DOLOMITIZATION AND STRUCTURAL RELATIONS OF THE DEEP RIVER, NORTH ADAMS AND PINCONNING OIL FIELDS, MICHIGAN

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DOLOMITIZATION AND STRUCTURAL RELATIONS OF THE DEEP RIVER, NORTH ADAMS AND PINCONNING OIL FIELDS, MICHIGAN

by

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A THESIS

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ABSTRACT

The Deep River, North Adams and Pinconning oil fields are narrow and linear, producing from the Rogers City-Dundee interval. The Rogers City-Dundee interval, although normally a marine limestone, has been altered to a porous dolomite in the producing area of these three fields. The Deep River field trends in a northwest-southeast direction and parallels the major anticlinal structures of the area. The North Adams and Pinconning fields trend nearly perpendicular to the Deep River field in a northeast-southwest direction, and cut directly across the general anticlinal trends of the area.

Stress has produced intersecting fractures or cracks, which have formed large blocks in the Deep River and North Adams fields. These blocks have settled or have been raised slightly producing irregular and complex structure along the extent of the field. The stress in the Pinconning field has been of sufficient strength to form a major fault which extends the entire length of the productive area.

The fracturing, cracking and faulting in the three fields have provided the passageways by which the magnesium bearing waters have ascended into the Rogers City-Dundee interval forming the dolomite found in the productive areas.

In the Deep River, North Adams and Pinconning fields structural position is not related to dolomitization. The dolomitization is confined to the zone of fracturing and faulting and the porosity accompanies dolomitization, allowing the oil to accumulate.

TABLE OF CONTENTS

PAGE

INTRODUCTION 1

Scope 1

Location of the Area of Study 1

History, Development and Production in the Deep River, North Adams and Pinconning Oil Fields 3

Laboratory Procedure 5

STRATIGRAPHY 7

STRUCTURE 12

Regional Structure of the Rogers City-Dundee Interval 12

Structure of the Deep River Field 13

Structure of the North Adams Field 20

Structure of the Pinconning Field 26

RELATIONSHIP OF SECONDARY DOLOMITIZATION TO STRUCTURE.. 30

RELATIONSHIP OF PRODUCING WELLS TO SECONDARY DOLOMITIAZTION..... 31

SUMMARY AND CONCLUSIONS 39

APPENDIX A 42

APPENDIX B 45

BIBLIOGRAPHY 56

LIST OF FIGURES

FIGURE		PAGE
1	Generalized and informal designation of the post-Silurian rock units found in the Deep River, North Adams and Pinconning oil fields	8
2	Generalized columnar section of the Devonian system in Michigan	10
3-7	Cross-sections of the Deep River oil field	14-18
8-11	Cross-sections of the North Adams oil field	21-24
12-13	Cross-section of the Pinconning oil field	27-28

LIST OF MAPS

MAP		PAGE
1	Location map	2
2	Outline of the Extent of Dolomitization in the Deep River Oil Fields	33
3	Outline of the Extent of the Dolomitization in the North Adams Oil Fields	35
4	Outline of the Extent of the Dolomitization in the Pinconning Oil Fields	37
5	Structure Contour - Deep River Oil Field	(Back Pocket)
6	Structure Contour - North Adams Oil Field	(Back Pocket)
7	Structure Contour - Pinconning Oil Field	(Back Pocket)

INTRODUCTION

Scope:

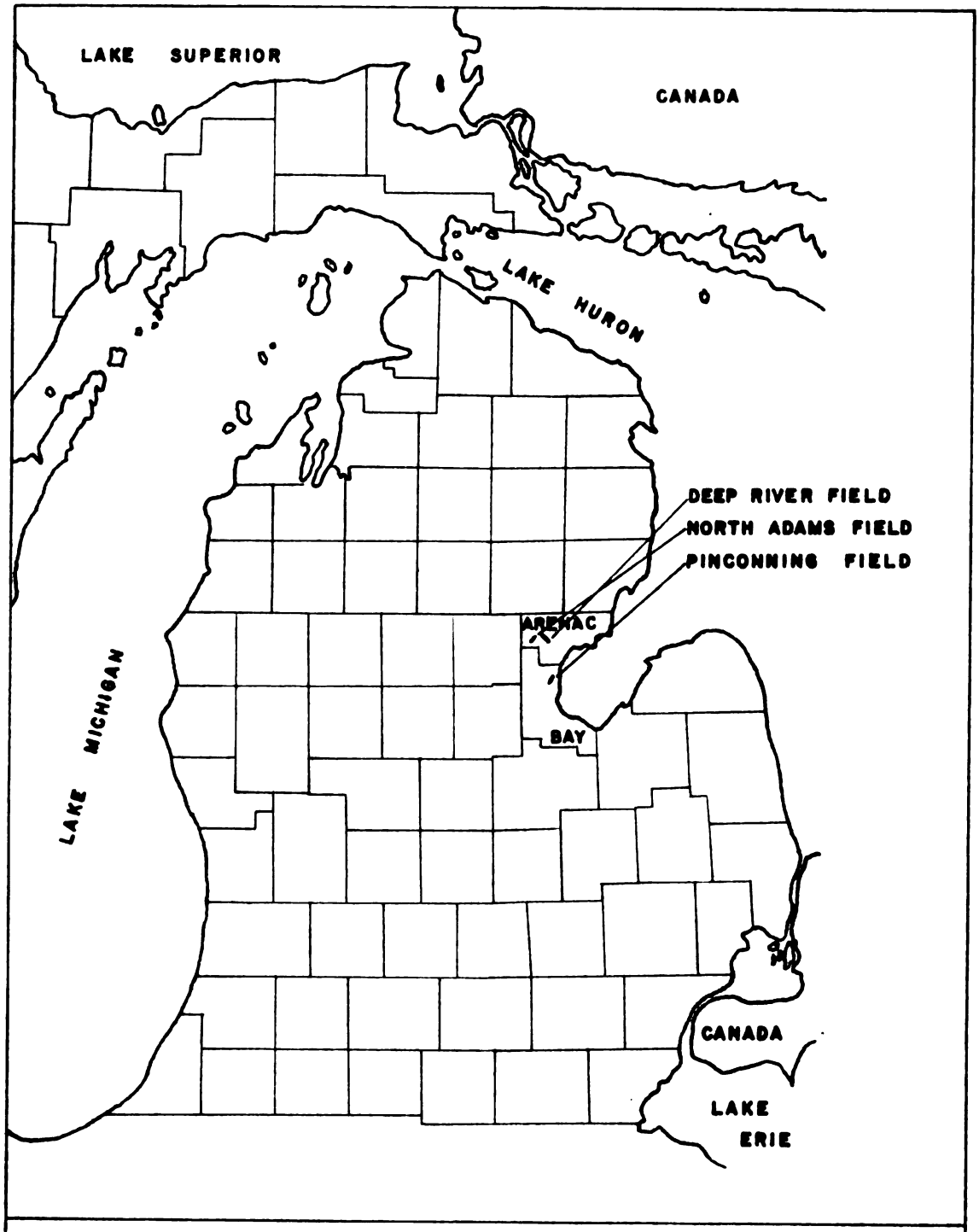
This paper is a study of the relationships between production, structure and dolomitization of the Deep River, North Adams and Pinconning oil fields in Michigan. All fields are narrow and linear, but have differing trends; the North Adams and Pinconning fields trend nearly perpendicular to the Deep River field. Some work has been published on the Deep River field but none on the other two fields The Deep River field has been compared to the other two in order to establish any patterns or similarities that may exist.

Study of the cuttings have determined relationships existing between production, structure and dolomitization in the three fields. Structural contour maps have been constructed for each of the fields to establish the relationships between possible faulting or fracturing in the three fields.

Location of the Area of Study:

The Deep River oil field is located in the northern half of Deep River township in Arenac County, Michigan. The field extends for 5½ miles in a northwest direction and is about ½ mile at its widest point The field is about 1½ miles northeast of the town of Sterling and approximately 30 miles north of Bay City.

The North Adams field is located in the western half of Adams



MAP 1: LOCATION OF THE DEEP RIVER, NORTH ADAMS, AND PINCONNING OIL FIELDS IN MICHIGAN.

Township, Arenac County, immediately west of Deep River Township. The field extends for three miles in a northeast direction and is about ¼ mile in width. Production has been found in sections 11, 14, 15, 22, 23 and 27 of Adams Township (Map 6).

The Pinconning oil field is located in the southeast quarter of Pinconning Township and in the northeast quarter of Frazer Township, Bay County. The field extends for two miles in a northeast direction and is only one well in width. Production is received from sections 25, 35 and 36 of Pinconning Township and from section 2 of Frazer Township. The field is located about one mile southeast of the town of Pinconning and about 14 miles south of the Deep River and North Adams oil fields.

The relative positions of the Deep River, North Adams and Pinconning oil fields can be seen on Map 1, which shows their location in the southern peninsula of Michigan.

History, Development and Production in the Deep River, North Adams and Pinconning Oil Fields:

The discovery well in the Deep River field was the Werblo Comm. #1, drilled by the Basin Oil Co. and Don Rayburn in the S½, NW¼, NW¼, of section 8, T19N, R4E, Arenac County. The well was completed on December 30, 1943, at a total depth of -2846 feet, eight feet below the top of the Rogers City formation. The pay zone was from -2838 feet to -2840 feet and produced 235 barrels of oil before being

acidized on January 1, 1944. After acidization the well flowed 80 barrels of oil the first hour. By the end of 1946, one hundred producers had been completed with an initial production ranging up to 7,000 barrels of oil. The total number of producers to the end of 1957 was 106 and the cumulative production up to that time was 24,642,215 barrels of oil. At the end of 1957, 65 wells were still producing and the production for the year was 544,984 barrels of oil. The number of drilled acres has been 1,060 with a recovery of 23,247 barrels per drilled acre.

In the North Adams field the discovery well was the O. Yenior #1, in the NE¼, SW¼, NE¼, of section 22, Adams Township, Arenac County. The well, which was drilled by Don Rayburn, was completed on July 18, 1940, at a depth of -2879 feet in the Rogers City formation. The pay zone was from -2878 feet to -2879 feet and initial production was 21 barrels per hour of 33 API gravity oil. After acidation the well produced 1985 barrels of oil during the first 19 hours. At the end of 1957, 23 of the 47 total productive wells were still producing. The total yield for the year was 53,302 barrels of oil, and the cumulative production to the end of 1957 was 8,797,655 barrels of oil. The number of drilled acres have been 470 acres with a recovery per drilled acre of 18,718 barrels of oil.

The discovery well in the Pinconning field was the Margaret Koth #1, in the SW¼, NE¼, NW¼, section 2, Frazer Township, Bay County. The well was drilled to a total depth of -3012 feet in the Dundee-

Rogers City interval by the Shell Oil Company as a result of a seismic survey. The well was completed on September 15, 1944. The pay zone was fron -2898 feet to -2900 feet, 75 feet below the top of the Rogers City formation and produced 36.3 API gravity oil. It was not until 1947 that the second producer was completed in the Pinconning field, and by the end of 1952, nine successful wells had been drilled in addition to a number of dry holes. At the end of 1957, four wells were still producing in the field giving a total of 31,403 barrels of oil for the year. The cumulative production to the end of 1957 was 730,270 barrels of oil and the recovery per drilled acre was 8,114 barrels.

Laboratory Procedure:

The samples used in this problem were obtained from the collection of Gulf Oil Company samples from the Department of Geology, Michigan State University, and from the Michigan State Geological Survey.

The samples from the Dundee-Rogers City interval were examined from the top of the Rogers City formation to the total depth in the Dundee-Rogers City interval. In wells that penetrated the Detroit River group, the entire Dundee-Rogers City interval was examined. The method of examination was patterned after the method described by Low (1951), for the examination of carbonate rocks. Each sample was examined under the binocular microscope using a power of 9X to 12X. A drop of 6 Normal solution of HCl acid was added to five drops of water in a porcelain acid dish. To this solution a small piece of the

rock sample was added and the reaction was observed.

On the basis of the observed reaction the samples were classified into the following semi-quantitative groups:

1. Limestone: Violent effervescence; frothy, audible reaction; specimen bobs about.
2. Dolomitic-Limestone: Brisk quiet effervescence; specimen skids about on the bottom of the container, rises slightly off the bottom; continuous flow of CO_2 beads through the acid.
3. Limy-Dolomite: Mild emission of CO_2 beads; specimen may rock up and down but tends to remain in one place.
4. Dolomite: No effervescence; no immediate reaction; slow formation of CO_2 beads on the surface of the specimen; reaction slowly accelerates until a thin stream of fine beads rises to the surface.

