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INFORMATION ON MICHIGAN SILURIAN OIL AND GAS POOLS

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CONTENTS

Introduction.....	1
Michigan Basin.....	2
Silurian Period.....	2
Silurian Subsurface Terminology.....	3
Silurian-Devonian Unconformity.....	4
Silurian Oil and Gas Pools.....	4
Oil and Gas.....	10
Silurian Oil and Gas Pool Tables.....	11
Gas Storage Reservoirs.....	12
Silurian Prospects.....	12
References.....	14

TABLES

I. Annual Oil Production by Formations, Bbls.	11
II. Annual Gas Production by Formations, Mcf	11
III. Active Silurian Oil and Gas Pools Through 1962.....	12
IV. Silurian Gas Pools Converted to Gas Storage Reservoirs Non-Developed Silurian Gas Storage Reservoirs	12

FIGURES

1. Generalized Columnar Section of Michigan	3
2. Generalized Areal Geologic Map of Michigan	3
3. Paleogeologic Map of Eroded Silurian Strata.....	5
4. Overisel Field	6
5. Overisel Fidle – Generalized Cross-Section.....	6
6. East Pullman Field	7

7. East Pullman Field – Genearlized Cross-Section.....	7
8. Core Photographs – Ray and Belle River Mills Fields.....	8
9. Berlin Field	9
10. Boyd Field	10
11. Boyd Field – Generalized Cross-Section	10
12. Location of Silurian Gas and Oil Fields	12

INTRODUCTION

Michigan's first commercial oil field was discovered at Port Huron, St. Clair County, in 1886. By 1910, 21 shallow wells had been completed in the Dundee formation at depths of about 500 to 650 feet. In 1910 the daily production from this field amounted to about 10 barrels of oil per day, all of which was used locally in the manufacture of lubricants. However, it was not until 1925 when the Saginaw field was discovered that Michigan began to produce significant quantities of petroleum. The wells in the Saginaw field produced oil from the Berea sandstone, a Mississippian formation lying at a depth of about 1825 feet in the city of Saginaw. In 1927 on the western side of the state at Muskegon, oil and gas were found in the Dundee formation. By 1928 a Dundee oil field had been established near Mt. Pleasant in Isabella County. Since then more than 400 oil and gas accumulations have been found in Mississippian, Devonian, Silurian, and Ordovician formations. In drilling to Devonian reservoir rocks, formations of Pennsylvanian and Mississippian age are penetrated. In the course of exploration, Mississippian and Devonian formations have received the most attention and are thus credited with a greater number of oil and gas pools. To date the Devonian formations have produced most of Michigan's petroleum and Mississippian formations have produced most of the gas. But, since 1942, Mississippian and Devonian oil production has steadily decreased, and Mississippian gas production has shown an annual decline which began about 1947, the peak year. In contrast, oil and gas production from Silurian and Ordovician rocks has increased in recent years. Exploitation of these rocks is not entirely new to Michigan since gas was produced from Silurian formations in St. Clair County as early as 1927, and some Ordovician oil was produced from wells in Monroe County as early as 1920. However, the productive history for these older formations essentially begins in 1938 for the Silurian, and in 1935 for the Ordovician, Silurian and Ordovician formations have been increasingly popular drilling objectives in recent years, especially in the shallower parts of the basin. Accordingly, as more exploration of these older formations has been done, more new pools have been found, and substantial gains have been made annually in the amount of oil and gas produced from them. Since 1960 more than half of Michigan's annual oil production and nearly one-third of the annual gas production has come from Ordovician rocks. The large increase from Ordovician reservoirs is mainly due to the discovery and

development of the Albion-Scipio Trend in 1957, through 1961. The increase in Silurian oil and gas production has been less spectacular, but the gain is impressive. In the recent cycle of exploration activity in Michigan, Silurian rocks have played an important part, and the results have been encouraging. Four Silurian pools were found from 1927 through 1941; 5 from 1951 through 1953; 5 from 1955 through 1956; 6 from 1958 through 1959; and 17 from 1960 through 1962. The increasing number of new Silurian pools points out the probability that a large share of Michigan's future oil and gas reserves may be hidden in these rocks. It is probable that a large number of new pools will be found in these rocks in the years ahead.

The purpose of this report is to present general information of value to individuals or groups interested in the Silurian rocks of Michigan as a source of petroleum and natural gas. The geology of Michigan's Silurian rocks is complicated in numerous ways. Some aspects of the stratigraphy relating to the oil and gas producing formations are controversial. There is no intent herein to present the complete geology of Silurian oil and gas pools, or to compare various viewpoints relating to them. Those interested in the Silurian System will no doubt pursue their own investigations and form their own conclusions. The views expressed by statement and by illustration represent but one of several interpretations. The information has been compiled from Michigan Geological Survey reports, other reports relating to Silurian geology, from well records, and from electric log-sample description studies.

THE MICHIGAN BASIN

The Michigan basin is a relatively shallow intracratonic basin which includes the Southern Peninsula, the Northern Peninsula, and portions of Wisconsin, Illinois, Indiana, Ohio, and Ontario, Canada which are contiguous to Michigan. The basin is nearly circular in shape and is flanked by several prominent geanticlines. It is bordered on the west by the Wisconsin arch in central Wisconsin; on the south by the Kankakee arch in northern Indiana and the Findlay arch in northwestern Ohio; and on the east by the Algonquin arch in Ontario, Canada. On the north, the basin abuts a part of the Canadian Shield.

The deepest part of the basin is projected to be in a part of Clare and Gladwin counties in central Michigan. In this region it is estimated that about 14,000 - 15,000 feet of sediments overlie the Precambrian. With the exception of the Pleistocene glacial deposits, all the rocks lying above the Precambrian belong to the Paleozoic, and are represented by formations of the Cambrian, Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian Systems. Some rocks of possible Permian age are also present. The sediments of these systems are principally carbonates, shales, evaporites, and sandstones (Figure 1). The basin is almost everywhere covered with Pleistocene glacial drift which

may be as much as 1000 feet thick in some northern counties.

SILURIAN PERIOD

Rocks of Early, Middle, and Late Silurian age are present throughout most of the Michigan basin. They are thickest in the central part of the basin where they are estimated to be over 4,000 feet thick. They are almost everywhere overlain by Devonian formations (Figure 2) and from the central part of the basin they thin outward "toward the margin where they subcrop beneath the Pleistocene glacial drift, or are exposed at the surface at various localities. Outcrops of Silurian rocks in Michigan are found in the Northern Peninsula in the Straits of Mackinac region. From this region they extend in an arcuate belt southwestward to form a part of the Dorr Peninsula of Wisconsin, and southeastward to form part of the island chain extending into the Bruce Peninsula of Ontario, Canada. At the southern edge of the basin, Silurian rocks also subcrop beneath the glacial drift, or are exposed at the surface in parts of Monroe County in southeastern Michigan, in northern Ohio, northern Indiana, parts of Ontario, and at various localities in northeastern Illinois around the southern end of Lake Michigan.

It has been estimated that the Michigan basin contains 108,000 cubic miles of sediments. Silurian rocks account for over 30 percent of this volume (Cohee and Landes, 1958, pp. 478-479). A large part of this volume, probably one-third to one-half, can be attributed to beds of nearly pure rock salt contained in the Upper Silurian sequence. The rocks of the Silurian System have been variously divided into a number of biostratigraphic and lithostratigraphic units, most of which are based on outcrop studies. Early Silurian rocks (Alexandrian Series) consist of the Cataract group composed of two formations, the Manitoulin dolomite and the overlying Cabot Head shale. Middle Silurian rocks (Niagaran Series) are predominantly carbonates with some chert zones and thin, minor shale beds. These rocks are commonly divided, in ascending order, into the Burnt Bluff group, the Manistique group, and the Engadine dolomite-often referred to as Guelph-Lockport. The Burnt Bluff group consists of three formations which, in ascending order, are called: Lime Island dolomite, Byron dolomite, and Hendricks dolomite. The Manistique group consists of the Schoolcraft dolomite and the overlying Cordell dolomite.

The stratigraphy of Niagaran rocks is complicated by extensive reef and carbonate bank-type deposits associated with the basin margin. Further, the Niagaran sequence as recognized in the outcrop areas and in the subsurface of the basin margin does not correspond entirely to the sequence as known in the deeper parts of the basin. The Niagaran rocks are thickest on the basin margins and platform areas and thinnest in the basin interior. Extensive reef development on the margins of the basin in late Niagaran time is believed to have been

instrumental in the development and deposition of a thick sequence of evaporites and carbonates of Late Silurian age. These rocks appear to conformably overlie the Niagaran in most parts of the basin.

