pay as determined from logs and core analyses, is 3,095,000 barrels. A summary of the factors used in this calculation is presented in Appendix II, Table 1 and 2.

RESERVOIR DRIVE MECHANISM:

The original reservoir pressure was 1125 psig as obtained in July, 1954. The latest pressure obtained on May 8, 1958, was 1106 psig, representing a decline of only 19 psig since discovery. This minor pressure drop is indicative of a very active water drive. The activity of the water drive was illustrated in May of this year. B.A.-Union Woodnorth 12-28 flowed 54 barrels of oil in 8 hours on a 9/64-inch choke and was then shut in for 14-1/2 hours. A recording bottom hole pressure gauge showed no change in pressure over this 22-1/2 hour period and consequently no measureable drawdown with production.

The relative contribution of water as a drive mechanism may be approximated by the use of a material balance equation modified for application to a reservoir with no gas cap.

Water encroachment is first obtained by the following formula:

$$N(u - uo) = N\ (u + (Rc - ro)v) - (W - w)$$

N = the number of barrels of stock tank oil which were originally in the reservoir.

N = the number of barrels of stock tank oil which have been produced up to the time the balance is made.

u = volume in the reservoir occupied by one barrel of stock tank oil plus all the gas in solution in that oil at existing conditions.

uo = volume in the reservoir occupied by one barrel of stock tank oil plus all the gas in solution in that oil at original reservoir conditions.

Rc = cumulative gas-oil ratio, cubic feet per stock tank barrel.

ro = solution gas-oil ratio, cubic feet per stock tank barrel under original reservoir conditions.

v = the space in barrels occupied in the reservoir by one S.C.F. of gas when not in solution.

W = cumulative water encroachment, barrels.

w = cumulative water production, barrels.

Substituting the known quantities, the water encroachment is obtained as follows:

$$3,095,000\ (1.0578 - 1.0577) = 566,934\ (1.0578 + 0\ ) - W + 301,713$$

$$W = 901,106 \text{ barrels.}$$

The water drive index may then be obtained by the following formula:

$$\text{Index} = \frac{W - w}{N\ (\ (u + v\ (Rc-ro)\ )}$$

Substituting in the above equation, the water drive index

$$= \frac{901,106 - 301,713}{566,934\ (1.0578 + 0)} \times 100 = 99.95\%$$

This would indicate that the field is being depleted almost entirely by a water drive. It should be stressed that this index is merely a ratio of estimated net water influx to the reservoir volume of oil and gas produced and has no direct bearing on recovery efficiency.

FLUID INTERFACES:

The pay section in most Woodnorth wells was drill stem tested since this procedure provides the best means of determining oil-water interfaces. Logs are of little value for determining oil-water interfaces in this field.

Wells in the central part of the field are completed in the upper part of the Woodnorth fracture zone and did not penetrate the oil-water interface. In the flank wells that penetrated the water table, the elevation of the first water recovery on drill stem tests varies considerably and there is no clear relationship between the proportions of water and oil and the elevation of the tested interval. This could be attributable to:

1. variable oil-water interface,
2. the passage of fluids through open vertical fractures from above or below the tested interval,
3. variable water saturation in the pay section.

The second is believed to be the dominant factor.

The lowest elevation of a test that recovered water-free oil was 935 feet subsea. In several wells, water was recovered with oil from test intervals above -935 feet, but there is generally a marked increase in the water recovery where the base of the tested interval is below -935 feet. These observations indicate an oil-water interface at approximately -935 feet for the most of the field. The -935 feet contour line on the top of the Woodnorth fracture zone, shown on Figure 5 is believed to be the best approximation that can be made of the original areal extent of the reservoir. The discovery well in Lsd. 3-33 is the only well in which drill stem test data indicate the presence of oil pay below -935 feet. A drill stem test of the interval -935 to -947 feet recovered 30 feet of oil-cut mud, 300 feet of mud-cut oil and 60 feet of salt water.

Increasing water production from flank wells has led to the suspension of production from progressively higher wells. Figures 10 and 11 are iso-water-cut maps for early and recent production and illustrate the effect on production of the advancing oil-water front. The present water level in the reservoir can be estimated from the relationship between water cuts and the elevations of producing intervals. These relationships indicate that by February, 1958, the water table had advanced from its original level of approximately -935 feet to approximately -921 feet. The approximate present extent of the reservoir, represented by the area enclosed by the -921 contour line on the top of the Woodnorth fracture zone, is shown on Figure 5.

RECOVERY EFFICIENCY:

The planimetered area of the net pay isopach, Figure 8, gave 8,196 acre feet of net reservoir containing 3.095×10^6 barrels of stock tank oil in place above the original oil-water interface of 935 feet subsea.

Figure 12 is an isopach of the net pay remaining above the present oil water interface estimated at 921 feet subsea. The net pay figures were determined by applying the ratio of net to gross pay by wells against their gross pay remaining above 921 feet subsea.

The volume was planimetered to be 2067 acre feet. The remaining oil in place above the 921 foot contour is then estimated to be 0.780×10^6 stock tank barrels, (assuming a constant reservoir pressure). Taking the difference yields the original oil in place between the two oil-water interfaces (the "flushed" zone) as 2.315×10^6 stock tank barrels. Of this, we have produced 0.567×10^6 stock tank barrels of oil. The recovery efficiency was then 24.49%.

Assuming equivalent recovery efficiency from the remaining reservoir, we may anticipate the additional production of 0.191×10^6 barrels of stock tank oil for a cumulative pool production of 0.758×10^6 barrels of oil.

This relatively low recovery by water drive is a result of the highly fractured nature of the reservoir. As previously discussed, the reservoir pressure is efficiently maintained by water influx and conseouently, the pressure differential across the sand face is insufficient to permit drainage of hydrocarbons from less permeable strata. The oil within the fracture porosity is flushed but additional oil in the matrix porosity does not develop mobility prior to being bypassed by the more mobile aquifer. This bypassing cannot be prevented or controlled by changing the withdrawal rate.

PRODUCING HISTORY:

Cumulative fluid production to March 31, 1958, was 566,934 barrels of oil and 301,713 barrels of water.

The field water production is rapidly increasing. Figure 13 shows the percent oil in total fluid as a function of accumulative oil production. Extropolating this curve to the economic limit of 10% oil in total fluid indicates a total recovery of 765,000 barrels of oil to abandonment. This figure compares most favorably with the forecasted cumulative recovery of 758,000 determined by application of the recovery efficiency or flushing efficiency to the remaining undepleted reservoir.

The maximum permissive rate for oil withdrawal in Woodnorth has been set at 45 barrels per well per day. This rate has not resulted in premature water breakthrough in that the water cuts, as shown on Figures 10 and 11, have increased as a function of elevation. At present only four wells are capable of producing the allowable but this is not unreasonable at this advanced state of depletion.

APPENDIX I

WOODNORTH FIELD - WELL DATA

Well	Status March, 1958	Completion	Initial Acid Treatment	Cumulative Prod. to March, 1958 Oil Bbls.	Water Bbls.	Remarks
Cleary Wilson 10-21-8-27-WPM	Suspended					Suspended October, 1955. Flowed 20 bbls. fluid through 18/64" choke in 12 hours cut 90% water.
Cal.Std. Wdnth. 14-21-8-27-WPM	Suspended	Open Hole 2471-2483	280 gals. mud acid. Squeezed one bbl.	16,618	21,708	Suspended November, 1956
Cleary Wilson 15-21-8-27-WPM	Suspended	Open Hole 2458-2474	250 gals. mud acid.	17,982	57,455	Suspended October, 1957
Cal.Std. Wdnth. 2-28-8-27-WPM	Suspended	Open Hole 2455-2468	300 gals. mud acid, and 175 gals. regular Squeezed 75 gallons.	13,097	7,846	Suspended July, 1957
Cal.Std. Wdnth. 3-28-8-27-WPM	Oil Well	Open Hole 2460-2480	325 gals. mud acid and 175 gals. 15% acid.	43,622	17,799	
Cal.Std. Wdnth. 4-28-8-27-WPM	P & A					D.S.T. 2475-88': Fluid to surface Rec. 2000' oil-cut muddy salt water; 475' salt water. D.S.T. 2465-80': 5' oil flecked mud.
Cal.Std. Wdnth. 5-28-8-27-WPM	Oil Well	Open Hole 2465-2476	325 gals. mud acid	56,228	113	
Cal.Std. Wdnth. 6-28-8-27-WPM	Oil Well	Open Hole 2455-2475	200 gals. mud acid	57,801	12,481	
Cal. Std. Wdnth. 7-28-8-27-WPM	Oil Well	Open Hole 2463-2470	250 gals. mud acid and 250 gals. 15% acid	45,755	27,223	
B.A.-Union Wdnth 9-28-8-27-WPM	Salt Water Disposal Well	Open Hole 3225-3275				Completed open hole in Duperow

Well	Status March, 1958	Completion	Initial Acid Treatment	Cumulative Prod. to March, 1958 Oil Bbls.	Water Bbls.	Remarks
B.A.-Union Wdnth. 10-28-8-27-WPM	Oil Well	Open Hole 2455-2461	No treatment	44,893	4,059	
B.A.-Union Wdnth. 11-28-8-27-WPM	Oil Well	Open Hole 2474-2478	No treatment	59,296	8,762	
B.A.-Union Wdnth. 12-28-8-27-WPM	Oil Well	Perfs. 2465-2470 4/ft.	200 gals. mud acid and 50 gals. 15% acid. Squeezed 100 gallons.	55,180	106	
B.A.-Union Wdnth. 13-28-8-27-WPM	Oil Well	Perfs. 2474-2477 (sq.) 2455-2463 4/ft.	250 gals. 15% acid. Squeezed 165 gals.	44,527	25,298	
B.A.-Union Wdnth. 14-28-8-27-WPM	Oil Well	Perfs. 2468-2476 4/ft.	300 gals. 15% acid.	38,931	10,883	
B.A.-Union Wdnth. 15-28-8-27-WPM	Suspended	Open Hole 2484.5-2485.5	50 gals. 15% acid.	30,608	3,481	Suspended August, 1956
Cal.Std. Wdnth. 8-29-8-27-WPM	Suspended	Open Hole 2478-2483	No treatment	3,779	8,921	Suspended August, 1957
Cal.Std. Wdnth. 9-29-8-27-WPM	Suspended	Open Hole 2486-2491	No treatment	14,032	20,719	Suspended September, 1957
Cal.Std. Wdnth. 2-33-8-27-WPM	P & A					D.S.T. (fracture zone) Rec. 780' salt water
B.A.-Can. Sup. Wdnth. 3-33-8-27-WPM	Abandoned	2506-2510(Sq.) 2469-2471(Sq.) 2499-2501(Sq.) 2479-2482(Sq.)	No treatment	24,585	74,859	Discovery well; Abandoned May, 1958

APPENDIX II

WOODNORTH FIELD

ROCK AND FLUID CHARACTERISTICS

TABLE 1

ROCK CHARACTERISTICS

Volume	8196 acre feet
Areal Extent	985 acres
Average Net Pay	8.32 feet
Average Net Porosity	8.58 per cent
Connate Water Saturation	40 per cent
Oil in Place	3,095,000 S.T. Barrels

TABLE 2

FLUID CHARACTERISTICS

Original B.H. Pressure	1125 psig
Original Saturation Pressure	124 psig
Solution Gas-oil Ratio (differential)	87 c.f. per bbl.
Shrinkage	.9454
Reservoir Oil Viscosity	3.24 cps
Oil Gravity	35° API
Sulfur Content	1.30%
Reservoir Temperature	84° F.