Appendix A contains a list of the wells from the Deep River, North Adams and Pinconning fields which were examined. Appendix B contains the results of the examination of two wells, one a producer and the other a dry hole, from each of the three fields.

STRATIGRAPHY

Because a large number of wells have been drilled in both Arenac and Bay Counties, the sequence of the rock units from the surface into the Dundee formation has been accurately described. In addition many wells in the counties have penetrated into the Detroit River in the search for production below the Dundee-Rogers City interval.

The generalized sequence of rock units found in the Deep River, North Adams and Pinconning fields is listed in Figure 1. The colomnar section of the Devonian system in Michigan is shown in Figure 2.

The bedrock in the Deep River and North Adams fields is overlain by 175 to 200 feet of glacial drift and in the Pinconning field by 50 to 100 feet of glacial drift. The drift in this region consists essentially of glacial-lake clays and some sand beds.

The glacial deposits lie directly on the Pennsylvanian deposits, consisting of the Saginaw group and the Parma sandstone, or on the Michigan formation or Bayport limestone of Mississippian age. The Saginaw group consists predominantly of clastic sediments and the Parma sandstone is a clean white sandstone which unconformably overlies the tan to brown Bayport limestone. Lying unconformably below the Bayport limestone is the Michigan formation consisting of gray shale, gypsum, dolomite, limestone and sandstone. In many wells of the Deep River field the glacial drift lies directly on the dark gray shale of the basal part of the Michigan formation. The Marshall formation is a

PLEISTOCENE:

Glacial drift

PENNSYLVANIAN:

Saginaw group
Parma sandstone

MISSISSIPPIAN:

Bayport limestone
Michigan formation
Marshall sandstone
Coldwater shale
Sunbury shale
Berea sandstone

MISSISSIPPIAN - DEVONIAN:

Bedford shale
Antrim shale

DEVONIAN:

Traverse group
Rogers City formation
Dundee formation
Detroit River formation

Figure 1: Generalized and informal designation of the post-Silurian rock units found in the Deep River, North Adams and Pinconning oil fields.

white to gray sandstone, calcareous in the lower part. The Coldwater shale consists of a thick series of alternating blue-gray shale with beds of typical dolomite, sandstone and siltstone.

The Sunbury shale is a thin black shale which averages only 25 feet in thickness. It is similar in appearance to the Antrim but is less carbonaceous. The Bedford-Berea consists of gray shale, sandy shale, siltstone and sandstone and lies conformably on the Antrim. The Bedford-Berea and Sunbury derive their names from lithologically similar units in Ohio but the age of the units has never been definitely established in Michigan. The Antrim is a thick black carbonaceous shale with some gray argillaceous limestone near the base.

The Antrim lies above the thick Traverse group consisting of gray and shaly limestones and shale. The lowest formation in the Traverse group and immediately overlying the Dundee-Rogers City interval is the Bell shale. The Bell shale is soft, fossiliferous, gray shale. Some geologists believe that an unconformity exists between the top of the Rogers City formation and the overlying Bell shale but this has not been definately established.

The Bell shale overlies the Rogers City-Dundee sequence of Middle Devonian age, which has produced more oil than the rocks of any other age in Michigan. The Rogers City is the oil producing formation in the Deep River, North Adams and Pinconning oil fields. It varies in thickness from 75 to 100 feet in the Pinconning field and from 100 to

MICHIGAN DEVONIAN SYSTEM

System	Group	Formation
D E V O N I A N	TRAVERSE	Squaw Bay Thunder Bay Potter Farm Norway Point Four Mile Dam Alpena Newton Creek Genshaw Ferron Point Rockport Quarry Bell Shale
	CAZENOVIA	Rogers City Dundee
	DETROIT RIVER	Lucas Amherstberg Flat Rock Sylvania Bois Blanc Garden Island

Figure 2: Generalized columnar section of the Devonian system in Michigan (After Helen M. Martin, Michigan Geological Survey).

125 feet in the Deep River and North Adams fields. The thickness of the Rogers City in Arenac County is the maximum for the formation throughout the state. The Rogers City formation is predominantly a brownish-buff limestone, but changes to dolomite in the Deep River, North Adams and Pinconning oil fields. In the center of the Michigan basin the Rogers City is dark brown or black becoming lighter in color toward the margins of the basin.

Immediately below the Rogers City formation lies the Dundee formation. Although the Dundee is productive in many fields in Michigan, the Deep River, North Adams and Pinconning fields produce primarily from the top of the Rogers City formation. The Dundee varies in thickness from about 275 to 350 feet in the Deep River and North Adams fields and about 300 to 325 feet in the Pinconning field. The Dundee formation is a buff to light brown cherty limestone, dolomitic limestone and dolomite. Although the Rogers City has been described as a separate formation (Ehlers and Radabaugh, 1938), the Rogers City-Dundee interval is still refered to as the "Dundee" in oil field terminology.

Conformably below the Dundee is the Detroit River group consisting of alternating beds of dolomite, limestone, sandstone, salt and gypsum.

STRUCTURE

Regional Structure of the Rogers City-Dundee Interval:

The Dundee underlies most of the southern peninsula of Michigan and the Rogers City formation underlies most of the northern two thirds of the southern peninsula. It is absent in the southern part of the state. The combined thickness of the Rogers City-Dundee interval is at a maximum in the Saginaw Bay Area, attaining a thickness of more than 475 feet. The Rogers City-Dundee interval has more than 3,800 feet of relief in the Michigan Basin (Cohee and Underwood, 1945). The top of the Rogers City is about 780 feet above sea level in Presque Isle County and is approximately -3,000 feet below sea level in the center of the basin.

A regional structural contour map on the top of the Rogers City-Dundee interval by Cohee, (1945), shows that the dominant anticlinal structures in the center of the basin are generally northwest-southeast and around the margins of the basin other trends are noted as well. East-west trends occur in Tuscola and Sanilac Counties near Saginaw Bay, and northeast-southwest trends occur on the northern and southern rims of the basin.

The Rogers City-Dundee interval is structurally complex in the area of Ogemaw, Gladwin, Arenac and Bay Counties. The Deep River and North Adams fields are located on an anticlinal structure having a

southeast-northwest trend. The northeast flank dips at about 18 feet per mile and the southwest flank dips at about 50 feet per mile. The Pinconning field is situated on a structural high trending northward. The east flank dips at about 25 feet per mile and the west flank at about 40 feet per mile.

Structure of the Deep River Field:

Map 5 is a structure contour map of Deep River Township, Arenac County, on the top of the Rogers City formation. The depths to the Rogers City were taken from the driller's logs and well logs and where the well was used in testing for dolomite or limestone, the depths were checked with the well samples. Because the contact between the black shale of the Bell, and the limestone of the Rogers City formation is easily distinguished, it is believed that these depths are fairly accurate. Figures 3 through 7 are southwest-northeast cross-sections of the Deep River field showing the depths to the Rogers City formation.

The dominant structural feature in the Deep River field is the Deep River anticline with the highest part of the fold being -1990 feet below sea level in the NE¼ of section 18 and the NW¼ of section 17. The upper part of the Deep River anticline produces gas from the Berea sandstone. The Deep River anticline, with a southeast-northwest trend, has a structurally low area along the axis of the fold in the NW¼ of section 21 and in the SE¼ of section 17, forming a saddle in the center of the two structurally higher portions of the fold. The NW portion of the Deep River anticline has a closure of 50 feet and the

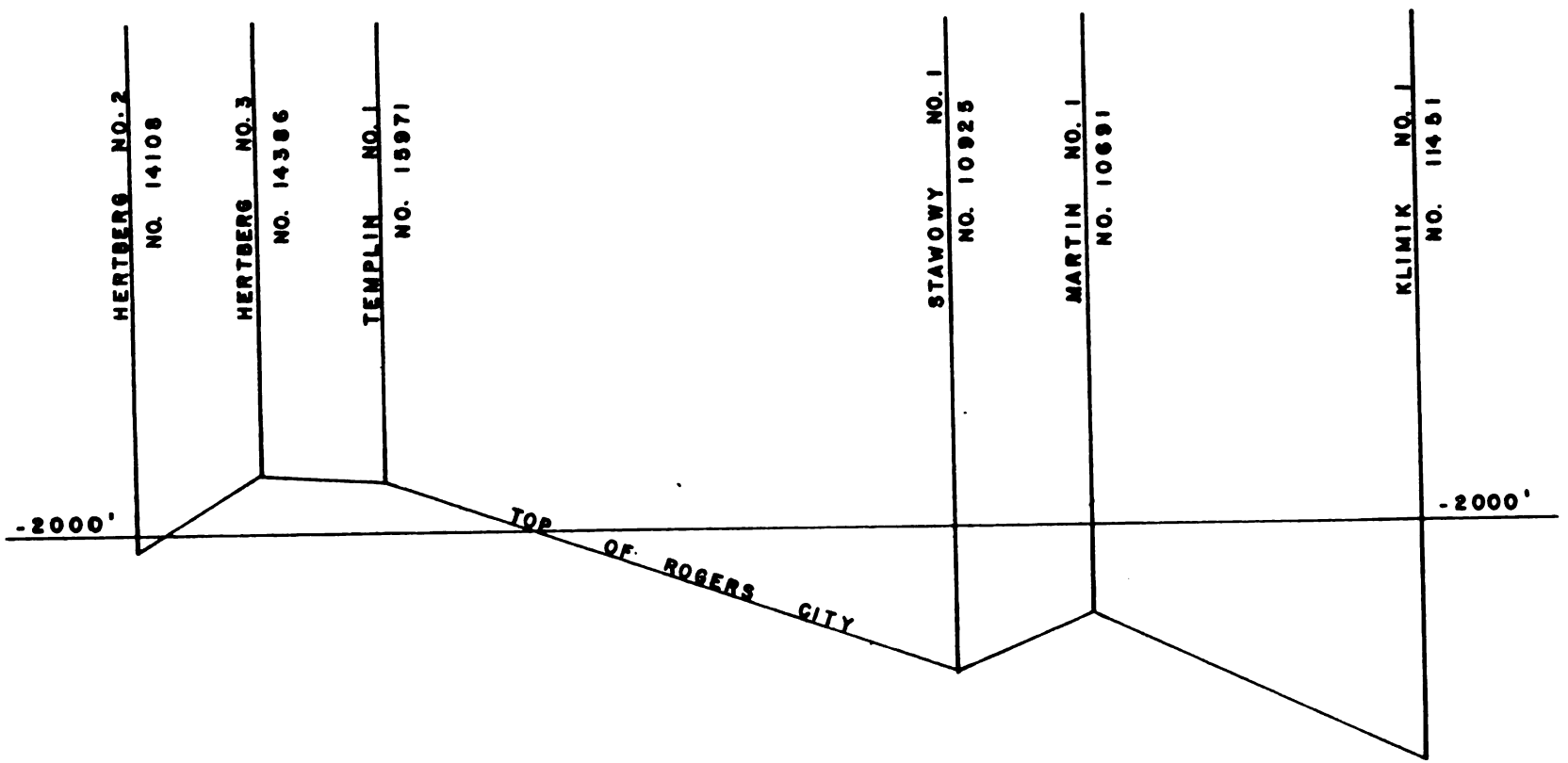
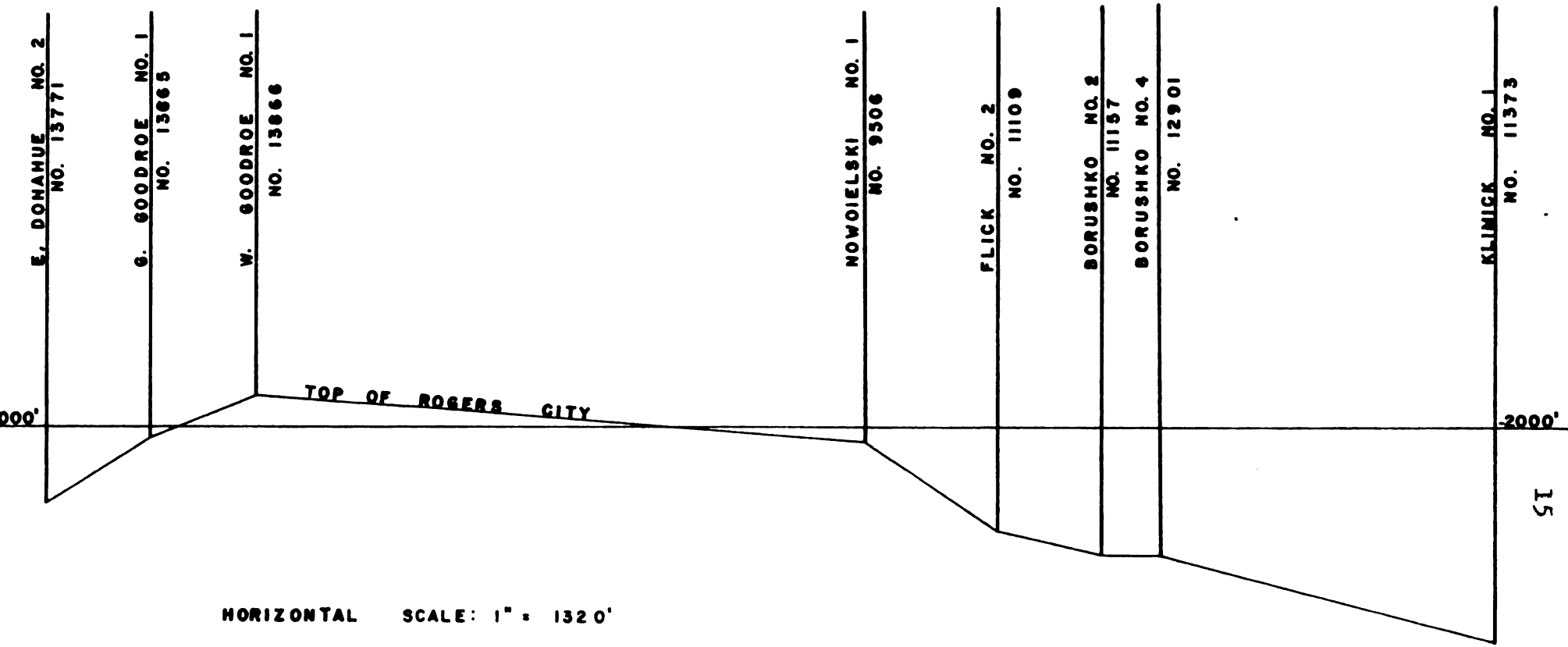