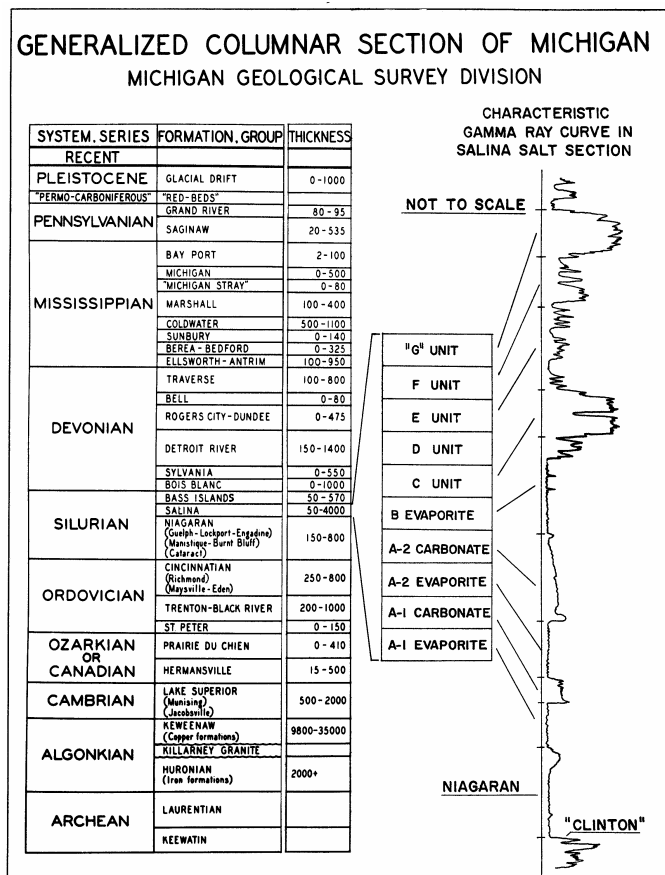


Figure 1

Late Silurian rocks (Cayugan Series) consist of the Salina group and the overlying Bass Islands group. In the Mackinac Straits area where these rocks crop out, they are known, respectively, as Pointe aux Chenes shale and St. Ignace dolomite. Rocks of the Bass Islands group are also exposed at the surface in Monroe County in southeastern Michigan, in parts of northern Ohio, and on several islands in western Lake Erie. In the subsurface where Late Silurian rocks are best developed and widespread, a different terminology is applied to the rock units.

SILURIAN SUBSURFACE TERMINOLOGY

The formal names applied to outcrops of Silurian rocks are infrequently used in everyday, routine subsurface geology. Different terms are applied to the subsurface sequence of Middle and Late Silurian age rocks. Early Silurian rocks of the Alexandrian Series are generally called by their formal names, either as Cataract group or as Cabot Head Shale and Manitoulin Dolomite. The rocks of the Niagaran Series are sometimes mapped and designated as Niagara group (Cohee, 1948). More

commonly, the names used are drillers terms such as "Brown Niagaran," "White Niagaran," or "Gray Niagaran." These terms have some utility and are based on color differences, textural differences, and stratigraphic occurrence. In some areas it is possible to divide the Niagaran into two or three gross lithological units which are useful for subsurface mapping purposes. The general drillers terms, or other unit designations, are used because it is difficult, except in limited areas, to recognize most of the formations as defined from outcrop studies based largely on paleontological criteria.

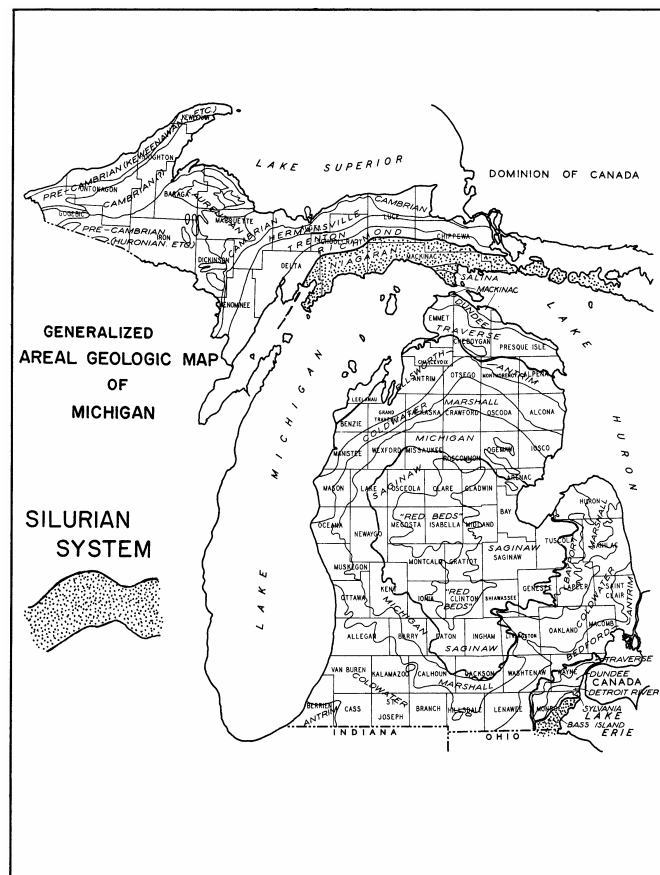


Figure 2

The rocks of Late Silurian age have the most extensive subsurface terminology, based largely on the original subsurface work of Landes (1945) and others. The terms applied to Cayugan rocks are being modified as more information becomes available. The Salina and Bass Islands rocks have been divided into units which are equivalent to formations. In some cases it is possible to further divide individual units into members. Figure 1 shows the terms commonly applied to Salina and Bass Islands rocks by many geologists working in the gas and oil industry.

The subsurface units are based on lithologic character and stratigraphic position. Most of these units may be traced laterally over a large part of the Michigan basin, especially where the evaporite (salt or anhydrite) units are present. Thick salt beds separate the important oil and gas bearing carbonates of the Salina group. Where the Salina is thickest, the salt beds

are well developed and may be traced laterally for many miles. But as they are traced toward the edge of the basin, they thin, often grade into anhydrite, and finally pinch out against the basinward flanks of the carbonate bank and reef complex. In the parts of the basin where salt or anhydrite beds are present, the normal sequence for the lowermost units of the Salina overlying the Niagaran rocks are, in ascending order, as follows: A-1 Evaporite (salt or anhydrite), A-1 Carbonate, A-2 Evaporite (salt or anhydrite), A-2 Carbonate, B Evaporite, etc. The evaporite beds pinch out on the edge of the basin and the A-1 and A-2 Carbonates converge and lie directly on Niagaran rocks. On the edges of the basin there is some lateral change in the character of the A-1 and A-2 Carbonates and also differences in thickness due to non-deposition, erosion, or influence of underlying Niagaran reefs. In those areas where evaporite beds are absent, and where convergence and change in character of A-1 and A-2 Carbonates occurs, differentiation of Salina carbonates from Niagaran carbonates is not always possible.

The oil and gas bearing units of the salina are the A-1 Carbonate, the A-2 Carbonate, possibly dolomite beds in the lower part of the B unit in some areas, and a porous dolomite in the E unit. Terms that are synonymous with these units, and also smaller divisions of these units, are as follows:

A-1 Carbonate. Another term commonly applied to this unit is "A-1 dolomite." The A-1 Carbonate is predominantly composed of limestone, dolomite, or both. On the edge of the basin where the salt units are very thin or are absent, the unit is a dolomite. Over reefs (St. Clair and Macomb counties) the unit may be entirely a dolomite. Over large areas it contains a small division of rock called "poker chip shale." The "poker chip shale" is composed of very thin laminations of dolomite separated by carbonaceous films. Upon weathering, the laminations split along the carbonaceous layer. The A-1 Carbonate may locally contain one or two thin beds of anhydrite which are included within the unit.

A-2 Carbonate. In western and southwestern Michigan this unit is commonly divided into two parts; a lower part called "A-2 lime," and an upper part called "A-2 dolomite." The A-2 Carbonate, like the A-1 Carbonate, may be all limestone, dolomite, or both. The basal part of the unit also may contain "poker chip shale." In the basin proper it may also contain thin beds of anhydrite in the upper part.

The A-1 Evaporite is nearly a pure salt over most of the basin. On the edge of the basin the unit is represented by an anhydrite bed. Where anhydrite is dominant the unit is called "A-1 anhydrite"; where salt is the main constituent, the unit is called "A-1 salt." The A-2 Evaporite is also often called according to the dominant evaporite component. In the basin the unit is predominantly a salt bed, but on the edges of the basin it is represented by anhydrite. Over Niagaran reefs the A-2 Evaporite is often represented entirely by anhydrite, usually found at the top and at the base of the salt in off-

reef wells. In the reef fields the practice is to call an "A-2 anhydrite" and an "A-2 salt." The occurrence of an all anhydrite A-2 Evaporite in areas where this unit is a thick salt may indicate the presence of an underlying, or nearby reef.

E unit. Oil is produced from a porous dolomite in the E unit in the Diamond Springs field, Allegan County. The porous dolomite is usually called "E zone," and less frequently, "Kintigh zone."

SILURIAN-DEVONIAN UNCONFORMITY

Salina and Bass Islands rocks are thickest in the central part of the basin, and from this region they thin outward toward the edge of the basin. Much of the thinning is due to the non-deposition of salt beds, the solution and leaching out of salt beds in local areas, and one or more periods of post-Silurian erosion. Truncation of Upper Silurian rocks is especially evident for a large area of southwestern Michigan. Because Salina and Bass Islands formations can be traced with considerable confidence over most of the Michigan basin, it is possible to map the Silurian erosional surface in its general and broader aspects (Figure 3). The erosion surface in southwestern Michigan is overlain everywhere by Devonian strata but the age varies because of probable unconformities involving Lower and lower Middle Devonian formations. From the central basin southwestward, Devonian rocks lie upon successively older and stratigraphically lower formations of the Salina group. In the extreme southwestern corner of Michigan, Salina rocks appear to have been completely removed so that Devonian rocks are in direct contact with those of the Niagaran. The oil and gas bearing A-1 and A-2 Carbonates, as well as the potentially productive "E zone," appear to have been removed over a considerable area.