APPENDIX III

WOODNORTH FIELD - PRODUCTION HISTORY

		Oil Production		Water Production		Total Monthly			
	Date	Monthly Bbls.	Cumulative Bbls.	Monthly Bbls.	Cumulative Bbls.	Fluid Prod.	Percent Oil in Total Fluids	Daily Oil Prod. Bbls/day/well	No. of Producing Wells
1954	April	589	589	-	-	589	100	20	1
	May	973	1562	168	168	1141	85.2	32	1
	June	1343	2905	133	301	1476	91.1	45	1
	July	4574	7479	467	768	5041	90.8	51	3
	August	5096	12575	334	1112	5430	93.8	34	5
	September	4257	16832	244	1346	4501	94.6	28	5
	October	6839	23671	472	1818	7311	93.4	28	8
	November	8395	32066	290	2108	8685	96.4	31	9
	December	15973	48039	704	2812	16677	95.8	53	10
1955	January	18654	66693	895	3707	19549	95.4	56	11
	February	16943	83636	1450	5157	18393	92.2	47	12
	March	17425	101061	779	5936	18204	95.8	48	12
	April	2470	103531	1129	7065	3599	68.7	7.5	11
	May	124	103655	3	7068	127	97.7	1	4
	June	11728	115383	1589	8657	13317	88.1	33	12
	July	19005	134388	2986	11643	21991	86.5	53	12
	August	19945	154333	3109	14752	23054	86.6	51	13
	September	20060	174393	3196	17948	23256	86.2	48	14
	October	22309	196702	5877	23825	28186	79.2	50	15
	November	20550	217252	8740	32565	29290	70.2	46	15
	December	18763	236015	7629	40194	26392	71.1	45	14
1956	January	17161	253176	3972	44166	21133	81.3	41	14
	February	19748	272924	7378	51544	27126	72.9	47	14
	March	20979	293903	7969	59513	28948	72.4	50	14
	April	20271	314174	9326	68839	29597	68.5	45	15
	May	20820	334994	12111	80950	32931	63.2	46	15
	June	18806	353800	9173	90123	27979	67.2	39	16
	July	18751	372551	15810	105933	34561	54.3	42	15
	August	18767	391318	7895	113828	26662	70.3	39	16
	September	14877	406195	12025	125853	26902	55.2	33	15
	October	12947	419142	16156	142009	29103	44.5	29	15
	November	10701	429843	13646	155655	24347	44.0	27	13
	December	9051	438894	5064	160719	14115	64.1	27	11

	Date	Oil Production Monthly Bbls.	Oil Production Cumulative Bbls.	Water Production Monthly Bbls.	Water Production Cumulative Bbls.	Total Monthly Fluid Prod.	Percent Oil in Total Fluids	Daily Oil Prod. Bbls/day/well	No. of Producing Wells
1957	January	9458	448352	4245	164964	13703	69.0	32	10
	February	8161	456513	3781	168745	11942	68.4	27	10
	March	9842	466355	5426	174171	15268	64.6	33	10
	April	9321	475676	5175	179346	14496	64.4	35	9
	May	9176	484852	6519	185865	15695	58.5	26	12
	June	8483	493335	11551	197416	20034	42.4	28	10
	July	8708	502043	11806	209222	20514	42.4	29	10
	August	8925	510968	11764	220986	20689	43.1	27	11
	September	9091	520059	16098	237084	25189	36.2	25	12
	October	8916	528975	15456	252540	24372	36.6	27	11
	November	8066	537041	10340	262880	18406	43.8	27	10
	December	7982	545023	10165	273045	18147	43.9	27	10
1958	January	7796	552819	8974	282019	16770	46.5	26	10
	February	6684	559503	7010	289029	13694	48.8	25	9
	March	7431	566934	6383	295412 *	13814	53.7	27.5	9

* Individual well data shows a cumulative water production of 301,713 (Appendix I). Discrepancy cannot be reconciled from available production data.

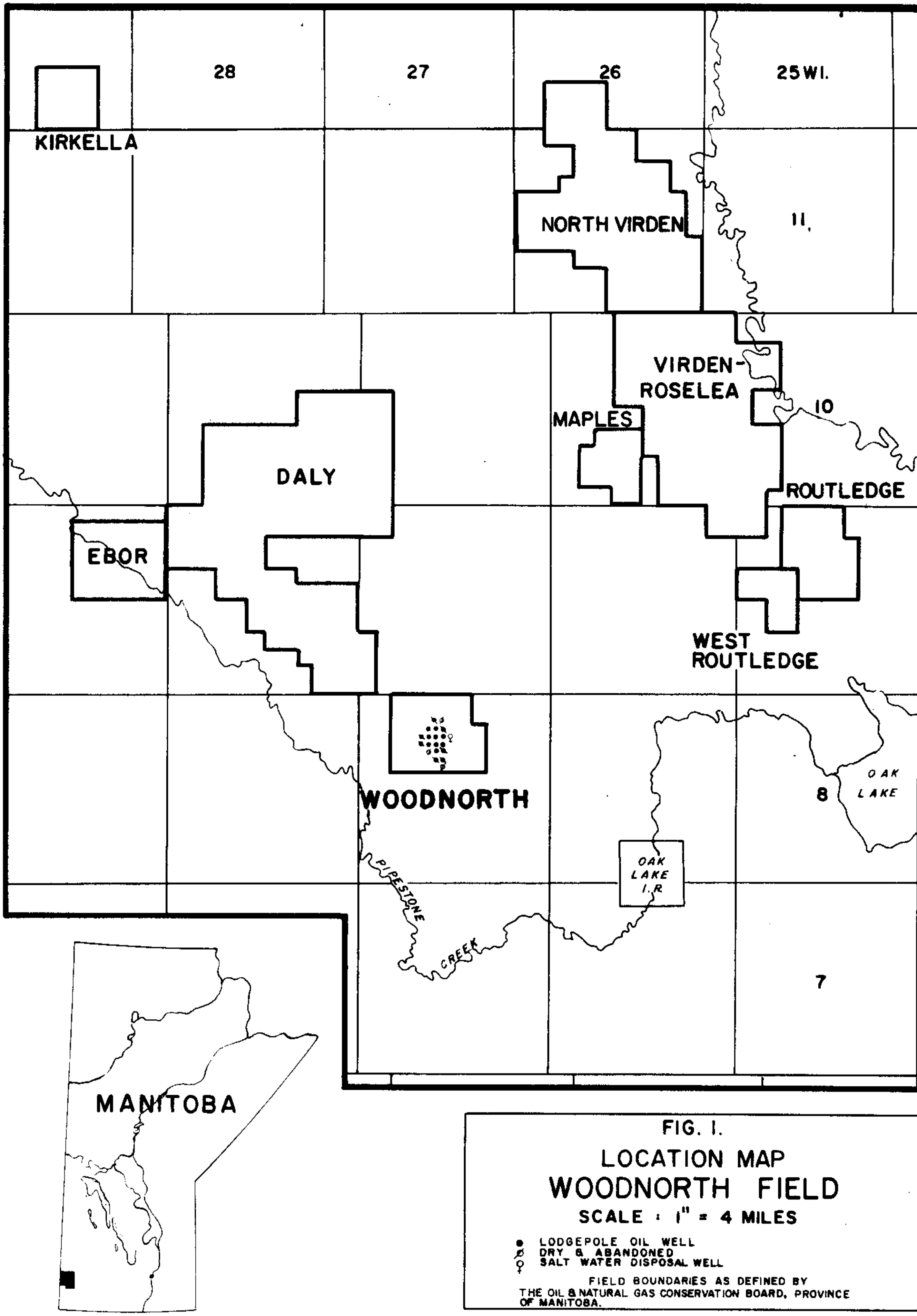


FIG. I.

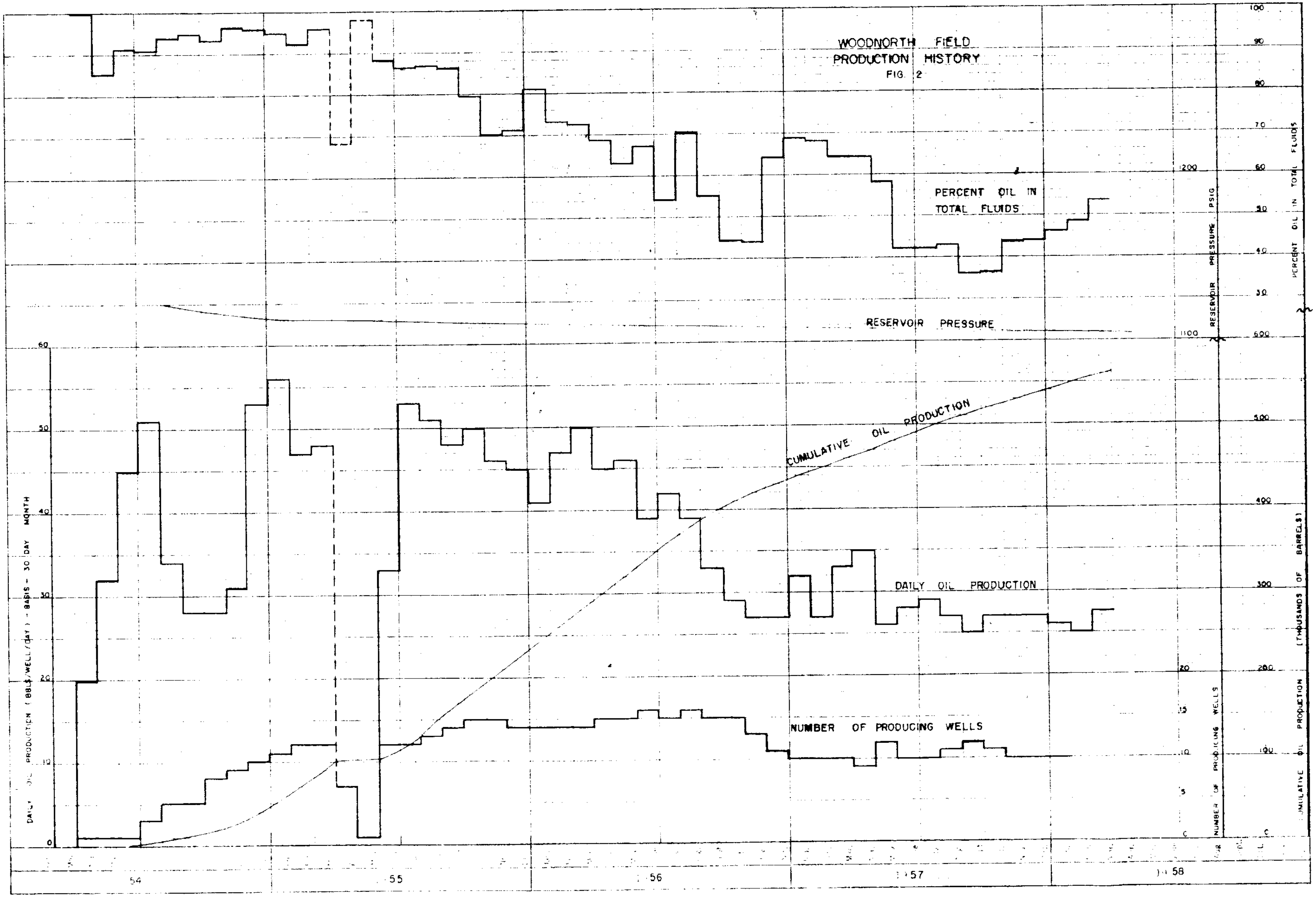
LOCATION MAP

WOODNORTH FIELD

SCALE : 1" = 4 MILES

- ● LODGEPOLE OIL WELL
- ⌀ DRY & ABANDONED
- ♀ SALT WATER DISPOSAL WELL

FIELD BOUNDARIES AS DEFINED BY THE OIL & NATURAL GAS CONSERVATION BOARD, PROVINCE OF MANITOBA.



