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Mark B. Friestad

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STRUCTURAL EVOLUTION
OF THE BEAVER LODGE PORTION
OF THE NESSON ANTICLINE, NORTH DAKOTA

by Mark B. Friestad

a thesis

Submitted to the Geology Department

of the

University of North Dakota

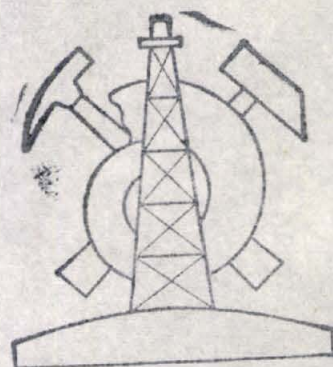
in partial fulfillment of the requirements

for the degree of

Bachelor of Science in Geology

Grand Forks, North Dakota

October, 1970



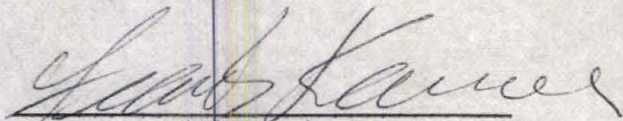
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This Thesis submitted by Mark B. Friestad in
partial fulfillment of the requirements for the degree of
Bachelor of Science in Geology from the University of
North Dakota is hereby approved by the Faculty Advisor under
whom the work has been done.


(Advisor)

ABSTRACT

The structural development in the area of Beaver Lodge Field, Williams County, North Dakota, has been determined from Cambrian (Deadwood) through Late Cretaceous (Greenhorn) time. Detailed structural data defines two areas of structural closure occurring along a basement structural trend. One of these is the site of a Precambrian topographic high. Detailed isopachous data indicates that this high was the site of structural activity during deposition of many of the units studied. Significant growth occurred during Cambrian, Ordovician, Silurian, Early Devonian, Pennsylvanian, Permian, and Jurassic times.

A possibility for petroleum accumulation exists along the flanks of the Precambrian high, where a productive sand zone in the Deadwood Formation is absent over the high.

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STRUCTURAL EVOLUTION
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INTRODUCTION

General

The purpose of this study is to determine the structural development of the Beaver Lodge portion of the Nesson Anticline in western North Dakota from Cambrian (Deadwood) through Late Cretaceous (Greenhorn) time. Thinning of sediments over the Beaver Lodge structure was the basis for determining periods of structural activity. Isopachous maps of the formations, groups, and systems were constructed at the bases of all the Paleozoic and Mesozoic sequences and at the top of the Greenhorn Formation.

Previous work

The structural activity in the area of Beaver Lodge Field has been noted in numerous stratigraphic studies that pertain to western North Dakota; however, no previous isopachous maps have been constructed on a scale detailed enough to show thinning of the various intervals.

A Beaver Lodge structure map constructed on the top of the Interlake Formation was published by Carlson and Eastwood (1962). Structure maps constructed on the tops of the Madison, Devonian, and Silurian Beaver Lodge pools were published by Carlson (1969). Thinning of the Winnipeg and Deadwood formations over the Beaver Lodge structure was noted by Carlson (1960); thinning of the Red River Formation over the Beaver Lodge structure was noted by Friestad (1969); and inactivity of the Beaver Lodge structure during Spearfish time was noted by Dow (1967).

Acknowledgements

The writer wishes to express his appreciation to A. Kirth Erickson for suggesting a problem involving structural development; to Sidney B. Anderson of the North Dakota Geological Survey for advising the area of study and making many helpful suggestions; to Drs. Walter L. Moore and Frank R. Karner of the University of North Dakota geology department staff for their helpful suggestions and criticisms; and to Dr. Edwin A. Noble, State Geologist of North Dakota, for use of the facilities of the North Dakota Geological Survey.

METHOD OF STUDY

The study was conducted at the University of North Dakota, with North Dakota Geological Survey well data and mechanical logs constantly at hand. The study was limited to Greenhorn and lower horizons, because mechanical logs were not usually run above the Greenhorn Formation. Interval tops were on file for the Precambrian, Deadwood, Winnipeg, Red River, Stony Mountain, Interlake, Winnipegosis, Prairie, Dawson Bay, Souris River, Duperow, Birdbear, Three Forks, Bakken, Madison, Kibbey Limestone, Triassic, Jurassic, Dakota, and Greenhorn units. The writer used most of these tops after checking them with mechanical logs. Tops which had not been picked, and thus had to be determined from mechanical logs by the writer, were the Kibbey Sandstone, Otter, Pennsylvanian, and Permian.

The study area is located in Townships 155 and 156 North, Ranges 95 and 96 West, in the eastern part of Williams County, North Dakota (Figure 1). In all there were 285 control wells used in the study area. Their locations are plotted on Plate 1. An appendix (p. 19) lists each

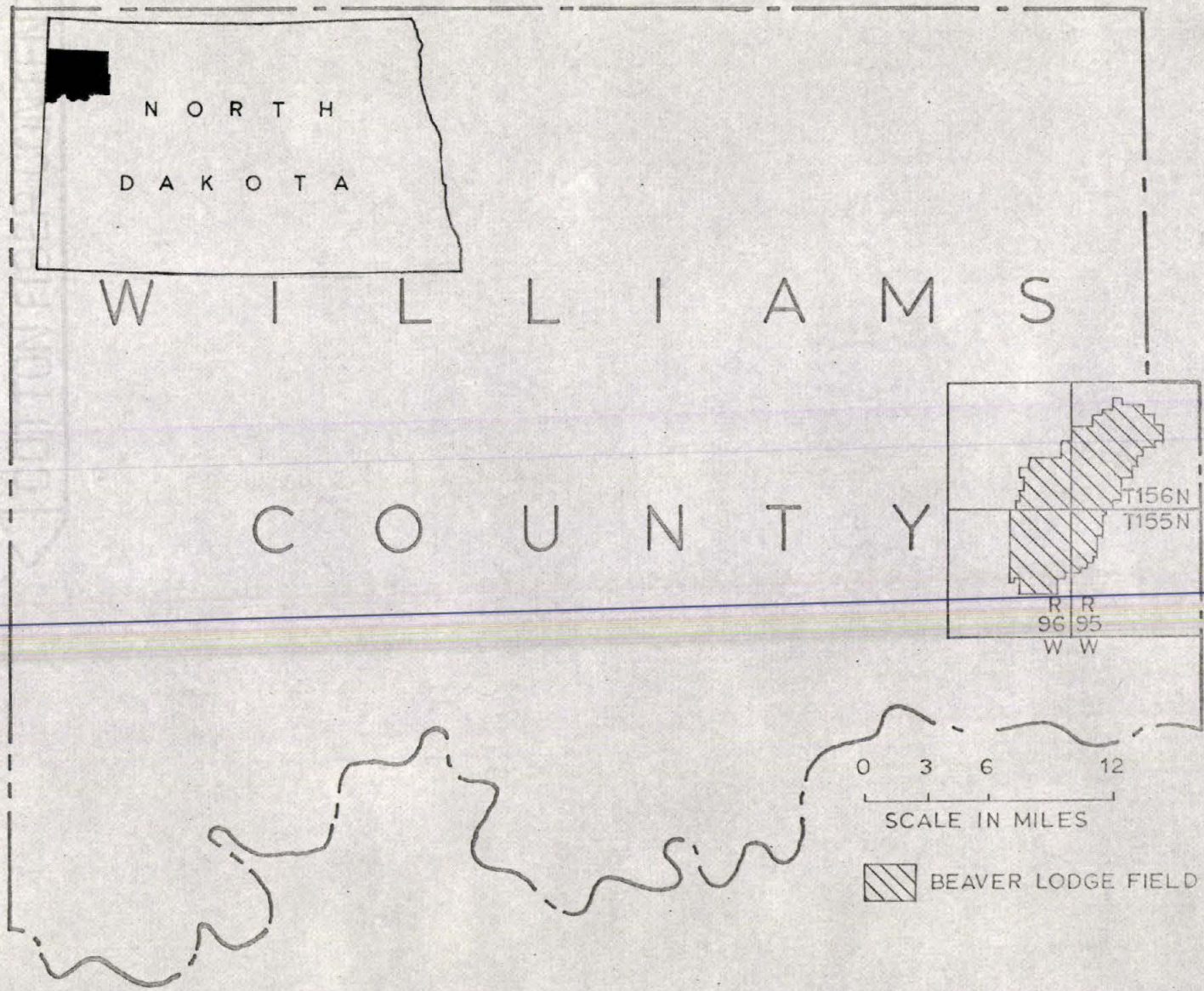


Figure 1 -- Map of Williams County, North Dakota, showing location of Beaver Lodge Field.

of the control wells according to North Dakota Geological Survey well number. Location, Kelly Bushing elevation (K. B.), and depths to tops of units are included. The appendix contains all the raw data used in constructing the isopachous and structure maps (Plates 2 - 30) and the cross sections (Figures 2, 3, and 4).

GENERAL STRUCTURAL SETTING

A record of Phanerozoic activity through Greenhorn time is summarized from Eardley (1962): The study area lies within the Algonian and Penokean Precambrian orogenic belts. In Cambrian time the Trans-continental Arch, a northeast-trending structure in eastern South Dakota and Minnesota, began rising, and remained active until Pennsylvanian time. The Williston Basin formed in Ordovician time, and the closely-allied Alberta Basin formed in Devonian time. The Ancestral Sweetgrass Arch located near the Montana-Alberta-Saskatchewan borders was active in Cambrian, Ordovician, Mississippian, Triassic, and Jurassic times. The Cambridge Arch of west-central Nebraska, western South Dakota, and southeastern Montana formed in Early Pennsylvanian time. The Sheridan Arch in southern Montana formed in Middle Jurassic time and remained active through late Jurassic time. The Belt Island Arch of western Montana was active in early Jurassic time. The Cordilleran Geanticline along the Montana-Idaho border became extensive in Jurassic time and was very active in early Cretaceous time.

The Cedar Creek Anticline, in the southwestern part of the Williston Basin, near the North Dakota-South Dakota-Montana borders, began to rise in Middle Devonian time and continued to grow in Late Devonian time (Sandberg and Hammond, 1958). Renewed uplift took place near the

end of Bakken deposition (Kume, 1963).

Ballard (1963) graphed the structural activity of four eastern North Dakota highs from Deadwood through Madison time, and found all of them to be active during deposition of the Winnipeg, Red River, Stony Mountain, Stonewall, and Duperow units. None of the highs were active during Three Forks and Bakken time. Two of the highs, the Stutsman and Foster highs, showed much thinning of Deadwood sediments, and did not migrate. The Burleigh and Cavalier highs did not show Deadwood thinning, and tended to migrate over large areas.

The Beaver Lodge structure, trending northeast-southwest, is a part of the southward-plunging Nesson Anticline complex. It is located near the center of the Williston Basin, and was the site of the first oil field discovered in the state with the Amerada-Iverson No. 1 discovery well (N. D. G. S. Well No. 25, Plate 1). The first well in Beaver Lodge Field drilled to the Precambrian (N. D. G. S. Well No. 1231, Plate 1) was drilled on a seismic high which turned out to be the site of a Precambrian topographic high or knob. This knob has by far the most relief of any Precambrian high yet discovered in the basin, and has been a center of structural growth throughout much of the Phanerozoic, as is evidenced by thinning of sediments over it.

STRUCTURAL HISTORY OF BEAVER LODGE AREA

Five wells penetrate the Precambrian in Beaver Lodge Field. N. D. G. S. Wells Nos. 1385 and 1231 define a Precambrian surface with 1151 feet of relief. The contour map on top of basement rocks (Plate 2) shows the Precambrian knob to be centered in NE $\frac{1}{4}$, Sec. 2, T. 155 N., R. 96 W. Due to lack of well control, the Precambrian surface map was

constructed with reference to the contour of the Interlake surface, which is penetrated by 38 wells (Plate 9). Basement closure is also present in the northeast portion of Beaver Lodge Field, centered in NE $\frac{1}{4}$, Sec. 19, T. 156 N., R. 95 W. Both areas of closure appear to occur along the same basement structural trend. Cross sections A - A', B - B', and C - C' (Figures 2, 3, and 4) show that the Precambrian knob is elongated in a northeast-southwest direction along this trend. The axis of Beaver Lodge Field also lies along this trend.

Deadwood sediments in the study area vary in thickness from 50 feet in N. D. G. S. Well No. 1231 on the Precambrian knob to 683 feet in N. D. G. S. Well No. 1385 (Plate 3). Mechanical logs from N. D. G. S. Well No. 1385 were compared with logs from the Precambrian wells in the southwestern part of Beaver Lodge Field. Individual beds within the Deadwood Formation were correlated and found to thin slightly over the Precambrian knob. Only the uppermost beds were present in wells directly adjacent to the knob. However, the lower Deadwood beds are present in N. D. G. S. Well No. 1385, about five miles northeast of the knob; therefore these beds presumably occur lower along the flanks of the knob. This indicates that most of the relief of the knob was present before deposition of the Deadwood Formation. The thinning of the upper Deadwood beds that are present over the high indicate structural activity during Deadwood time. (Though thinning of sediments can occur across an anticlinal axis by way of differential compaction, this process probably did not account for the thinning over the Beaver Lodge high, because the rocks are for the most part poorly compressible carbonates and sandstones. Such thinning presumably is due to structural uplift with respect to the basin.)

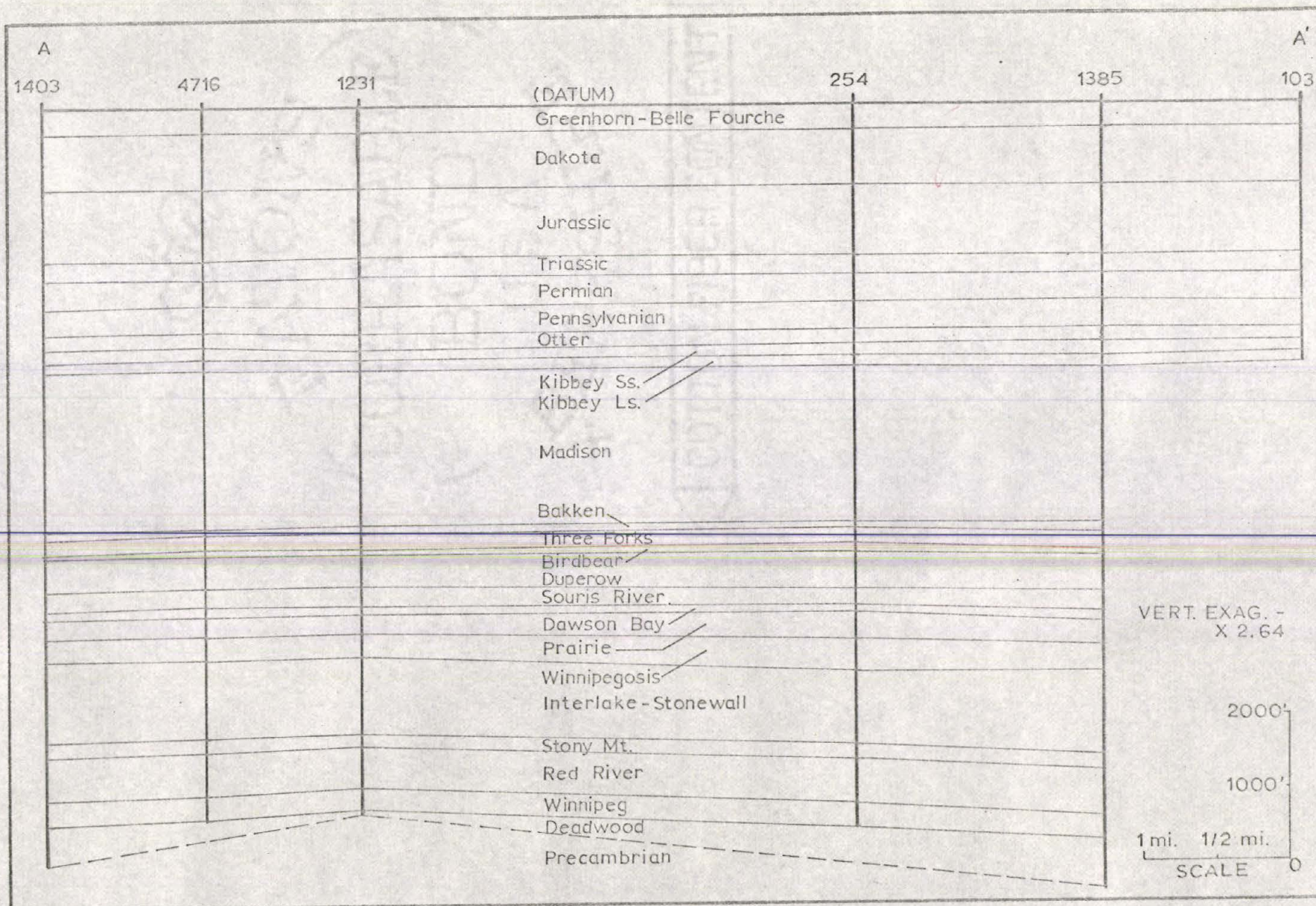


Figure 2 -- Structural Cross Section A - A'. (Location on Plate 1)

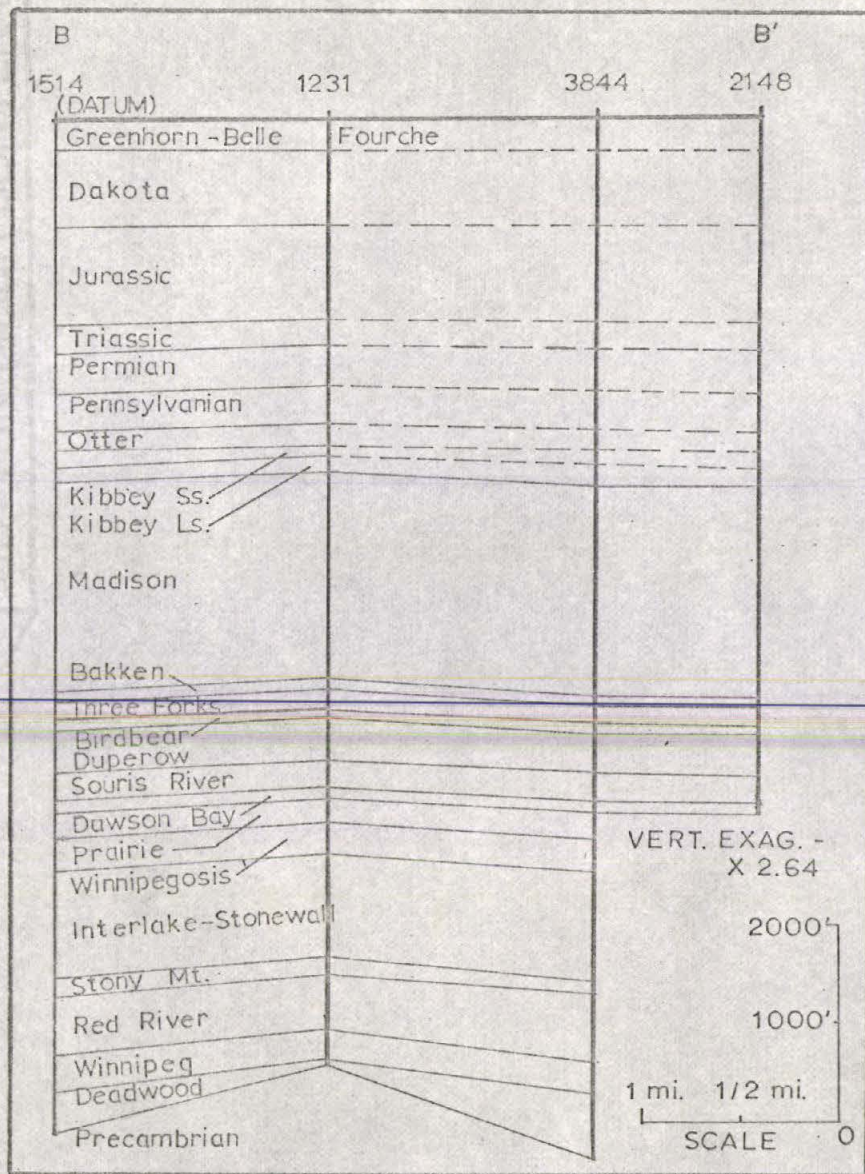


Figure 3 -- Structural Cross Section B-B'.