SILURIAN OIL AND GAS POOLS

The Silurian oil and gas pools discovered to date are in the upper part of the Niagaran Series and in the lower formations of the Salina group. Early Silurian rocks (Manitoulin dolomite and Cabot Head shale) have not produced oil or gas although the Manitoulin dolomite is often porous and water bearing. Most Niagaran oil and gas pools are related to reefs and reef associated sediments. A few may be related to biostromes. Salina oil and gas pools are found in the A-1 and A-2 Carbonates and, in one field, a porous dolomite in the E unit.

Most Silurian pools are located around the southern edge of the basin (Figure 12). The bulk of those so far discovered are found in the St. Clair-Macomb county areas in southeastern Michigan and in Allegan County, southwestern Michigan. Others occur at random in different areas around the rim of the basin. The Silurian

pools are of several general types; Niagaran reefs, reef associated structures, accumulations relating primarily to deformation, and porosity traps apparently not related to reefs or to deformation. All the aforementioned types of accumulations have porosity and permeability variations particular to the pool. In the southeastern part of the state, oil and gas are contained in Guelph-Lockport reefs and in the A-1 Carbonate which overlies the reef. In southwestern Michigan, most production is obtained from the A-1 and A-2 Carbonates where deformation, or some other mechanism, has formed anticlinal type traps. The majority of A-1 and A-2 pools have been found by deeper drilling on Devonian Traverse limestone structures. Whether or not this type of accumulation is unique to this area cannot be judged at this time.

Anticlinal Traps.

Most Silurian oil and gas pools related to anticlinal traps are found in Allegan County. All have been found by deeper drilling in older, Devonian Traverse limestone fields. The earliest Silurian production from this area was from a single gas well drilled in the Salem field in 1937. Also, an attempt was made to develop a Silurian oil pool in the Dorr field in 1942. A small amount of heavy, black, 22 gravity oil was produced from the A-1 Carbonate, but the venture was shortly abandoned, and no further development took place until 1956. In 1956 gas was discovered in the A-2 Carbonate beneath the Overisel Traverse limestone structure, Allegan County. Since then a number of Traverse structures have been drilled deeper and new Silurian gas and oil pools have been added to these older fields. Where enough Silurian wells have been drilled on the Traverse structures to furnish adequate data. It is seen that structure in the Salina A-1 and A-2 Carbonates conform remarkably well with Traverse structure. Salina units younger than A-2 Carbonate, and Devonian beds older than Traverse limestone also conform to the general structural pattern. There is some thinning in various formations over these structures and also some slight shift in closure. The porosity and permeability in the oil and gas bearing intervals of the A-1 and A-2 Carbonates varies over the structures. Silurian tests drilled off structure or where little Traverse structure is present, have not resulted in oil or gas wells.

Allegan County is partly situated on the pinch-out line of the Salina salt beds. The F & D Evaporites do not extend into this area. and the B and A-2 Evaporites are represented by relatively thin anhydrite beds. However, the A-1 Evaporite, as a salt bed, extends part way into Allegan County, and then grades into a thin anhydrite bed. Data obtained from drilling "on" and "off" structure seems to indicate that the larger structures such as Overisel, Salem, and others, are salt cored. Structure in the A-1 and A-2 carbonates appear to be related to a localized A-1 salt body. The salt lense is about 150 feet thick in Overisel and 100 to 186 feet thick in the Salem field, a multi-closure structure.

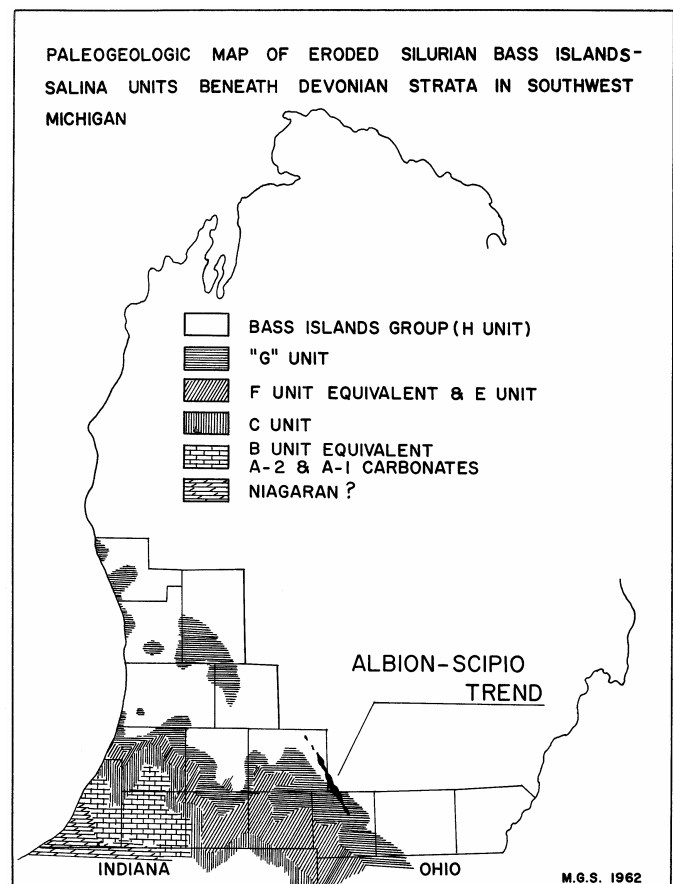


Figure 3

The Overisel field is cited as an example of a salt cored structure (Figures 4 and 5). The Silurian pool is representative of the larger Salina A-2 Carbonate pools that have been developed by deeper drilling on Traverse structures. The Traverse oil pool was discovered in 1938 and covers about 1770 acres. The A-2 pool was discovered in 1956. The area of A-2 gas production covers about 6,600 acres. Approximately 25 feet of lensed gas pay has been recorded in this field at a depth of about 2,650 feet. A few wells are reported to make a very small amount of oil along with the gas. The A-1 Carbonate has not been explored adequately in this field and little is known of its potential. The Overisel A-2 pool was converted to a gas storage reservoir in 1960.

The gas pay is possibly in the lower part of the B Evaporite equivalent and in the upper part of the A-2 Carbonate. It is generally described as a light tan to buff, finely crystalline dolomite, imbedded with thin layers of anhydrite. The producing interval has an overall thickness of 58 to 60 feet but usually not more than one-half the section is permeable. The porosity is intercrystalline and no solution porosity has been observed except for some isolated vugs. Porosities measured in those parts of the section which have a permeability of 0.1 md. or more, are said to range from a minimum of 2.6 percent to a maximum of 22.2 percent. The permeability of the dolomite within the reservoir is said to range from 0.1 md. to a maximum of 29.0 md. Permeable lenses are separated by beds of low

permeability or beds of no permeability, which in some cases are anhydrite. The producing section is said to have an interstitial water content of approximately 29 percent (Fruechtenicht, p. 42, 1960).

The Salem field, another Traverse structure a few miles to the east of the Overisel field, also has a Salina A-2 Carbonate gas pool apparently associated with localized A-1 salt lenses. The first Salina gas well was drilled in 1937, but it was not until 1958, following Overisel, that the Salina A-2 pool was developed. The A-1 Carbonate in this field has not been extensively drilled and little is known of its gas potential. A small amount of oil is produced from a few wells in the A-2 Carbonate.

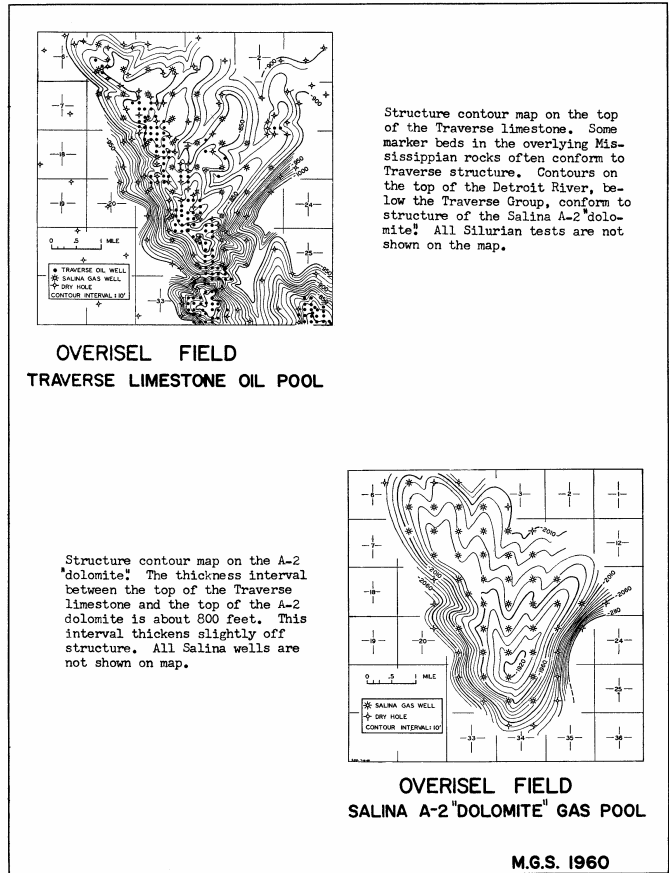


Figure 4

Some reservoir data are tabulated for the Overisel and Salem A-2 dolomite pools.