WOODNORTH FIELD PRODUCTION HISTORY

FIG. 2

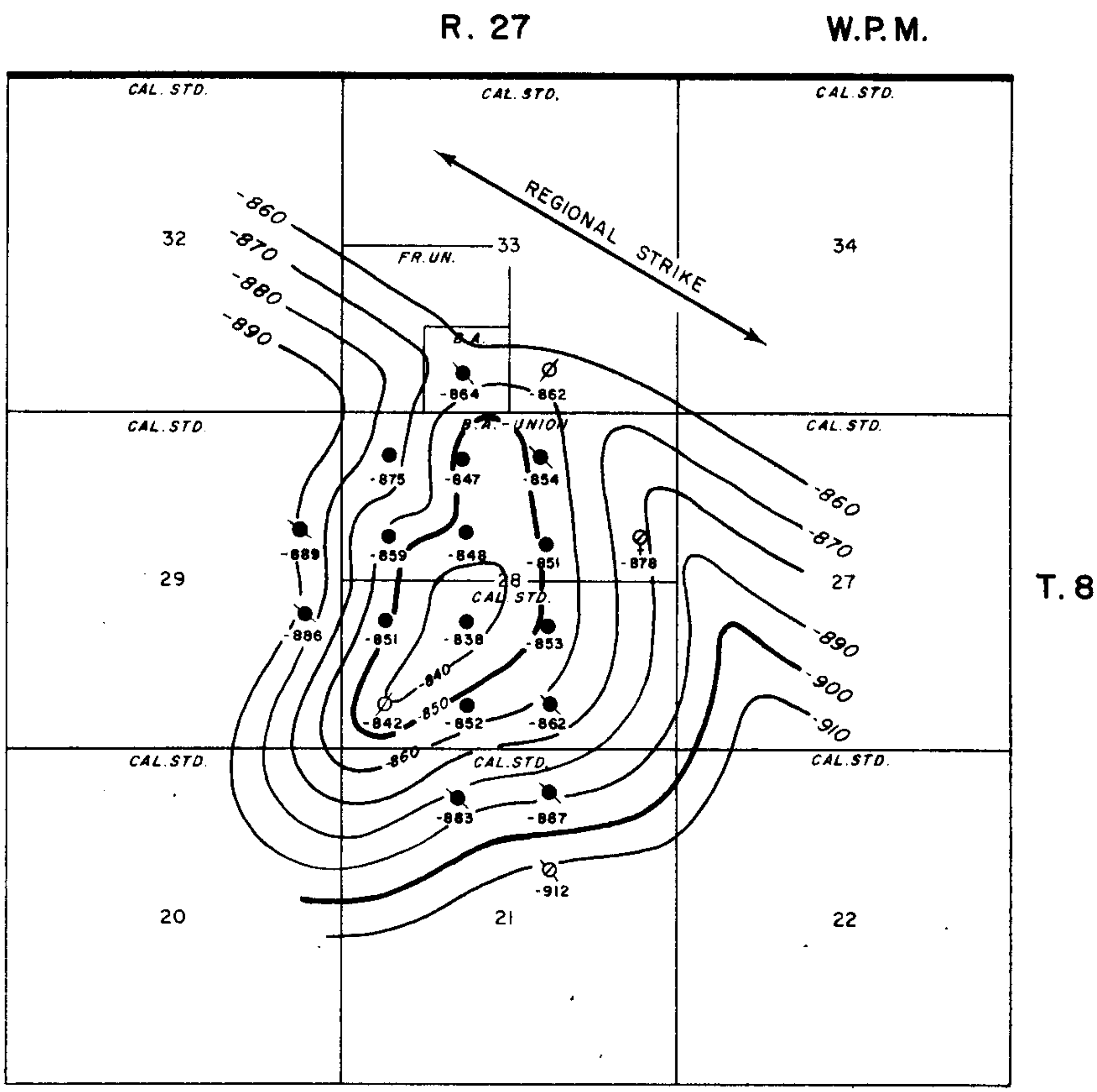


FIG. 4

WOODNORTH FIELD

TOP OF LODGEPOLE FORMATION

(MISSISSIPPIAN UNCONFORMITY)

WELL LEGEND

- ● LODGEPOLE OIL WELL
- ∅ DRY & ABANDONED
- SUSPENDED
- SALT WATER DISPOSAL WELL

C.I.: 10 Ft.

SCALE: 2" = 1 MILE

DATE: MAY 1958

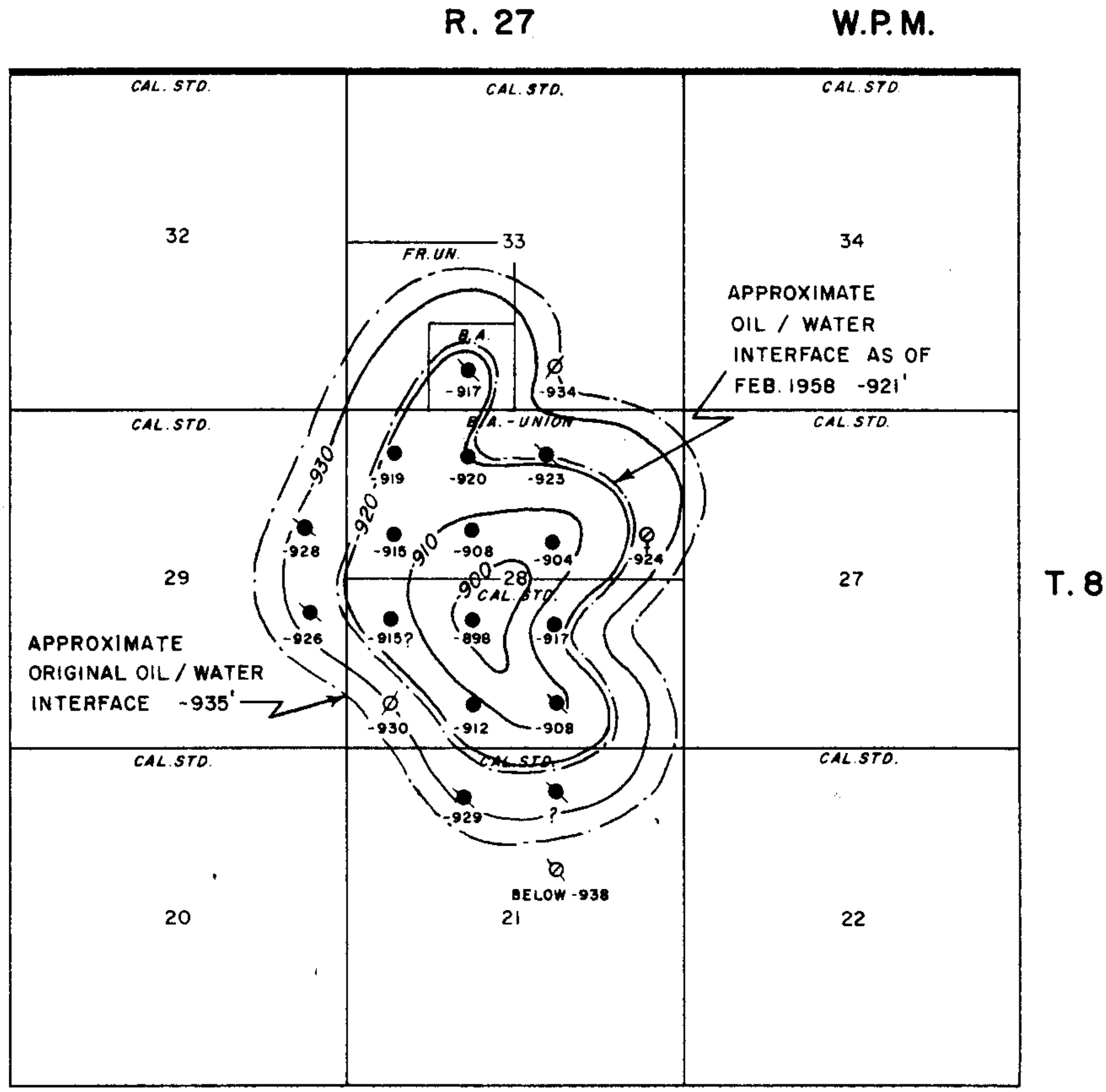


FIG. 5

WOODNORTH FIELD

TOP OF WOODNORTH FRACTURE ZONE

(OPEN FRACTURES)

WELL LEGEND

- ● LODGEPOLE OIL WELL
- Ø DRY & ABANDONED
- SUSPENDED
- SALT WATER DISPOSAL WELL

C.I.: 10 Ft.