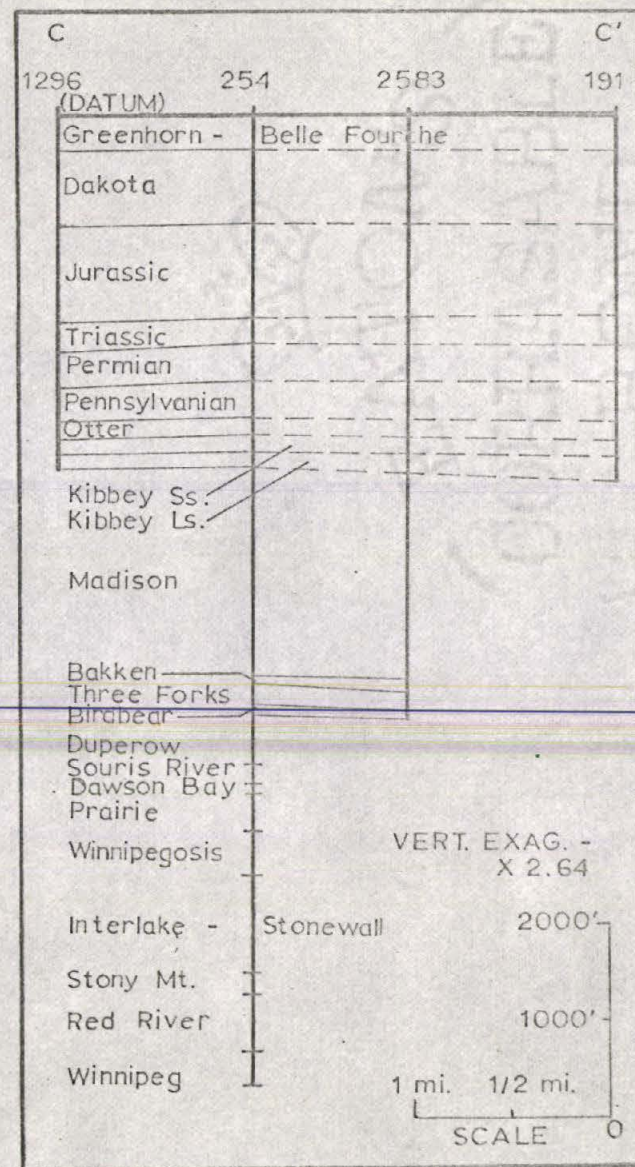


Figure 4 -- Structural Cross Section C-C'.

The top of the Deadwood Formation is penetrated by six wells in Beaver Lodge Field. The Deadwood structure map (Plate 4) shows the structural high of the Deadwood surface to coincide with the Precambrian knob. Again there is closure in both the northeast portion and the southwest portion of the field, but in both areas it is much less than closure on the Precambrian surface.

The Winnipeg Group isopachous map (Plate 5) shows thinning of sediments occurring over the Precambrian knob and in the northeast portion of the field. Sediment thickness varies from 289 feet in N. D. G. S. Well No. 1231 to 368 feet in N. D. G. S. Well No. 1514. Sediment in the northeast area of the field is much thinner than that in N. D. G. S. Wells Nos. 1514 and 3844, and it is interpreted that the northeast area of the field rose during Winnipeg time. The centers of thinning in the northeast and the southwest areas of the field appear to occur along the basement structural trend mentioned earlier.

The Red River Formation (Plate 6) thins over the Precambrian knob. Sediment thickness varies from 575 feet in N. D. G. S. Well No. 1231 to 651 feet in N. D. G. S. Well No. 1385, indicating significant structural activity in the area of the knob during Red River time.

The Stony Mountain Formation (Plate 7) thins slightly over the Precambrian knob. Sediment thickness varies from 189 feet in N. D. G. S. Well No. 1231 to 200 feet in N. D. G. S. Well No. 1403, indicating structural growth in the area of the knob during Stony Mountain time.

The Interlake-Stonewall isopachous map (Plate 8) indicates structural growth in the area of the knob during deposition of that interval. Sediment thickness varies from 1037 feet in N. D. G. S. Well No. 1231 to 1156 feet in N. D. G. S. Well No. 1385.

Thirty eight wells penetrate the top of the Interlake Formation in Beaver Lodge Field. The Interlake structure map (Plate 9) shows the structural highs of the Interlake surface to coincide with the structural highs of the Deadwood surface. As a result of the structural activity that occurred during deposition of the Tippecanoe Sequence, there is much less closure on the Interlake surface than on the Deadwood surface.

The Winnipegosis Formation (Plate 10) thins in the area of the Precambrian knob and in the northeast area of the field. Sediment thickness varies from 296 feet in N. D. G. S. Well No. 2371, a short distance southwest of the Precambrian knob, to 358 feet in N. D. G. S. Well No. 2092, in the northeast area of the field.

The Prairie Formation (Plate 11) thins in the area of the Precambrian knob, and also thins southwestward regionally (Carlson and Anderson, 1966). Slight structural activity in the area of the knob is interpreted to have occurred during Prairie time.

All Devonian sediments deposited above the Prairie Formation (ie., the Dawson Bay, Souris River, Duperow, Birdbear, and Three Forks formations) thin southward regionally (Carlson and Anderson, 1966). Iso-pachous maps of these formations (Plates 12 - 16) indicate little or no evidence of structural activity during their deposition.

The Bakken Formation thins southward regionally (Carlson and Anderson, 1966), but thickens slightly in the area of the Precambrian high (Plate 17). The Madison Group (Plate 18) thins over the high in precisely the same place the Bakken Formation thickens. It is interpreted that the Bakken surface was slightly irregular before deposition of the Madison Group, and that neither the thickening of Bakken sediments

nor the thinning of Madison sediments is related to structural activity.

Well control increases sharply for Madison and younger sediments. The top of the Madison is penetrated by 257 wells in Beaver Lodge Field, an average of slightly more than seven wells per square mile. The Big Snowy Group (ie., Kibbey Limestone, Kibbey Sandstone, and Otter Formation) isopachous maps (Plates 19, 20, and 21) have numerous areas of thickening and thinning, but none are interpreted to have any relationship to structural activity.

The contour map on top of the Otter Formation (Plate 22) does not differ significantly from the contour map on top of the Interlake Formation (Plate 9). The major difference is that the northeast structure is 150 feet lower than the southwest structure on the Interlake surface, whereas the two structures are at the same elevation on the Otter surface. This results from the fact that most of the beds of the Kaskaskia Sequence thin southward regionally.

The Pennsylvanian and Permian systems thicken southward regionally (Carlson and Anderson, 1966), but thin considerably in the area of the Precambrian knob (Plates 23 and 24), indicating significant structural activity during the Pennsylvanian and Permian periods.

The Triassic System thickens southward regionally (Carlson and Anderson, 1966), and thins slightly in numerous places in Beaver Lodge Field (Plate 25). The areas of thinning do not appear to be related to structural activity.

The contour map of the top of the Spearfish Formation (Plate 26) differs significantly from the contour map of the top of the Otter Formation (Plate 22). Only one area of closure exists on the Spearfish surface, whereas two areas of closure exist on the Otter surface.

Regional thinning of the Absaroka Sequence northward results in disappearance of the northeast area of closure that is present below the sequence. The structural high on the Spearfish surface is about a mile and a half southeast of the Precambrian high. All deeper structure maps show structural highs directly above the Precambrian knob.

The Jurassic System (Plate 27) thins appreciably over the axis of the Beaver Lodge structure. The thinning is interpreted to be related to structural activity, because it occurs approximately along the northeast-southwest basement structural trend mentioned earlier.

The Dakota Group and Greenhorn-Belle Fourche isopachous maps (Plates 28 and 29) have numerous small thick and thin areas, but appear unrelated to structural activity.

The structure contour map drawn on the Greenhorn Formation (Plate 30) is almost identical with that on the Spearfish Formation (Plate 26).

A chart comparing thickness of sediment in N. D. G. S. Well No. 1231 to the average thickness of sediment in N. D. G. S. Wells Nos. 1514 and 3844 (Figure 5) was compiled to show structural activity of the high during deposition of the various intervals studied. Total net thinning over the high from Precambrian to Greenhorn time was 838½ feet. A bar graph showing structural relief (Figure 6) was constructed from the chart, as was a bar graph comparing the structural relief of each unit to its average thickness (Figure 7). These graphs summarize the structural activity of the high quite well, but with two reservations. One is that the amount of Deadwood "structural relief" includes also the relief present on the Precambrian knob prior to Deadwood deposition. Actual structural growth during Deadwood time has not been determined by this study. The other reservation is that all thinning and thickening

Interval	Thick. #1514	Thick. #1231	Thick. #3844	Ave. thick. 1514 & 3844	Thinning over high (#1231)	Struc. grow./ thickness (%)
GH - BF	340'	343'	350'	345'	2'	0.6%
Dakota	810'	777'	778'	794'	17'	2.1%
Jurassic	989'	958'	977'	983'	25'	2.5%
Triassic	282'	287'	290'	286'	-1'	-0.4%
Permian	421'	415'	497'	459'	44'	9.6%
Penns.	406'	371'	399'	402½'	31½'	7.8%
Otter	200'	194'	189'	194½'	½'	0.3%
Kib. Ss.	162'	150'	158'	160'	10'	6.2%
Kib. Ls.	148'	152'	150'	149'	-3'	-2.0%
Madison	2143'	2118'	2142'	2142½'	24½'	1.1%
Bakken	100'	114'	104'	102'	-12'	-11.8%
Three F.	187'	193'	192'	189½'	-3½'	-1.6%
Birdbear	105'	98'	90'	97½'	-½'	-0.5%
Duperow	443'	438'	438'	440½'	2½'	0.6%
Sour. R.	277'	262'	252'	264½'	2½'	0.9%
Daws. B.	122'	133'	134'	128'	-5'	-3.9%
Prairie	265'	260'	282'	273½'	13½'	4.9%
Wpgosis.	340'	330'	325'	332½'	2½'	0.8%
Int.-St.	1085'	1037'	1119'	1102'	65'	5.9%
Stony M.	197'	189'	198'	197½'	8½'	4.3%
Red R.	606'	575'	620'	613'	38'	6.2%
Winnipeg	368'	289'	334'	351'	62'	17.7%
Deadwood	446'	50'	683'	564½'	514½'	91.1%

Figure 5 -- Chart showing thinning over Beaver Lodge high (well no. 1231).
(Sediment thicknesses in wells no. 1514 and no. 3844 used for comparison.)

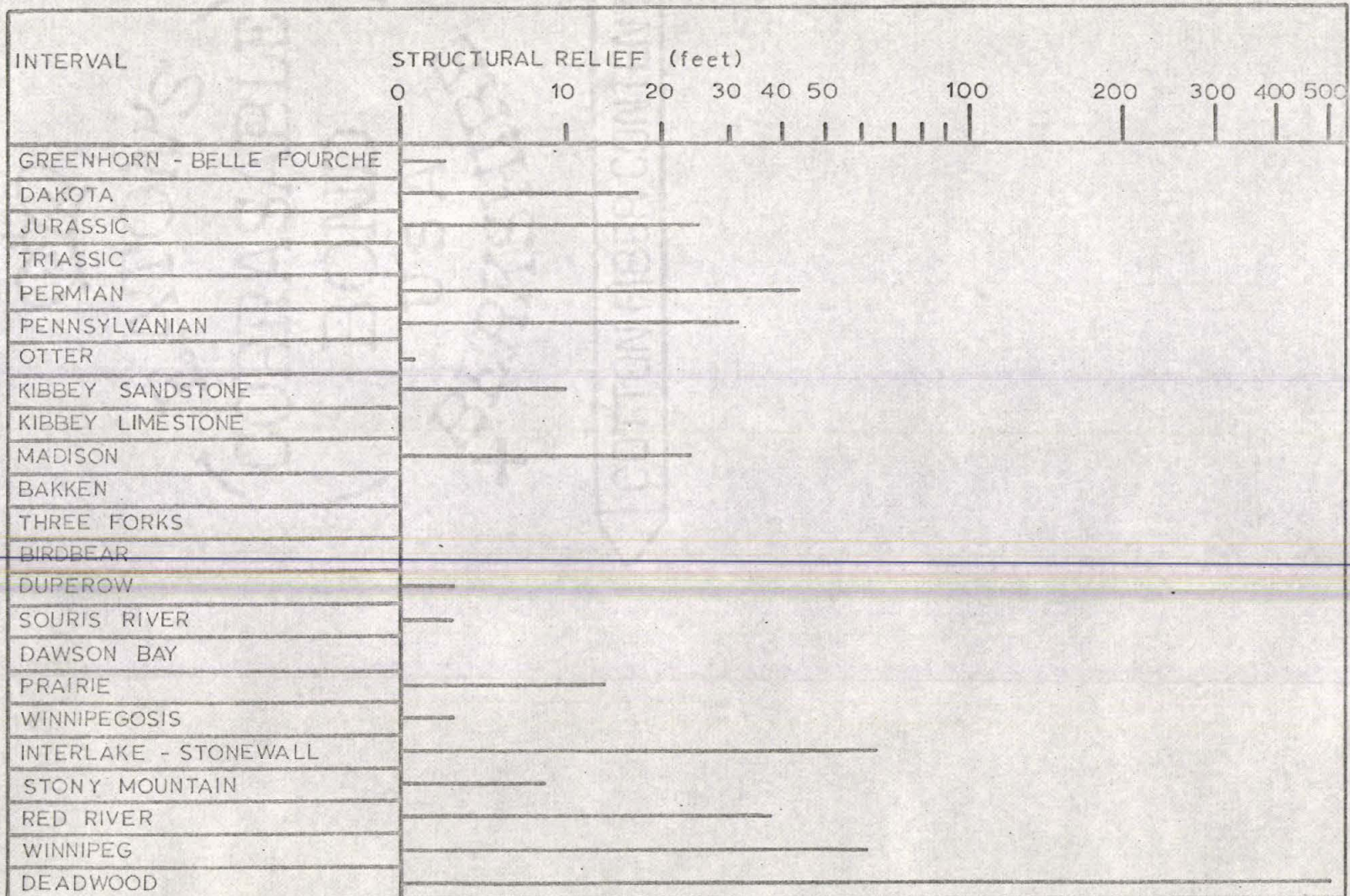


Figure 6 -- Structural growth of the Beaver Lodge high during Paleozoic and Mesozoic time.

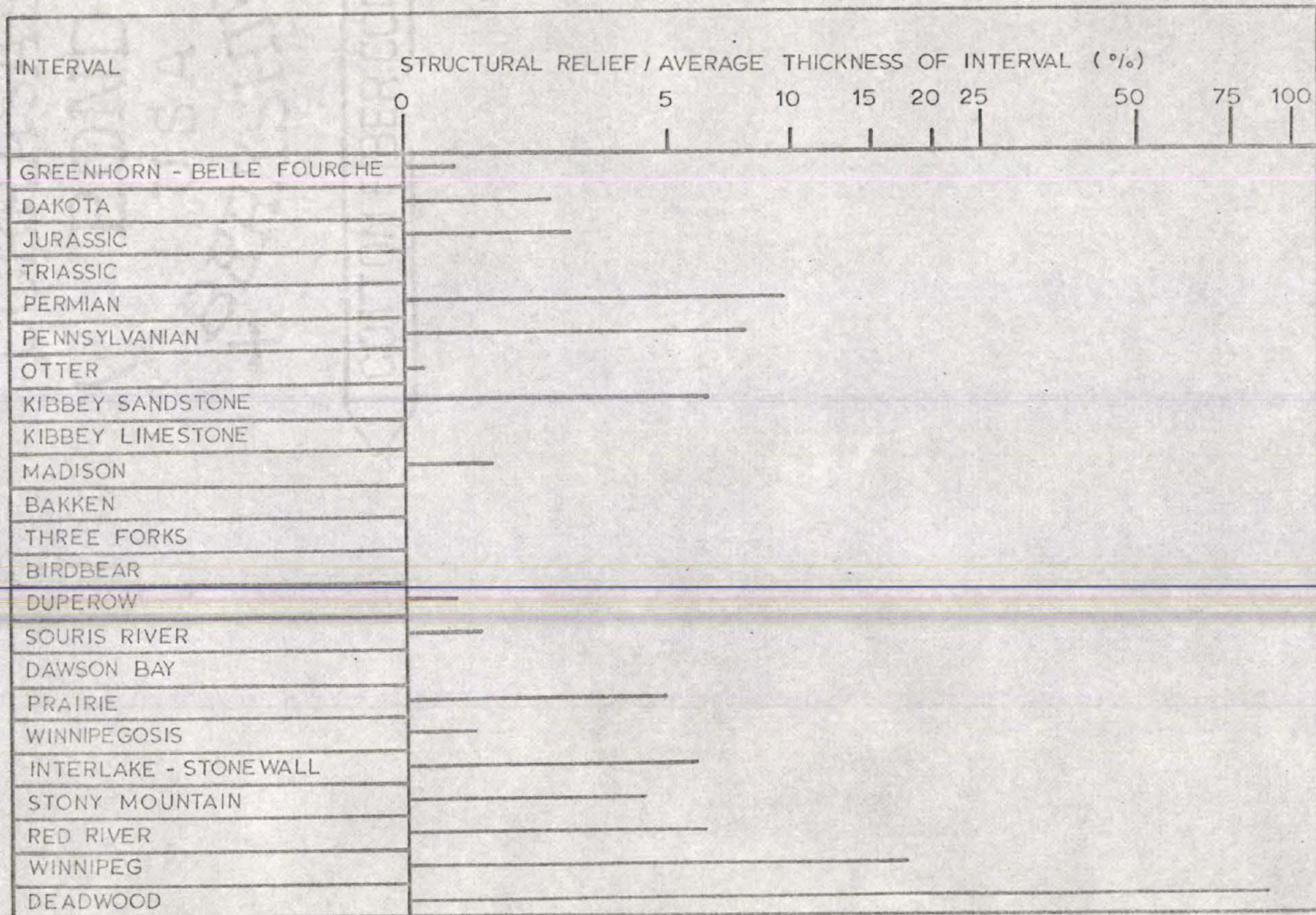


Figure 7 -- Structural growth of the Beaver Lodge high with respect to average thicknesses of the various intervals, expressed in percentage.

is shown to result from structural activity, with the assumption that the upper surface of each unit was flat before deposition of the next higher unit. In actuality these surfaces were probably not flat, in which case the thin and thick areas should not be considered to be related to structural activity.

The charts and isopachous maps discussed in this study indicate that significant structural growth occurred in the area of the Beaver Lodge high during Cambrian, Ordovician, Silurian, Early Devonian, Pennsylvanian, Permian, and Jurassic times. This compares very closely with the structural activity of the four eastern North Dakota highs studied by Ballard (1963), especially the Statsman and Foster highs. Activity of the Cedar Creek Anticline is in no way correlative with the activity of the Beaver Lodge high.

PETROLEUM POSSIBILITIES

A commercial condensate-producing sand zone exists at a depth of 14,000 - 14,040 feet in N. D. G. S. Well No. 1636 in the northeast area of Beaver Lodge Field (Plate 1). The same sand zone should have occurred at a depth of about 13,587 - 13,627 feet in N. D. G. S. Well No. 1231 in the southwest area of the field. However, the Precambrian knob occurs in this well at a depth of 13,588 feet; thus the producing zone is absent in the well, but presumably occurs lower on the flanks of the knob. Approximately the upper 20 feet of this producing zone in N. D. G. S. Well No. 1636 contains impermeable shales, thus supplying a vertical seal. This shale is also present in the southwest portion of the field in N. D. G. S. Well No. 1403, so it is reasonable to assume that it is present along the flanks of the Precambrian knob, providing a seal for petroleum. Figure 8 illustrates how petroleum should be trapped beneath

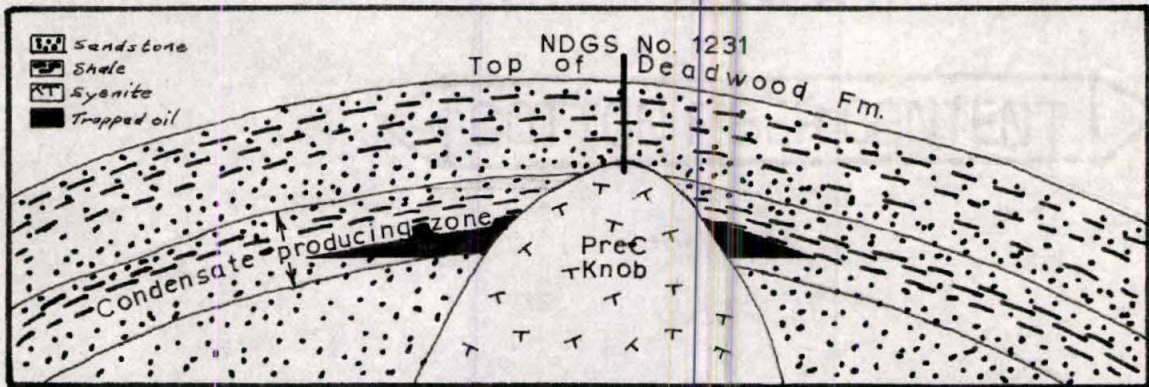


Figure 8 -- Cross-sectional sketch illustrating petroleum trapped along the flanks of the Precambrian knob in the study area.

this impervious shale along the flanks of the knob. From the structure map of the top of the Deadwood Formation (Plate 4), one can see that the southwest structure is a much more extensive collecting mechanism for petroleum than is the northeast structure.