	Overisel	Salem
Average Porosity of Gas Pays	10.8% (50 wells)	11.3% (50 wells)
Average Permeability of Gas Pays . .	2.04 md. (50 wells)	2.09 md. (50 wells)
Estimated Original Gas Reserves . .	67,000,000 MCF	57,272,000 MCF

Abrupt thinning or absence of salt a short distance from thick salt beds has been attributed to leaching of the salt and subsequent collapse of the overlying beds, thereby forming "psuedo-anticlines" over localized salt bodies (Landes, 1948). This is a definite possibility and some localised salt bodies may be attributed to those factors. Cores of the A-1 and A-2 Carbonates frequently show fractures which are sometimes filled with salt or anhydrite. The fractures strengthen the collapse theory

but do not necessarily indicate collapse. Gamma Ray-Neutron logs of field wells "on" and "off" structure, and away from the structure, show excellent correlation of Salina units and other formations, and do not seem to indicate collapse and brecciation. Many of the fractures are in thin bands and apparently of an intraformational nature. The fractures may be due to movement of the underlying salt bed upon loading with sediments and before the sediments were completely indurated. Further deformation at later times served to fracture the confining rocks and localize, by flowage, salt bodies giving rise to structural closure in the A-1 and A-2 Carbonates. Close structural similarity between Upper Silurian, Devonian, and sometimes Early Mississippian rocks suggests at least post-Devonian deformation. The similarity may actually be due to a combination of post-Devonian deformation, Salina A-1 salt movement, and some leaching of salt and resulting collapse of overlying rock.

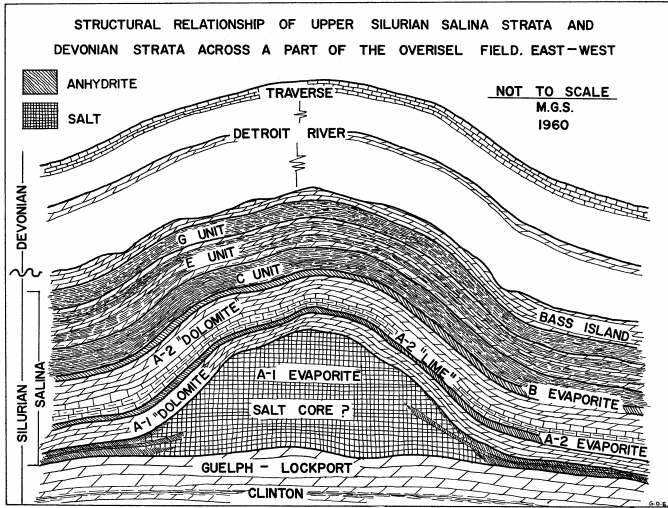


Figure 5

Known Silurian oil and gas pools coincident with Traverse structures, and apparently with localized A-1 salt bodies beneath the A-1 carbonate, are as follows:

Field	County	Pools	Production
Dorr	Allegan	Traverse limestone	oil
		Detroit River	oil & gas
		A-2 Carbonate	oil & gas
		A-1 Carbonate	oil & gas
Fillmore	Allegan Ottawa	Traverse limestone	oil
		A-2 Carbonate	gas
Hilliards	Allegan	A-1 Carbonate	gas
		Traverse limestone	oil
Hopkins, West	Allegan	A-1 Carbonate	gas
		Traverse limestone	oil
		A-2 Carbonate	oil
Overisel	Allegan	A-1 Carbonate	oil
		Traverse limestone	oil
		A-2 Carbonate	gas
Field	County	Pools	Production
Salem	Allegan	Traverse limestone	oil
		Detroit River	gas
		A-2 Carbonate	gas
Wayland	Allegan	Traverse limestone	oil
		A-1 Carbonate	oil

Reef Associated Structures.

The East Pullman field, Allegan County, is an example of a Niagaran reef coincident with structural closure in Devonian and Mississippian rocks. The East Pullman field was drilled and developed as a Traverse Limestone

oil pool in 1949. The first deeper pool test was drilled in 1961. Located high on the Traverse structure (Figure 6) the well was drilled through the Niagaran and into rocks commonly called "Clinton" in this area. Over 725 feet of Niagaran section was logged in this hole (the discovery well for the Berlin field, one of the taller Niagaran reefs in St. Clair County, was drilled completely through the Niagaran and about 475 feet of section was logged). The deeper pool test was plugged back to about 1810 feet and completed as a gas well in the A-2 Carbonate rather than the reef which appears to be mainly water-filled. The (A)IP of this well was 4,800 MCF gas per day, gauged. Two other wells were drilled on structure and the Niagaran was found to be high. Other wells were drilled on the north and south flanks of the Traverse structure (Figure 6) and the Niagaran was structurally low. The well on the south flank was drilled to the Clinton markerbeds but only about 400 feet of Niagaran section was logged. This well was unproductive of oil or gas in all formations. The well on the north flank was also reported unproductive of oil or gas in the Silurian formations.

The East Pullman field is well outside the area of Salina salt deposition, but the A-1, A-2, and B Evaporites are represented by relatively thin anhydrite beds. The response of the Salina units to the topographic features of the reef beneath the East Pullman field is similar to that of the Salina over the reefs in St. Clair and Macomb counties. Off-reef the A-1 Evaporite and A-1 Carbonate are represented by thicknesses normal for the region. These beds pinch-out against the flank of the reef and are not present on the reef crest. The A-2 Evaporite also thins against the reef and is not present on the higher parts. The A-2 Carbonate (generally divided into two units, an upper "A-2 dolomite" and a lower A-2 "lime" in this region) is well developed off-reef. But over the reef it thins, principally by pinch-out of the lower unit, and by some thinning of the upper unit. Other units of the Salina, the B Evaporite equivalent, the C unit, the E, F, and G units, are represented off-reef by thicknesses normal for the region. However, over the reef all units from about the middle of the C unit upward appear to have been truncated by erosional processes. The relationship of Salina units, and the truncation of these units, over the reef are illustrated by Figure 7. The illustration is based on Gamma Ray-Neutron log correlations, lithologic logs, and other field and regional geologic data.

From the few Silurian wells drilled to date in this field, it is apparent that a Niagaran reef is coincident with structural closure in Upper Silurian Salina units, in formations of Devonian age, and as high stratigraphically as the base of the Coldwater "red rock," a Mississippian marker-bed. In the Illinois basin which is similar to the Michigan basin, structure in Devonian and Mississippian formations in some oil and gas fields is said to be related to Niagaran reefs (Lowenstam, p. 34, 1949).

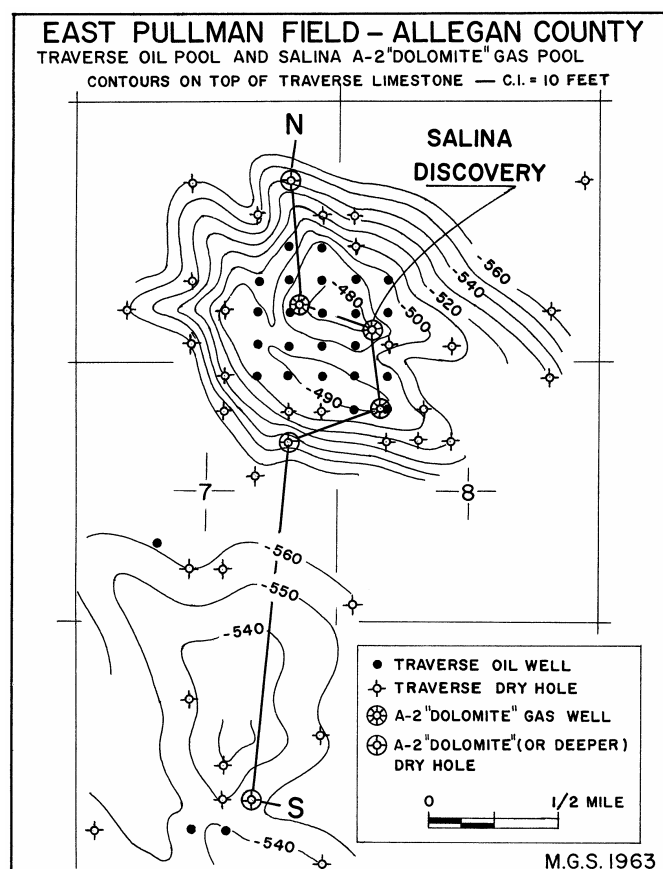


Figure 6

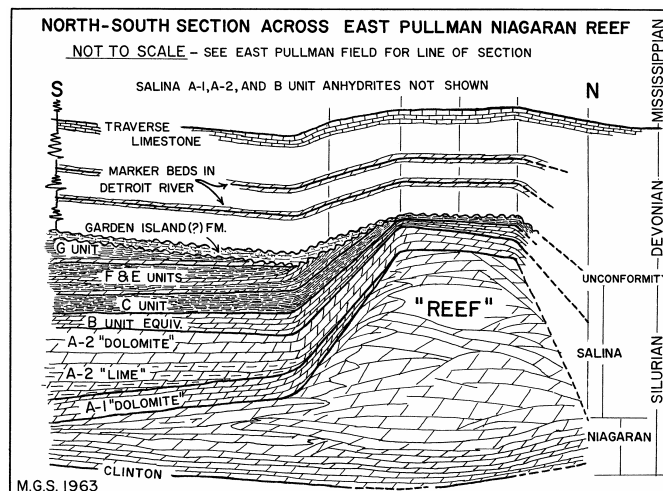


Figure 7

Niagaran reefs.