SCALE: 2" = 1 MILE

DATE: MAY 1958

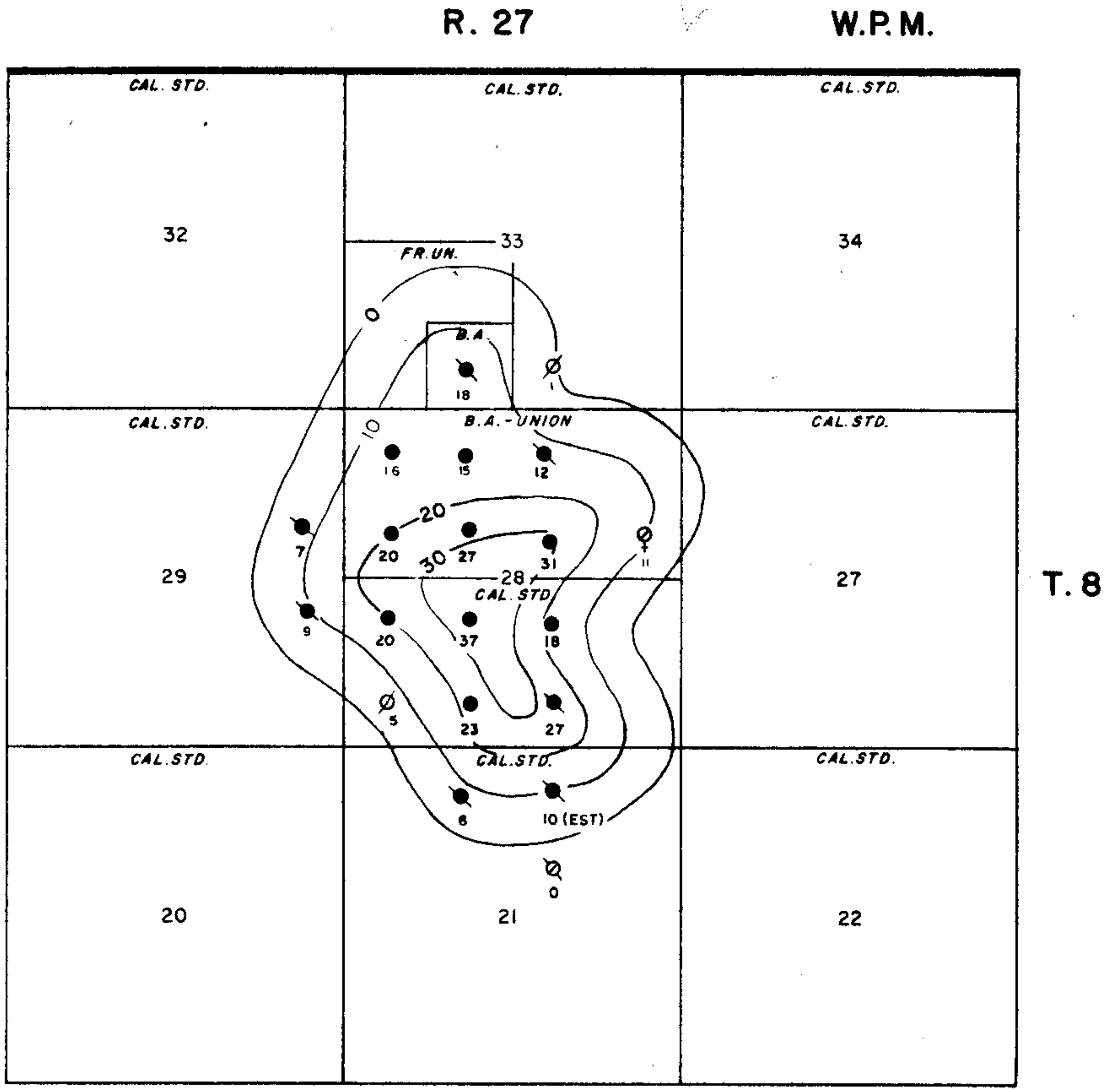


FIG. 7

WOODNORTH FIELD

ISOPACHOUS MAP

ORIGINAL GROSS FRACTURE ZONE PAY

WELL LEGEND

- ● LODGEPOLE OIL WELL
- Ø DRY & ABANDONED
- SUSPENDED
- SALT WATER DISPOSAL WELL

ISOPACH INT.: 10'
SCALE: 2" = 1 MILE
DATE: MAY 1958

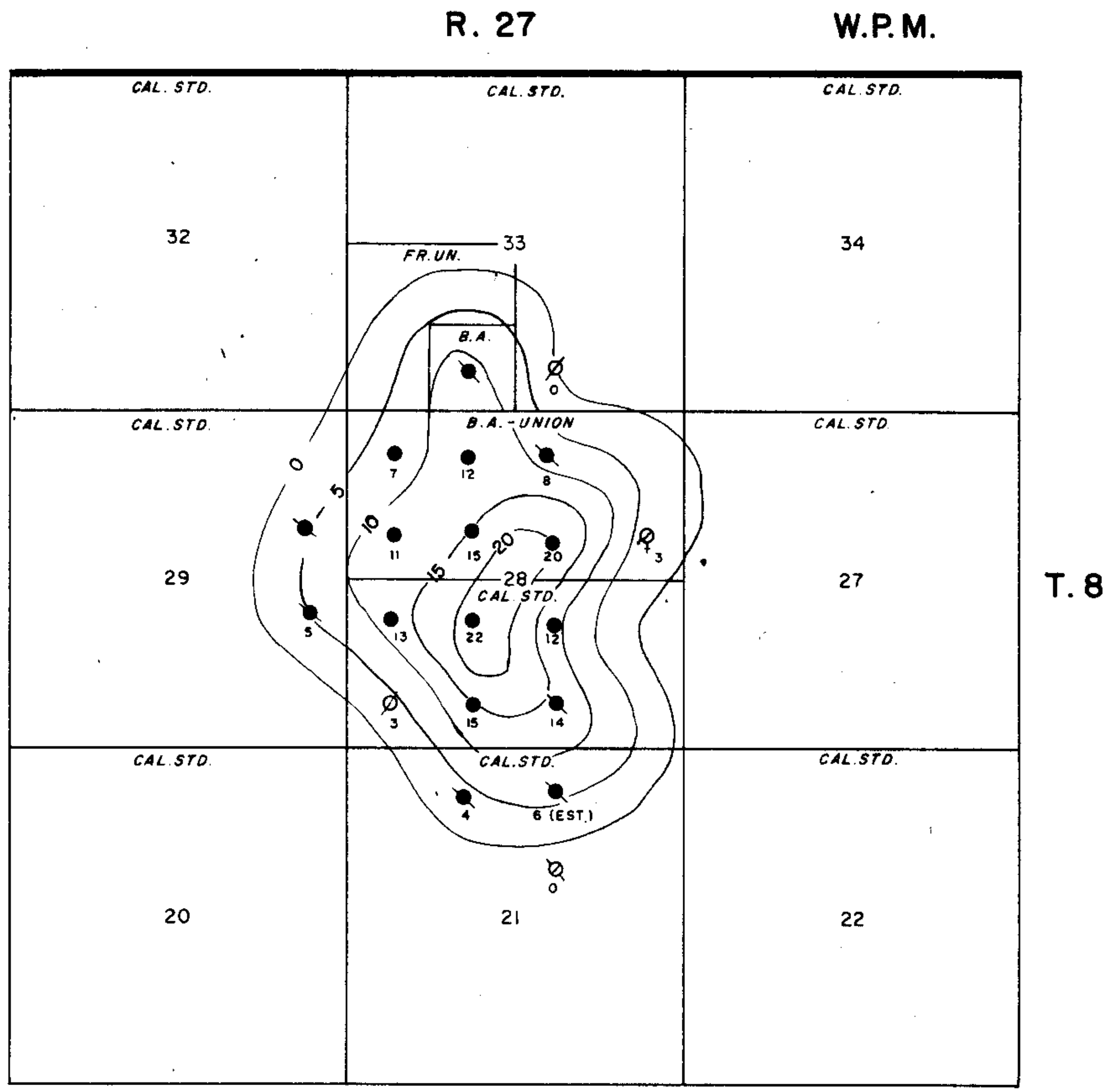


FIG. 8

WOODNORTH FIELD

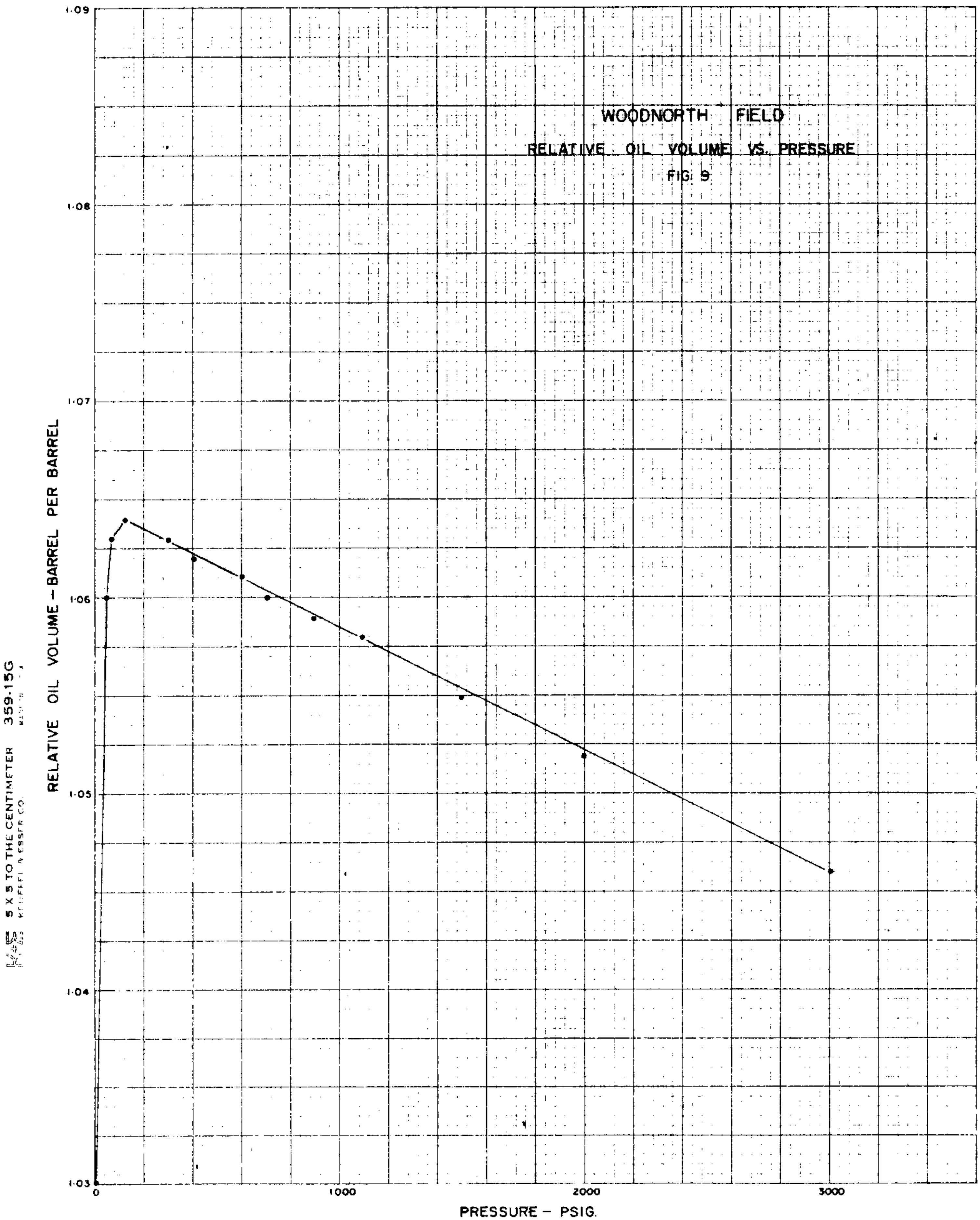
ISOPACHOUS MAP

ORIGINAL NET FRACTURE ZONE PAY

WELL LEGEND

- LODGEPOLE OIL WELL
- DRY & ABANDONED
- SUSPENDED
- SALT WATER DISPOSAL WELL

ISOPACH INT.: 5'
SCALE: 2" = 1 MILE
DATE: MAY 1956


WOODNORTH FIELD
RELATIVE OIL VOLUME VS. PRESSURE
FIG. 9
RELATIVE OIL VOLUME – BARREL PER BARREL
PRESSURE – PSIG.
1.09
1.08
1.07
1.06
1.05
1.04
1.03
0
1000
2000
3000
5 X 5 TO THE CENTIMETER 359-15G
KEUFFEL & ESSER CO.