Figure 3 : Cross section of the Deep River field, Deep River Twp.



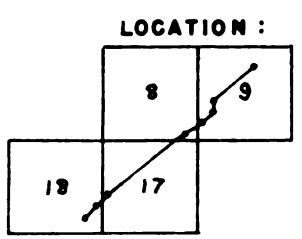


Figure 4 : Cross section of the Deep River field, Deep River Twp.

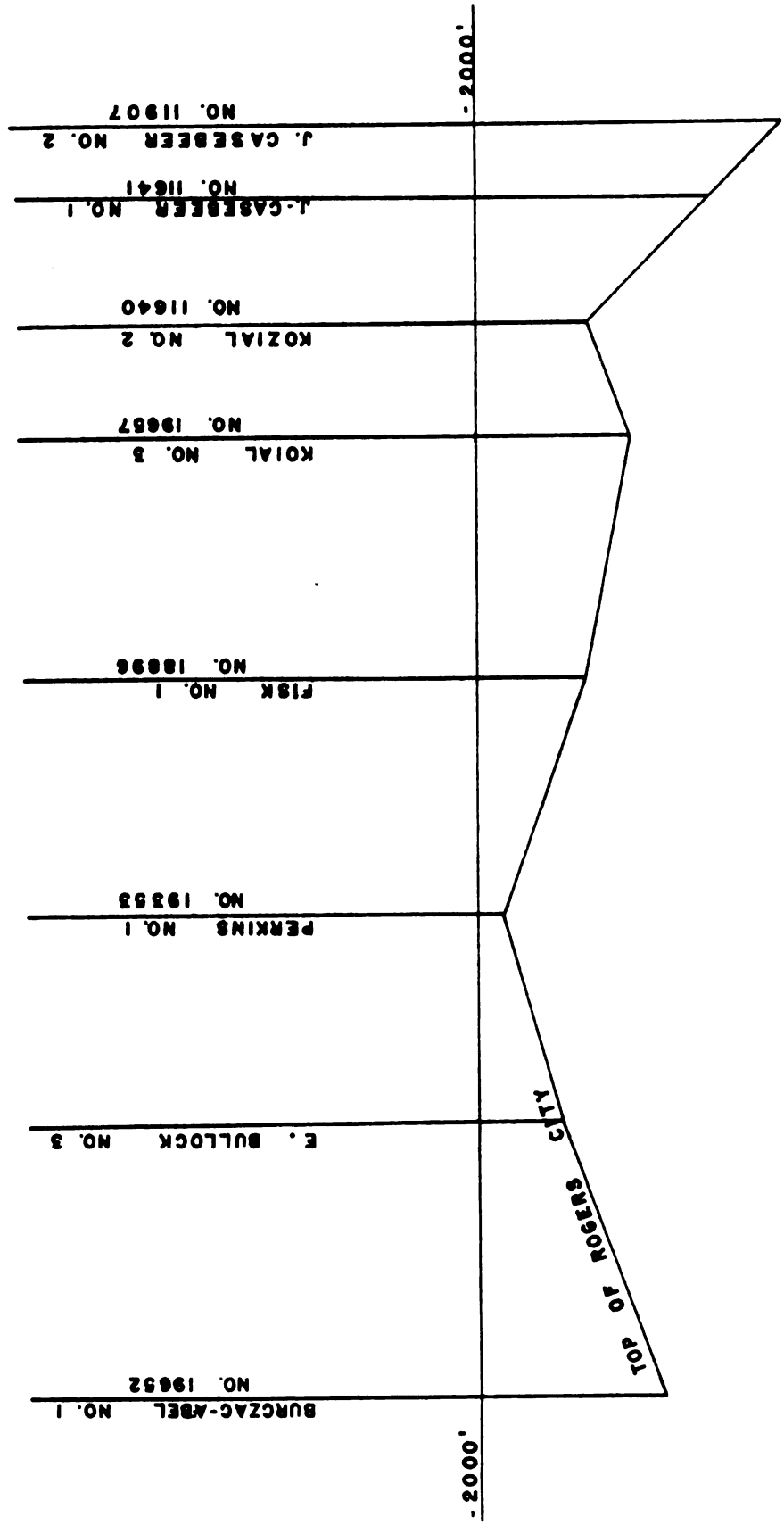


Figure 5 : Cross section of the Deep River field, Deep River Twp.

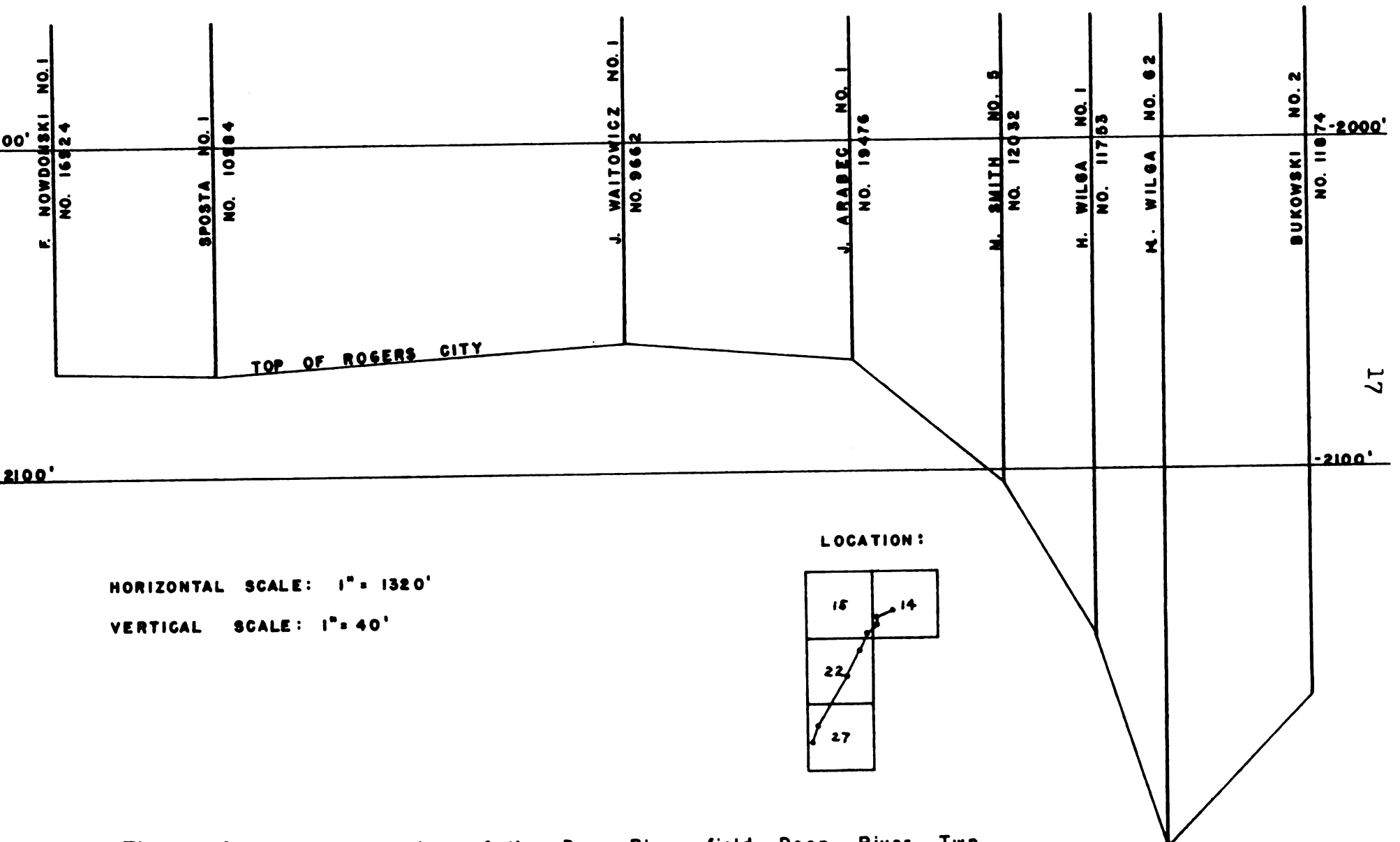


Figure 6 : Cross section of the Deep River field, Deep River Twp.

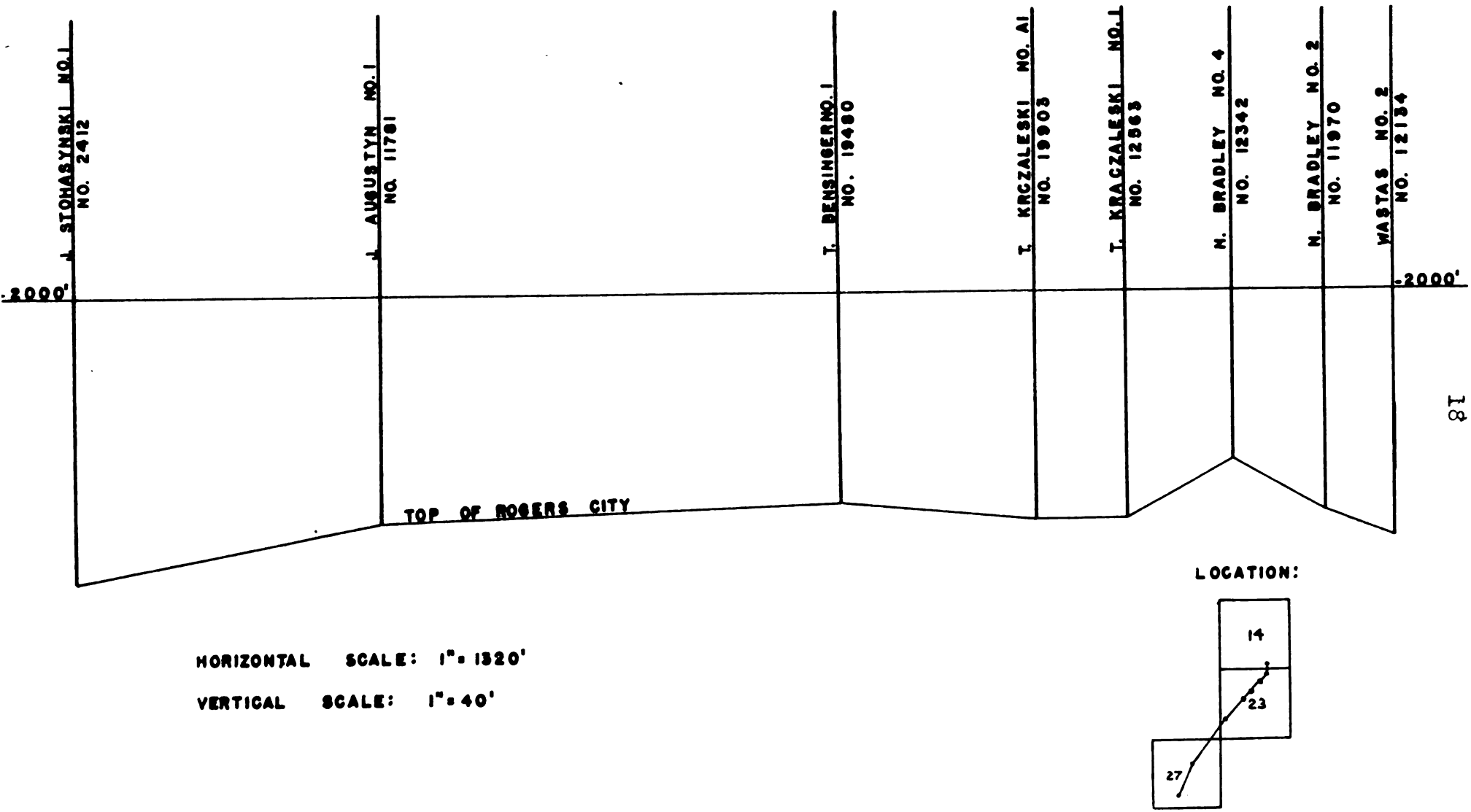


Figure 7: Cross section of the Deep River field, Deep River Twp.

southeast portion has a closure of 30 feet. The Deep River anticline produces oil from the Traverse, Dundee and Detroit River formations.