SUMMARY

This study deals with the structural activity in the area of Beaver Lodge Field in Williams County, North Dakota, from Cambrian (Deadwood) through Late Cretaceous (Greenhorn) time.

Detailed isopachous and structural data define a Precambrian high in NE $\frac{1}{4}$, Sec. 2, T. 155 N., R. 96 W., which is elongated along a basement structural trend. Another area of basement closure exists to the northeast of the Precambrian high in NE $\frac{1}{4}$, Sec. 19, T. 156 N., R. 95 W., along the same trend. Both areas were structurally active during deposition of some of the intervals studied. Significant growth occurred during Cambrian, Ordovician, Silurian, Early Devonian, Pennsylvanian, Permian, and Jurassic times. This activity is very similar to the activity of four eastern North Dakota highs, but does not correlate with the activity of the Cedar Creek Anticline.

A productive sand zone occurring in the Deadwood Formation is absent over the top of the Precambrian high. A shale seal exists above the sand zone, so trapped petroleum should be present along the flanks of the high.

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APPENDIX

LIST OF SYSTEM, GROUP, AND FORMATION TOPS

The following is a list of system, group, and formation tops in wells in the area of Beaver Lodge Field. Some of the tops were taken from well files of the North Dakota Geological Survey and verified by mechanical logs, and some tops were determined from mechanical logs. The wells are listed in order according to North Dakota Geological Survey well number. Well location and Kelly Bushing elevation (K. B.) are included. Depths to the various tops are in feet. An absent top indicates that the top was questionable or that the interval was not logged.

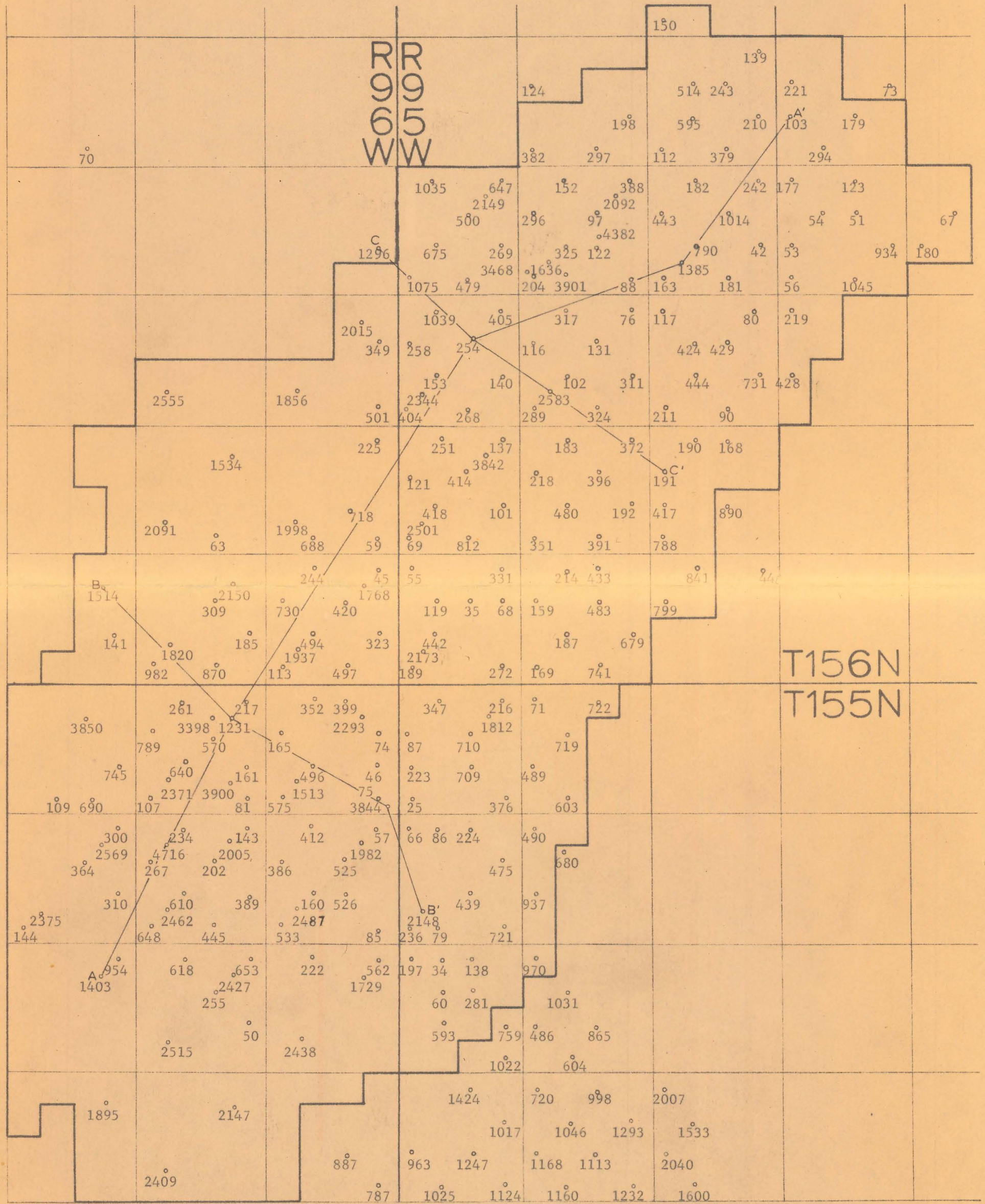
Well No.	890	934	937	954	963	970	982	998	1014	1017	1022
Location	28	15	8	15	19	17	35	20	16	19	18
	-156	-156	-155	-155	-155	-155	-156	-155	-156	-155	-155
	-95	-95	-95	-96	-95	-95	-96	-95	-95	-95	-95
K. B.	2418	2343	2317	2208	2265	2243	2283	2115	2334	2223	2258
TOPS - GH	4045	3985	3827	3747	3770	3755	3836	3644	3945	3724	3759
Dakota	4395	4330	4187	4103	4127	4120	4173	3997	4283	4084	4100
Jurassic	5163	5100	5000	4893	4944	4920	4975	4810	5076	4900	4920
Triassic	6130	6067	5962	5863	5920	5900	5942		6042	5878	5904
Permian	6436	6360	6257	6140	6212	6190	6232	6090	6318	6172	6195
Penns.	6832	6747	6713	6538	6686	6652	6614	6575	6678	6660	6658
Otter	7266	7127	7114	6913	7076	7045	7000	6975	7070	7050	7063
Kib. Ss.	7448	7314	7313	7113	7278	7246	7190	7180	7255	7253	7264
Kib. Ls.	7606	7469	7467	7267	7432	7388	7348	7330	7407	7405	7418
Madison	7757	7620	7615	7426	7586	7550	7498	7485	7574	7555	7566
Bakken											
Three F.											
Birdbear											
Duperow											
Sour. R.											
Daws. B.											
Prairie											
Wpgosis.											
Interl.											
Stony M.											
Red R.											
Winnipeg											
Deadwood											
Prec.											

THE EAGLE'S
CORPORATION
BOND
SA
REGISTERED
COTTON FIBER CONTENT

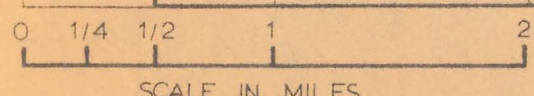
Well No.	1231	1232	1247	1293	1296	1385	1403	1424	1513	1514	1534
Location	2	20	19	20	13	16	15	19	1	34	26
	-155	-155	-155	-155	-156	-156	-155	-155	-155	-156	-156
	-96	-95	-95	-95	-96	-95	-96	-95	-96	-96	-96
K. B.	2316	2053	2209	2167	2358	2360	2165	2257	2339	2286	2340
TOPS - GH		3624	3714	3735	3967		3716	3762	3828	3875	3914
Dakota	4198	3997	4068	4095	4316	4275	4068	4113	4174	4215	4250
Jurassic	4975	4807	4893	4920	5106	5069	4855	4915		5025	5037
Triassic	5933	5803	5870	5902	6103	6050	5833	5903	5943	6014	6033
Permian	6220	6062	6167	6175	6388	6328	6111	6193	6222	6296	
Penns.	6635	6522	6642	6645	6762	6698	6517	6680	6702	6717	
Otter	7006	6933	7034	7050	7127	7088	6885	7065	7072	7123	
Kib. Ss.	7200	7137	7236	7252	7310	7280	7090	7271	7260	7323	
Kib. Ls.	7350	7285	7389	7400	7471	7437	7245	7426	7422	7485	7450
Madison	7502	7437	7540	7553	7622	7588	7408	7575	7570	7633	7595
Bakken	9620					9735	9570			9776	9720
Three F.	9734					9864	9678			9876	9832
Birdbear	9927					10086	9870			10063	10025
Duperow	10025					10188	9954			10168	10122
Sour. R.	10463					10680	10393			10611	10573
Daws. B.	10725					10966	10655			10888	10842
Prairie	10858					11095	10789			11010	10971
Wpgosis.	11118					11417	11036			11275	11245
Interl.	11448					11770	11367			11615	11585
Stony M.	12485					12926	12457			12700	
Red R.	12674					13124	12657			12897	
Winnipeg	13249					13775	13262			13503	
Deadwood	13538					14100	13607			13871	
Prec.	13588					14783	14145			14317	

Well No.	2569	2583	3398	3468	3842	3844	3850	3900	3901	4716
Location	10	20	2	17	30	1	3	2	17	11
	-155	-156	-155	-156	-156	-155	-155	-155	-156	-155
	-96	-95	-96	-95	-95	-96	-96	-96	-95	-96
K. B.	2242	2409	2325	2395	2376	2370	2268	2329	2421	2294
TOPS - GH				3975					3997	
Dakota	4154		4206	4303	4273		4200	4334	4195	
Jurassic	4936		4984		5072		4985	5115	4994	
Triassic	5914			6073			5964	6090	5970	
Permian	6185			6352	6315			6370	6237	
Penns.	6567			6717	6705			6737	6611	
Otter.	6938			7087	7100			7110	6981	
Kib. Ss.	7133			7272	7280			7305	7170	
Kib. Ls.	7296			7428	7441		7380	7454	7332	
Madison	7437			7569	7593	7648	7518	7518	7588	7487
Bakken	9614	9802			9738	9790	9684	9669		9655
Three F.	9709	9912			9855	9894	9780	9768		9753
Birdbear	9903	10121	9947		10057	10086	9970	9957		9942
Duperow	9987	10223	10034		10160	10176	10054	10046		10036
Sour. R.	10430		10482		10633	10614	10506	10484		10476
Daws. B.	10693		10740			10866				10746
Prairie	10828		10874			11000				10872
Wpgosis.	11108		11140			11282				11139
Interl.	11409		11468			11607				11465
Stony M.						12726				12530
Red R.						12924				12723
Winnipeg						13544				13316
Deadwood						13902				13653
Prec.						14561				

LOCATION MAP SHOWING CONTROL WELLS BEAVER LODGE FIELD



T156N
T155N

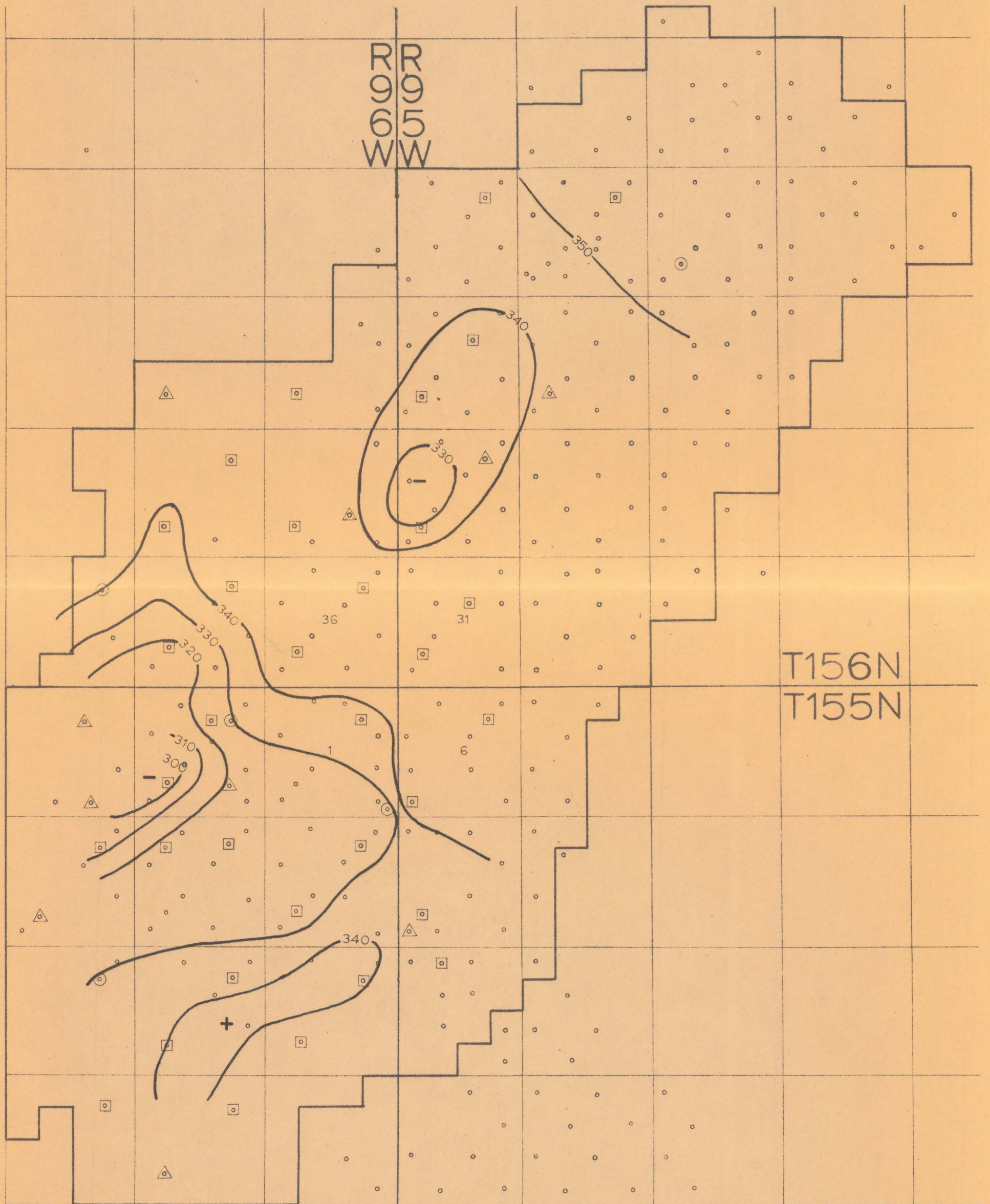


WILLIAMS COUNTY, NORTH DAKOTA

• CONTROL WELL
2409 NORTH DAKOTA GEOLOGICAL SURVEY WELL NUMBER
A———A' LOCATION OF FIGURES 2, 3, AND 4

PLATE 1

WINNIPEGOSIS FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2

SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 10 FEET

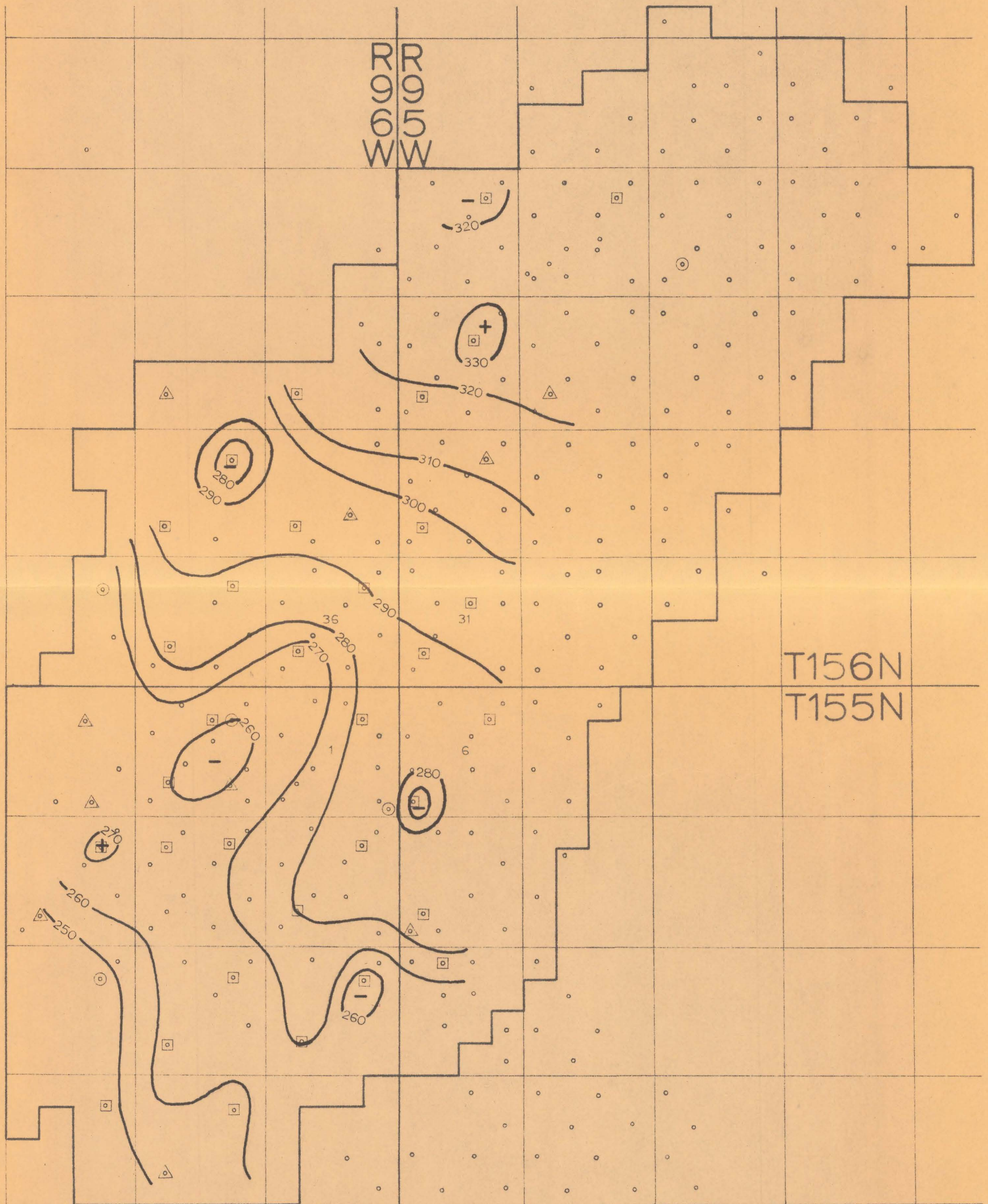
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

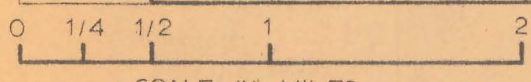
WILLIAMS COUNTY, NORTH DAKOTA

PLATE 10

PRAIRIE FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



T156N
T155N



SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 10 FEET

CONTROL WELLS:

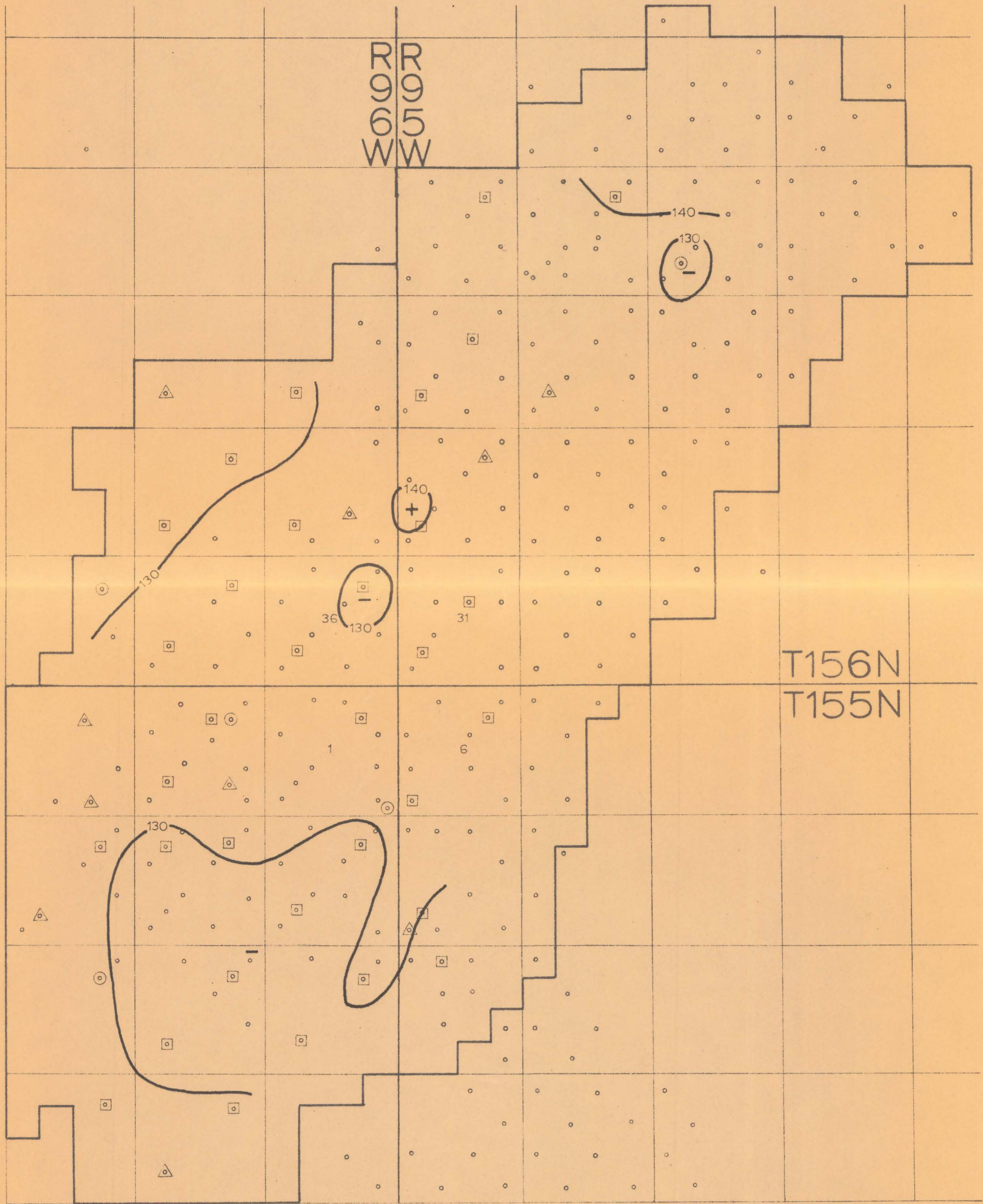
- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 11

DAWSON BAY FORMATION ISOPACHOUS MAP

BEAVER LODGE FIELD



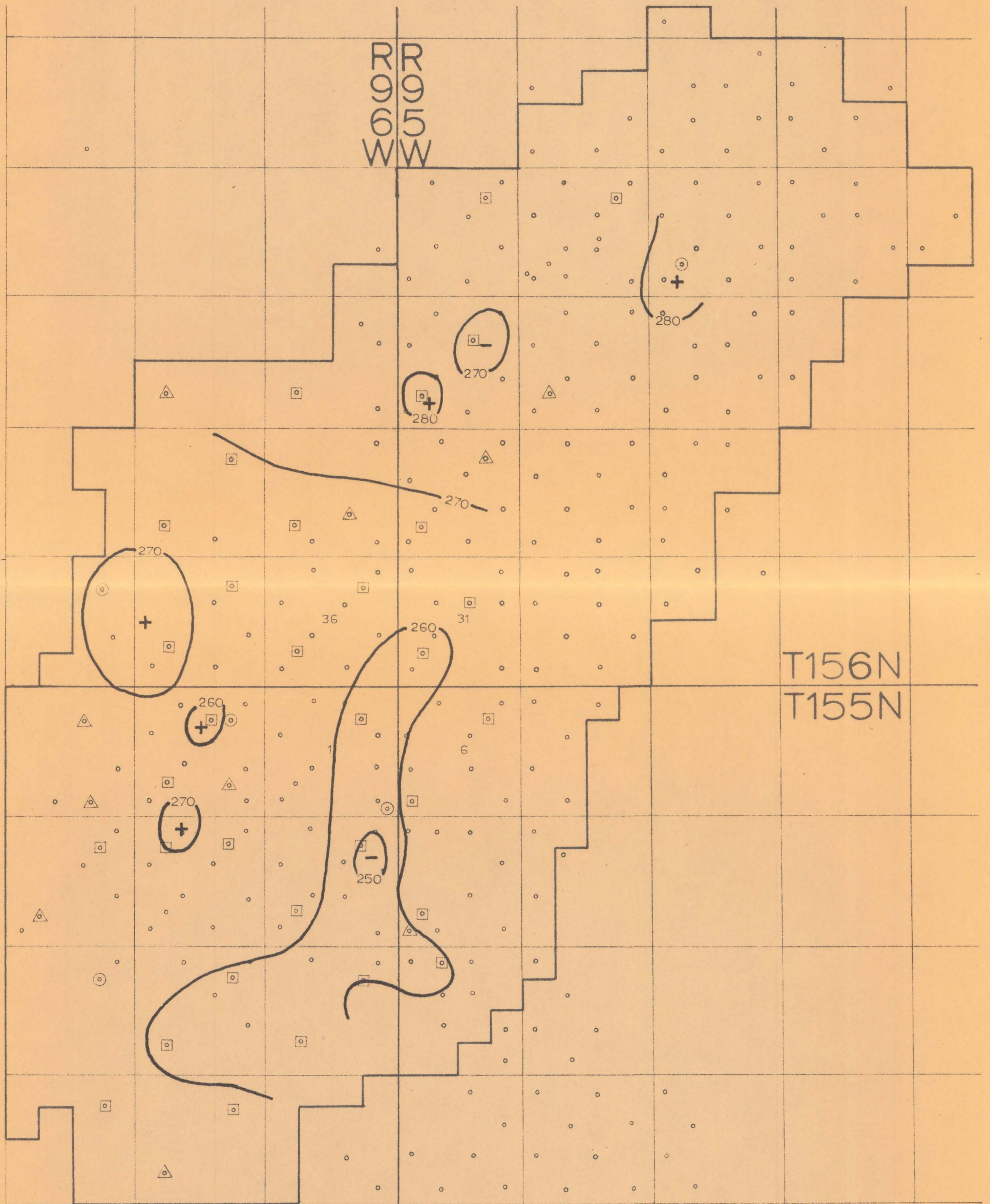
SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 10 FEET

- CONTROL WELLS:
- Madison penetration
 - △ Duperow penetration
 - Interlake penetration
 - ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 12

SOURIS RIVER FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2

SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 10 FEET

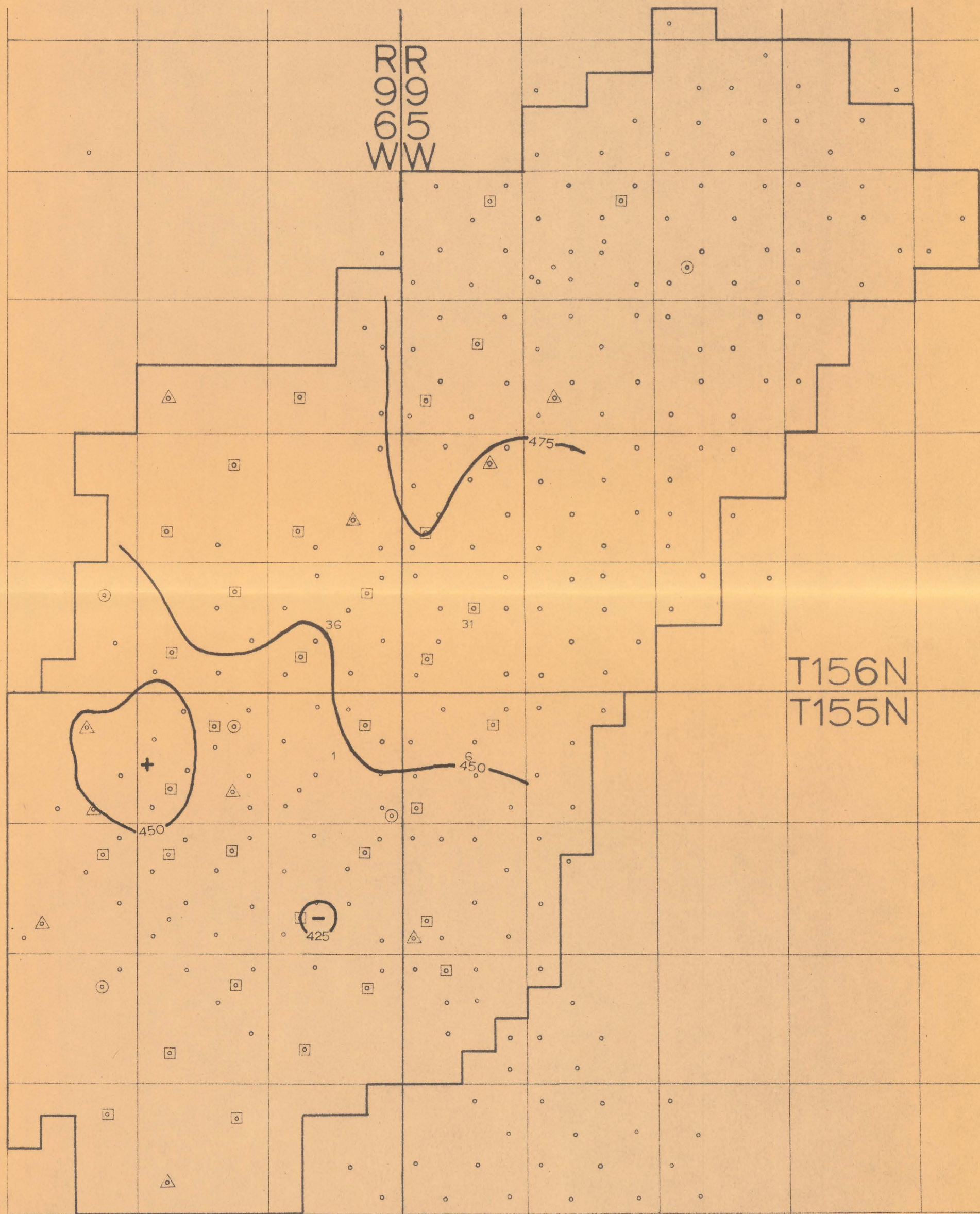
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 13

DUPEROW FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2

SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 25 FEET

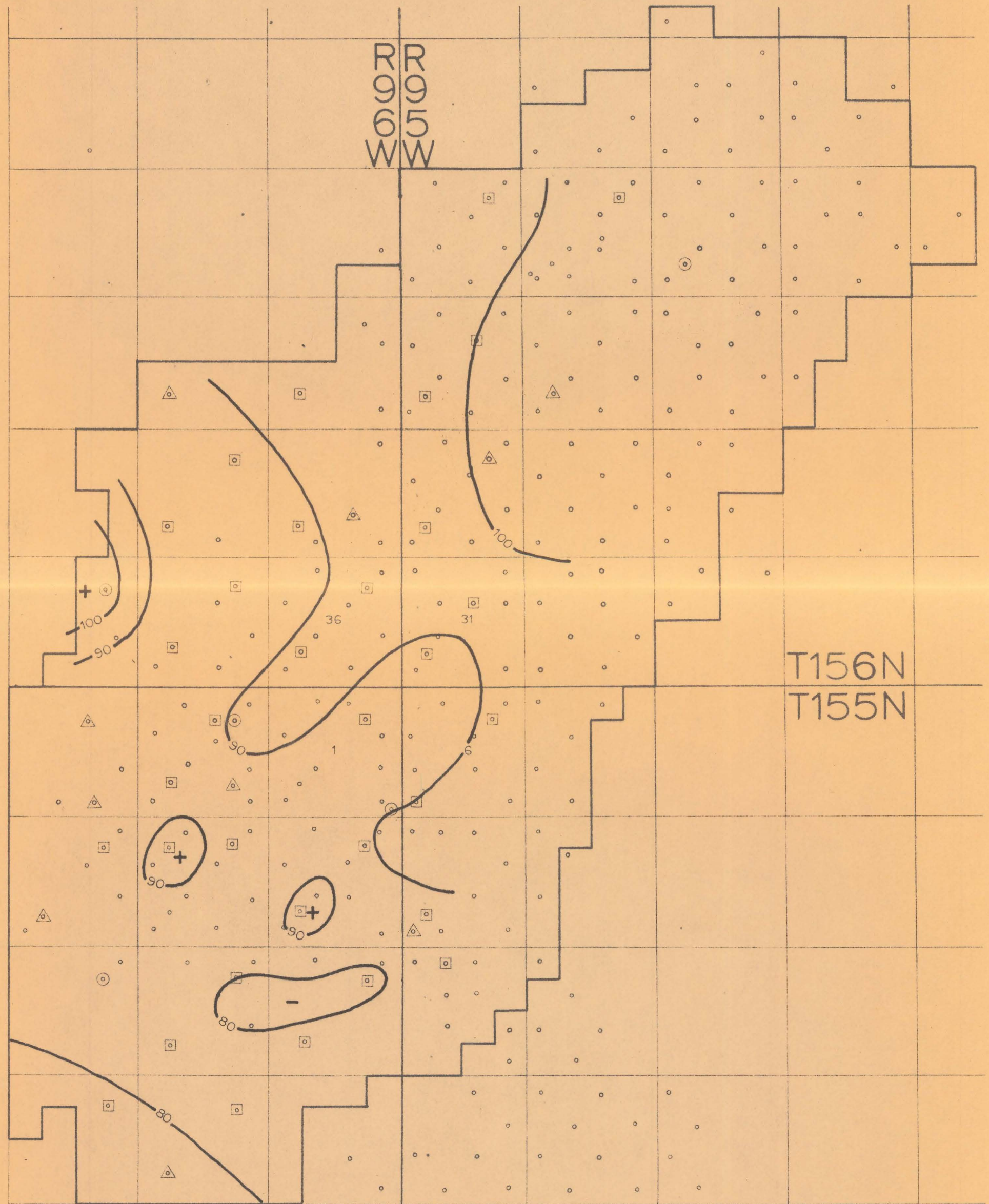
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 14

BIRDBEAR FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



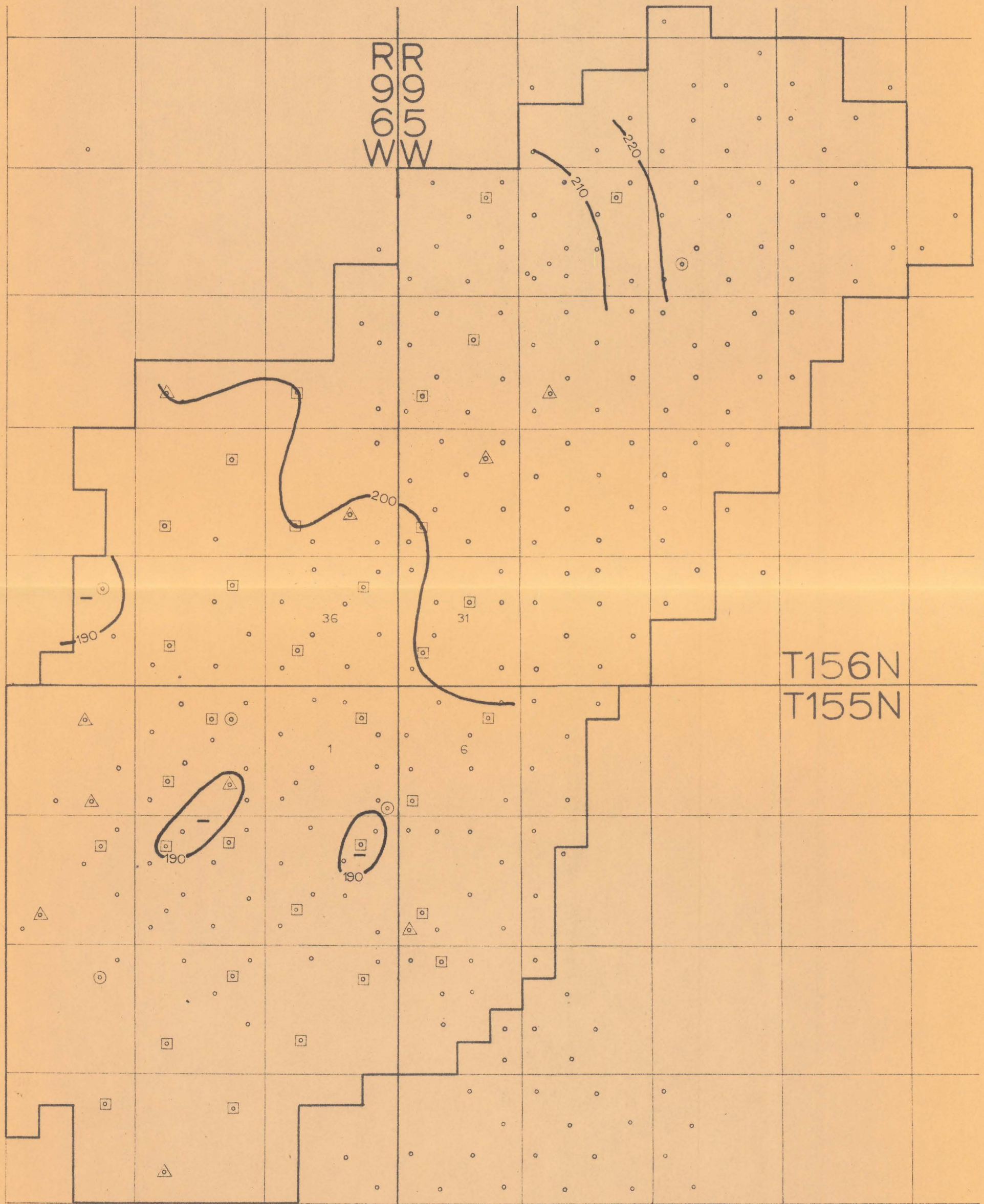
0 1/4 1/2 1 2
 SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 10 FEET

CONTROL WELLS:
 ○ Madison penetration
 △ Duperow penetration
 □ Interlake penetration
 ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 15

THREE FORKS FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 10 FEET

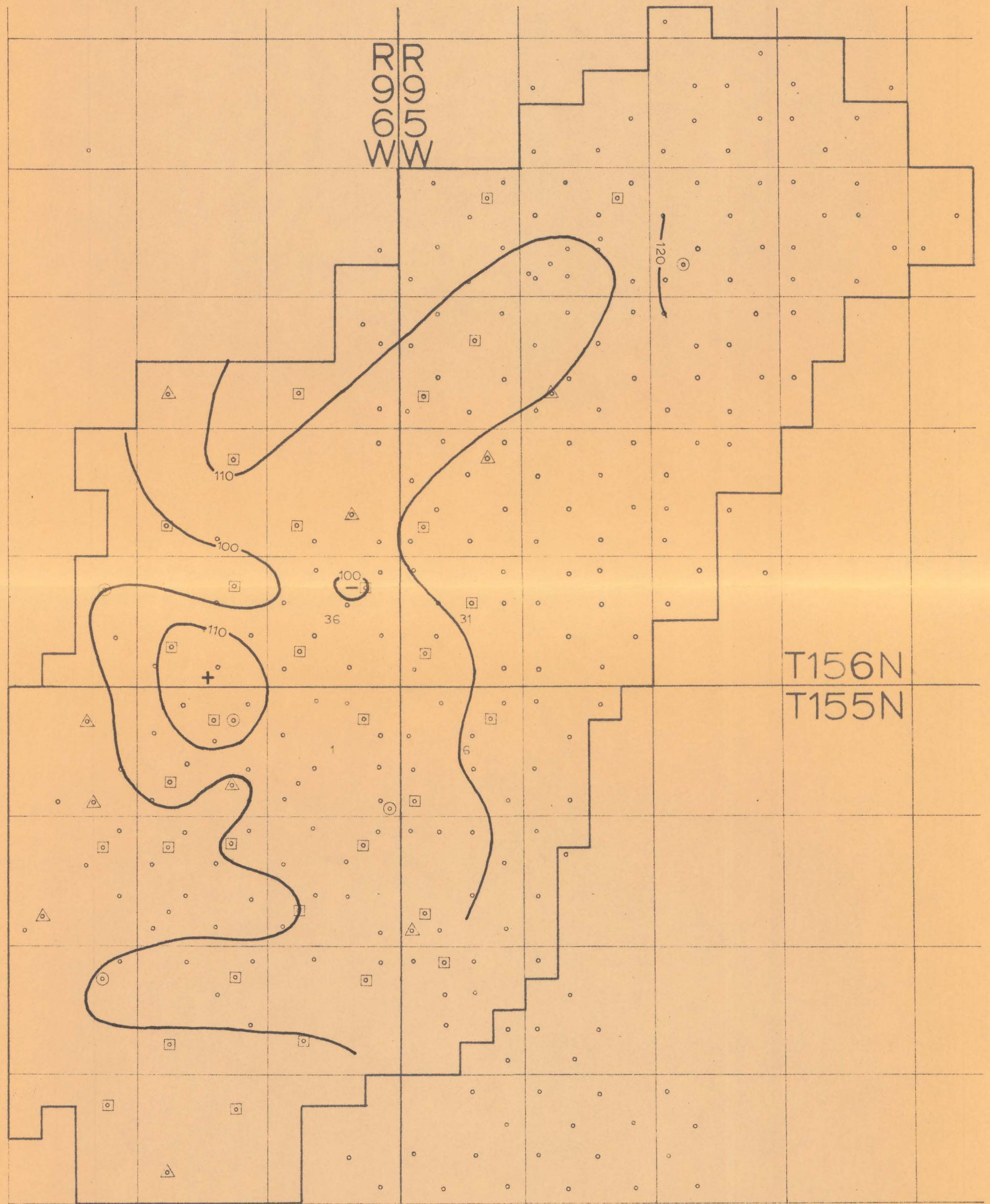
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 16