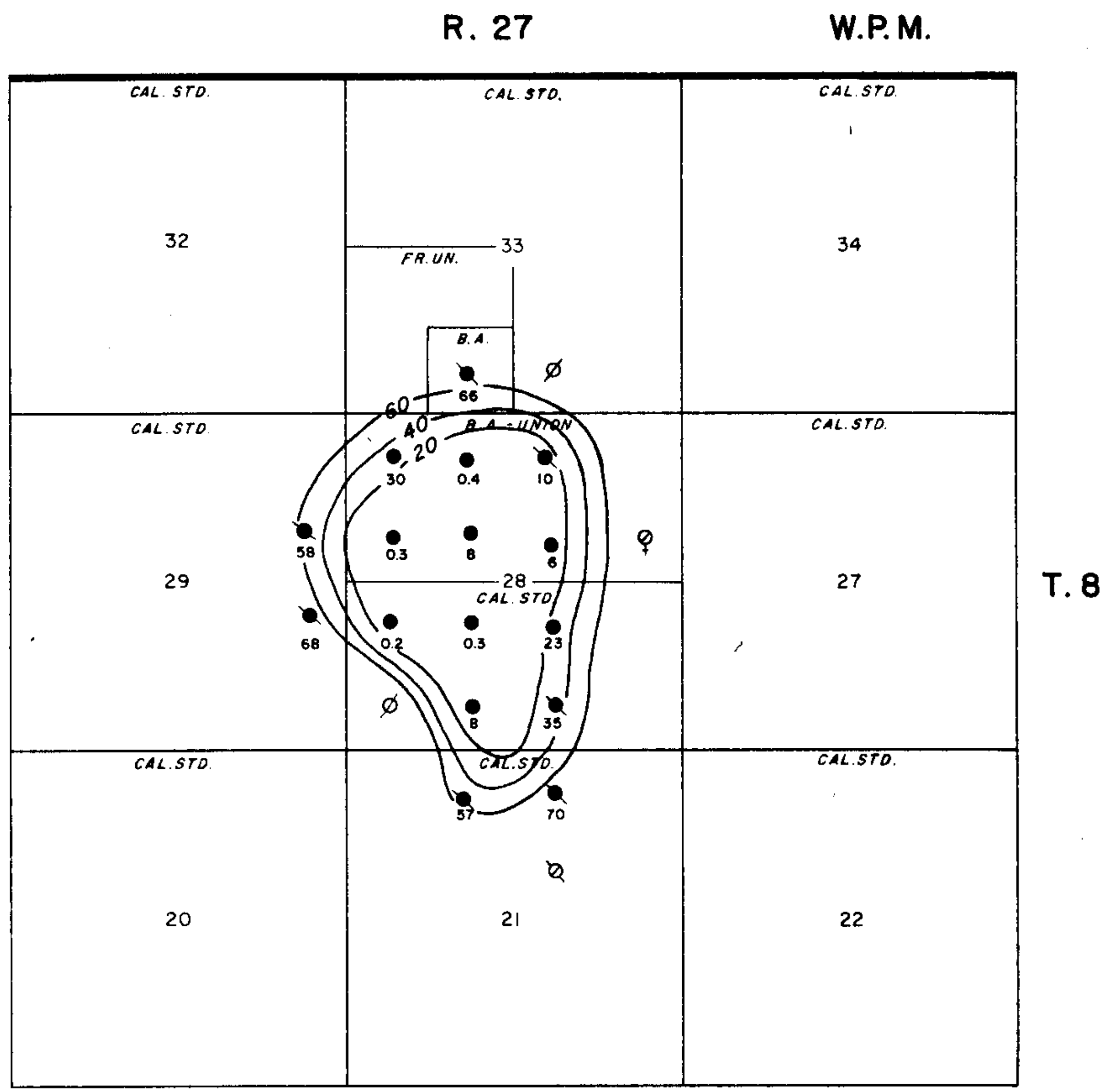


FIG. 10

WOODNORTH FIELD

WATER CUTS

CUMULATIVE PRODUCTION TO DEC. 31, 1956

WELL LEGEND

- ● LODGEPOLE OIL WELL
- Ø DRY & ABANDONED
- SUSPENDED
- SALT WATER DISPOSAL WELL

C.I.: 20%

SCALE: 2" = 1 MILE

DATE: MAY 1958

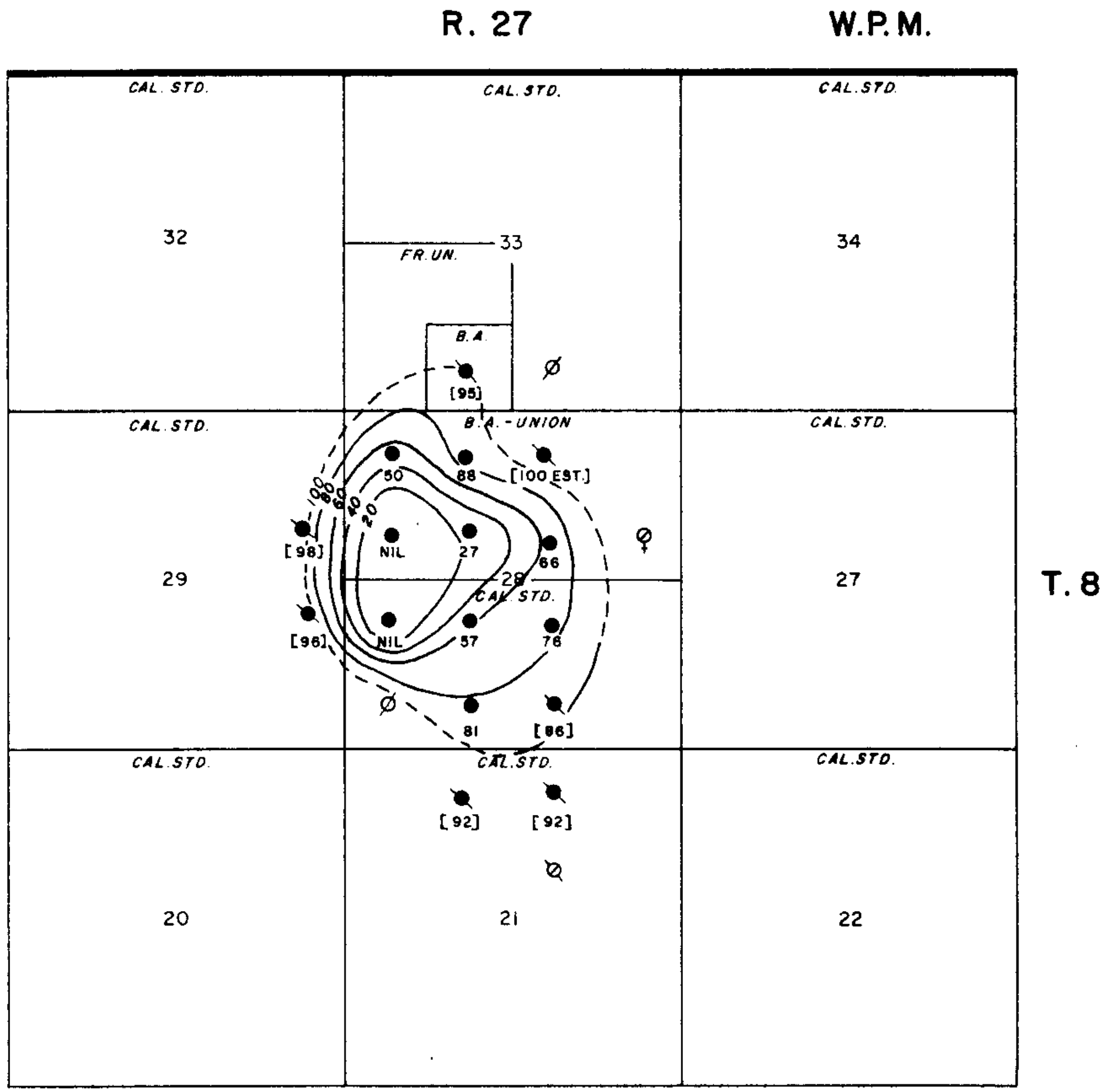


FIG. II

WOODNORTH FIELD

WATER CUTS

FEBRUARY, 1958 PRODUCTION

WELL LEGEND

- ● LODGEPOLE OIL WELL
- Ø DRY & ABANDONED
- SUSPENDED
- SALT WATER DISPOSAL WELL

NOTE: BRACKETED VALUES ARE FOR THE LAST PRODUCTION OF WELLS SUSPENDED PRIOR TO FEB. 1958, AND ARE CONTOURED ASSUMING FURTHER WATER ENCROACHMENT.