Most of the known Niagaran reef pools in Michigan are located in St. Clair and Macomb counties, but others occur in Wayne, Calhoun, Muskegon, and Mason counties. The reefs in southeastern Michigan are best known and are commonly called "pinnacle reefs." The productive reefs lie mainly basinward of the thicker Niagaran sequence. Reefs, or bioherms, are exposed at the surface in Silurian outcrop areas which ring most of the Michigan basin. Reefs and reef associated sediments may occur at various levels within the Niagaran sequence, but the productive reefs so far

A few productive reefs such as Berlin and Ray are partially salt plugged. In the Berlin reef, most of the salt plugging occurs in the upper part of the reef. In the Ray reef, the salt plugging is apparently near the base of the reef. The occurrence of salt - and anhydrite - filled porosity in Niagaran reefs, and in some places in beds of the A-1 Carbonate unit, is of special interest. Salt-filled reefs are known in the Ontario. Canada, Niagaran reef province. Some salt - and anhydrite - filled vugs are commonly encountered in the productive reefs. A few reefs in which the porosity is completely filled with salt, or to a degree that effectively prevents the production of contained oil and gas, have been drilled in Michigan, but little specific information is available on the probable areal distribution of this type of reef. How widespread this occurrence is in the Michigan basin is a matter of speculation at the present stage of Silurian development. Salt - and anhydrite - filled reefs are probably not limited to any specific geographic area but they may be related to the reef front and the general depositional edge of the A-1 and A-2 Evaporite units around the basin. It is evident that the salt-filled reefs are directly related to the overlying Salina evaporite sequence. It is likely that several factors, acting at different times, have contributed, to the deposition of salt or anhydrite in the vugs and pore spaces. Critical factors may have been

an unusual set of conditions involving reefs of high topographic expression above the sea floor, their influence on the lower units of the Salina, and their position in the basin relative to the pinch-out edge of the A-1 and A-2 Evaporite units. On the higher parts of the tall reefs the A-1 Evaporite is not present as a bedded salt or anhydrite; however, anhydrite-and salt-filled vugs are commonly present in the top of the reef and reef associated sediments. Reef growth probably ceased with the development of the hypersaline sea which gave rise to the A-1 Evaporite, and the reef was subjected to the salt saturated waters thus initiating one phase of salt plugging. Following the deposition of the A-1 Evaporite which is represented by several hundred feet of pure salt in the deeper parts of the basin, the A-1 Carbonate was deposited. Where this unit is missing on the higher parts of the reef due to nondeposition or ero-sional processes, the reef was subjected again to a hypersaline sea which gave rise to the A-2 Evaporite, a salt bed also several hundred feet thick in the deeper part of the basin. Figure 9 shows the stratigraphic relationship between the lower Salina units and the Niagaran reef, and illustrates how this relationship could be instrumental in salt plugging.

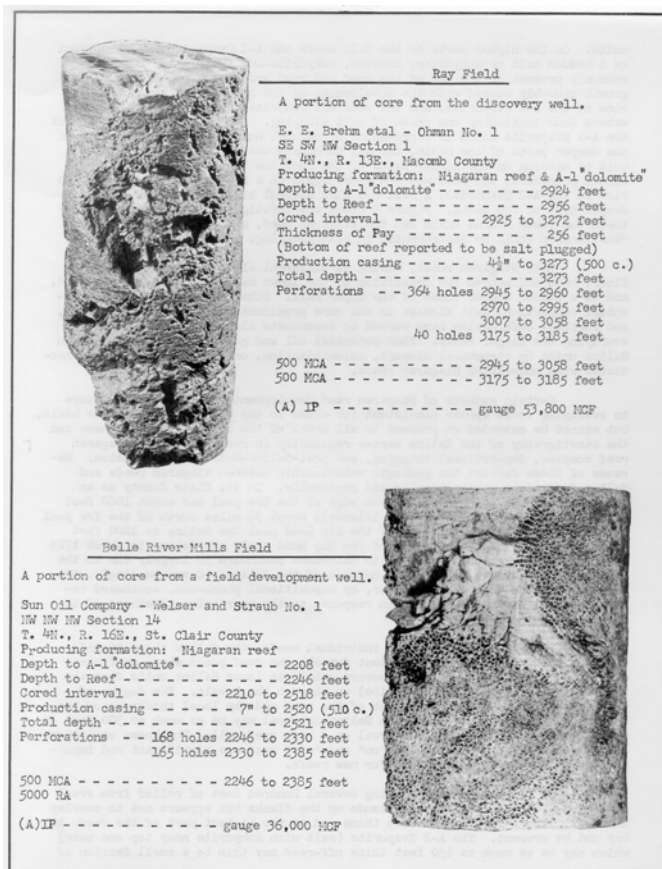


Figure 8

Late Niagaran reefs, rising to different elevations above the sea floor, have influenced the deposition of the loiter half of the Salina sequence, and to a lesser degree those of the upper half. Other factors such as differential compaction, salt flowage in the more prominent salt beds of the Salina, and regional deformation have worked to accentuate closure in Salina rocks overlying

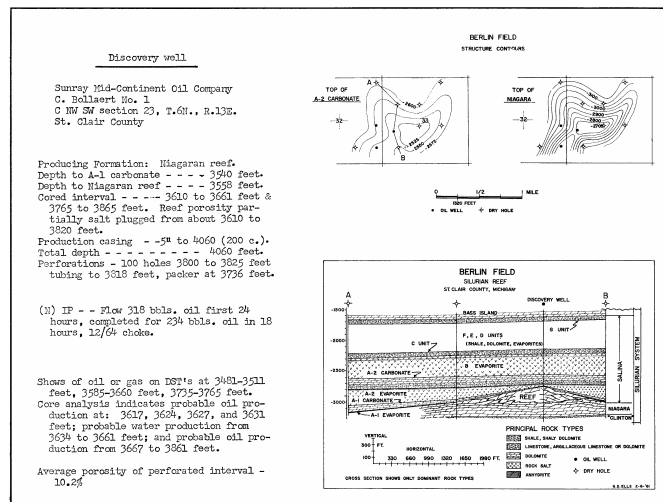
the larger reefs. Thus potential oil and gas traps may be formed in Salina units by structural closure, dolomitization, or porosity variations associated with underlying Niagaran reefs.

Certain aspects of Niagaran reef development and associated closure in overlying rocks appear consistent for areas on the southern edge of the basin, but cannot be extended at present to all areas of the basin. The thickness and the stratigraphy of the Salina varies regionally in response to the Niagaran reef complex, depositional thinning, and post-Salina-Bass Islands erosion. Because of these factors the geologic relationship between Niagaran reefs and Salina formations varies locally and regionally. In St. Clair County as an example, a dry hole on the northeast edge of the Ira pool has about 1060 feet of Salina section (excluding Bass Islands); about 9½ miles north of the Ira pool in a dry hole on the north edge of the Big Hand pool the Salina is 1200 feet thick; and about 22½ miles north of the Big Hand pool, the Salina is about 1725 feet thick. The gradual increase in thickness basinward is largely due to the increase in thickness of the salt members of the Salina. Correspondingly, the Salina salt beds thin and disappear, by depositional pinch-out, southward toward the edge of the basin, and in response to the increasing thickness of the Niagaran sequence.

Locally, in response to individual reefs, the Salina thins significantly. These conditions are evident for all the reef pools where sufficient data is available. The thinning occurs mainly in lower Salina units from the base of the A-1 Evaporite (anhydrite) up through the D salt. The degree of thinning varies according to height of the reef and the local thickness of the Salina. In off-reef dry holes the Salina interval may be as much as 300 feet or more thicker than the Salina interval on a high reef well. Thickness variations of the salt beds and other units "on" and "off" reef are significant and important in gravimeter exploration for new reefs.