BAKKEN FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2

SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 10 FEET

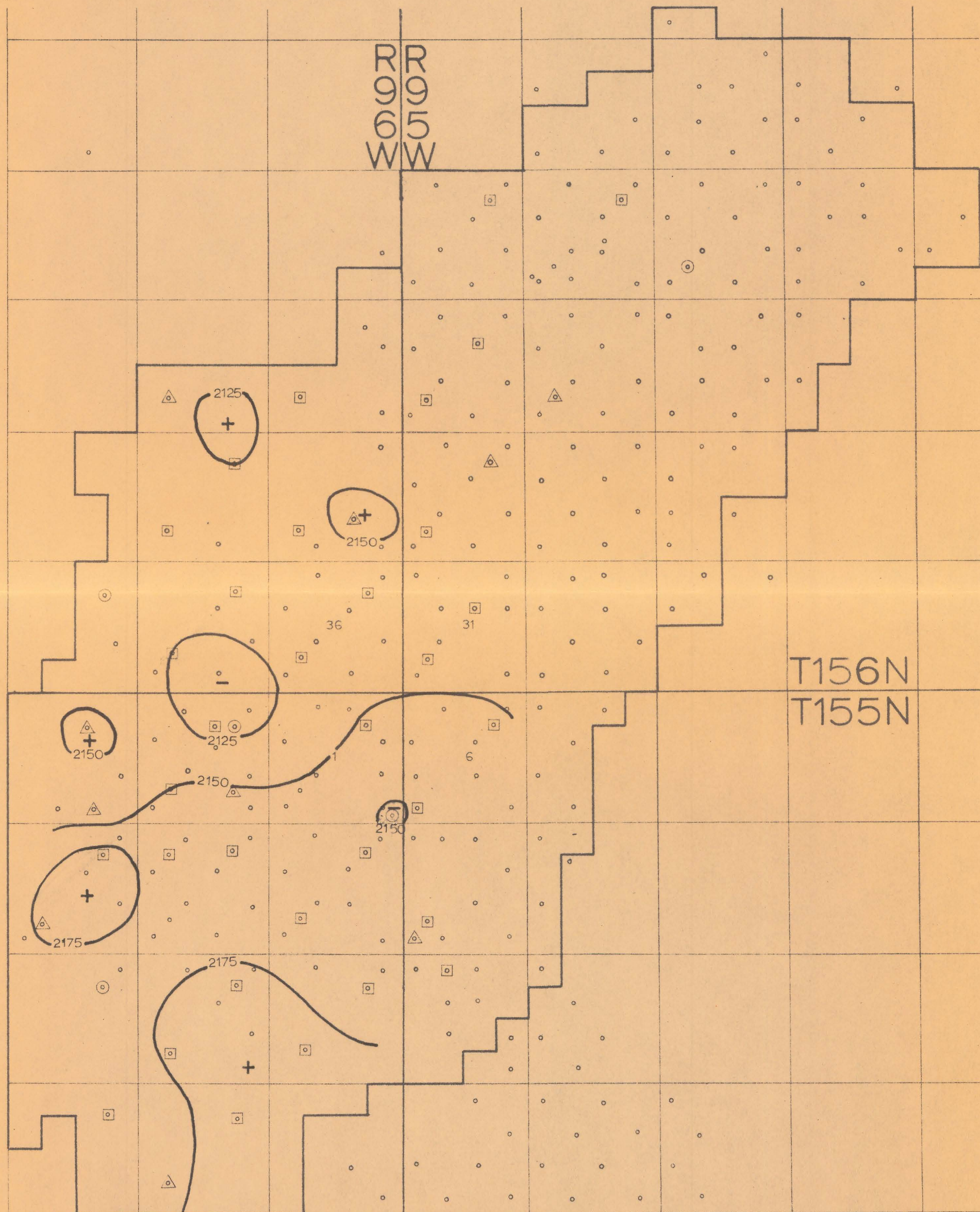
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 17

MADISON GROUP ISOPACHOUS MAP BEAVER LODGE FIELD



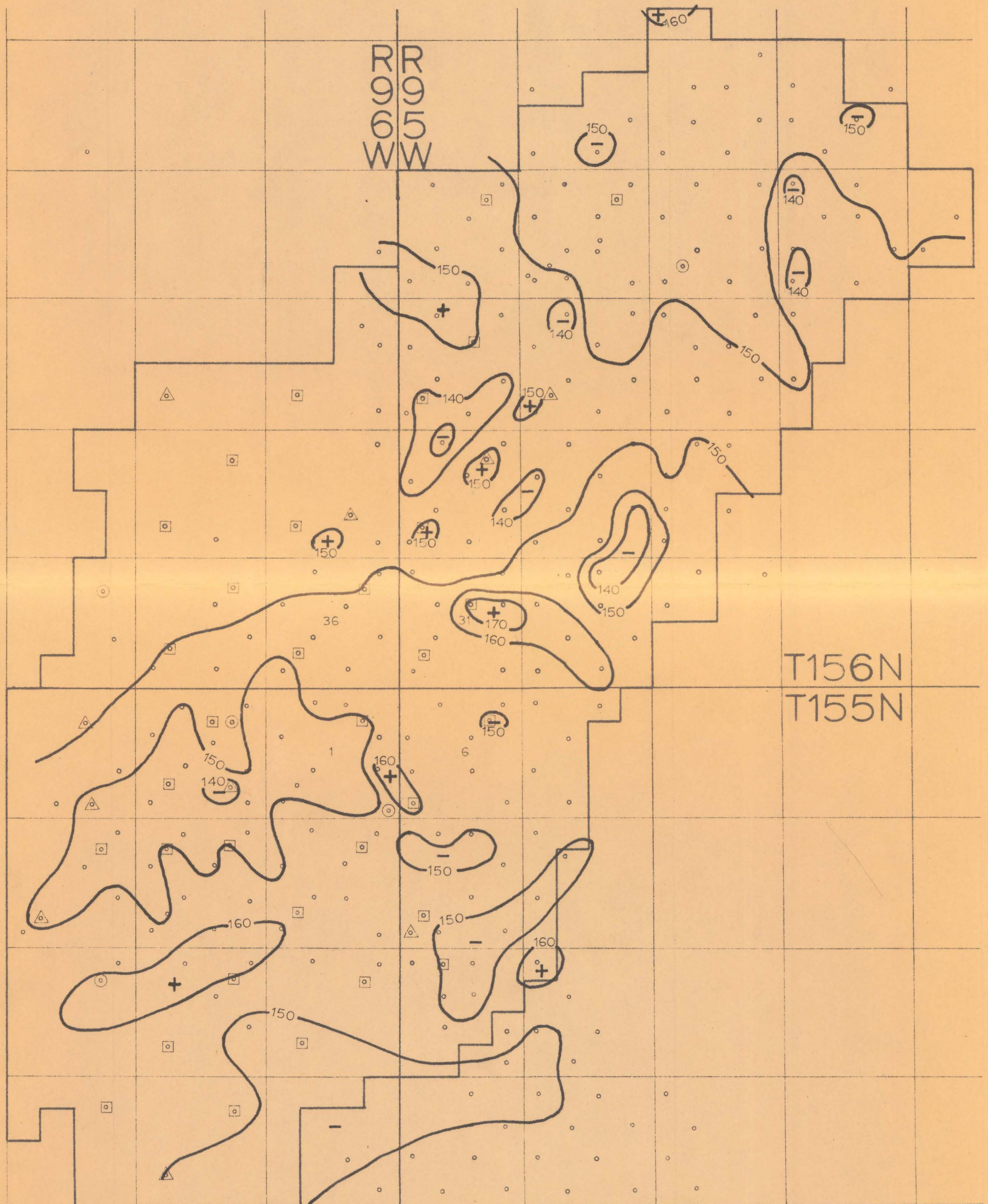
SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 25 FEET

- CONTROL WELLS:
- Madison penetration
 - △ Duperow penetration
 - Interlake penetration
 - ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 18

KIBBEY LIMESTONE ISOPACHOUS MAP BEAVER LODGE FIELD



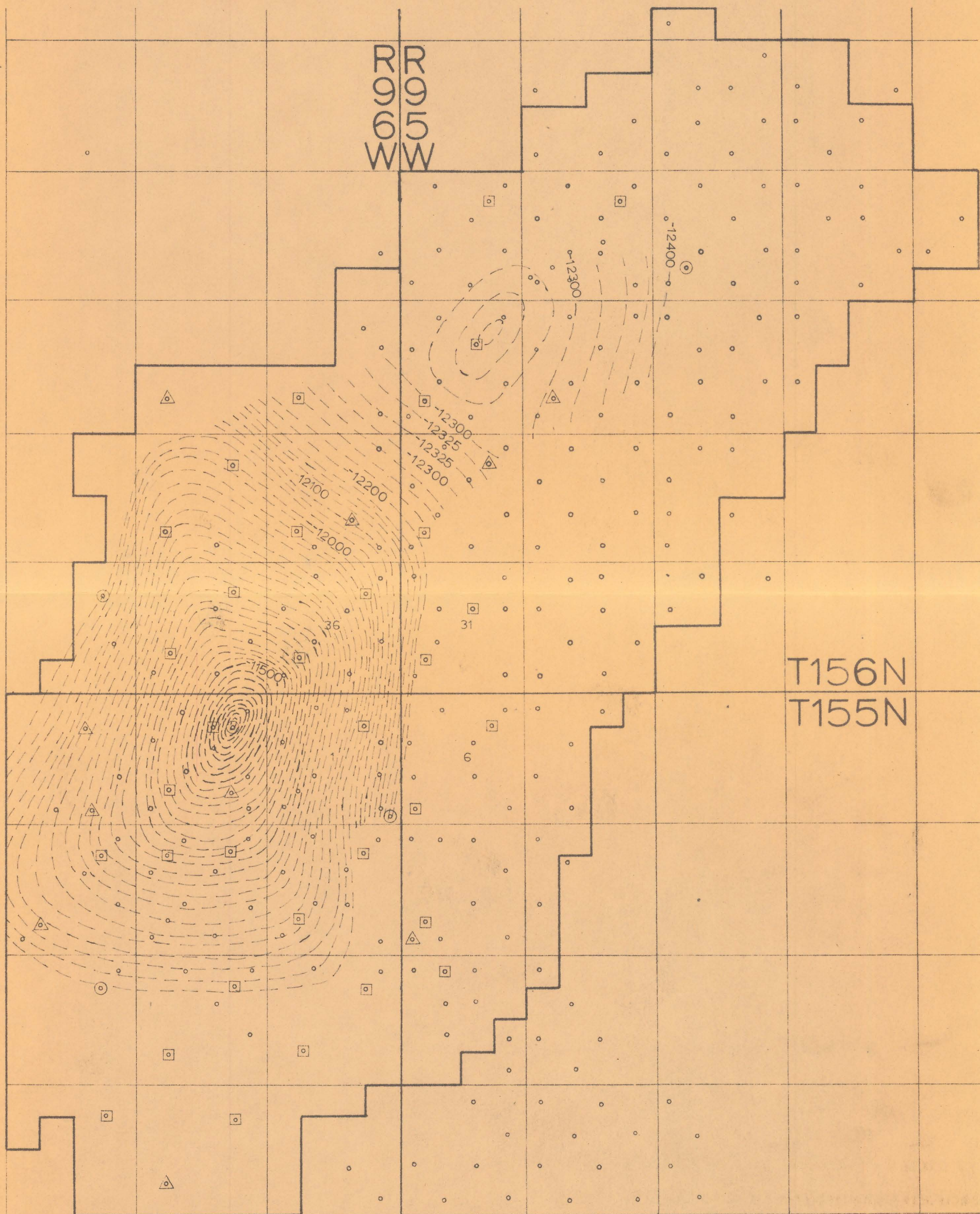
0 1/4 1/2 1 2
 SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 10 FEET

CONTROL WELLS:
 ○ Madison penetration
 △ Duperow penetration
 □ Interlake penetration
 ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 19

CONTOUR MAP TOP OF PRECAMBRIAN BEAVER LODGE FIELD



0 1/4 1/2 1 2
SCALE IN MILES

CONTROL WELLS:

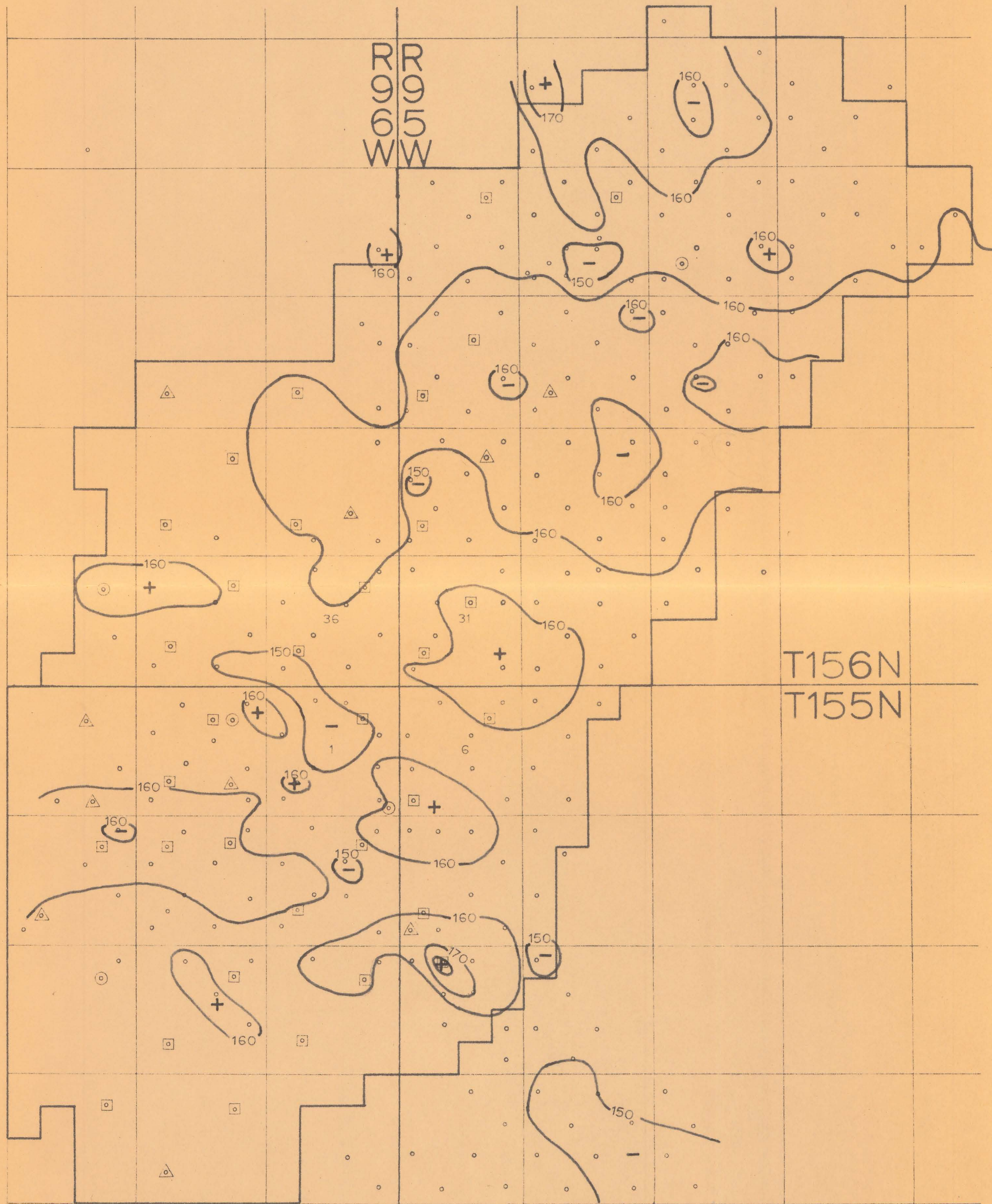
- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

CONTOUR INTERVAL - 25 FEET

PLATE 2

KIBBEY SANDSTONE ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2
SCALE IN MILES

CONTOUR INTERVAL - 10 FEET

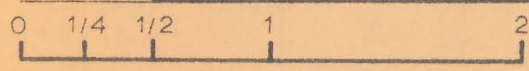
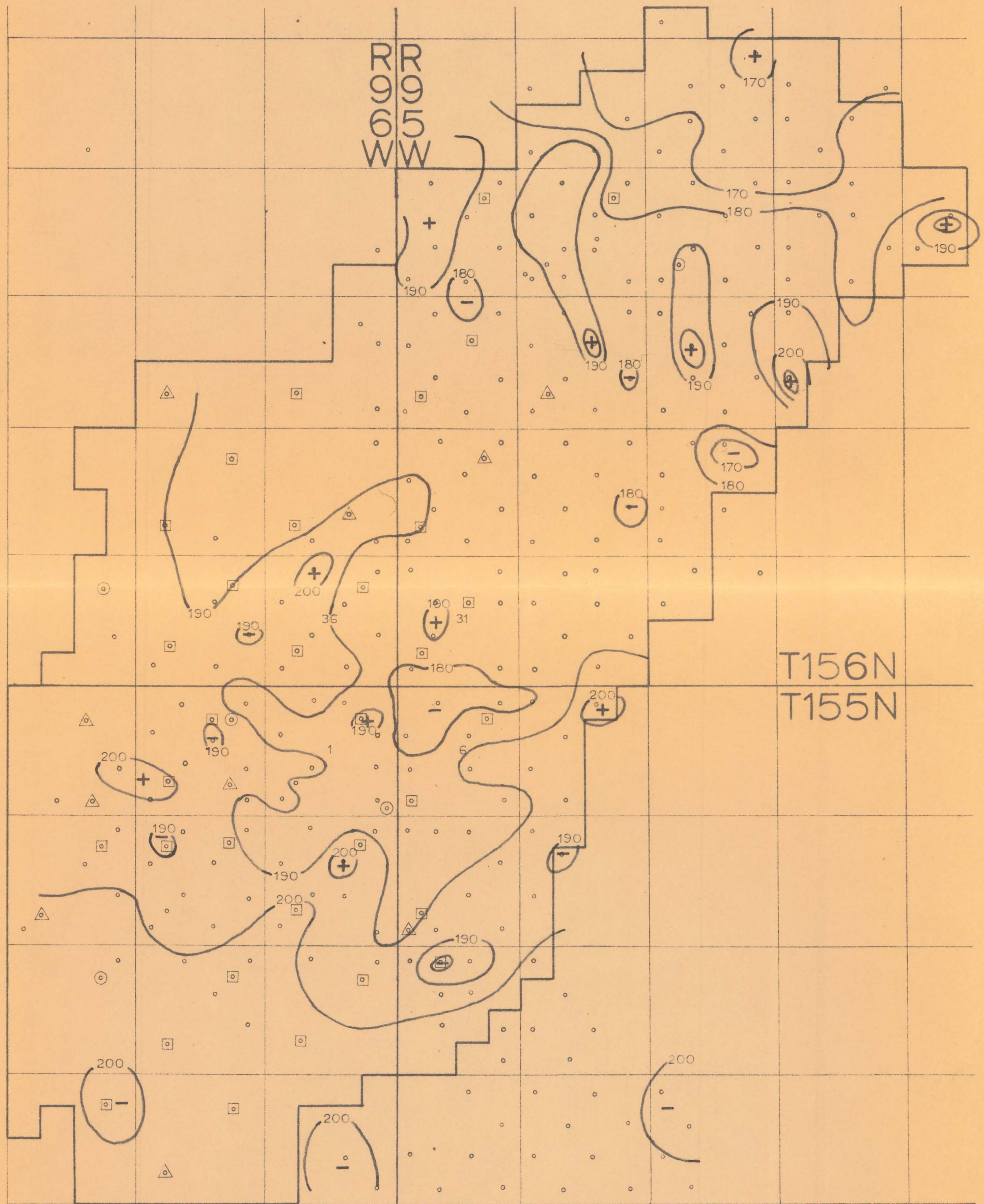
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interiorlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 20