The Deep River field is located along the north, northeast and east flanks of the Deep River anticline. The most striking feature of the field is its narrow linear extent. The field extends for 5¼ miles in a direction 55 to 60 degrees NW along the Deep River anticlinal fold and at its widest point is over a quarter of a mile.

Oil accumulation in the field has not been controlled directly by structural position. Production is received from the Rogers City formation, 30 to 210 feet structurally below the top of the Deep River anticline. The structure contours show extreme irregularity throughout the extent of the field. The contours close around isolated highs and lows which serve to break up the general contour pattern of the field. An example of this configuration is the isolated high in the NE¼, NE¼, NE¼, of section 7, Deep River Township.

Landes (1946), believed that the location of the dolomite in the Deep River field was controlled by "a crack or fissure cutting through Rogers City limestone on the north flank of the Deep River Dome", which was caused by "local diastrophism". The field is cut by numerous fissures or fractures throughout the extent of the productive area. Intersecting fissure planes have produced large blocks which have settled or have been raised slightly producing the isolated high and low closed contoured areas in the Deep River field.

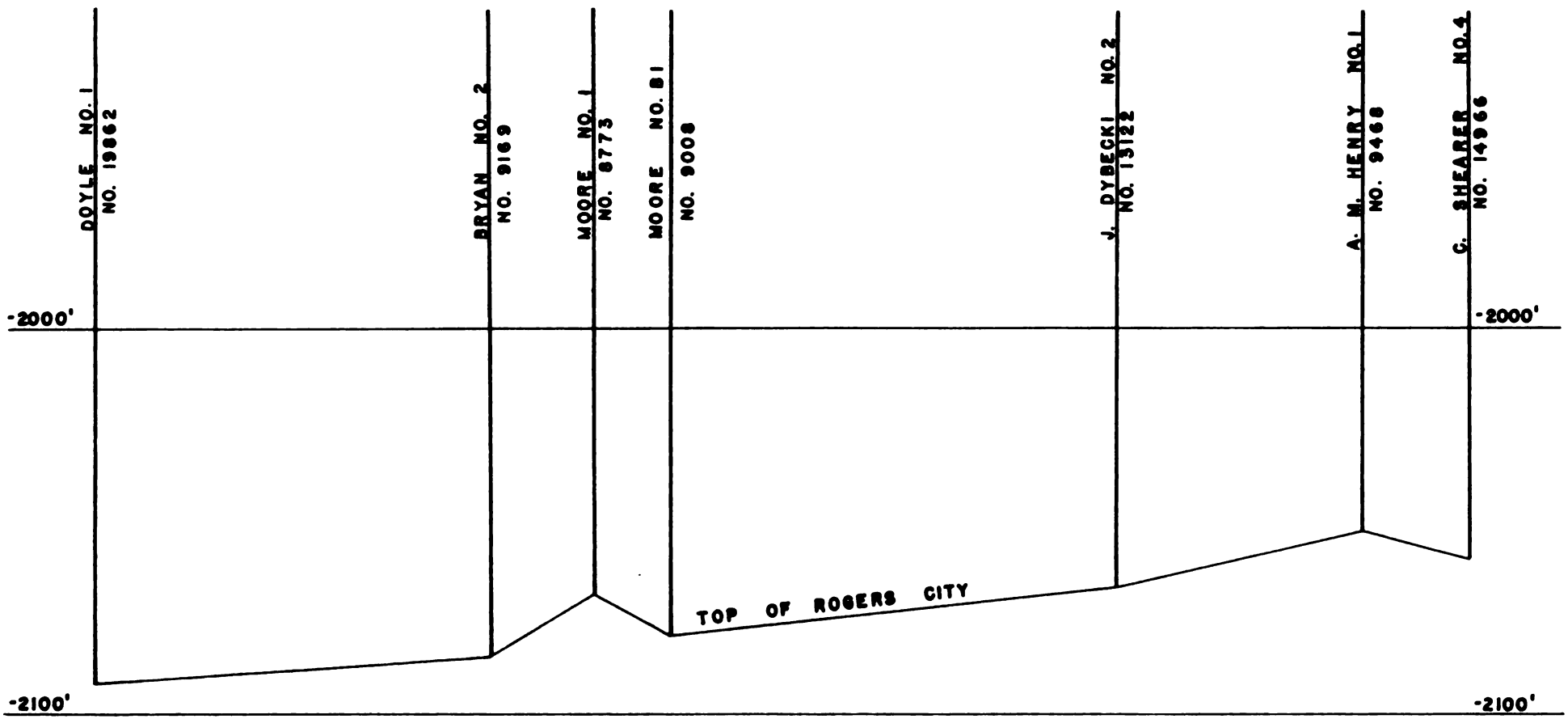
A high structural position in the field does not insure production. Although most of the wells produce within the top 20 feet of the Rogers City formation, structurally high wells may be dry whereas adjacent low wells may be producers.

There have been very few wells drilled northeast of the field, and as a result, little is known of the structural features in this area.

Structure of the North Adams Field:

Map 6 is a structure contour map on the top of the Rogers City formation in Adams Township, Arenac County. The depths on this map have been taken from driller's logs and well logs made available by the Michigan Geological Survey. Figures 8 through 11 are northwest-southeast cross-sections of the North Adams field showing the depths to the top of the Rogers City formation.

The North Adams field is located in the eastern part of Adams Township, Arenac County. The field extends for three miles in a direction approximately N 25 degrees E and varies from a single well to over one quarter mile in width. The dominant feature of the field is its narrow linear extent which cuts directly across the generally northwest-southeast trending structures in Adams Township. The Adams field is located on two northwest-southeast trending anticlines in the southeast quarter of the Township. The anticlines are separated by a structural saddle in the northern half of section 35. In the northern



HORIZONTAL SCALE: 1" = 1320'

VERTICAL SCALE: 1" = 40'

LOCATION:

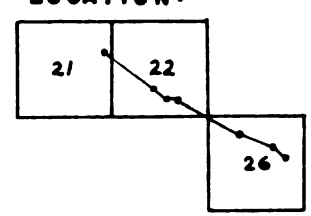
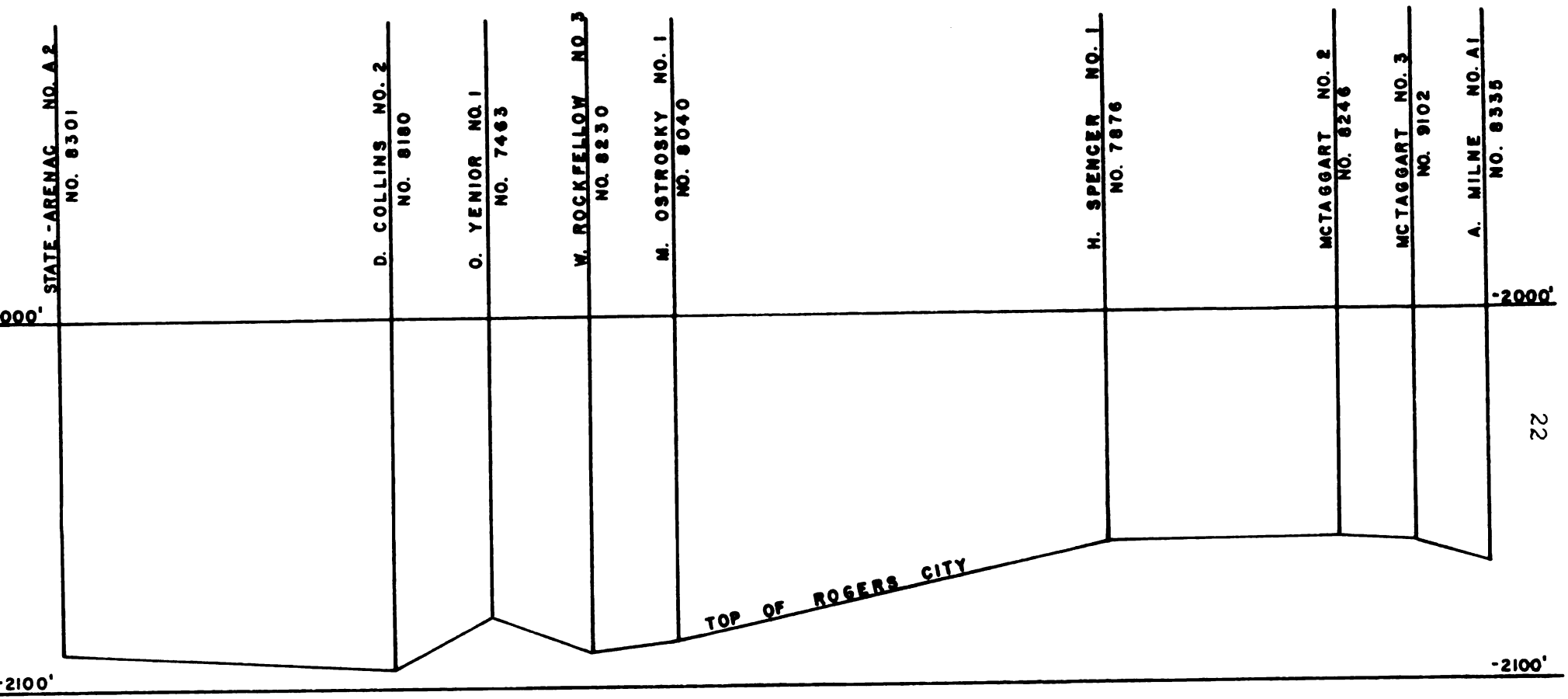


Figure 8: Cross section of the North Adams field, Adams Twp.