C.I.: 20%
SCALE: 2" = 1 MILE
DATE: MAY 1958

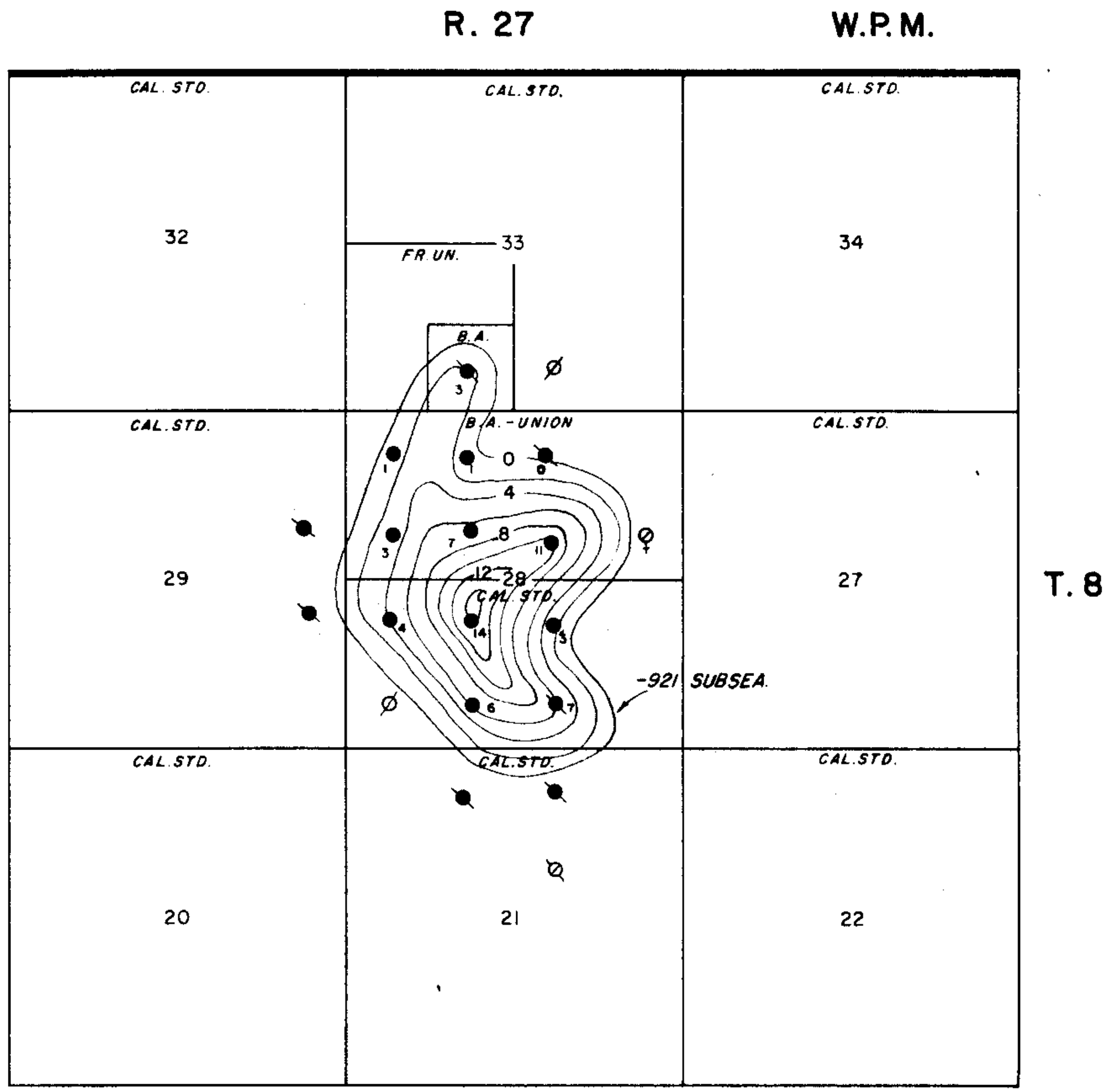


FIG. 12

WOODNORTH FIELD

ISOPACHOUS MAP

REMAINING NET FRACTURE ZONE PAY
ABOVE -921 OIL/WATER

WELL LEGEND

- ● LODGEPOLE OIL WELL
- Ø DRY & ABANDONED
- SUSPENDED
- SALT WATER DISPOSAL WELL

ISOPACH INT.: 2'
SCALE: 2" = 1 MILE
DATE: MAY 1958

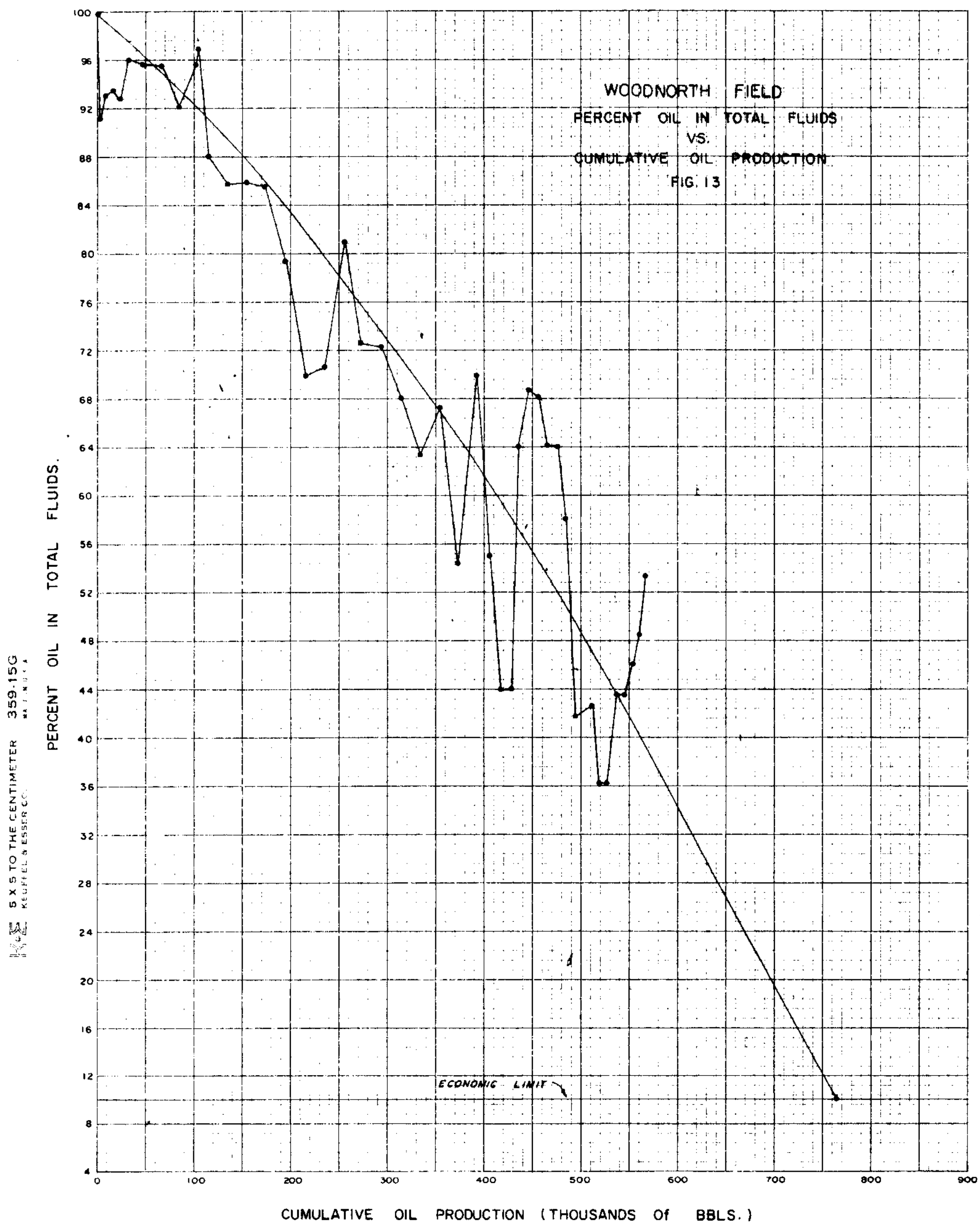

WOODNORTH FIELD
PERCENT OIL IN TOTAL FLUIDS
VS.
CUMULATIVE OIL PRODUCTION
FIG. 13
PERCENT OIL IN TOTAL FLUIDS.
CUMULATIVE OIL PRODUCTION (THOUSANDS Of BBLS.)
ECONOMIC LIMIT
100
96
92
88
84
80
76
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
100
200
300
400
500
600
700
800
900
5 X 5 TO THE CENTIMETER 359.15G
KEUFFEL & ESSER CO.

FIGURE 3

TYPICAL LODGEPOLE SECTIONS
DALY & WOODNORTH FIELDS

RADIOACTIVITY LOGS

B.A. OIL CO. LTD
WOODNORTH FIELD
RESERVOIR STUDY

SEPT. 5/1958

DALY

CAN. SUP. JONES 10-12