OTTER FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 10 FEET

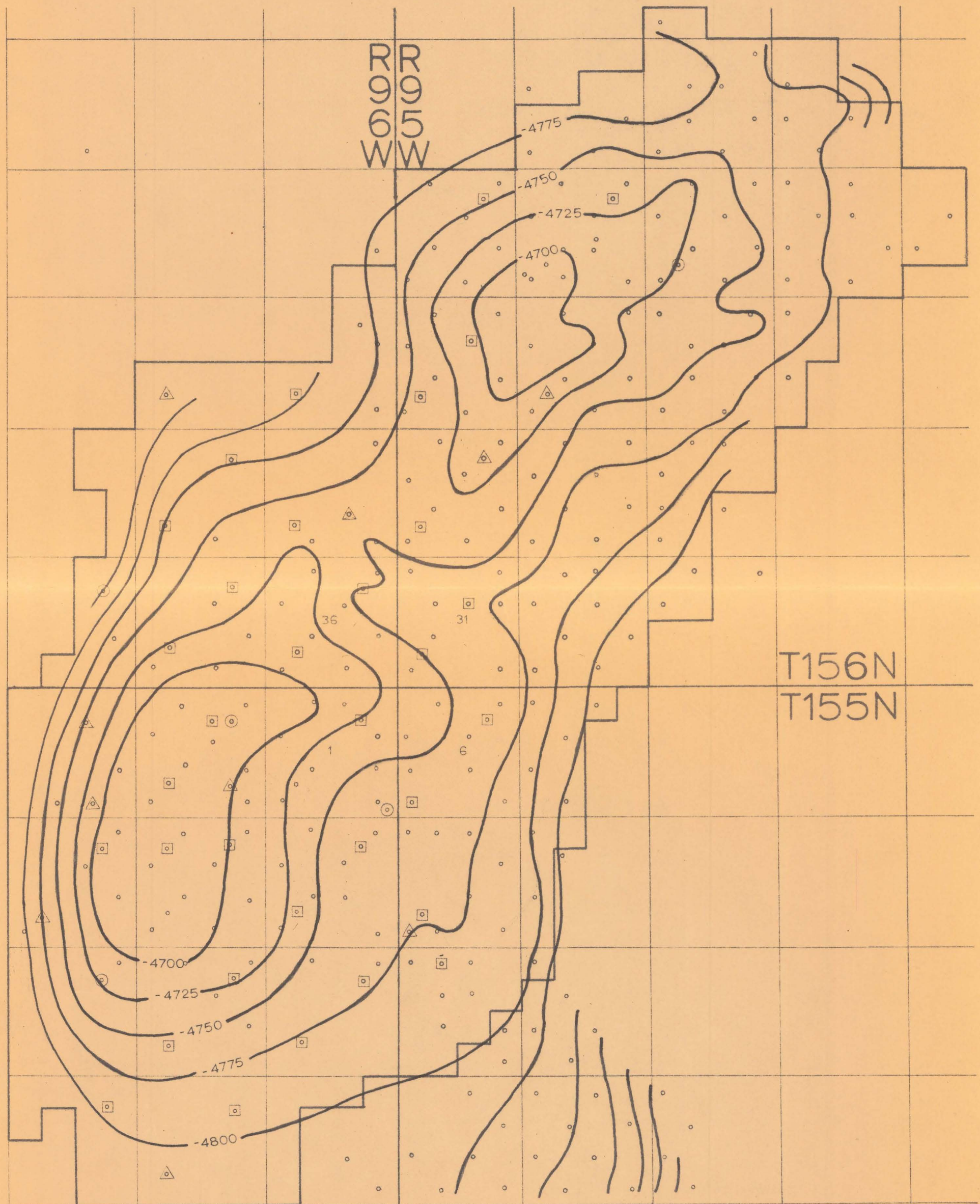
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 21

CONTOUR MAP TOP OF OTTER BEAVER LODGE FIELD



0 1/4 1/2 1 2
SCALE IN MILES

CONTOUR INTERVAL - 25 FEET

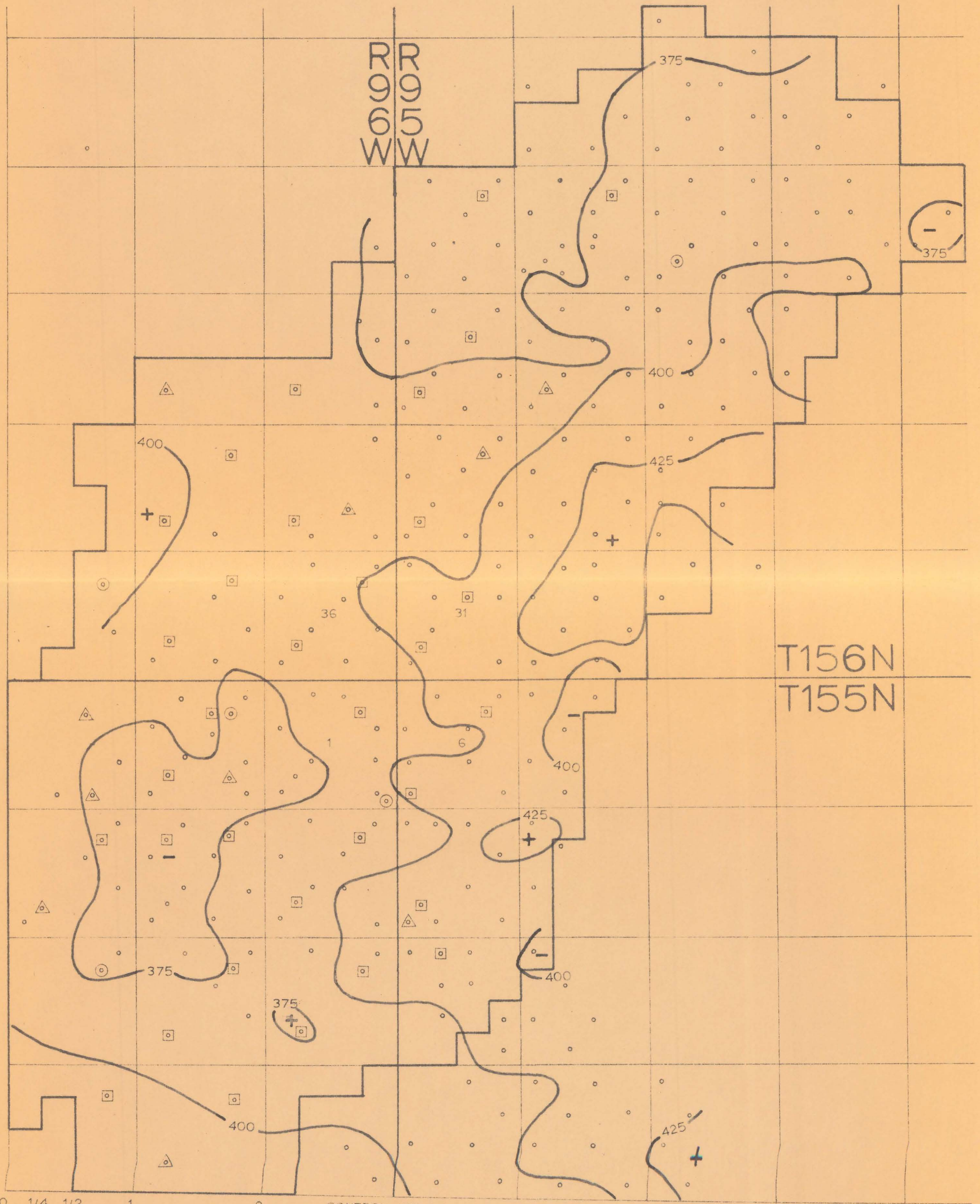
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 22

PENNSYLVANIAN SYSTEM ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2

SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 25 FEET

CONTROL WELLS:

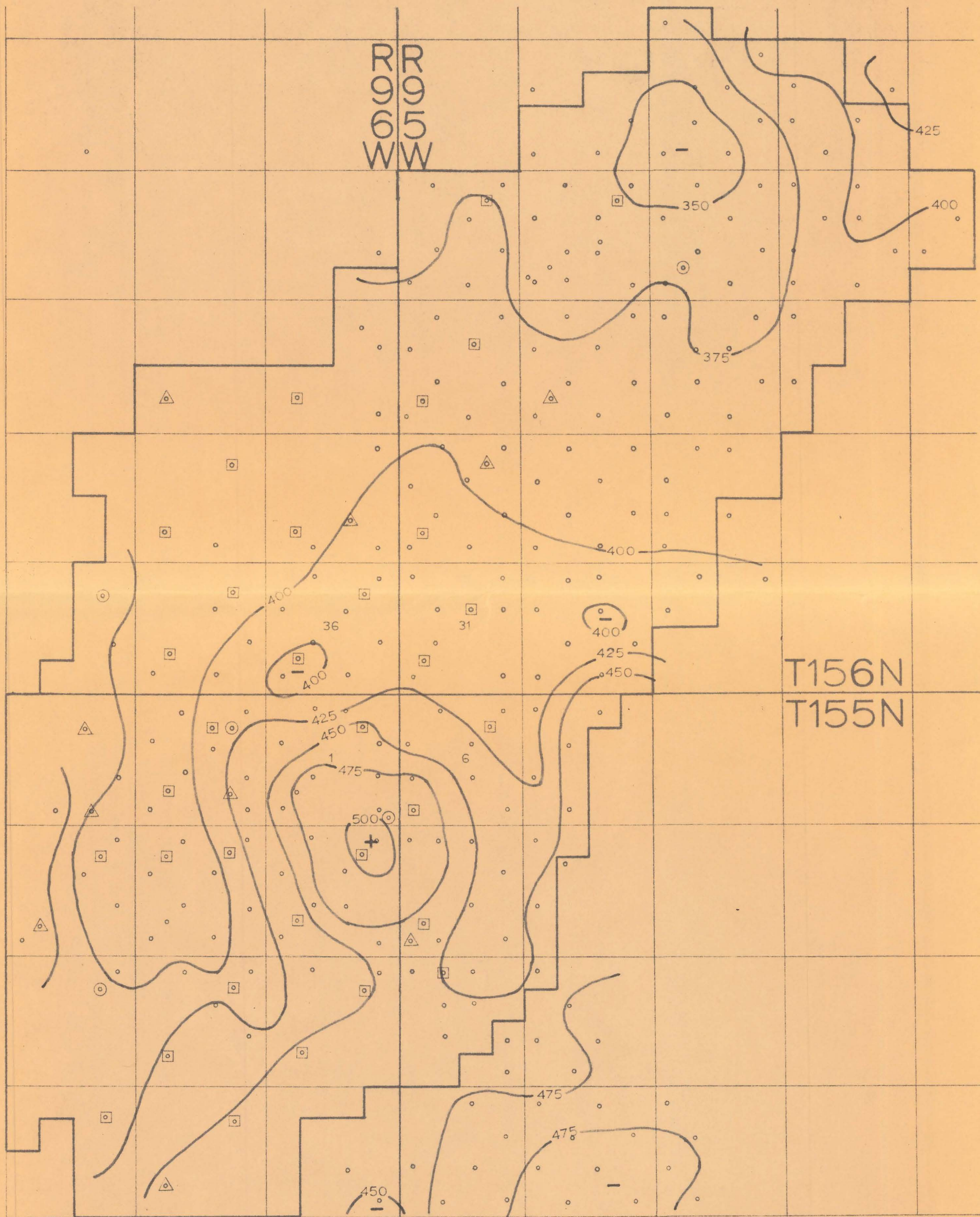
- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 23

PERMIAN SYSTEM ISOPACHOUS MAP

BEAVER LODGE FIELD



SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 25 FEET

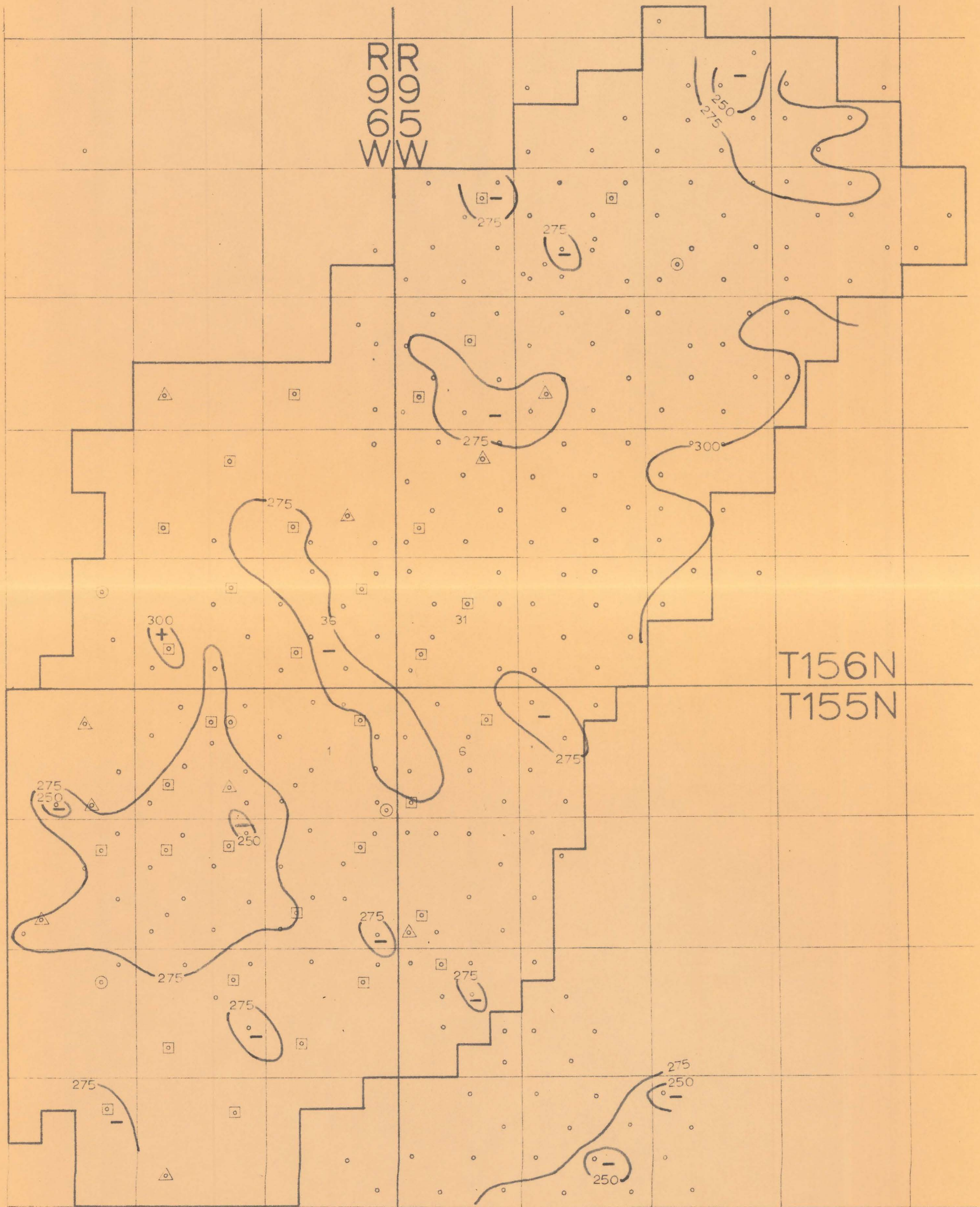
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 24

TRIASSIC SYSTEM ISOPACHOUS MAP BEAVER LODGE FIELD



SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 25 FEET

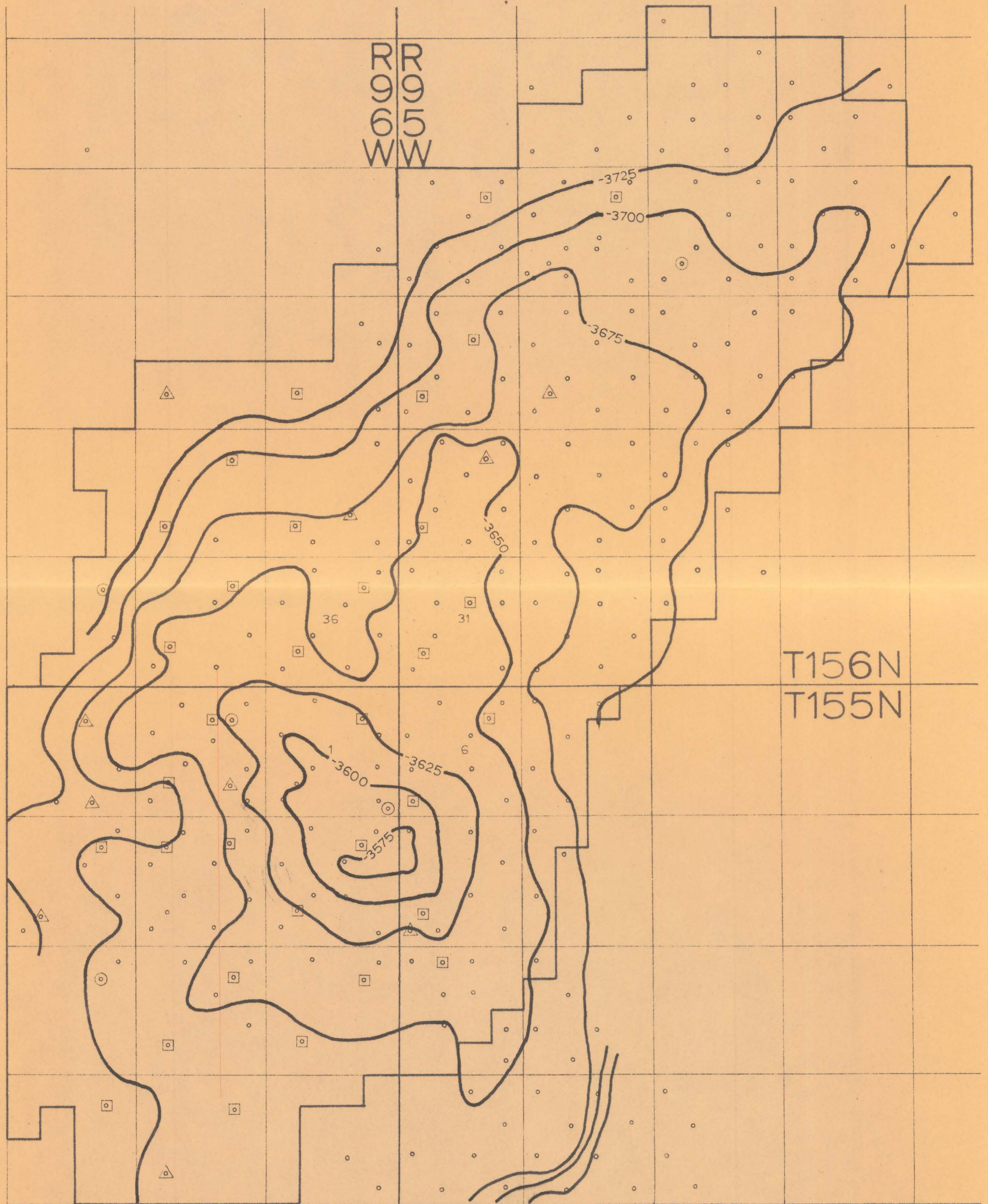
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 25

CONTOUR MAP TOP OF SPEARFISH BEAVER LODGE FIELD



0 1/4 1/2 1 2
SCALE IN MILES

CONTOUR INTERVAL- 25 FEET

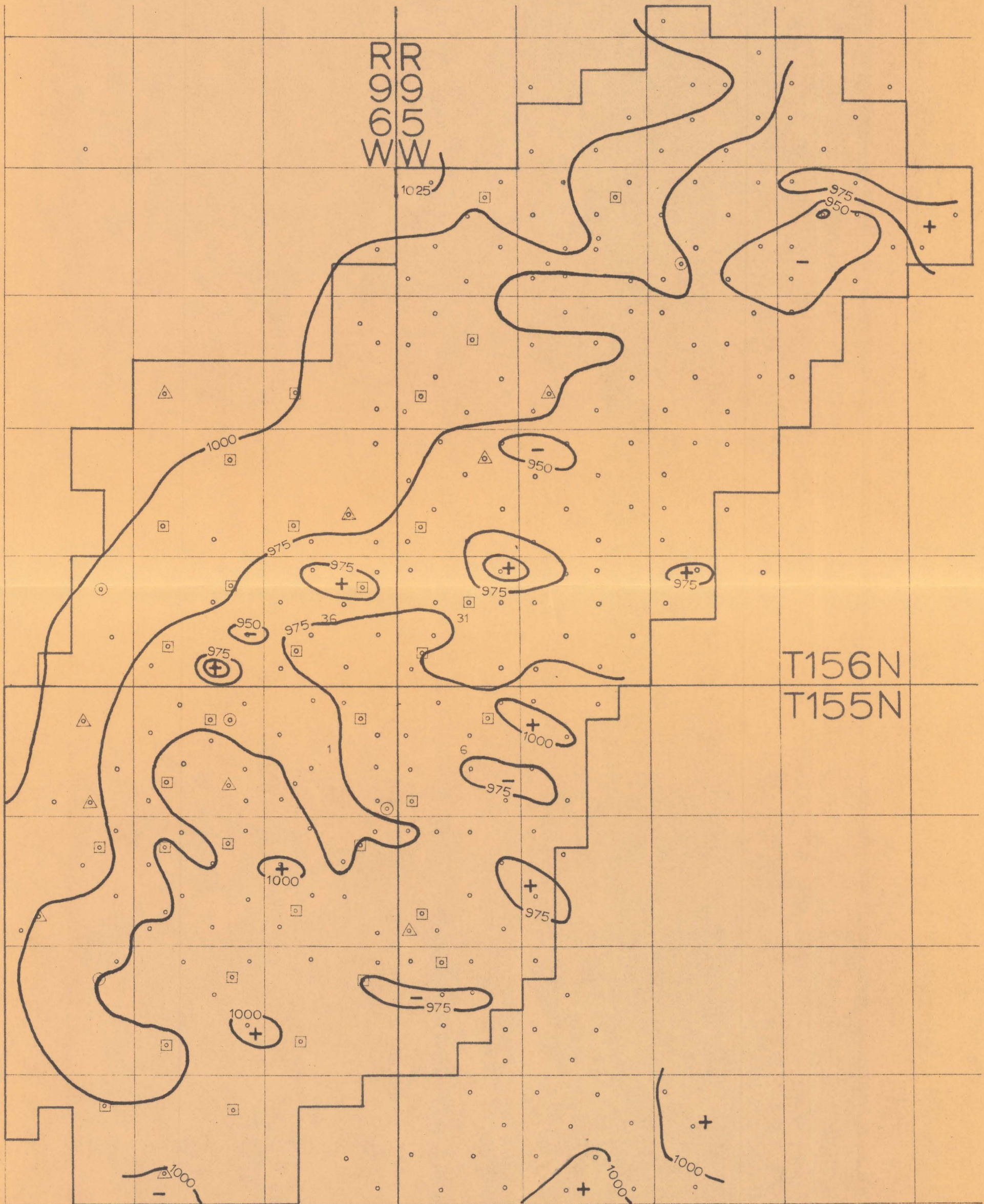
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 26