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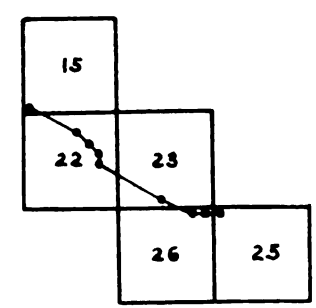
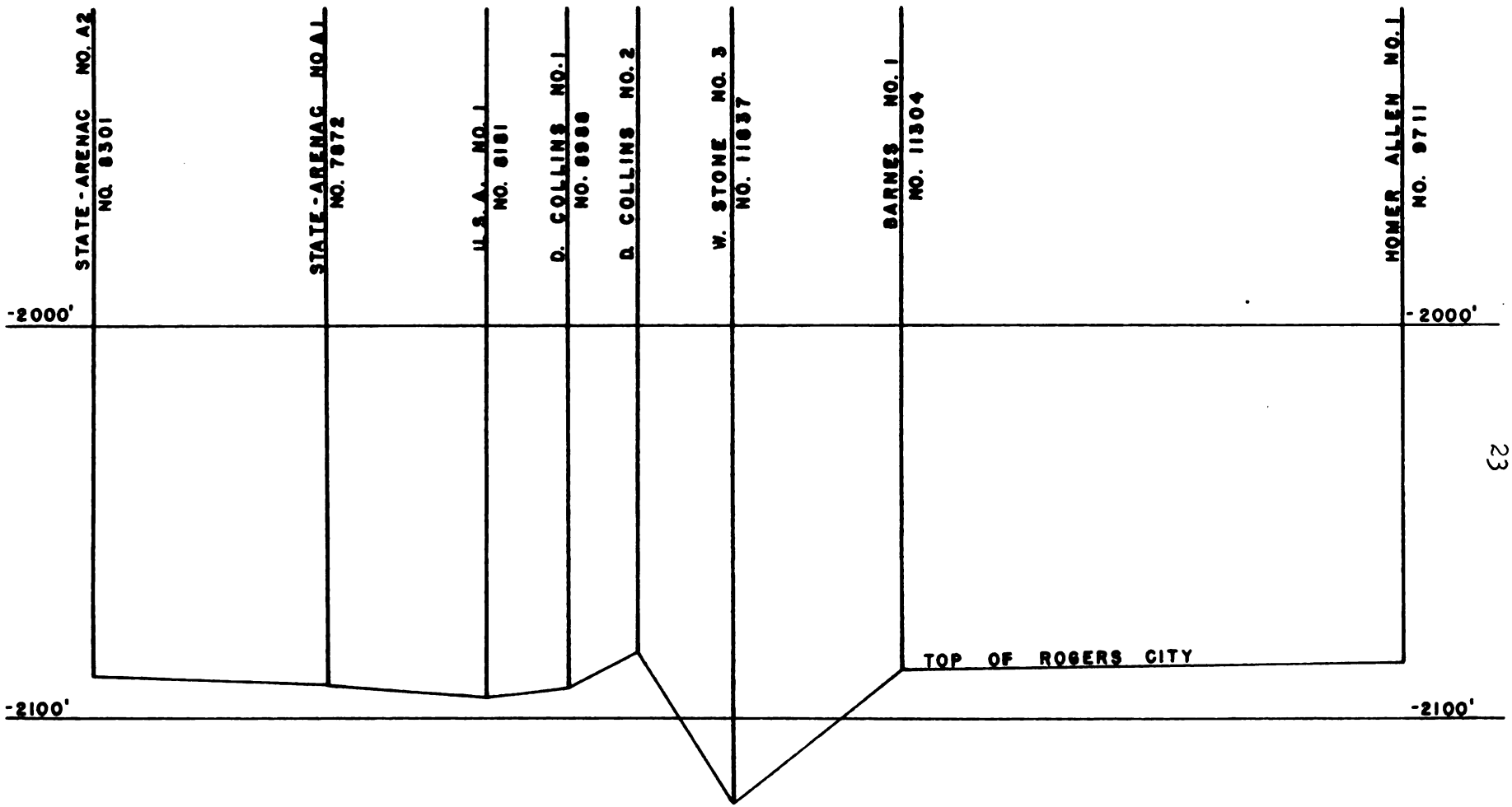


Figure 9: Cross section of the North Adams field, Adams Twp.



HORIZONTAL SCALE: 1" = 1320'

VERTICAL SCALE: 1" = 40'

LOCATION:

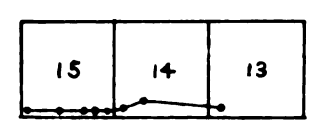


Figure 10: Cross section of the North Adams field, Adams Twp.

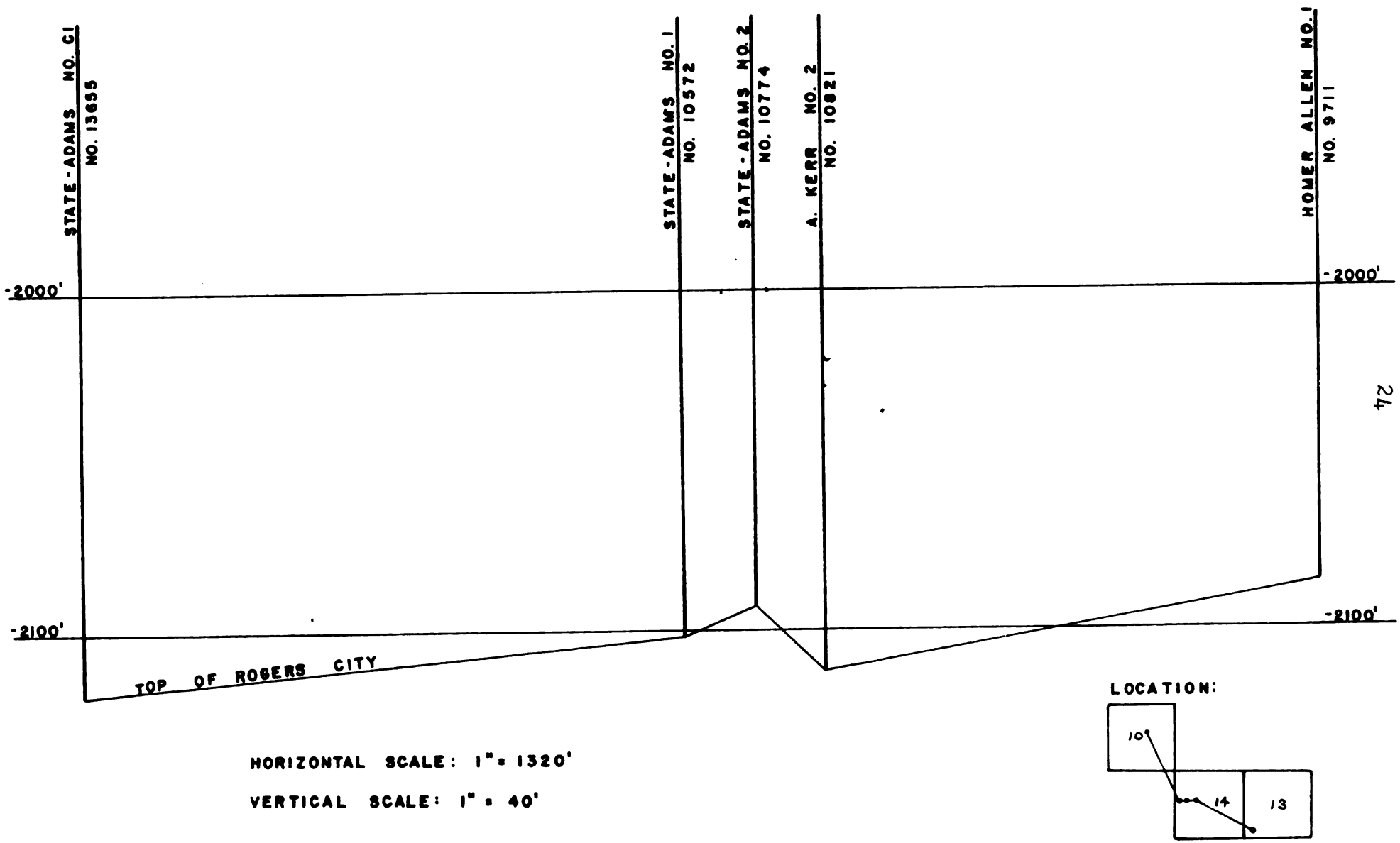


Figure 11: Cross section of the North Adams field, Adams Twp.

anticline, located in sections 23, 24, 25 and 26, oil is produced from the Traverse and Dundee formations with a little production from the Detroit River formation. Production from the anticline in sections 34, 35 and 36 is from the Detroit River and the Traverse formations with a little production from the Dundee. A structural nose extends with a northwest-woutheast trend in the northwest quarter of the Township. This structural nose is transected and separated from the anticlines of the Adams field in the southeast quarter of the Township by the linear northeast trending North Adams field.

The structural contours throughout the extent of the North Adams field are extremely irregular and show a pattern similar to that found in the Deep River field. The contours show isolated highs and lows throughout the field. Landes (1946), states that the dolomitization in the North Adams field was caused by "percolating waters along vertical or almost vertical fractures". The configurations of the contours in this field are settled or raised blocks which have been formed by intersecting fractures or fissures in the Rogers City-Dundee interval. These large blocks show up in the field as isolated highs and lows along the extent of the field.

Structure does not control production in the North Adams field. Structurally high wells may be dry, and a structurally low well, only one well removed, may be a producer. Most of the wells received production from the top 30 or 40 feet of the Rogers City formation but a few wells received production from deeper zones.

Structure of the Pinconning Field:

Map 7 is a structure contour map on the top of the Rogers City formation of the Pinconning oil field. The depths to the Rogers City formation were taken from well logs and driller's logs made available by the Michigan Geological Survey. Figures 12 and 13 are northwest-southeast cross-sections of the Pinconning field.

The Pinconning field is located in sections 25, 35 and 36 of Pinconning Township and in section 2 of Frazer Township. Extending for two miles in a direction N 30 degrees E, the field is in no place more than one well in width.

The area is characterized by a northwest-southeast structural alignment. In sections 33 and 29, of Pinconning Township, a northwest-southeast trending high is paralleled, to the north in sections 27 and 28, by a northwest-southeast trending trough. The Pinconning oil field trends in a northeast-southwest direction and cuts perpendicularly across the general structural alignments for the area. In the southwestern part of the field a fault has been drawn in on the contour map which follows immediately along the line of the producing area. Because of the fewer number of drilled wells in the northeast part of the area and the resulting lack of control, the fault has not been extended into the northeast part of the field. It is presumed that the fault does extend the entire distance, approximately two miles, along the length of the field. Mr. G. Ells, of the Michigan Geological Survey, stated that he has observed a section of core from an unknown

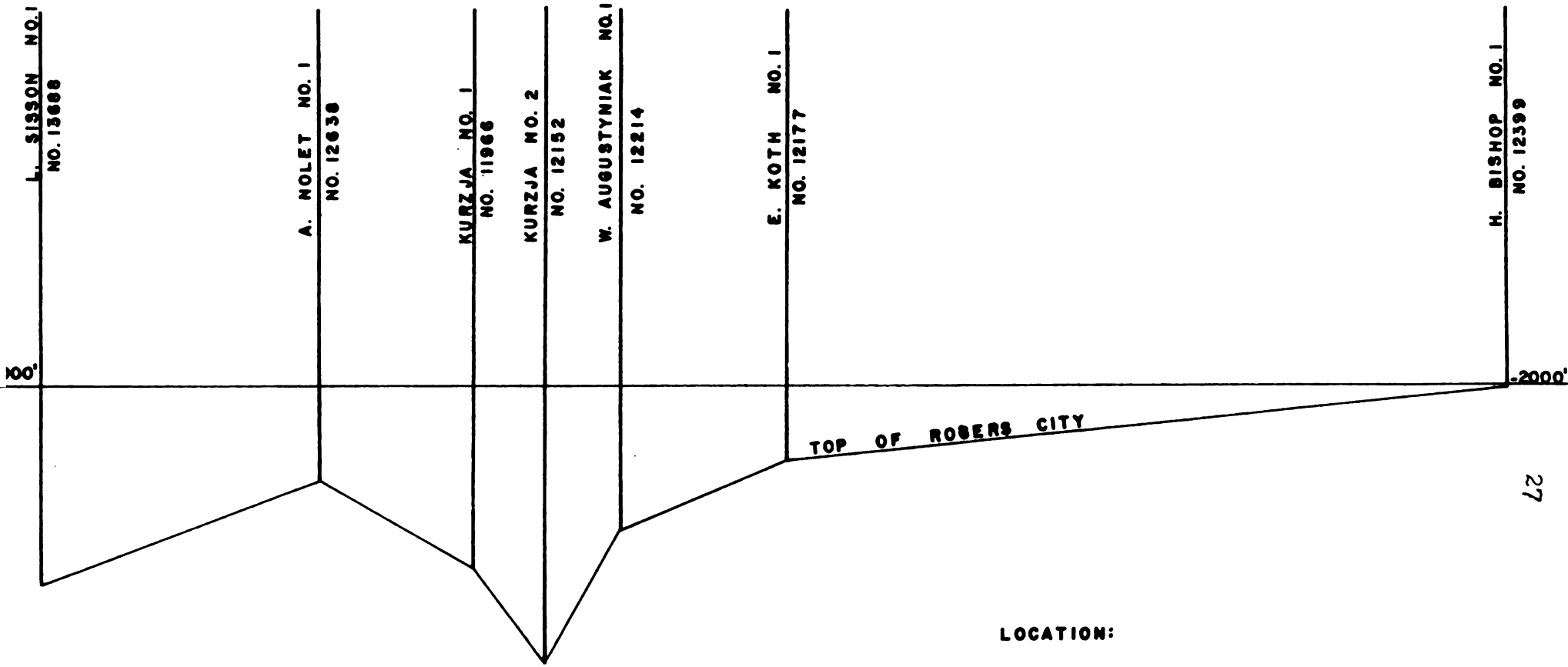


Figure 12: Cross section of the Pinconning field, Pinconning and Frazer Twps.