On the taller reefs having several hundred feet of relief from crest to off-reef, the A-1 Evaporite extends up the flanks but appears not to overlap the reef. The A-1 Carbonate also thins and on the highest part of the reef, it may not be present. The A-2 Evaporite (salt with anhydrite near top and base) which may be as much as 150 feet thick off-reef may thin to a small fraction of the thickness found off-reef. On the crests of the reefs, the A-2 Evaporite is largely represented by anhydrite. The thickness of the A-2 Carbonate overlying the A-2 Evaporite is significantly less over the reefs, but the thinning of this unit is less than those of the underlying Salina units. Those lying above the A-2 Carbonate, especially the B evaporite (mainly salt) and C unit, also thin but to a lesser degree. Structural closure is found on the Salina units from the A-1 Evaporite up to the top of the Salina. But the amount of closure becomes less in the successively higher units, and is tempered by the overall thickness of the Salina and the magnitude of reef development. Some closure is found as high, stratigraphically, as the Devonian Dundee formation, but

this again depends on the particular reef and locality. Most Dundee structure associated with the reefs is small, and in many cases amounts to slight reversal of dip so as to form small flexures. Some slight shift of structure is evident in the formations of the Salina, and in the Devonian formations. The oil and gas pays of the Salina in the reef fields are, so far, limited to the A-1 Carbonate. Structural closure due to the underlying reef, dolomitization, and porosity-permeability variations in the A-1 Carbonate account for oil and gas entrapment.



submarine erosion of some units, differential compaction over the reefs, and deformation in Devonian or later times. A small amount of closure is indicated on the top of the Dundee formation, but the closure does not exactly coincide with the underlying reef.

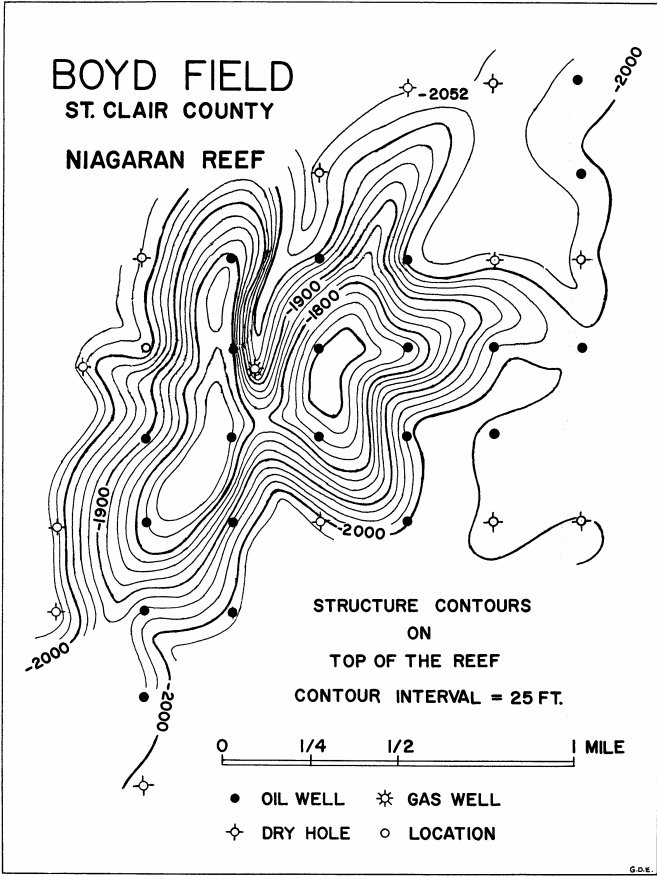


Figure 10

Some general reservoir data is tabulated for the Boyd, Peters, and Ira fields in St. Clair County, and for the Howell field in Livingston County. The Howell field, discovered in 1935, is one of the earlier fields developed in southeastern Michigan. Gas is produced from A-1 Carbonate and Niagaran rocks. The field was converted to a gas storage reservoir in 1962.

	Boyd		Peters	
	Average Porosity Range	Average Perm. Range	Average Porosity Range	Average Perm. Range
A-1 Gas	6.0% to 9.35%	1.7 md.	11.2% to 12.7%	2.66 to 6.3 md.
A-1 Oil	6.0% to 9.4%		10.6% to 12.7%	2.66 to 4.4 md.
Niagaran Gas	8.8% to 10.2%	23.0 md.	9.0% to 11.6%	17 to 42 md.
Niagaran Oil	7.3% to 8.8%	23.0 md.	10.0% to 11.1%	152 to 294 md.
Niagaran Water			11.6%	

	Howell	
	Average Porosity Range	Average Perm. Range
A-1 Gas		
A-1 Oil		
Niagaran Gas	7%	10 md.
Niagaran Oil		
Niagaran Water		

*Appreciation is expressed to the Panhandle Eastern Pipe Line Company for furnishing reservoir data and gas analyses for the Boyd, Peters, Ira, and Howell fields. Appreciation is also expressed to the Consumers Power

Company for furnishing reservoir data and gas analyses for the Overisel and Salem fields.

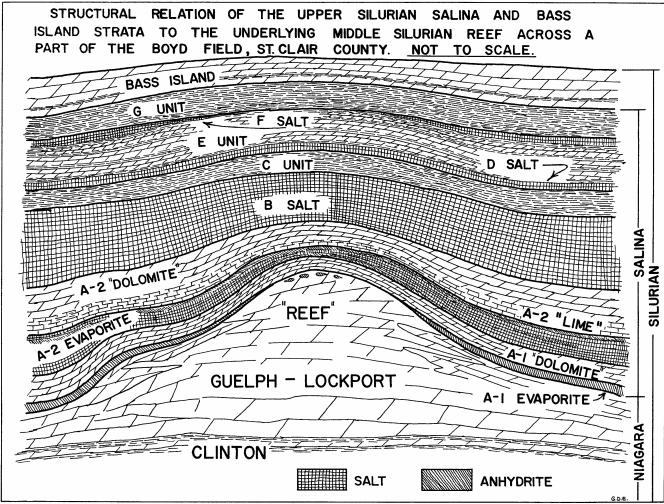


Figure 11

OIL AND GAS

Gas and oil reserve figures are generally not available for most Silurian oil and gas pools. Estimated reserves for a few fields have been made available and are tabulated below. The reserve estimates for St. Clair and Macomb fields are quoted from Alguire (1962, p. 37) who said: "All gas volumes are based on recent volumetric studies, except Ira field which is based on pressure decline. It must be pointed out that development in these fields has not ceased. Therefore estimates stated here should not be construed to be total reserves."

Field	Estimated Recoverable Gas Cap Gas	Estimated Recoverable Solution Gas	Estimated Recoverable Oil
Boyd	11,800,000 MCF	2,300,000 MCF	1,362,000 bbls.
Peters	17,100,000 MCF	5,300,000 MCF	4,013,000 bbls.
Marine City	5,200,000 MCF	2,600,000 MCF	1,320,000 bbls.
Lenox	4,300,000 MCF	-	-
Puttygut	14,800,000 MCF	-	-
Ira	6,200,000 MCF	-	-
Belle River Mills	41,600,000 MCF	-	-

Estimated original gas reserves for the Overisel and Salem fields, Allegan County are as follows:

Overisel	67,000,000 MCF	Salem	57,272,000 MCF
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	AVERAGE GAS ANALYSES (Mole %)	
	Overisel	Salem
Nitrogen	4.37	5.4
Helium	0.08	0.0
Carbon Dioxide	0.15	0.3
Methane	84.0	80.1
Ethane	6.8	8.7
Propane	2.63	3.4
N-Butane	0.66	0.75
Isobutane	0.86	1.1
Pentanes	0.28	0.3
Hexanes	0.13	0.14
Heptanes	0.03	0.06
Total	100.00	100.00
Gross Heating Value BTU/SCF	1090	1110
Specific Gravity (AIR=1)	.666	.693

GAS ANALYSES

	Boyd	Peters	Tra	Howell
Helium	.14%	-	-	-
Carbon Dioxide	-	.18%	-	-
Nitrogen	7.21	3.92	4.54%	4.83%
Methane	82.51	87.46	85.70	82.70
Ethane	5.60	4.67	4.66	7.06
Propane	2.51	1.83	2.05	2.50
Isobutane	.72	.74	1.10	.69
N-Butane	.78	.54	.95	.75
Iso-pentane	.21	.23	.50	.16
N-pentane	.14	.14	.25	.12
Hexanes	.20	.11	.25	.19
Heavier	-	.18	-	-
BTU	-	-	1093	1074

Tables I and II show the annual oil and gas production by a general designation such as Traverse, Detroit River, etc. Detroit River, for example, includes gas or oil production from two separate reservoirs; the "sour zone" in the Detroit River formation, and the Richfield located at or near the base of the Lucas formation. Similarly, Silurian production is listed under Salina-Niagaran. This designation includes all known Silurian reservoir rocks of the Niagaran, the A-1 and A-2 Carbonates, and the producing dolomite in the E unit of the Salina. Oil and gas production figures for Ordovician, Devonian, and Mississippian formations are included for comparison with those of the Silurian. Cumulative oil and gas production for individual Silurian oil or gas pools are shown on Table III.

TABLE I
ANNUAL OIL PRODUCTION FORMATIONS, BBLs.

These data include estimates for multiple pay wells and leases when an accurate breakdown was not available.