JURASSIC SYSTEM ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2

SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 25 FEET

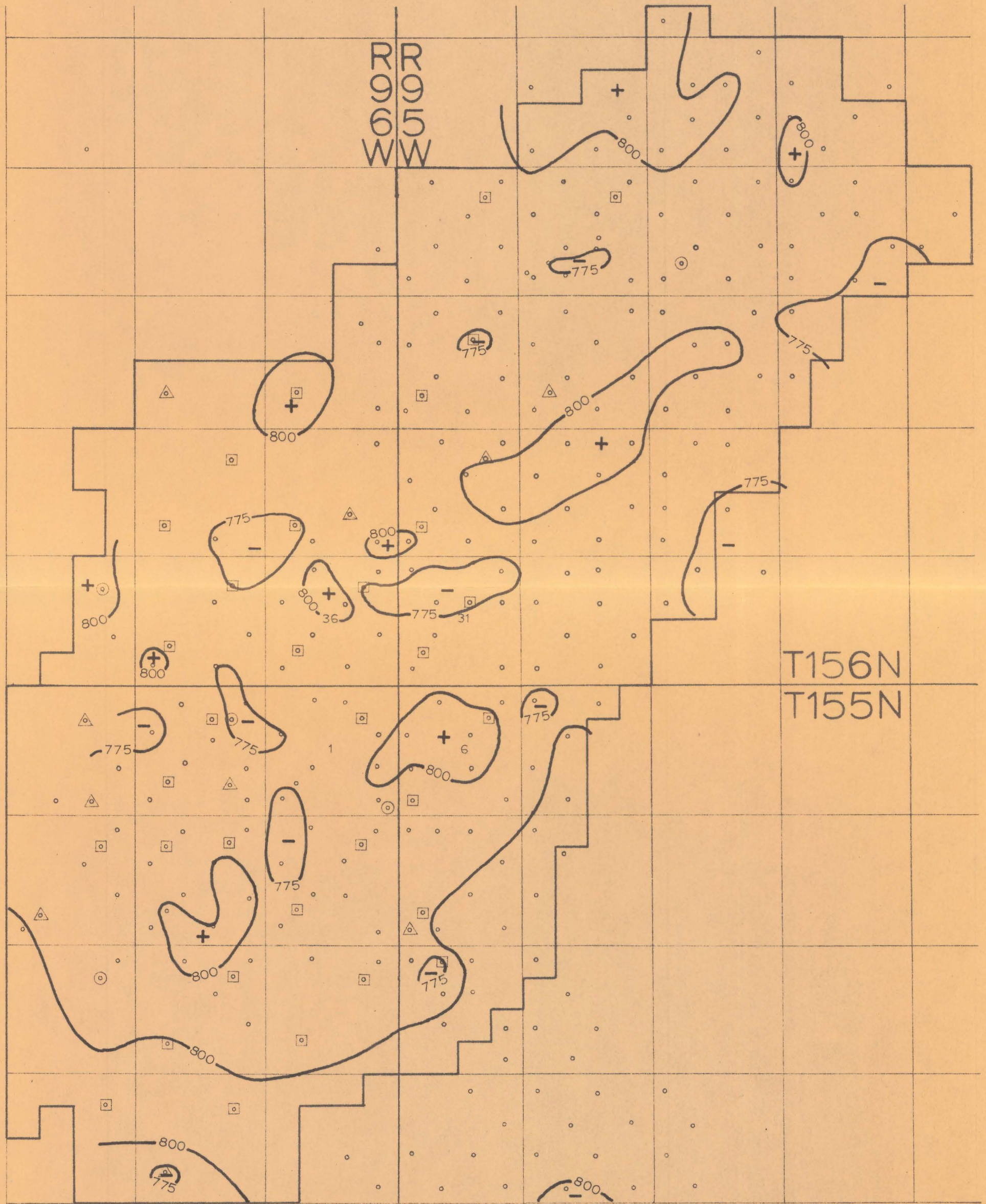
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 27

DAKOTA GROUP ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2

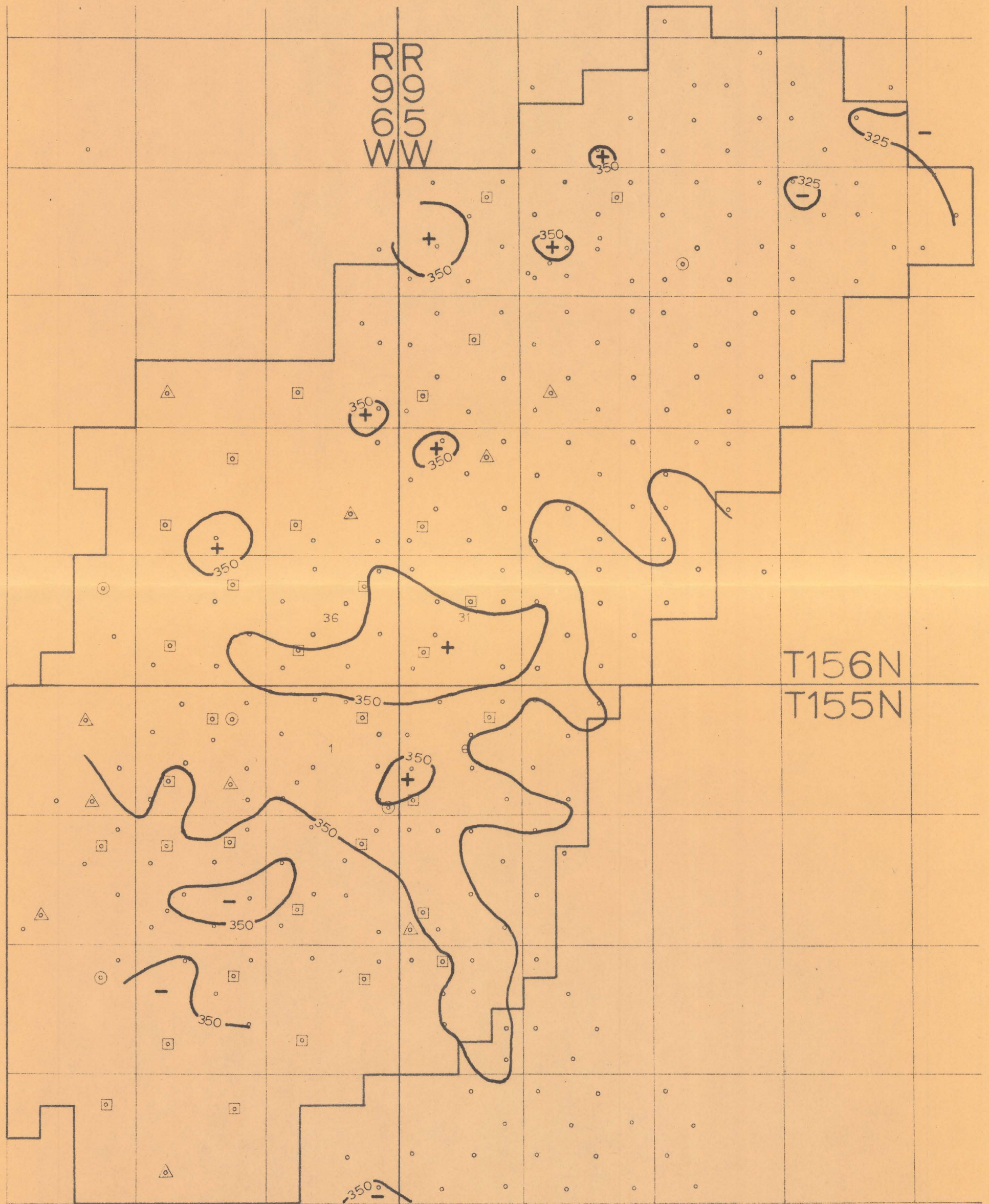
SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 25 FEET

CONTROL WELLS:
 • Madison penetration
 △ Duperow penetration
 □ Interlake penetration
 ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 28

GREENHORN-BELLE FOURCHE ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2

SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 25 FEET

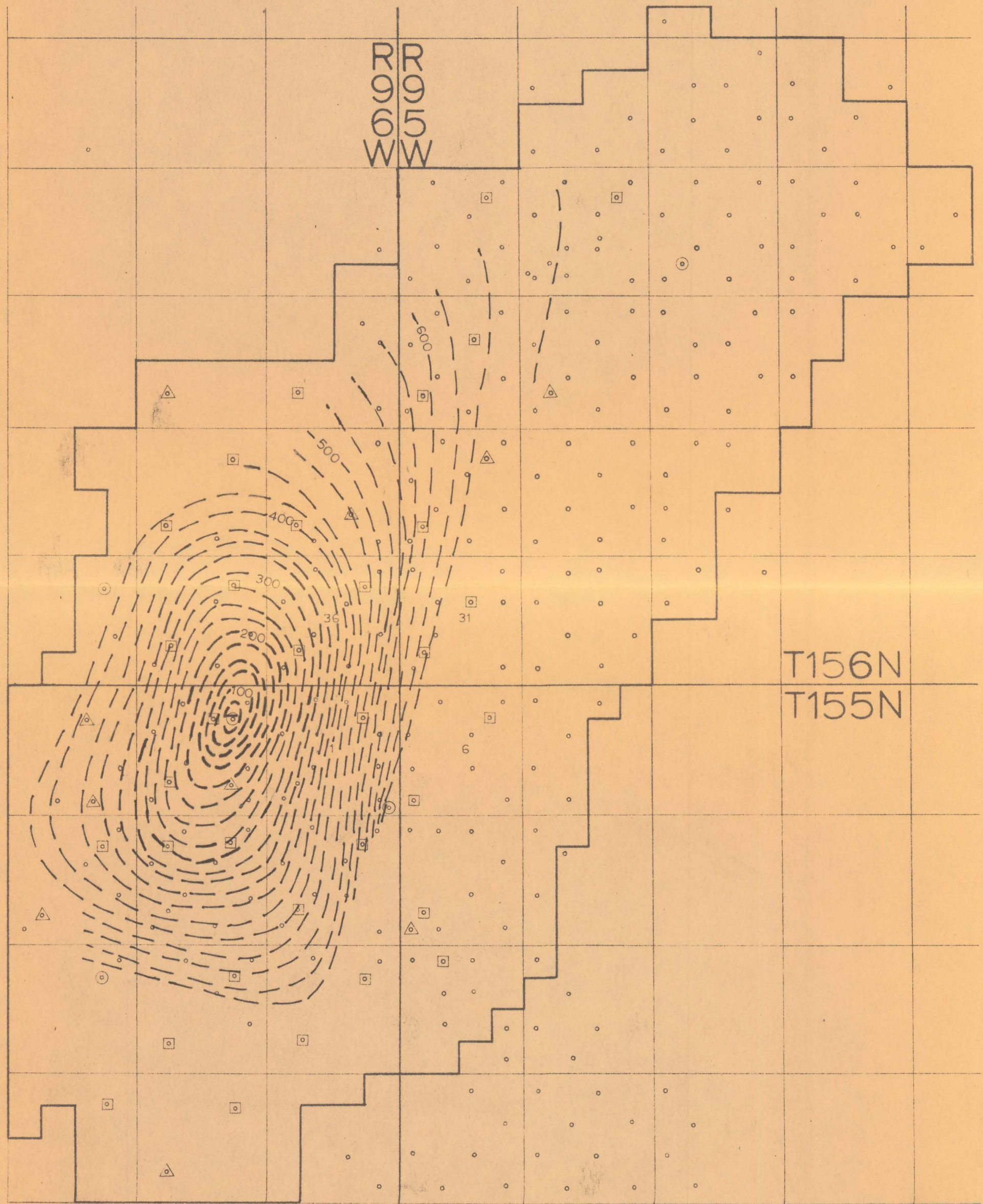
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 29

DEADWOOD FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2

SCALE IN MILES

+ = THICK - = THIN

CONTOUR INTERVAL - 25 FEET

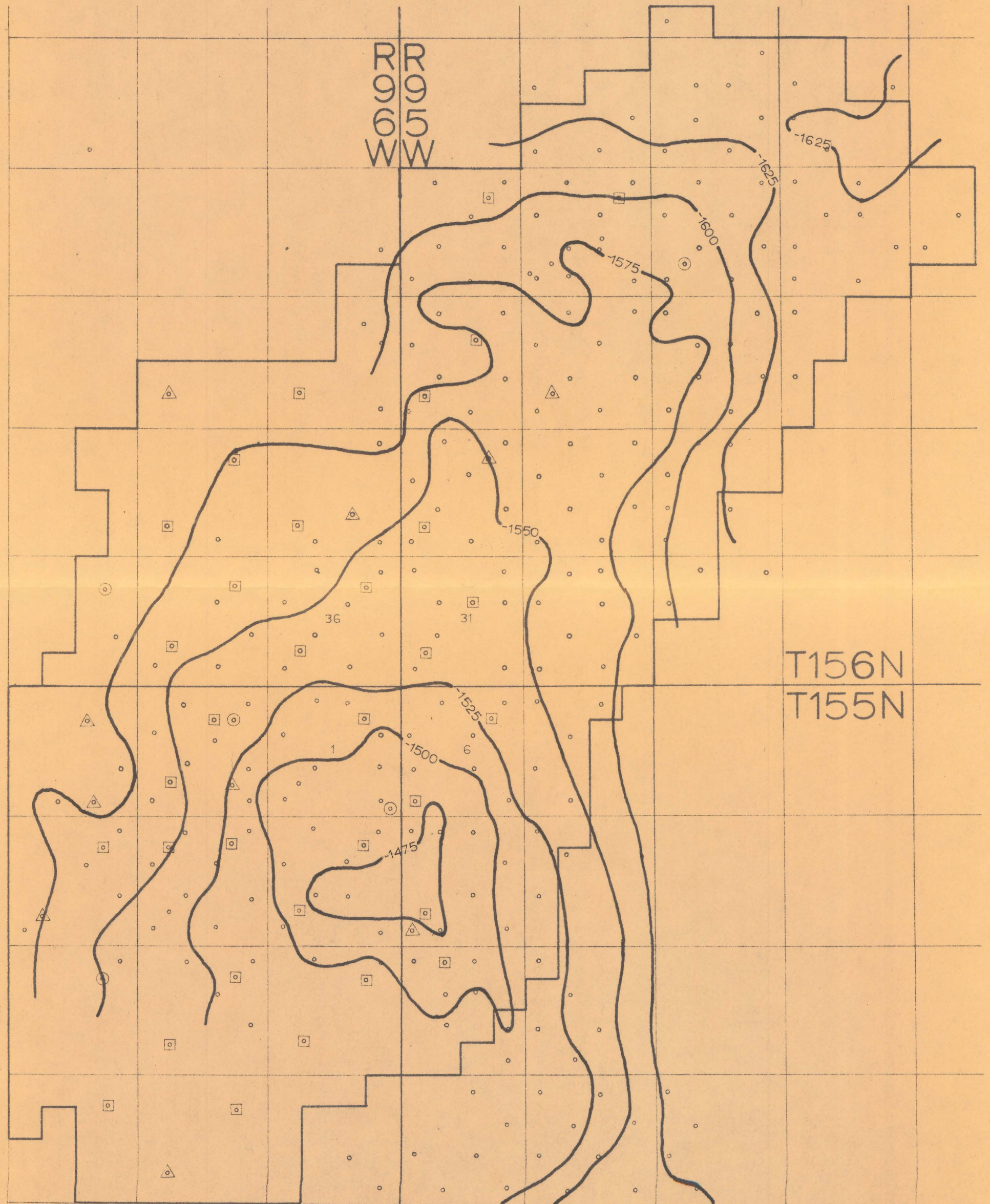
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 3

CONTOUR MAP TOP OF GREENHORN BEAVER LODGE FIELD



0 1/4 1/2 1 2
SCALE IN MILES

CONTROL WELLS:

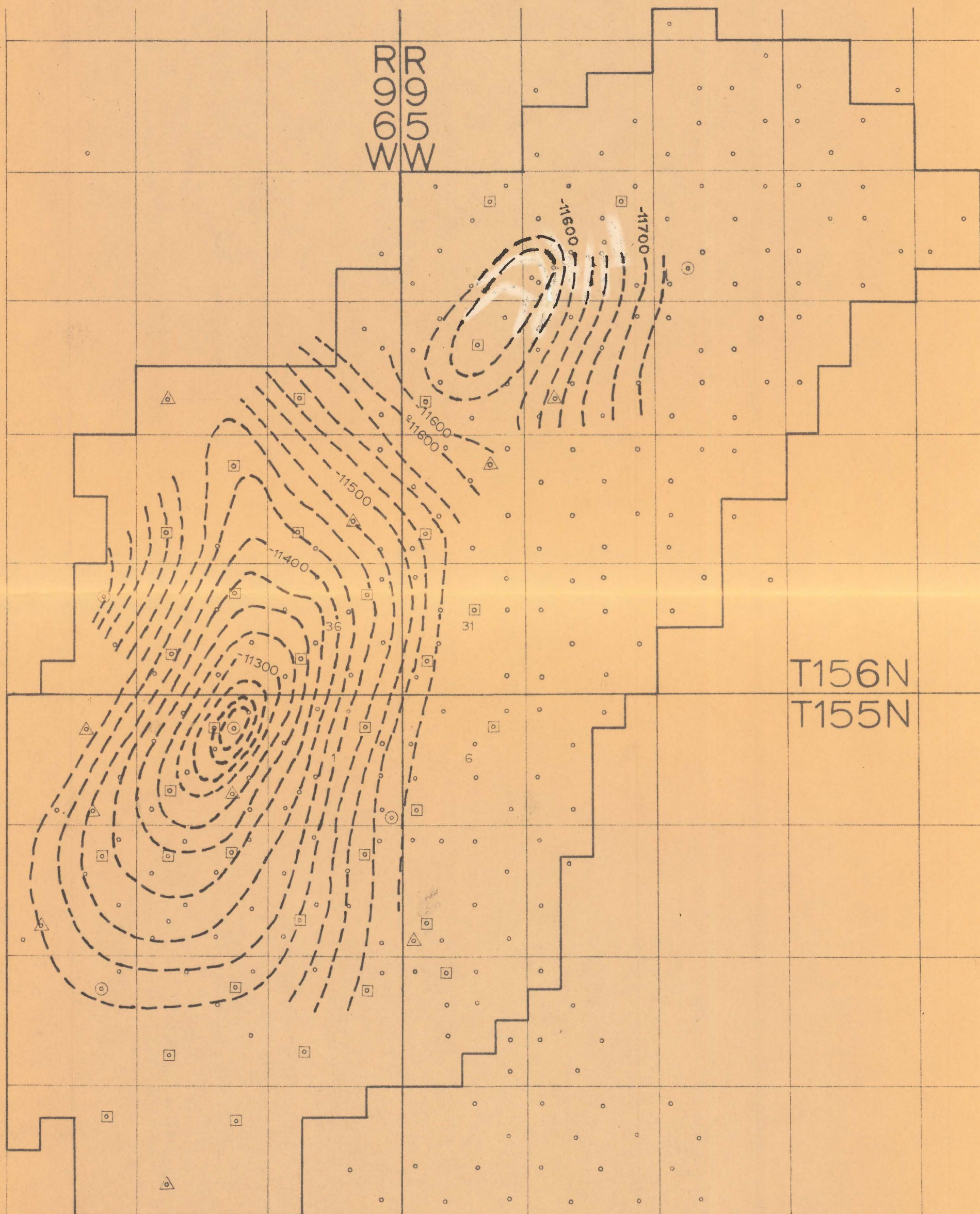
- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