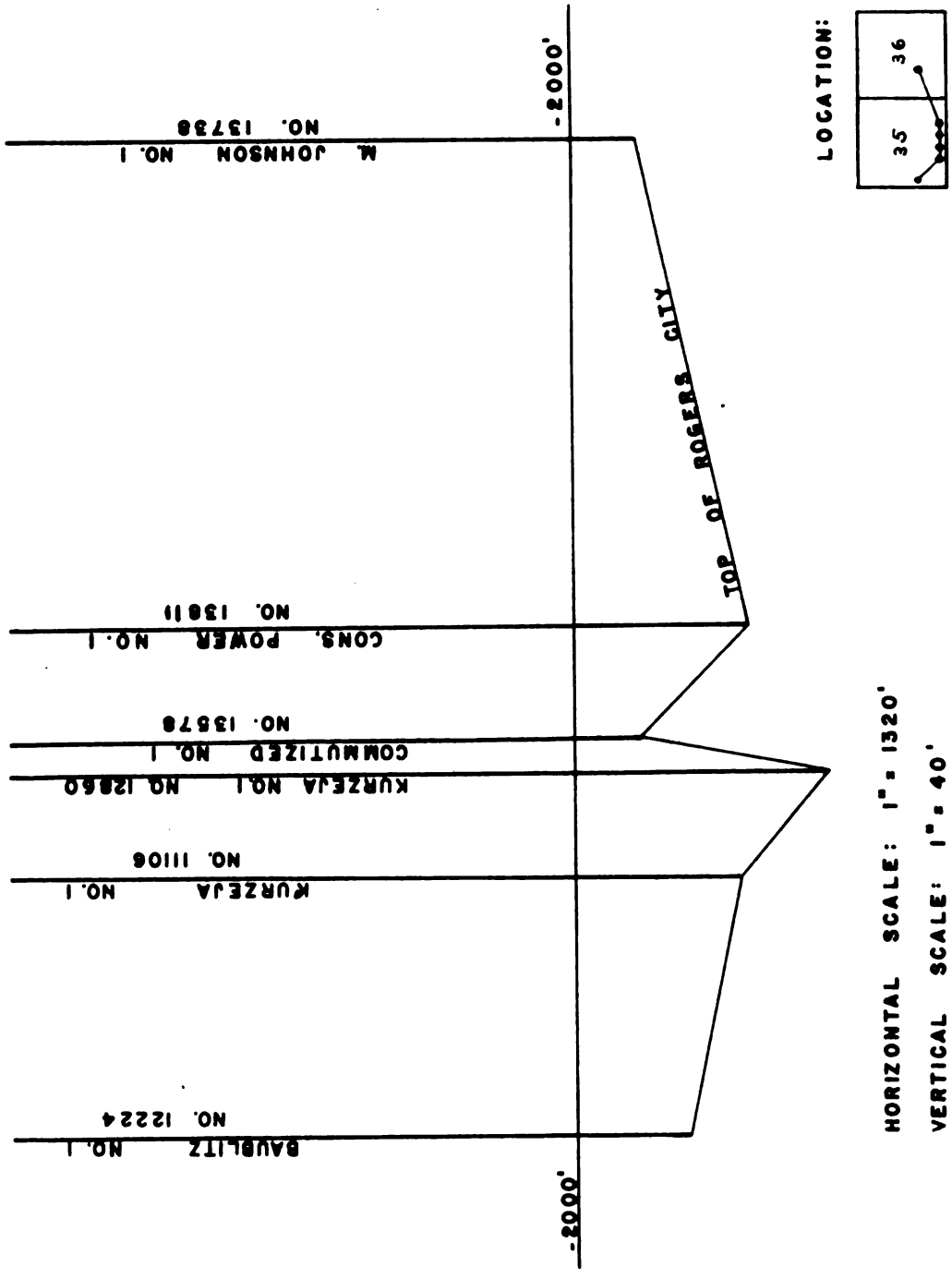


Figure 13: Cross section of the Pinconning field, Pinconning Twp.

well in the Pinconning field in which a fault zone was visible. The core was strongly brecciated, and slickensides were observed which dipped 45 to 50 degrees to the unoriented core length.

A scale model of the top of the Rogers City formation of the Pinconning oil field has been constructed by Mr. Ells. This fault is expressed much more clearly on the model than in the structure contour map and is believed to extend the length of the productive area in the Pinconning field.

Structure does not directly control production in the Pinconning field. Structurally high wells that are dry may be directly beside structurally low wells which are producers. Production is received from directly below the Bell shale in the top of the Rogers City formation, to 79 feet below the top of the Rogers City.

RELATIONSHIP OF SECONDARY DOLOMITIZATION TO STRUCTURE

Maps 2, 3 and 4 show the outline of the extent of the dolomitization in the Deep River, North Adams and Pinconning oil fields. There is a direct relationship between the outline of the dolomitization and the structural characteristics of each field.

In the Deep River field stress has created fissures or cracks in the area where the production occurs. These fissures intersect and have produced large blocks which have settled or have been raised slightly, which is shown in the irregularity of the contours in the structure contour map of the field. According to Landes (1946), the dolomite in the Deep River field was formed by "percolating waters along vertical or almost vertical fractures". In other words, the fractured structure in the pool formed the passageway by which dolomite bearing waters ascended from lower formations to form the dolomite in the Rogers City-Dundee interval. In the areas where fracturing did not occur extensively the waters were not able to percolate and the limestones were unaltered.

The North Adams field is similar to the Deep River field in that the passageways for the percolating solutions were also intersecting fractures or cracks. In the Pinconning field the stress was of sufficient magnitude to form a single master fault which may have served as the channelway along which the percolating waters were able to ascend.

In most wells in the three fields dolomitization occured within the top 20 or 30 feet of the Rogers City Formation. Landes (1946) has stated that the overlying thick Bell shale may have acted as a partial dam to the ascending solutions "so that they spread out and moved laterally in the upper part of the limestone".

Wells drilled in the Deep River and North Adams fields away from the fractured zone encounter tight limestone and result in dry holes. In the Pinconning field only wells drilled directly on or immediately adjacent to the fault encounter sufficient dolomite and porosity for oil accumulation. Wells drilled some distance from the faulted area encounter tight limestone and result in dry holes.

RELATIONSHIP OF PRODUCING WELLS TO SECONDARY DOLOMITIZATION

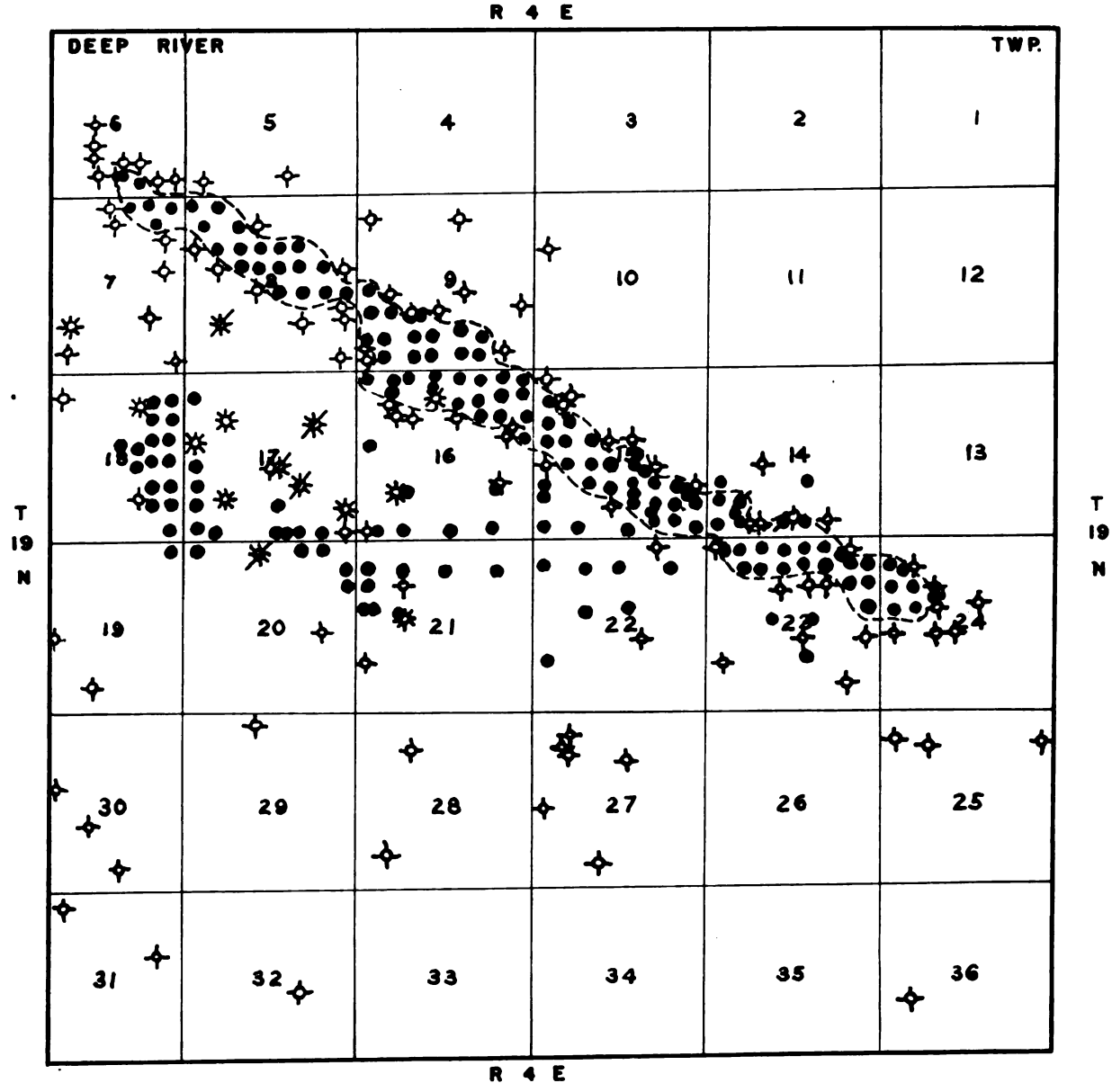
Maps 2, 3 and 4 show the extent of the dolomitized area in the Deep River, North Adams and Pinconning oil fields. In each field this outline of the dolomitized area is also the outline of the oil producing area. In other words, production is directly related to the degree of dolomitization.

Appendix B is a list of two wells for each of the three fields; one a producing well and the other a dry hole. The method of examination of the samples from these wells has been explained under the previous section Laboratory Procedure. The results of the examination of these six wells will be used as examples of the general overall conditions that exist in each field.

The Stanlisan Flick #1, permit #10924, in the NW¼, NW¼, SW¼, of section 9, in Deep River Township, was a producing well in the Deep River field. This well encountered the top of the Rogers City formation at -2805 feet and was drilled to a total depth of -2836 feet. After treating with acid, the well flowed 960 barrels of oil per day. The samples from -2802 feet to -2816 feet gave a test for limestone when treated with acid. The samples from -2816 feet to -2825 feet gave a test for limy-dolomite and the samples from -2825 feet to -2836 feet gave the reaction for dolomite. The pay section of the well was from -2825 feet to -2836 feet.

The Nowoielski-Switzer-Receiver Comm. #1 was a dry hole in the Deep River field. The well, which lies nearly a quarter of a mile from the nearest producer, penetrated the entire Rogers City-Dundee interval. In testing for dolomite content, the entire interval gave a test for limestone, except the samples from -2871 feet to -2880 feet which gave a test for dolomitic-limestone. A show of oil was recorded on the driller's log at the depth -2880 feet. A show of oil was also recorded at -2795 feet and -2912 feet but the samples at these intervals gave a test for limestone.