Year	Marshall	Berea	Traverse	Dundee-Reed City	Detroit River	Salina-Niagaran	Trenton	Yearly Totals
1925		4,000						4,000
1926		94,000						94,000
1927		434,000	482					435,988
1928		231,000	83,650	277,970				592,620
1929		113,559	789,645	3,738,035				4,641,239
1930		89,387	330,510	3,508,332				3,928,229
1931		61,876	152,787	3,570,970				3,785,633
1932		63,616	145,176	6,716,873				6,925,665
1933		55,066	143,630	7,743,299				7,941,999
1934		48,226	223,336	10,331,197				10,602,759
1935		63,305	174,992	15,537,778			162	15,776,237
1936		93,599	134,888	11,681,886			7,640	11,918,013
1937		62,877	509,299	16,047,245			8,923	16,628,344
1938	2,879	51,119	2,488,753	16,194,612			7,346	18,744,709
1939	4,532	39,413	10,906,884	12,877,772	14,000		19,494	23,462,095
1940		3,875	34,154	8,717,972	10,879,392	9,125	108,585	19,753,103
1941		5,504	43,764	4,455,607	11,695,296	73,763	84,783	16,358,717
1942		4,486	53,570	5,475,973	16,030,753	119,696	69,289	21,753,771
1943		4,118	50,310	4,958,236	15,623,591	180,282	51,187	20,767,724
1944		4,097	47,464	4,348,587	13,710,179	344,550	34,633	18,489,470
1945		3,876	42,485	2,943,994	13,651,857	598,240	27,041	17,267,493
1946		4,175	32,132	2,332,730	14,064,533	616,651	24,297	17,074,518
1947		3,263	32,794	3,157,115	12,443,546	556,028	22,867	16,215,713
1948		3,079	30,311	4,200,258	11,702,520	916,179	18,699	16,871,046
1949		2,890	28,965	4,280,674	10,575,987	1,615,211	13,606	16,517,333
1950		2,175	28,996	4,442,243	9,516,523	1,820,598	15,613	15,826,148
1951		1,609	27,254	3,639,227	8,242,103	1,952,899	13,426	13,926,518
1952		1,989	24,596	3,397,823	7,297,355	2,504,094	20,972	13,249,428
1953		1,420	22,026	2,997,465	6,599,408	2,632,204	24,800	12,284,510
1954		1,875	22,217	2,448,105	6,403,314	2,968,874	15,692	12,028,059
1955		1,662	26,193	2,048,256	5,959,338	3,101,121	11,258	11,265,832
1956		1,678	24,356	1,974,389	5,635,689	2,993,166	8,262	10,739,697
1957		1,830	19,926	1,805,959	5,342,961	2,811,865	24,082	10,168,602
1958		1,583	19,462	1,448,231	4,525,729	2,573,017	131,956	9,308,018
1959		1,430	20,702	1,511,950	4,155,217	2,238,621	392,527	8,438,608
1960		1,270	19,149	1,501,307	3,987,425	2,005,871	379,806	8,899,206
1961		1,268	16,945	1,380,081	3,539,682	1,748,644	916,157	18,900,948
1962		1,215	16,186	1,335,105	3,200,061	1,456,054	1,110,937	17,114,303

TABLE II
ANNUAL GAS PRODUCTION BY FORMATIONS, MCF

Year	Drift	Stray-Marshall	Berea	Antrim	Traverse	Dundee-Reed City	Detroit River	Salina-Niagaran	Trenton-Black River	Yearly Totals
1925										
1926										
1927										
1928						1,887,732		74,867		1,962,599
1929						2,319,620		49,930		2,369,550
1930						536,629		11,648		548,277
1931		46,238				865,120				1,436,159
1932		567,039				1,021,671				1,697,188
1933		675,517				1,291,166				3,008,005
1934		1,713,175			3,744	2,843,737				5,553,855
1935		2,697,388			12,730	1,843,722				6,864,726
1936		4,955,999	53,005		12,000	1,439,296				9,310,844
1937		7,415,631	447,485		8,232	1,637,990				9,422,509
1938		7,291,945	309,352		12,222	1,637,990		1,000		10,137,003
1939		6,408,326	581,234		24,710	1,117,420		5,331		14,126,346
1940		9,421,375	1,304,802		1,730,948	1,655,340		13,999		15,092,464
1941		11,395,657	1,022,886		1,280,257	1,362,256		12,000		17,749,294
1942		15,162,159	1,448,001		4,926,199	627,910		18,305		19,581,420
1943		17,609,027	1,288,438		212,108	487,605		18,242		21,253,903
1944		16,908,771	797,304					17,437		23,298,248
1945		18,365,481	669,403					14,386		23,774,495
1946		19,007,396	553,965					5,371		23,924,925
1947		19,817,437	250,950		30,321			310,294		21,389,287
1948		14,992,235	1,438		822,397			2,902,127		14,660,247
1949	8,020	8,015,131	804	13,570	591,647	1,920,088		120,165		12,614,024
1950		5,035,523	48,988	12,413	499,510	1,922,979		1,345,702		10,558,495
1951		3,161,518	369,641	7,787	1,087,459	977,435		3,617,414		8,671,737
1952		3,058,853	235,929	13,871	304,497	938,184		1,460,215		7,009,969
1953		3,780,281	152,247	14,027	17,102	612,000		1,298,275		5,686,175
1954		3,097,274	109,097	7,688	64,952	710,300		1,272,651	10,725	6,787,697
1955		2,378,082	54,582	8,289	31,671	623,664		1,432,635	1,056,056	8,840,913
1956		1,913,078	39,493	11,004	13,376	540,718		1,525,523	2,084,027	6,619,913
1957		1,031,250	26,234	11,004	13,062	444,272		2,386,744	1,168,915	10,964,378
1958		837,548	19,684	11,307	73,297	335,147		3,604,884	4,863,216	15,625,227
1959		674,131	8,032	14,912	135,217	343,265		3,649,466	9,720,047	19,840,168
1960		905,000	8,800	37,258	164,959	3,979,849		9,877,820	3,912,289	9,955,240
1961		616,710	7,357	25,573	208,367	348,084		4,054,480	9,928,375	27,766,128
1962		451,113	6,620	23,763	206,613	117,606		4,148,707	11,926,493	

SILURIAN OIL AND GAS POOL TABLES

Tables III and IV list the Silurian oil and gas pools discovered in Michigan to the end of 1962. Some of the pools have been abandoned and a few have been converted to gas storage fields. The tables were compiled from the "Summary of Operations Oil and Gas Fields," Geological Survey Division, Michigan Department of Conservation, for 1962 and preceeding years. In the "Year of Discovery" column, the year shown is that of the initial Silurian pool discovery well for the field. This is pointed out because a few fields, Boyd and Peters for example, were classified for several years as "one-well" gas fields. Later, oil wells were drilled in these fields, and the first oil well completed as a producer was credited as a new oil pay discovery for the field even though the well was completed in the same reservoir rocks.

In those fields listed as producing from Salina-Niagaran, gas and/or oil is produced from Salina reservoir rocks as well as from Niagaran reservoirs. Some of the wells are completed in the Niagaran, others in the A-1 Carbonate, and others are dual completed in A-1 Carbonate and Niagaran. In fields where the A-1 Carbonate and the Niagaran are not completely separated by the A-1 Evaporite, the reservoir appears to be continuous from the top of the A-1 down through the Niagaran reef to the gas-water, or oil-water contact.

Production from the A-1 Carbonate and Niagaran are lumped together and shown in the "Cumulative Production" column. Fields listed as "Shut in" are so classified due to lack of pipe line facilities at the time of this compilation, April, 1963. Some of the fields are currently subject to gas/oil proration regulations and others have been in the past. Prorated fields are not designated because proration regulations may be altered as warranted by changing reservoir conditions.

Special well spacing and drilling unit regulations are currently applied to some of the fields. Drilling units vary

from the standard or minimum 10 acre location, to units of 20, 40, 80, or 160 acres. In a given field the drilling units are of a uniform number of acres, except for a few special cases. The acreage figures shown in the "Drilled Acres" column are those assigned to the particular field as of December 31, 1962. As new field wells are added, an acreage value is assigned to each well, if necessary, according to the drilling unit regulation in effect at the time. The acreage assigned to gas storage reservoirs is generally the acreage designated prior to conversion of the field to storage.

GAS STORAGE RESERVOIRS

Prior to 1960 all of Michigan's gas storage reservoirs were located in the central part of the state where most of the Michigan Stray (Mississippian) gas fields occur. Here the storage reservoir rocks are the Michigan Stray sandstone. The discovery of Silurian gas pools such as Overisel in the southwest part of the state in 1954 opened the possibilities of gas storage reservoirs in areas closer to population and industrial centers. The Overisel pool was converted to gas storage in 1960 and is apparently a satisfactory storage reservoir. Since then the Ira and Howell fields in St. Clair and Livingston counties, respectively, have been converted to gas storage. The Salem Salina gas pool, Allegan County, is presently classified as a non-developed gas storage reservoir. In eastern Michigan, the possibilities of gas storage in some of the larger Salina-Niagaran gas fields are excellent. See Table IV for Silurian gas storage reservoirs.