CONTOUR INTERVAL - 25 FEET

PLATE 30

CONTOUR MAP TOP OF DEADWOOD BEAVER LODGE FIELD



0 1/4 1/2 1 2
SCALE IN MILES

CONTOUR INTERVAL - 25 FEET

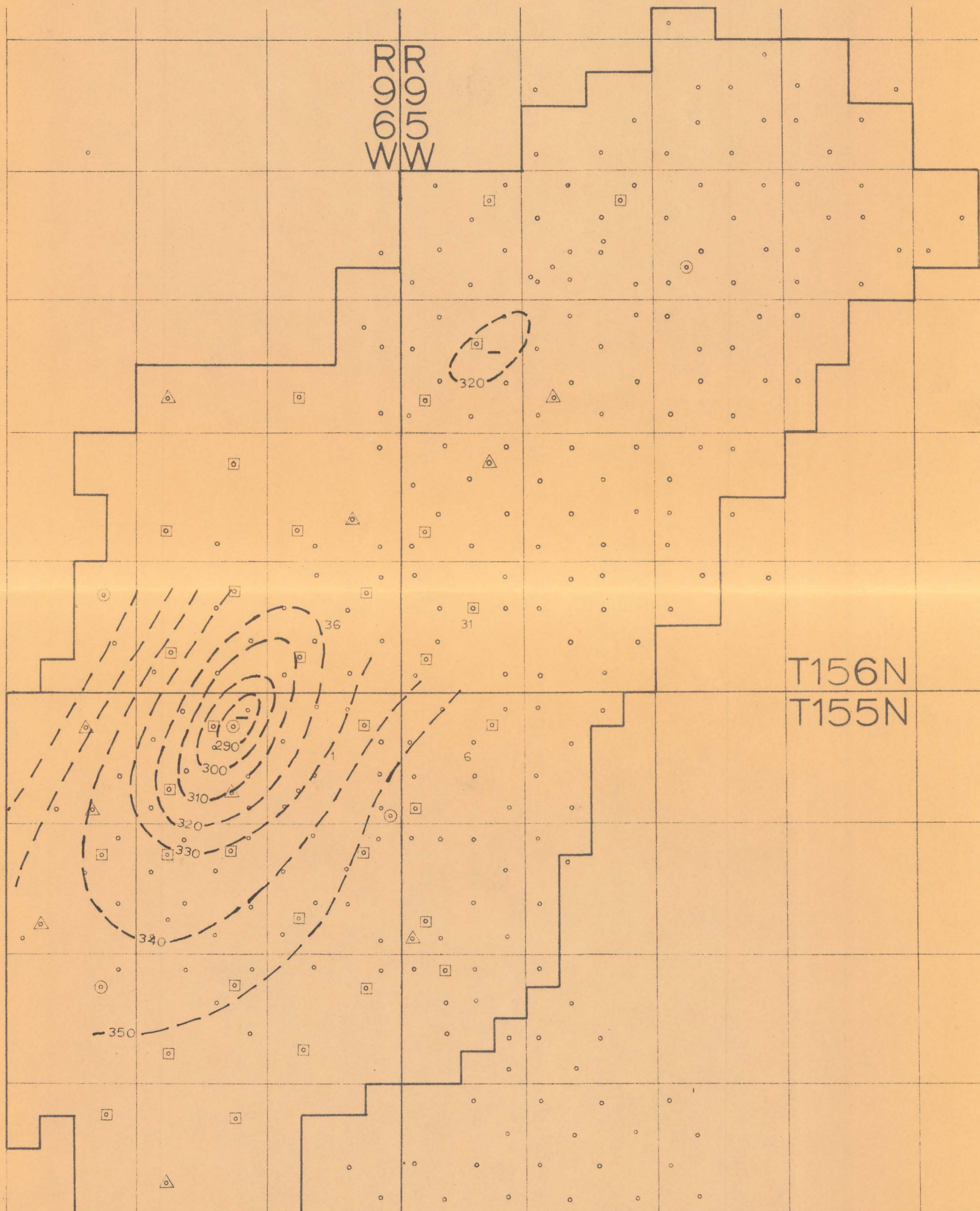
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 4

WINNIPEG GROUP ISOPACHOUS MAP BEAVER LODGE FIELD



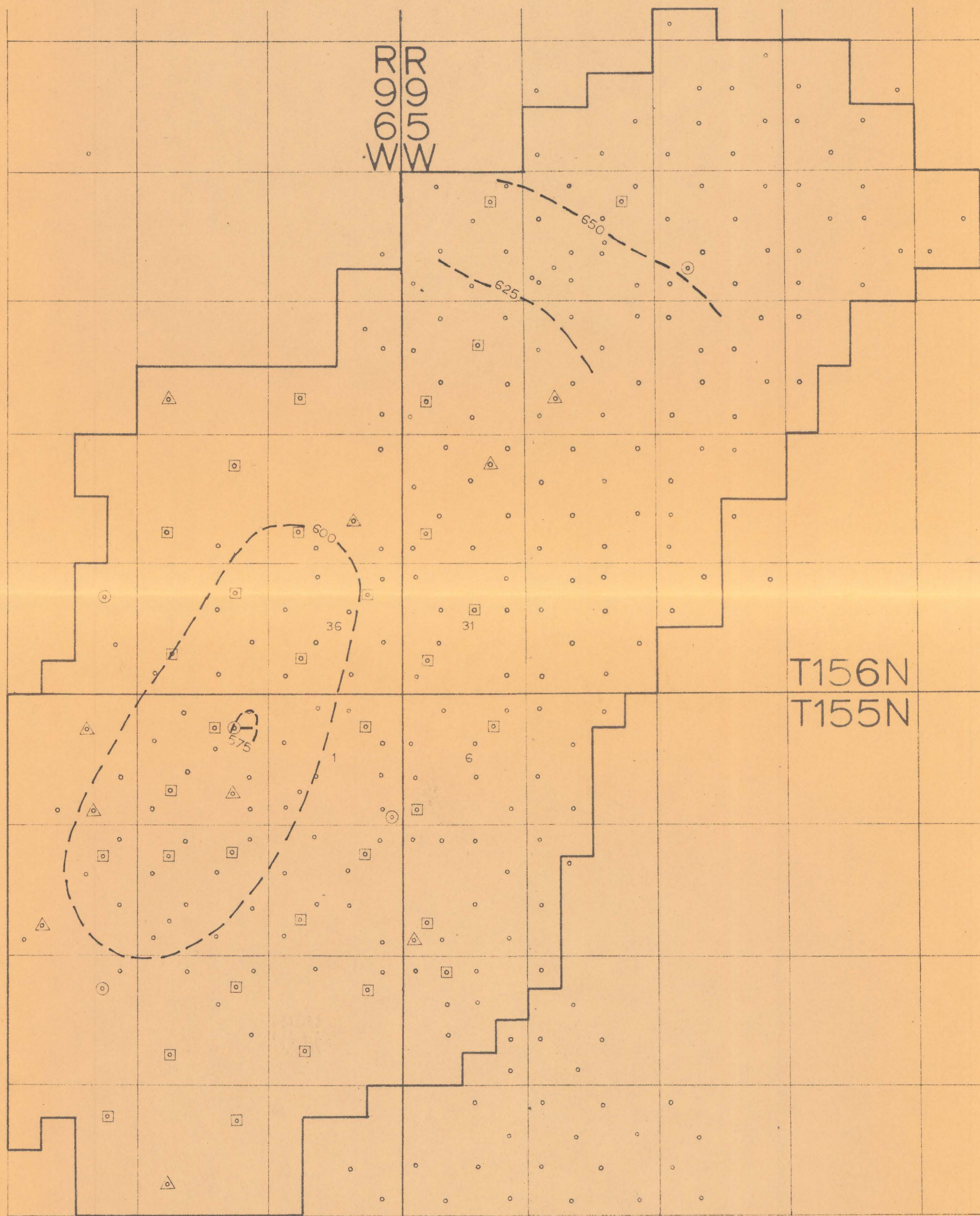
SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 10 FEET

- CONTROL WELLS:
- Madison penetration
 - △ Duperow penetration
 - Interlake penetration
 - ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 5

RED RIVER FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 25 FEET

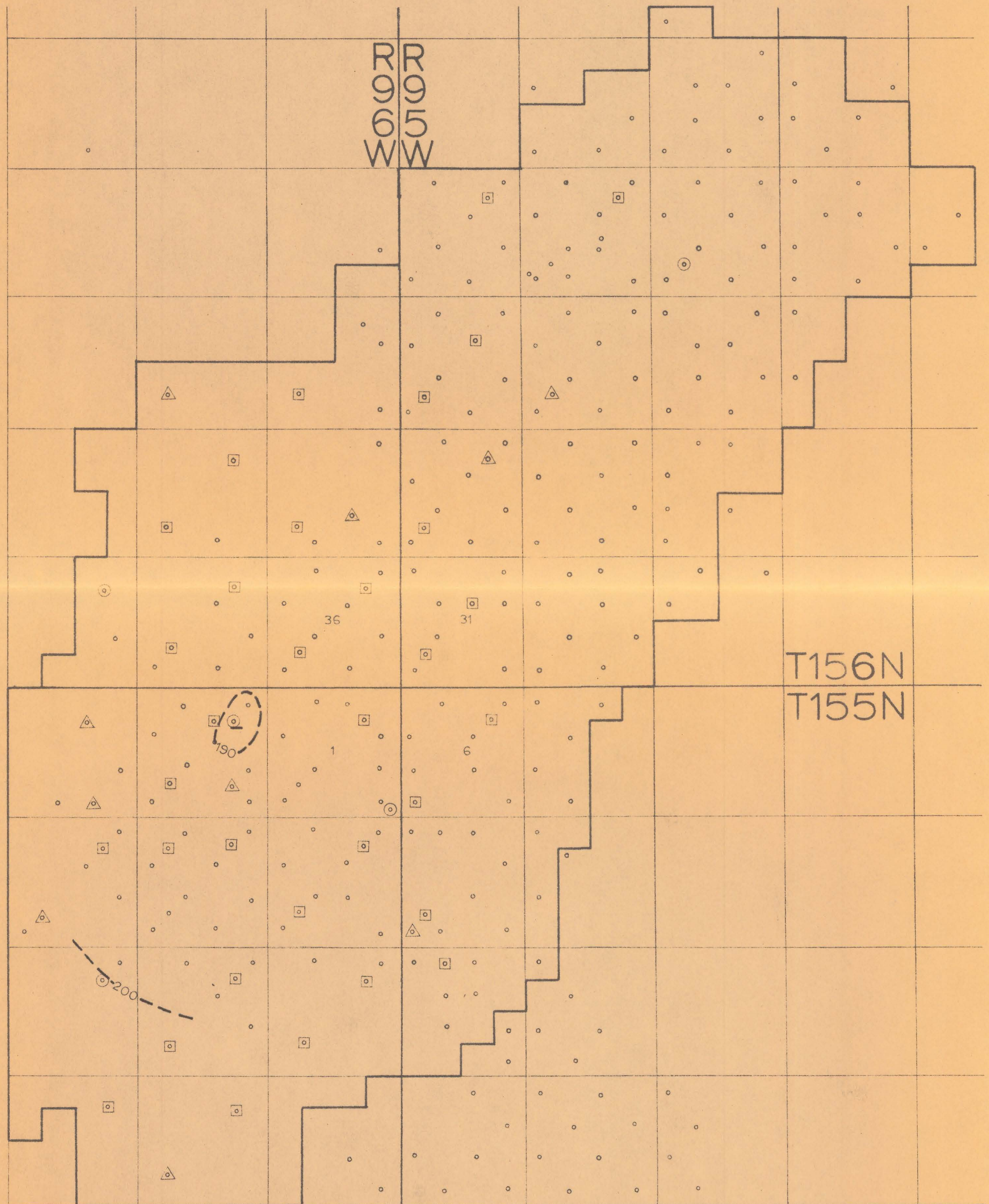
CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 6

STONY MOUNTAIN FORMATION ISOPACHOUS MAP BEAVER LODGE FIELD



0 1/4 1/2 1 2

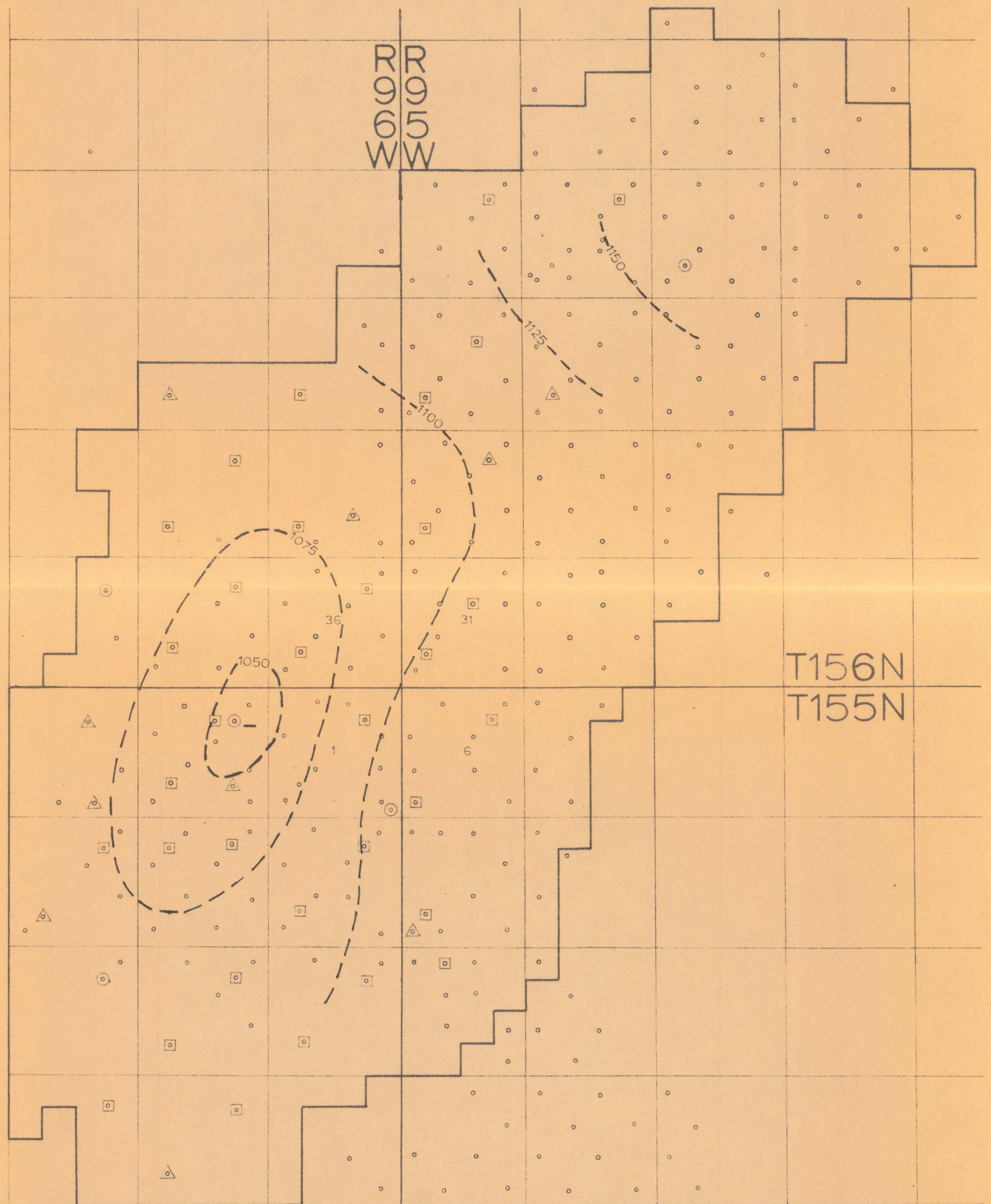
SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 10 FEET

CONTROL WELLS:
 ○ Madison penetration
 △ Duperow penetration
 □ Interlake penetration
 ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 7

INTERLAKE-STONEWALL ISOPACHOUS MAP BEAVER LODGE FIELD



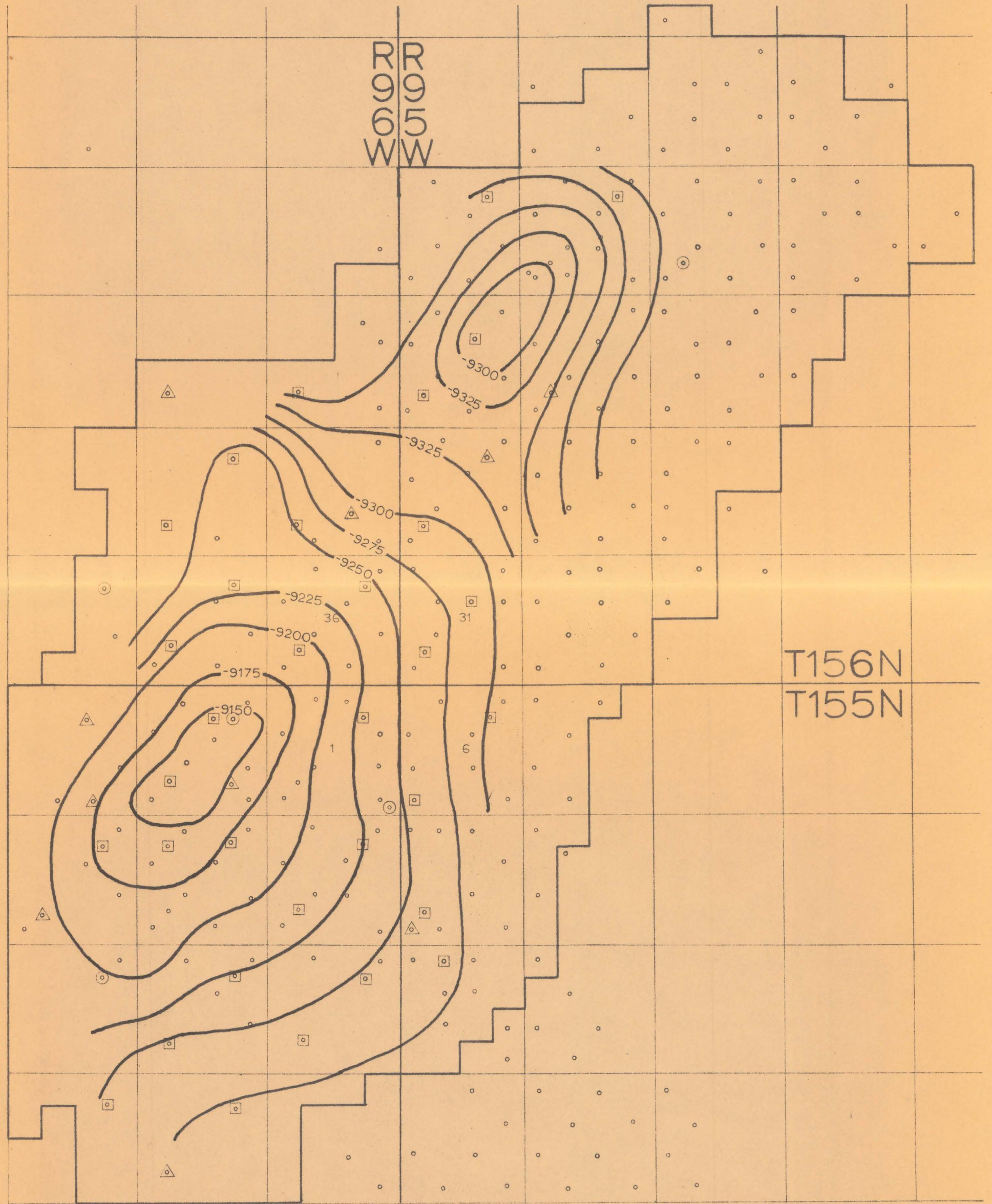
SCALE IN MILES
 + = THICK - = THIN
 CONTOUR INTERVAL - 25 FEET

- CONTROL WELLS:
- Madison penetration
 - △ Duperow penetration
 - Interlake penetration
 - ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 8

CONTOUR MAP TOP OF INTERLAKE BEAVER LODGE FIELD



0 1/4 1/2 1 2
SCALE IN MILES

CONTOUR INTERVAL - 25 FEET

CONTROL WELLS:

- Madison penetration
- △ Duperow penetration
- Interlake penetration
- ⊙ Precambrian penetration

WILLIAMS COUNTY, NORTH DAKOTA

PLATE 9