In the Deep River field all the samples tested from producing wells gave a test for dolomite in the interval taken from the pay section. In many of the dry holes immediately adjacent to the pay area, tests for dolomite were also recorded. Dry wells some distance away from the pay area tested as limestone for the entire Rogers City-

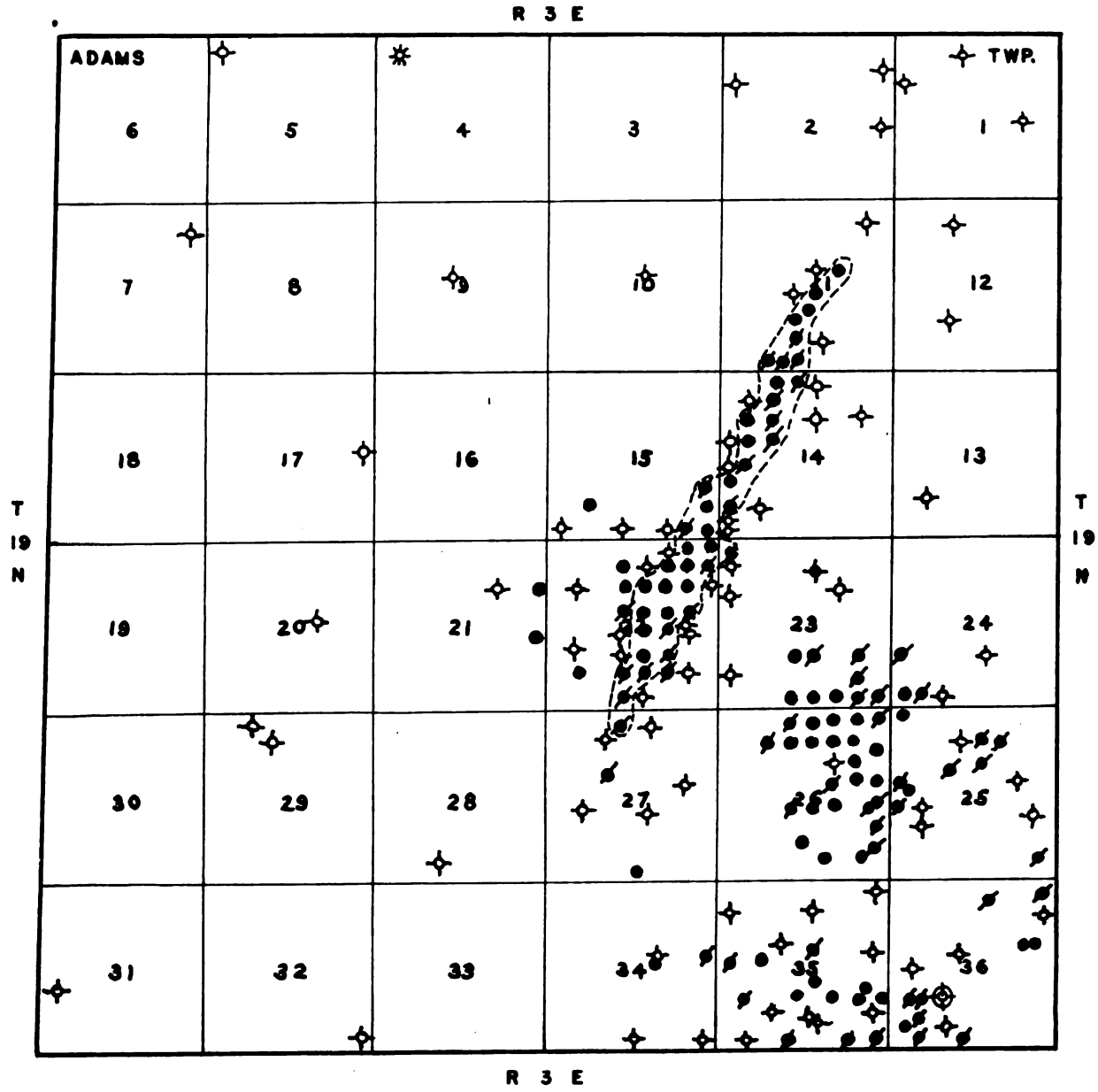


Map 2: Outline of the Extent of the Dolomitization in the Deep River Oil Field.

Dundee interval. It appears that in the Deep River field, only the rocks which have been dolomitized to a high degree have sufficient porosity for the accumulation of the oil. In the area of the producing zone of the field the fracturing has allowed the percolating waters to ascend and to alter the limestone to dolomite. These waters have altered the limestone proportionally less away from the fractured zone. The wells away from the fractured zone have not been altered to dolomite and the porosity of these rocks is not sufficient for oil accumulation.

The T. and E. Bryan #3, permit #10549, an oil well in the North Adams field, was examined for dolomite content. In this well the top of the Rogers City formation was encountered at -2881 feet and the total depth was -2916 feet. The samples from -2881 feet to -2890 feet gave a reaction for dolomite and the samples from -2890 to the bottom of the hole gave a reaction for limestone. Oil was produced from a four foot pay zone from -2886 feet to -2890 feet.

The Thomas Bryan #1, permit #8436, is an example of a dry hole in the North Adams field. This well was drilled to a total depth of -3042 feet after encountering the top of the Rogers City at -2874 feet. In testing for dolomite content the samples all gave a test for limestone except for the interval from -2979 feet to -2993 feet which gave a test for dolomitic limestone. According to the driller's log of this well, a show of oil was recorded at -2978 to -2779 feet. The well is located only 660 feet west and 660 feet south of two

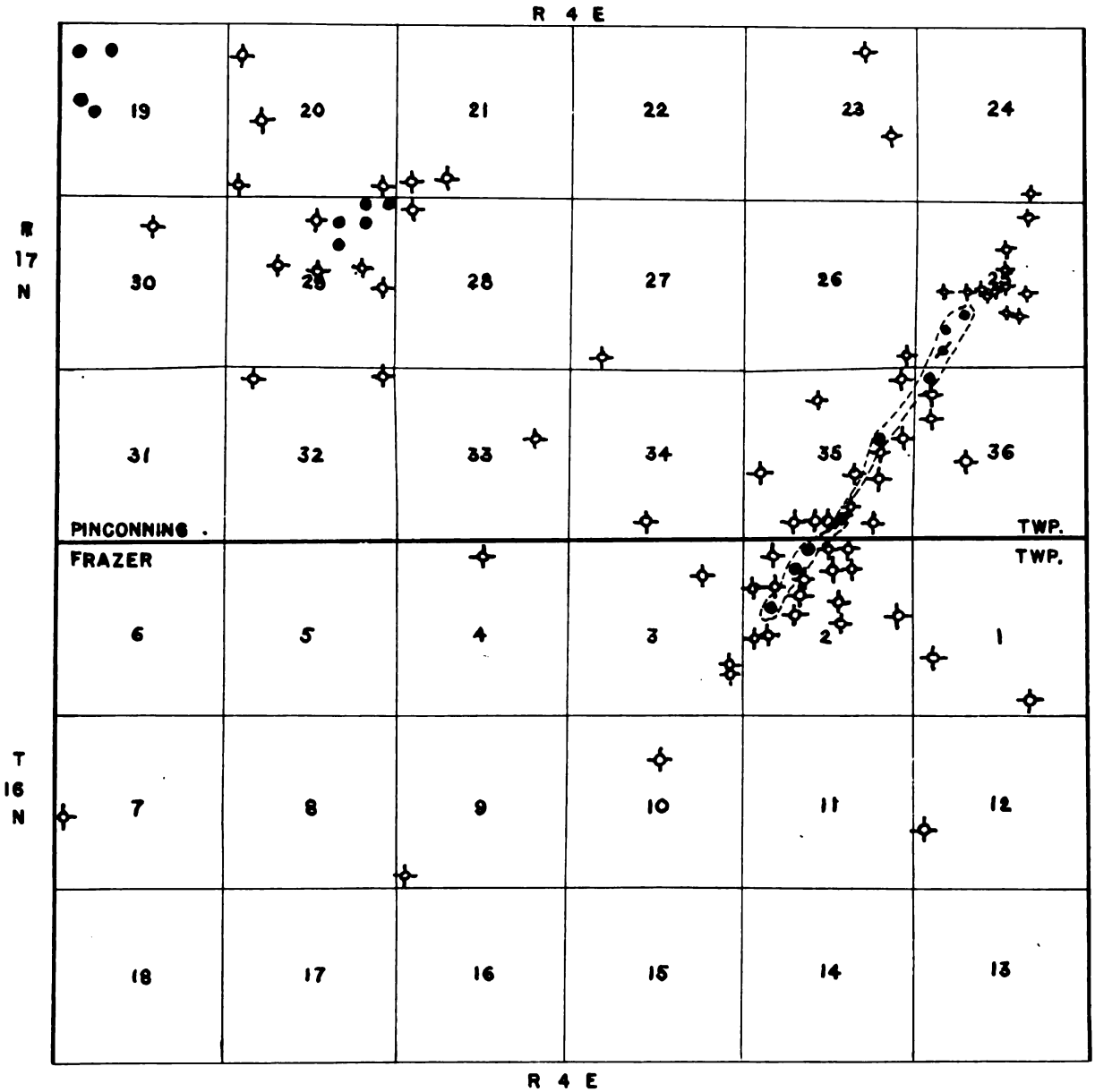


Map 3: Outline of the Extent of the Dolomitization in the North Adams Oil Field.

producing wells on the western side of the North Adams field, section 22.

As in the Deep River field, all the samples tested in the North Adams field gave a test for dolomite in the interval of the pay section. In the wells some distance away from the producing area the samples all consisted of limestone. Dolomitic-limestone and limy-dolomite tests were found in some samples immediately adjacent to producing wells. The fissures or cracks formed in the North Adams field have allowed the percolating waters to ascend into the Rogers City-Dundee interval and alter the limestone to a dolomite in the immediate area of the fracturing. The extent of the dolomite is also the outline of the zone where the fracturing took place in the field. The Rogers City-Dundee does not have sufficient porosity in the limestone areas for the accumulation of oil. Porosity accompanies dolomitization and accounts for the accumulation of oil in only the dolomitized rocks.

The Margaret Koth #1, permit #10944, was used to illustrate an oil producing well in the Pinconning field. This well was the discovery well for the Pinconning field and was drilled to a total depth of -3012 feet. In the top part of the well from -2822 to -2830 feet, the samples gave tests for limy-dolomite and dolomitic-lime. From -2830 to -2895 feet the samples tested mainly limestone with the occasional dolomitic-limestone reaction. From -2895 to -2900 feet the samples tested limy-dolomite and from -2900 feet to the bottom of the hole the samples were dolomite. The pay zone of the M. Koth #1 was from -2898 feet to -2900 feet.



Map 4: Outline of the Extent of the Dolomitization in the Pinconning Oil Field.

The Kurzeja and Drake #A-2, was a dry hole drilled only about 400 feet west of a producing well in the Pinconning field. From the top of the Rogers City formation at -2856 feet to -2915 feet the samples tested for limestone. The sample from -2915 feet to -2920 feet tested for dolomite and the samples from -2923 feet to -2926½ feet tested for limy-dolomite. Limestone occurred from -2927 feet to the bottom of the well at -2936 feet. The driller's log of the well recorded a show of oil from -2923 feet to -2927 feet.

All of the wells tested in the Pinconning field received production from a porous dolomite. The dry holes some distance away from the producing area encountered limestone in the Rogers City-Dundee interval. The producing area is a long linear area corresponding to the major fault which extends the entire length of the field. The percolating waters in this field have risen along the major fault to alter the limestone to a porous dolomite. The porosity which accompanies dolomitization allows the accumulation of the oil. The domomitization quickly dies out as the distance increases from the fault. Many of the dry wells immediately adjacent to producing wells encountered dolomite and oil shows but apparently the rocks had not been sufficiently dolomitized to allow for oil accumulation. The pay section of the producing wells in the Pinconning field occurred from 79 feet below the top of the Rogers City formation to immediately below the Rogers City-Bell shale contact. The pay sections varied from one to nine feet in thickness.

SUMMARY AND CONCLUSIONS

One of the most interesting facts concerning the Deep River, North Adams and Pinconning fields is their linear orientation. The Deep River field trends in a northwest direction and the North Adams and Pinconning fields trend perpendicularly to it in a northeast direction. The Deep River field parallels the general trend of the structure in Deep River Township and the North Adams and Pinconning fields cut directly across major folds and the regional structural trends of the area.

Stress has caused fracturing or cracking along a linear trend in the Deep River and North Adams fields. This intersecting fracturing, in the one case paralleling a major fold, and in the other case cutting across major folds, has produced large blocks which have settled or have been raised slightly producing the irregular structure along the extent of the fields. In the Pinconning field the stress has been of sufficient strength to result in a major fault which likely extends the entire length of the productive area.

The fracturing in the Deep River and North Adams fields and the fault in the Pinconning field have provided the passageways by which the magnesium bearing waters have ascended into the Rogers City-Dundee interval forming the dolomite found in the productive areas. It is the belief of Landes (1946), that an "artesian system" carried the waters up the fractures and fault and that "dolomitization porosity results from an excess of solution over precipitation during the process of

local replacement of limestone by circulating ground water". Although precipitation usually accompanies solution at the same rate, in a rapidly moving circulation solution may be able to overtake and exceed precipitation.

In the producing wells in the fields, the pay section is a porous dolomite. Dry wells usually encounter entirely limestone, if appreciable distance from the producing area, and some limy-dolomite if the well is very near the producing zone. Porosity accompanies dolomitization and allows the oil to accumulate. Even in dry holes in which samples gave a test for dolomite the interval usually recorded a show of oil in the driller's log. The dolomitization was sufficiently thorough only in the immediate vicinity of the fractured or faulted area to produce the porosity necessary for the oil accumulation.