10-12-10-28 W.P.M.
K.B. 1629'

	S. G. S. (1953)	ORGAN AND RUSSIN (1955)	FIELD NOMENCLATURE
	GYPSUM SPRING	WATROUS FM.	GYPSUM SPRING
LODGEPOLE FORMATION	WEATHERED ZONE	UNNAMED	UNNAMED
LODGEPOLE FORMATION	EARTHY LIMESTONE UNIT	DALY MEMBER – UPPER	EARTHY LIMESTONE UNIT
LODGEPOLE FORMATION	TRANSITIONAL UNIT	DALY MEMBER – MIDDLE	FIRST CRINOIDAL OR TRANSITION ZONE
LODGEPOLE FORMATION		DALY MEMBER – LOWER	SKELTON OR MAIN CRIN.
LODGEPOLE FORMATION	MASSIVE CRINOIDAL LIMESTONE UNIT	CRUIKSHANK SHALE FACIES	CRUIKSHANK SHALE
LODGEPOLE FORMATION		CRUIKSHANK CRIN. FACIES	CRUIKSHANK CRINOIDAL
LODGEPOLE FORMATION	MOTTLED SHALY LIMESTONE UNIT	CROMER SHALE FACIES	DALY SHALY ZONE
LODGEPOLE FORMATION		BASAL LIMESTONE FACIES	UNNAMED
—DATUM	BAKKEN FM.	BAKKEN FM.	BAKKEN FM.

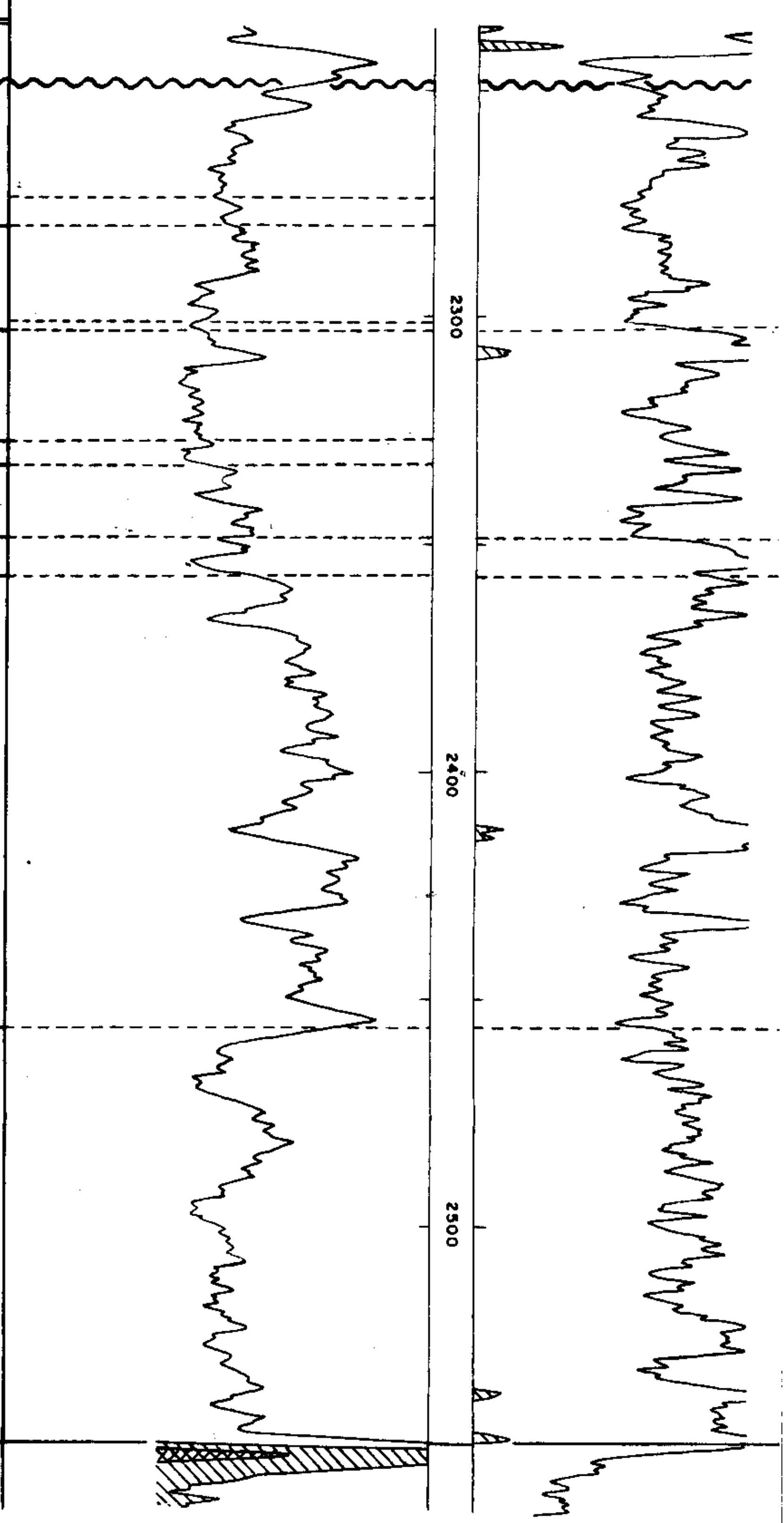
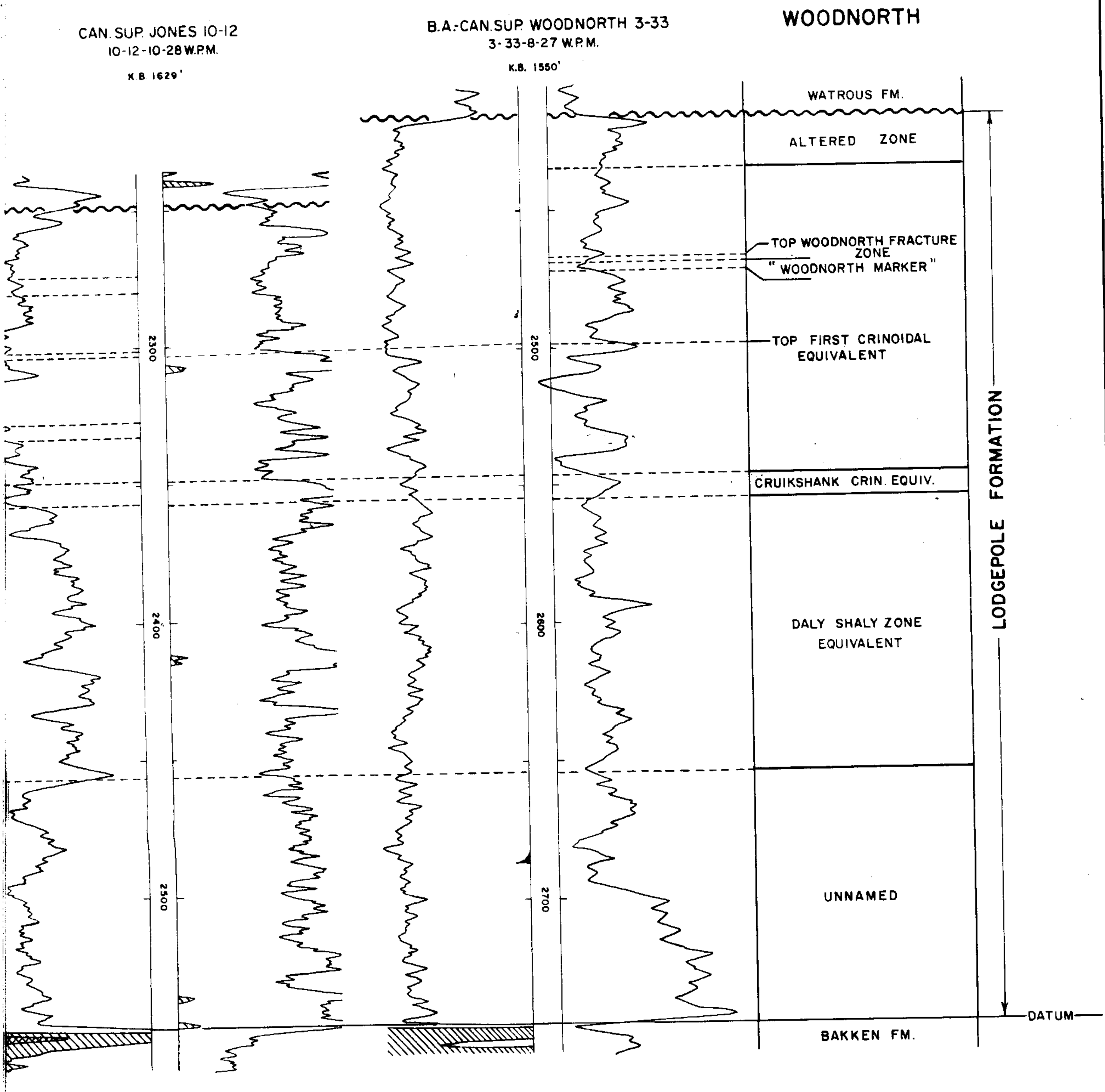
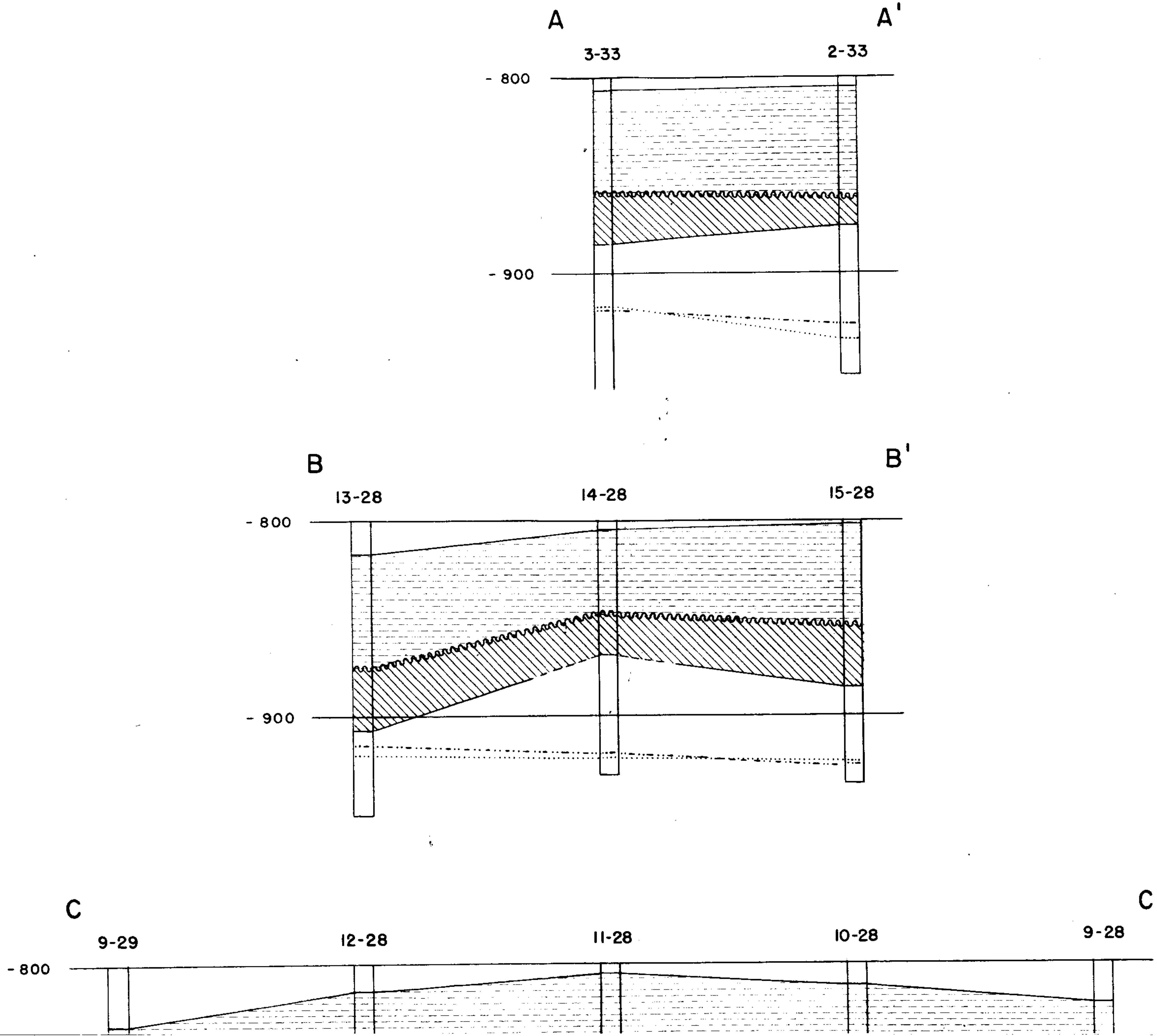