TABLE III
ACTIVE SILURIAN OIL AND GAS POOLS THROUGH 1962

* Oil Well Gas		** Gas reservoir Producing Some Oil			*** Combined with Oil from Other Pools				
Field	County	Year of Disc.	Producing Formation	Approx. Depth to Pay	Cumulative Production		A.P.I. Gravity	Through 1962	
					Bbls. Oil	MCF Gas		No. Wells	Drilled Acres
Adair	St. Clair	1961	Sal. & Niag.	2719	83,771	120,490		16	520
Belle River Mills	St. Clair	1961	Sal. & Niag.	2215	...	1,976,866		18	720
Berlin	St. Clair	1960	Niagaran	3800	115,494	...	42.8	3	120
Big Hand	St. Clair	1961	Niagaran	3898	10,485	...		2	80
Boyd	St. Clair	1952	Sal. & Niag.	2457	470,832	3,917,272*		37	1400
Cal-Lee	Calhoun	1962	Niagaran	7036	...	Shut-in	22.9	2	160
Cape	St. Clair	1961	Niagaran	4505	...	Shut-in		2	320
Cape, North	St. Clair	1962	Niagaran	4558	...	Shut-in		2	320
Cape, South	St. Clair	1961	Niagaran	4894	...	Shut-in		2	320
Chesterfield	Nacomb	1959	Niagaran	2504	1,595	134,498*		5	200
China, Sec. 12	St. Clair	1962	Niagaran	2509	...	...		1	40
China, Sec. 31	St. Clair	1959	Salina	...	Combined with Cottrellville in 1962				
China, South	St. Clair	1961	Sal. & Niag.	2384	...	Shut-in		8	320
Cottrellville	St. Clair	1961	Sal. & Niag.	2262	14,713	178,711*		11	200
Diamond Springs	Allegan	1958	Salina	2389	29,452	...	41.0	3	30
Dorr	Allegan	1956	Salina	2922	224,972	602,076*	17.0	16	540
Fillmore	Allegan	1959	Salina	2632	...	Shut-in		11	600
Fordville	Livingston	1961	Sal. & Niag.	3930	...	Shut-in		2	320
Havth, Sec. 21	Allegan	1960	Salina	2692	...	14,158		1	160
Hilliards	Allegan	1960	Salina	2938	2,271**	1,873,345		6	960
Hopkins, West	Allegan	1956	Salina	2755	1,069	...	17.9	7	260
Lemo	Nacomb	1960	Sal. & Niag.	2734	1,450**	927,151		7	260
Lynn	St. Clair	1962	Niagaran	4708	...	Shut-in		2	320
Marine City	St. Clair	1955	Sal. & Niag.	2176	93,588	25,922	38.0	18	650
Marine City, South	St. Clair	1962	Salina	2380	...	Shut-in		3	320
Montague	Nacomb	1953	Sal. & Niag.	3734*	...	41,482		3	480
Mr. Clemens	Nacomb	1961	Salina	2590	65	...		1	10
Northville	Westonsw	1960	Sal. & Niag.	3545	...	3,247,117		9	1210
Partello	Calhoun	1959	Salina	3192	...	Shut-in		2	160

Field	County	Year of Disc.	Producing Formation	Approx. Depth to Pay	Cumulative Production		A.P.I. Gravity	Through 1962	
					Bbls. Oil	MCF Gas		No. Wells	Drilled Acres
Peters	St. Clair	1955	Sal. & Niag.	2386	1,813,165	2,661,045*	39.0	81	1620
Peters, East	St. Clair	1961	Sal. & Niag.	2590	...	(Combined with Peters)		6	240
Pullman, East	Allegan	1961	Salina	2615	...	Shut-in		3	480
Crystal Valley	Oceana	1961	Salina	4102	...	8,583			
Pattysgut	St. Clair	1960	Sal. & Niag.	2423	...	2,628,023		11	440
Bay	Nacomb	1961	Sal. & Niag.	2945	...	Shut-in		5	200
Solumus	Wayne	1955	Salina	1980	...	45,045		2	320
Salem	Allegan	1957	Salina	2725	...	2,979**	28.0	48	4960
Wayland	Allegan	1960	Salina	3132	160,815	11,175,798		10	400

TABLE IV

SILURIAN GAS POOLS CONVERTED TO GAS STORAGE RESERVOIRS									
Field	County	Dis. Year	Producing Formation	Approx. Depth to Pay	(NCF Gas) Cumulative Production	No. Wells	Drilled Acres		
Howell	Livingston	1955	Salina-Niag.	3920	5,075,670	29	3020		
Ira	St. Clair	1953	Salina-Niag.	2276	2,790,184	4*	680		
Overisel	Allegan	1956	Salina	2650	14,645,948	187*	6660		
*Includes facility wells.									
NON-DEVELOPED SILURIAN GAS STORAGE RESERVOIRS									
Salem	Allegan	1957	Salina	2725	11,175,798	48	4960		
ABANDONED SILURIAN OIL AND GAS POOLS THROUGH 1962									
Field	County	Dis. Year	Year Abd.	Producing Formation	Approx. Depth to Pay	Cumulative Production	Gravity A.P.I.	No. Wells	Drilled Acres
Chester, Sec. 15	Oceaga	1951	1956	Salina	6610	2752 bbls. oil	47.0	1	40
Diamond Crystal Salt	St. Clair	1927	1931	Niagaran	2483	136,445 NCF		1	40
Hardin	Wasen	1952	1958	Niagaran	4224	60,532 bbls. oil	46.2	1	40
Kawkawlin	Bay	1941	1946	Salina	7760	(gas) No Record		1	40
Manistee	Manistee	1959	1961	Salina	3616	0		1	160
St. Clair, Sec. 18	St. Clair	1953	1961	Salina-Niag.	2567	16,101 NCF		1	160
Zeeland	Ottawa	1958	1962	Salina	2792	1,606 bbls. oil	20.5	1	10

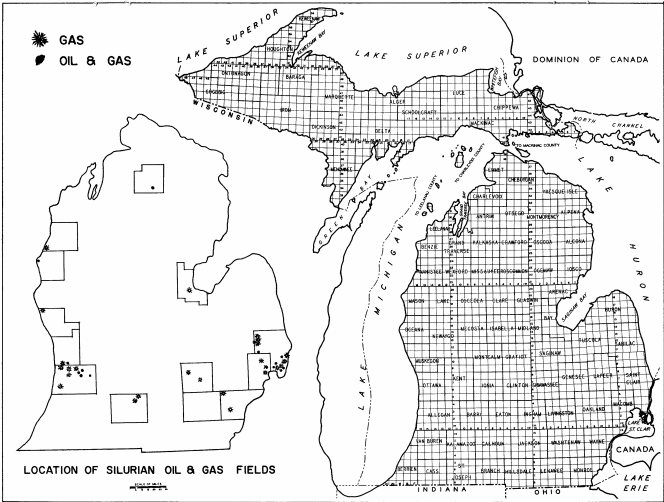


Figure 12

SILURIAN PROSPECTS

The Silurian rocks of the Michigan basin, except for limited areas, are virtually unexplored. Practically all the Silurian tests have been made in the southernmost and southeastern parts of the state where these rocks are at a relatively shallow depth. The deeper parts of the basin have a few widely scattered tests, but very few of the central basin structures have been drilled to the Silurian. Because of the lack of Silurian information for most of the central basin, little can be said about the oil and gas potential or the types of oil and gas traps to be expected in this region. Some indication of the Silurian potential is shown by data from a deep test drilled in the Kawkawlin field. Bay County.

Gulf Refining Company's Bateson No. 1 struck gas in the Salina A-1 Carbonate at a depth of about 7,778 and eventually blew-out and caught fire. The well was eventually drilled to the St. Peter sandstone at a total depth of 10,447 feet, plugged back to the Dundee, and completed as an oil well. A second test was drilled a mile northwest and higher on the Devonian structure. No shows were found in the Salina and the well was

abandoned. An unknown amount of gas was produced from the Bateson No. 1 before it was completed as a Devonian oil well. Data relating to the Salina gas pay are as follows:

Highest registered pressures		Gas Analysis	
Bottom hole (by pressure bomb)	4,950 p.s.i.	S.G.	<u>.7262</u>
Well head	4,050 p.s.i.	CO ₂	3.57%
		CH ₄	73.78%
Open flow capacity		C ₂ H ₆	22.23%
By pilot tube	5,000 MCF	N	<u>.42%</u>
By Bureau of Mines Method	7,000 MCF		100.00%

1,800 pounds pressure build-up in 2 hours

Calculated B.T.U. of gas 1,147.6 B.T.U.

Condensate produced with the gas was about 57° gravity.

It is probable that some of the more prominent basin structures will eventually yield gas and oil from Salina rocks. Whether or not the Niagaran rocks in the basin will contain oil and gas is yet to be determined. Porosity traps of different types not related to reefs or structure are definite possibilities for much of the Silurian section, especially the Alexandrian and Niagaran age rocks, in the basin and on the edges of the basin. It seems evident that most Niagaran reef and carbonate bank development occurred largely around the edges of the basin. The most successful methods of reef exploration on the edge of the basin has been by gravimeter and subsurface studies. Readily accessible oil and gas markets, the relatively shallow drilling depths in known areas of production, will make the basin edges a popular area for exploration. At the present time, depth and drilling costs, lack of well control, and the unimpressive performance of some Silurian reservoirs, prohibit exploration in the deeper parts of the basin. Most drilling will probably be confined to the shallower parts of the basin where there is more well control and where geophysical tools may be used to better advantage. But eventually, as in other oil provinces, the deeper parts of the basin will be explored and will yield oil and gas.

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