Tinklepaugh, Betty (1957), concluded that "the discovery of a locally dolomitized limestone does not ensure finding gas or oil". Tinklepaugh further concluded that favorable structural position along with porosity is necessary for oil accumulation. In the Deep River, North Adams and Pinconning fields dolomitization may occur in areas other than those of highest structural position. The dolomitization is confined to and dependent upon the zone of fracturing and faulting and the porosity accompanies the dolomitization, allowing the oil to accumulate.

Landes (1946), has suggested that in areas where oil is known to occur in reservoirs of the type in the Deep River field that exploration should not be confined to the tops of anticlines. He suggests that samples be analyzed for Ca/Mg content and that samples containing a high percent of Mg would encourage exploration laterally in the hope of finding true dolomite.

Further drilling in the Deep River, North Adams and Pinconning fields is unlikely. All attempts to extend the fields beyond their present limits have proven unsuccessful. At the present time one company is applying gravity meter readings, taken from the Deep River field, to similar anomalies in the Arenac County area in the hope of finding other similar fields.

APPENDIX A

The following is a list of the wells from the Deep River, North Adams and Pinconning fields which were examined for dolomite content. The method of examination has been explained under Laboratory Procedure.

Deep River Field:

Permit No.	Name & Operator	Location
#9506	Nowoielski #1 Basin & Rayburn	C-S½-SE¼-SE¼, sec. 8
#10924	S. Flick #1 Ervin Major	NW¼-NW¼-SW¼, sec. 9
#10621	Mann et al #1 Basin & Rayburn	C-S½-SW¼-SW¼, sec. 5
#10974	Sinn #1 Pure Oil Co.	NE¼-SE¼-NW¼, sec. 16
#10791	Kocot #1 M. Holloway	NE¼-NW¼-NW¼, sec. 16
#3619	Fish #1 Central Drilling	SW¼-NE¼-SE¼, sec. 16
#10672	Weber et al #1 Gordon Oil Co.	C-S½-NW¼-NE¼, sec. 7
#10433	Welbo #1 Basin & Rayburn	C-S½-NW¼-NW¼, sec. 8
#10869	Peters #B-1 Basin & Rayburn	SE¼-SE¼-NE¼, sec. 7

North Adams Field:

#8436	T. Bryan #B-1 Ervin Major	NE¼-NE¼-SW¼, sec. 22
#10549	T. & E. Bryan #3 Ervin Major	SE¼-SE¼-SW¼, sec. 22
#11318	Dunham #2 Major	NW¼-NW¼-NE¼, sec. 14
#9008	Moore #B-1 Rayburn & Major	NW¼-SW¼-SE¼, sec. 22
#10855	Dunham #1 Major	NW¼-SW¼-NE¼, sec. 14

APPENDIX A

North Adams Field: (Continued)

#8044	Ostrosky #1 Pure Oil Co.	NW¼-NE¼-SE¼, sec. 22
#9169	Bryan #2 Major	SE¼-NE¼-SW¼, sec. 22
#8181	U.S.A. #1 Rayburn	SE¼-SW¼-SE¼, sec. 15
#7872	State-Arenac #A-1 Pure Oil Co.	SE¼-SE¼-SW¼, sec. 15
#7901	Bryan #1 Pure Oil Co.	NW¼-SW¼-NW¼, sec. 23
#7880	Stone #1 Smith Pet.	SW¼-SW¼-SW¼, sec. 14
#14484	State-Adams #1 McClanahan	NE¼-NE¼-SE¼, sec. 2
#9711	Allen #1 Smith Pet.	C-SW¼-SW¼, sec. 13
#13655	State-Adams #C-1 Rayburn	SW¼-SW¼-NE¼, sec. 10
#7875	J. Ames #1 American Drilling	SW¼-NW¼-NW¼, sec. 23
#7961	Rockafellow #2 Teater	NW¼-SE¼-NE¼, sec. 22
#8300	McTaggart #A-1 Pure Oil Co.	NW¼-NW¼-SE¼, sec. 22
#8472	McTaggart #A-2 Pure Oil Co.	NE¼-NW¼-NE¼, sec. 22
#9158	Collins #2 Teater	SE¼-SE¼-SE¼, sec. 15
#10497	Collins et al #3 Teater	NE¼-SE¼-SE¼, sec. 15
#8043	Yenoir #1 Pure Oil Co.	NE¼-SE¼-NW¼, sec. 22
#10622	Haslett #1 Teater	SW¼-NW¼-SW¼, sec. 14
#10932	State-Adams #3 Bolger & Rose	NE¼-SW¼-NW¼, sec. 14

Pinconning Field:

#12213	Kurzeja & Drake #A-2 Swan-King Oil	SE¼-SE¼-SW¼, sec. 35 Pinconning Twp.
#10944	M. Koth #1 Shell Oil	SW¼-NE¼-NW¼, sec. 2 Frazer Twp.
#13811	State-Con. Power #1 Basin Oil Co.	SE¼-SW¼-SE¼, sec. 35 Pinconning Twp.

APPENDIX A

Pinconning Field: (Continued)

#13809	Paterek #1 Swan-King Oil	SW¼-SE¼-NE¼, sec. 35 Pinconning Twp.
#17595	Zuziak #2 Ogma	SW¼-NE¼-SW¼, sec. 25 Pinconning Twp.
#13765	Amoyotte et al #1 Swan-King Oil	NW¼-SW¼-SE¼, sec. 35 Pinconning Twp.
#11106	Kurzeja #1 Shell Oil Co.	SW¼-SE¼-SW¼, sec. 35 Pinconning Twp.
#12860	Kurzeja & Drake #3 Swan-King Oil	SE¼-SE¼-SW¼, sec. 35 Pinconning Twp.
#13919	S. Kurzeja #1 Swan-King Oil	NE¼-SE¼-NE¼, sec. 35 Pinconning Twp.
#12615	Bartman #1 Ward Oil	NE¼-NE¼-NE¼, sec. 35 Pinconning Twp.
#13578	Drake et al #1 Swan-King Oil	SE¼-SW¼-SE¼, sec. 35 Pinconning Twp.
#12152	Kurzeja #2 Swan-King Oil	NE¼-SW¼-NW¼, sec. 2 Frazer Twp.
#13688	Sisson #1 Ward Oil Co.	SE¼-SE¼-SW¼, sec. 34 Pinconning Twp.
#12224	Baublitz #1 C. Collin	C-SW¼-NW¼-SW¼, sec. 35 Pinconning Twp.

APPENDIX B

The following are the results of the laboratory examination of two wells, one well a producer and one well a dry hole, from each of the Deep River, North Adams and Pinconning oil fields. These wells are used as examples in showing the conditions existing in the fields as a whole and each well has been discussed under the previous section titled RELATIONSHIP OF THE PRODUCING WELLS TO SECONDARY DOLOMITIZATION.

APPENDIX B

Permit #: 10924 (Oil)

Well Name: Stanlisan Flick #1

Operator: Ervin Major

Location: NW¼-NW¼-SW¼, sec. 9, T19N, R4E

Sample Interval	Reaction with 6N HCl
2802-2807	Limestone
2807-2816	Limestone
2816-2820	Limy-Dolomite
2820-2825	Limy-Dolomite
2825-2832	Dolomite
2832-2836	Dolomite

APPENDIX B

Permit #: 9506 (dry hole)

Well Name: Nowoielski-Switzer-Receiver Comm. #1

Operator: Basin Oil Co. & Don Rayburn

Location: C-S½-SE¼-SE¼, sec. 8, T19N, R4E

Sample Interval	Reaction with 6N HCl
2773-2784	Limestone
2784-2788	Limestone
2788-2800	Limestone
2800-2810	Limestone
2810-2815	Limestone
2815-2820	Limestone
2820-2830	Limestone
2830-2837	Limestone
2837-2841	Limestone
2841-2852	Limestone
2852-2861	Limestone
2861-2871	Limestone
2871-2880	Dolomitic-Limestone
2880-2895	Limestone
2895-2904	Limestone
2904-2915	Limestone

APPENDIX B

Well Name: Nowoielski-Switzer-Receiver Comm. #1 (Continued)

Sample Interval	Reaction with 6N HCl
2915-2927	Limestone
2927-2941	Limestone
2941-2949	Limestone
2949-2960	Limestone
2960-2970	Limestone
2970-2978	Limestone
2978-2990	Limestone
2990-3003	Limestone
3003-3010	Limestone
3010-3013	Limestone
3013-3122	Limestone
3122-3028	Limestone
3028-3032	Limestone
3032-3040	Limestone
3040-3055	Limestone
3055-3067	Limestone
3067-3075	Limestone
3075-3082	Limestone
3082-3090	Limestone
3090-3103	Limestone

APPENDIX B

Well Name: Nowoielski-Switzer-Receiver Comm. #1 (Continued)

Sample Interval	Reaction with 6N HCl
3103-3110	Limestone
3110-3132	Limestone
3132-3147	Limestone

APPENDIX B

Permit#: 10549 (Oil)

Well Name: Thos. & Edith Bryan #1

Operator: Ervin Major

Location: SE¼-SE¼-SW¼, sec. 22, T19N, R3E

Sample Interval	Reaction with 6N HCl
2881-2886	Dolomite
2886-2890	Dolomite
2890-2896	Limestone
2896-2908	Limestone
2908-2916	Limestone

APPENDIX B

Permit Number: 8436 (Dry Hole)

Well Name: Thomas Bryan #B-1

Operator: Ervin Major

Location: NE¼-NE¼-SW¼, sec. 22, T19N, R3E

Sample Interval	Reaction with 6N HCl
2874-2877	Limestone
2877-2879	Limestone
2879-2883	Limestone
2883-2890	Limestone
2890-2896	Limestone
2896-2908	Limestone
2908-2918	Limestone
2918-2921	Limestone
2921-2928	Limestone
2928-2938	Limestone
2938-2944	Limestone
2944-2955	Limestone
2955-2961	Limestone
2961-2967	Limestone
2967-2970	Limestone
2970-2978	Dolomitic-Limestone

APPENDIX B

Well Name: Thomas Bryan #B-1 (Continued)

Sample Interval	Reaction with 6N HCl
2978-2979	Dolomitic-Limestone
2979-2983	Dolomitic-Limestone
2983-2993	Dolomitic-Limestone
2993-3000	Limestone
3000-3010	Limestone
3010-3025	Limestone
3025-3035	Limestone
3035-3042	Limestone

APPENDIX B

Permit Number: 10944 (Oil)

Well Name: Margaret Koth #1

Operator: Shell Oil Company

Location: SW¼-NE¼-NW¼, sec. 3, T16N, R4E

Sample Interval	Reaction with 6N HCl
2822-circ.	Limy-Dolomite
2822-circ. 1hr	Dolomitic-Limestone
2820-2825	Limy-Dolomite
2826-circ30	Limestone
2826-circ60	Limy-Dolomite
2825-2830	Limy-Dolomite
2830-2835	Limestone
2835-2840	Limestone
2840-2845	Dolomitic-Limestone
2845-2850	Limestone
2850-2855	Limestone
2855-2860	Limestone
2860-2865	Dolomitic-Limestone
2865-2870	Dolomitic-Limestone
2870-2875	Limestone
2875-2877	Limestone

APPENDIX B

Well Name: Margaret Koth #1 (Continued)

Sample Interval	Reaction with 6N HCl
2877-circ	Dolomitic-Limestone
2877-circ30	Limestone
2877-2880	Dolomitic-Limestone
2880-2885	Limestone
2885-2890	Limestone
2890-2895	Limestone
2895-2900	Limy-Dolomite
2900-2905	Dolomite
2905-2910	Dolomite
2910-2915	Dolomite
2915-2920	Dolomite
2920-2922	Dolomite
2922-2932	Dolomite
2932-2937	Dolomite
2937-2942	Limy-Dolomite
2942-2945	Dolomite
2945-2950	Dolomite
2950-2965	Dolomite
2965-2975	Dolomite
2975-Bottom of well at 3012'	Dolomite

APPENDIX B

Permit Number: 12213 (Dry Hole)

Well Name: Kurzeja and Drake #A-2

Operator: Swan-King Oil Company

Location: SE¼-SE¼-SW¼, sec. 35, T17N, R4E

Sample Interval	Reaction with 6N HCl
2853-2860	Limestone
2860-2871	Limestone
2871-2875	Limestone
2875-2880	Limestone
2880-2885	Limestone
2885-2890	Limestone
2890-2904	Limestone
2904-2909	Limestone
2909-2915	Limestone
2915-2920	Dolomite
2920-2925	Limy-Dolomite
2925½-2926½	Limy-Dolomite
2927-2931	Dolomitic-Limestone
2931-2934	Dolomitic-Limestone

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