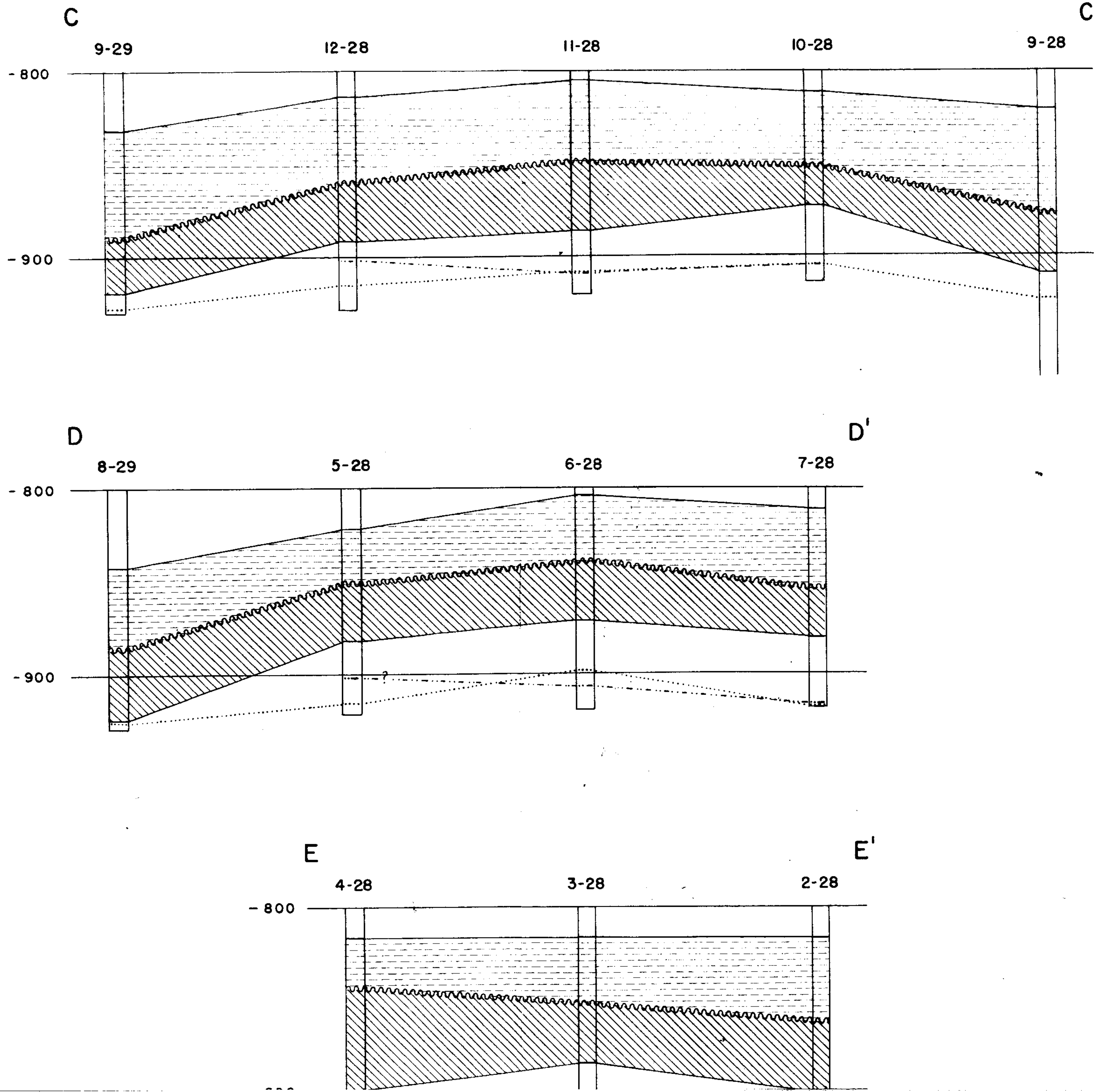
FIGURE 3

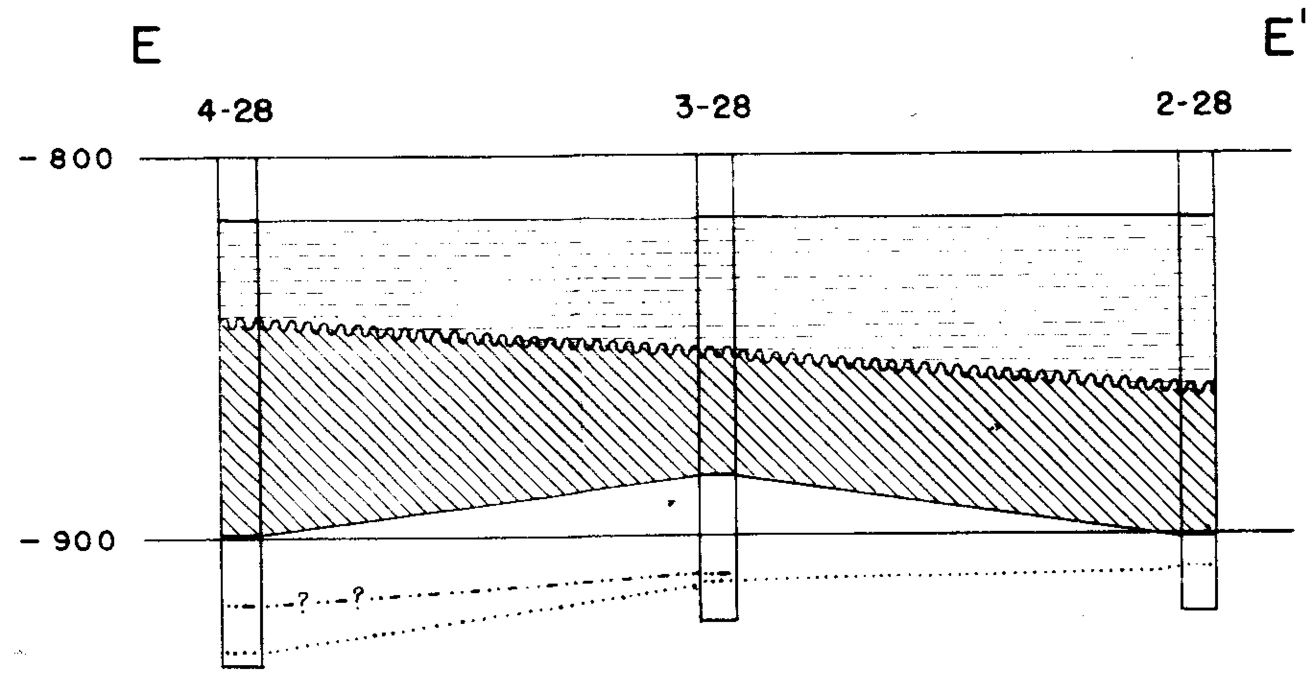
ODGEPOLE SECTIONS
WOODNORTH FIELDS

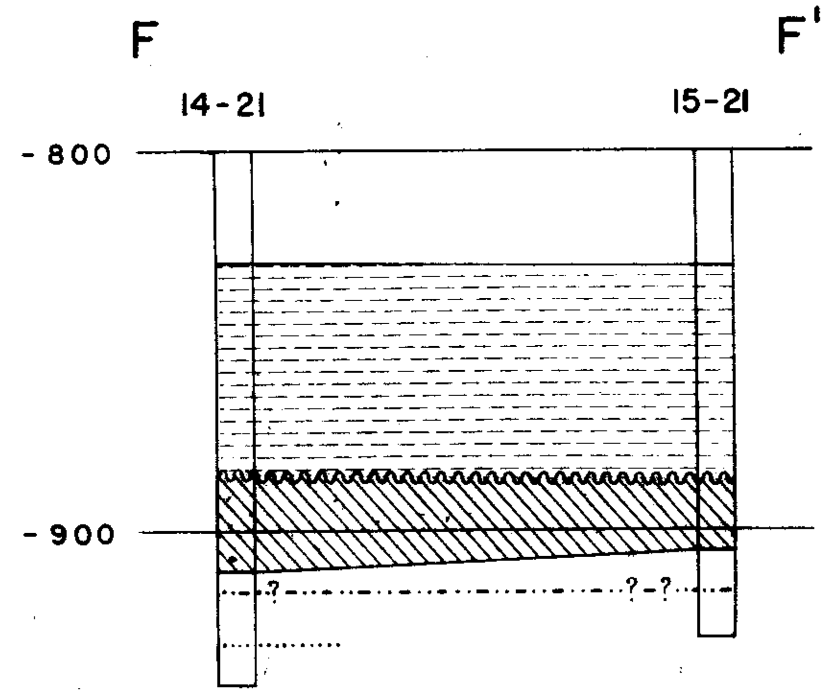
DIOACTIVITY LOGS

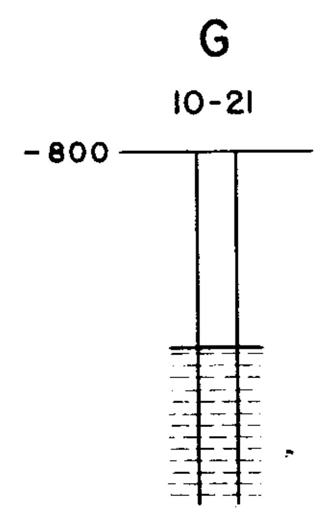


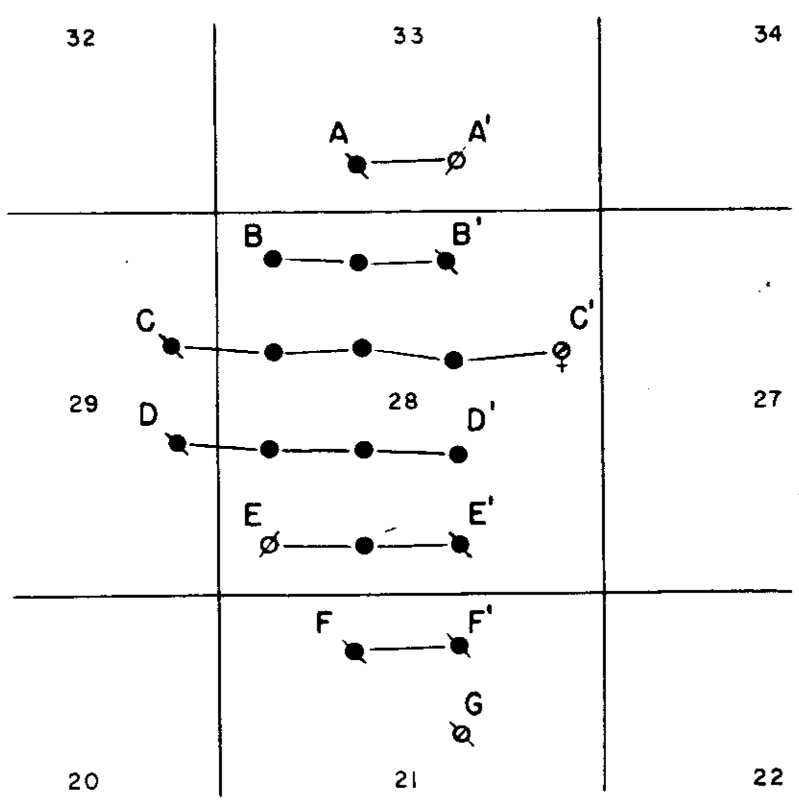

A
A'
3-33
2-33
- 800
- 900
B
B'
13-28
14-28
15-28
- 800
- 900
C
C'
9-29
12-28
11-28
10-28
9-28
- 800


C
C'
9-29
12-28
11-28
10-28
9-28
-800
-900
D
D'
8-29
5-28
6-28
7-28
-800
-900
?
E
E'
4-28
3-28
2-28
-800





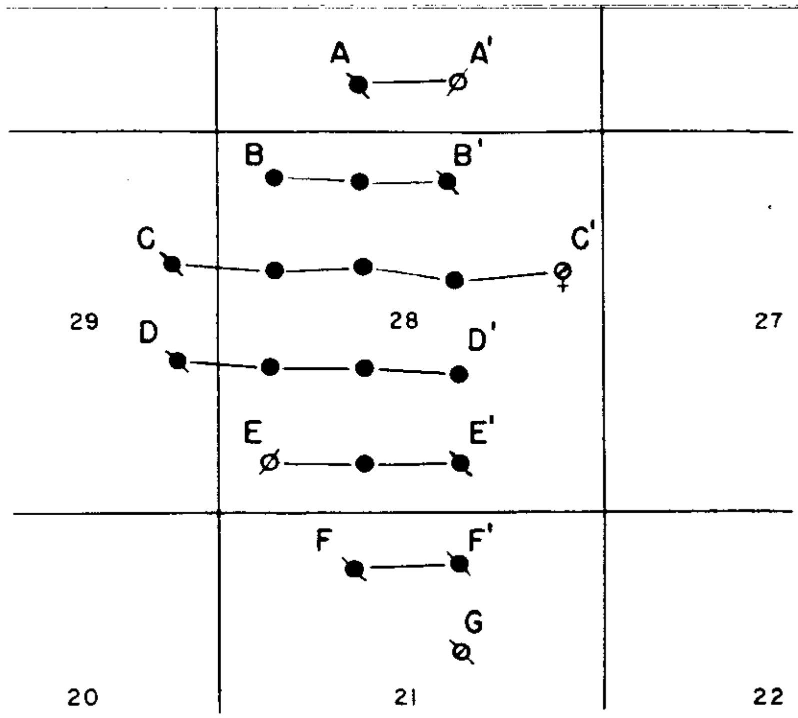




LOCATION MAP

TWP. 8 RGE. 27 W.P.M.

FIGURE 6



LOCATION MAP

TWP. 8 RGE. 27 W.P.M.

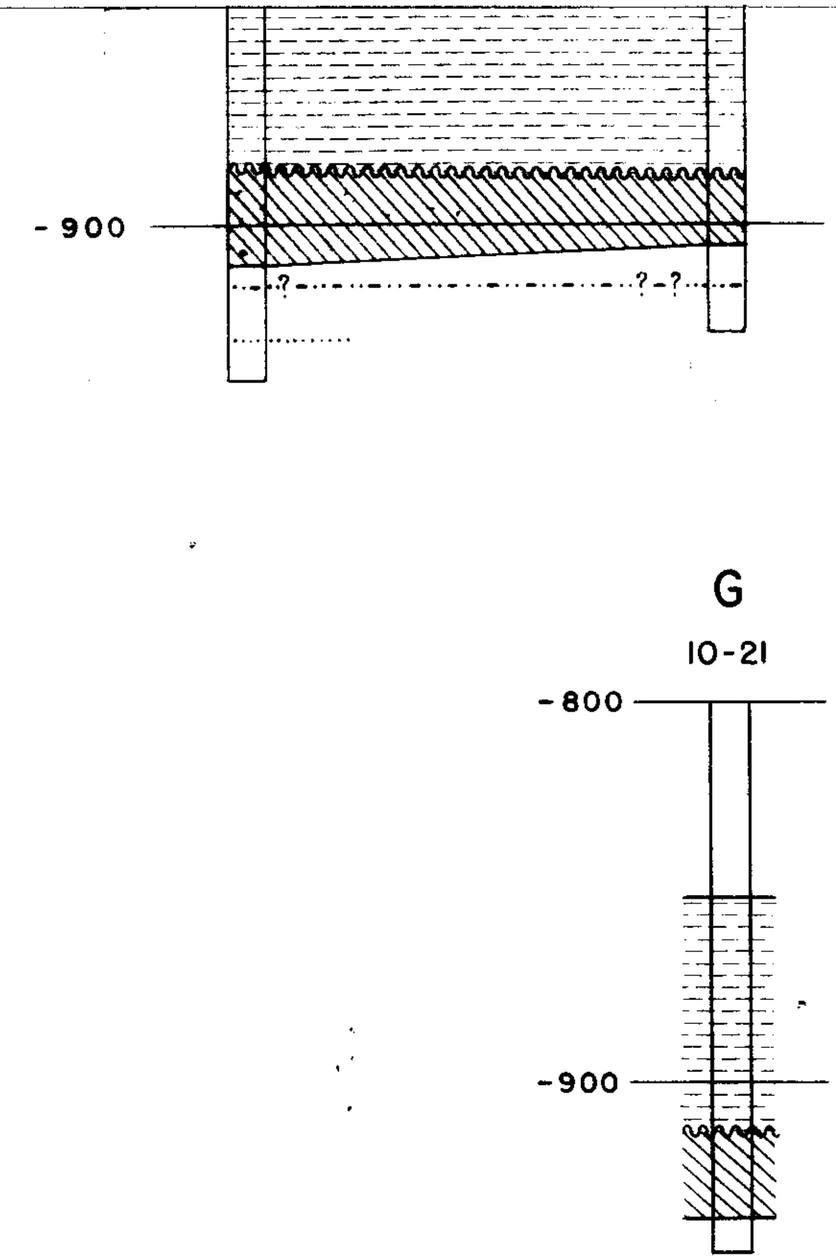


FIGURE 6

WOODNORTH FIELD

EAST-WEST CROSS SECTIONS

DATUM : SEA LEVEL

SCALES: HORIZONTAL 10" = 1 MILE
VERTICAL 1" = 50 FEET

LEGEND:

JURASSIC RED BEDS
ALTERED ZONE
TOP OF LODGEPOLE
TOP OF WOODNORTH MARKER
TOP OF WOODNORTH FRACTURE ZONE