STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

Geological Note No. 1

PRELIMINARY REPORT ON POTENTIAL HYDROCARBON RESERVES UNDERLYING THE OHIO PORTION OF LAKE ERIE

by

Michael J. Clifford

Columbus
1975

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ABSTRACT

Oil and gas are present beneath Ohio waters of Lake Erie. The oil will be more hazardous, more difficult, and less economical to produce than the gas. Probable reserves of gas are present in the "Clinton." Reserves classed as possible exist in Cambrian and Ordovician rocks (oil) and in the "Newburg" and Oriskany zones (gas). The volume of gas which can be produced from reserves classed as probable is not large compared to consumption. Assuming economic incentive for an active drilling program, an estimated 15 billion cubic feet of gas per year could be delivered for about 40 years (about 1 percent of demand). This rate is enough to supply about one-third of the domestic gas requirements of a city the present size of Cleveland.

INTRODUCTION

This study, a preliminary investigation of the reserves of hydrocarbons underlying the Ohio portion of Lake Erie, is based on material from industry in Ohio and from the files of the Ohio Division of Geological Survey. In addition, Mr. D. D. McLean, supervisor of the Petroleum Resources Section of the Ministry of Natural Resources in Ontario, Canada, was most cooperative and helpful in providing reservoir and geologic data bearing on Lake Erie. The province of Ontario has had 60 years experience in offshore operations in Lake Erie, where 776 wells have been drilled to date (1974). The study is intended to provide a reasonable evaluation of potential production, *but it is by no means a formal stratigraphic or reservoir analysis.*

DEFINITION OF RESERVES

Definitions of various classes of "reserves" are as diverse as the reasons for estimates and as the people making them. In this study reserves are defined as follows: *Proven reserves* are the quantities of hydrocarbons capable of being produced through existing wells. There are no proven reserves in offshore Ohio because no wells have been drilled. *Probable reserves* are those reserves which can be predicted with reasonable accuracy because the geologic and reservoir conditions of nearby areas are well understood; these conditions can be extrapolated with reasonable certainty into undrilled areas. Traps for hydrocarbons and suitable reservoirs are known to exist in the area under consideration, and production under similar circumstances is well established in adjoining areas. *Possible reserves* are those postulated because reservoir rocks and traps could be present but are not certain or because the given reservoir does not produce significant quantities of hydrocarbons in adjacent areas. In addition, mention is made in the following discussion of certain reservoirs which have some chance of production, but in which the potential reserves are too speculative to warrant serious consideration.

STRATIGRAPHY AND STRUCTURE

A generalized column showing the rocks present in the Ohio portion of the lake is shown in figure 1, along with symbols indicating formations which are prospective for hydrocarbons. Most of the formations shown are of marine origin, and hence have at least some potential of being source beds for oil or gas.

Figure 2 shows the depths to the Precambrian basement of the rocks in Ohio. Depths required to drill to the basement range from less than 3,000 feet in the western basin of Lake Erie to about 6,000 feet off eastern Ohio.

The only large structure beneath Ohio lake waters is the Findlay arch, which separates the Appalachian basin on the southeast from the Michigan basin on the northwest. The arch is a large but structurally simple uplift having relatively little faulting and with gentle dip off the flanks. Dips are commonly less than one degree. Some Ordovician and Cambrian production may be indirectly associated with this feature.

Indications from drilling in Ohio and Canada are that, updip from Ohio, some formations thin or pinch out under the lake. This thinning, in conjunction with changes in porosity of certain formations, provides the possibility of stratigraphic traps. Experience onshore shows also that a few structural traps will be present. In general, structure around Lake Erie is characterized by scattered low-amplitude folding and, in a few places, faulting, generally with throws

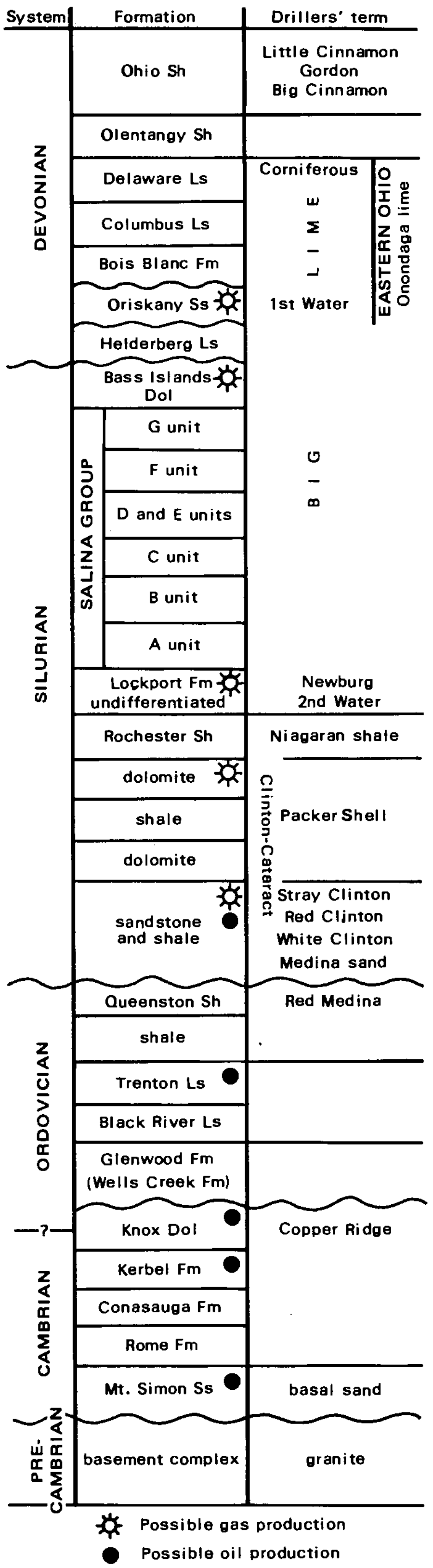

FIGURE 1.–Generalized stratigraphic column of rocks.

of 100 feet or less. These folds and faults have the capability of providing traps for several small pools of a few wells each. There is probably no potential for traps with large accumulations of hydrocarbons (greater than 1 trillion cubic feet of gas or 50 million barrels of oil).

The bedrock underlying Lake Erie is Silurian carbonate rock in the western portion of the lake, Devonian carbonate in the central part, and Devonian shale in the eastern part; the lake basin is overlain by a thin veneer of Pleistocene glacial drift and Recent sediment.

POTENTIAL PRODUCING FORMATIONS AND RESERVES

CAMBRIAN SYSTEM

The Cambrian System, which has produced oil and gas in Ohio and in Canada, ranges in thickness from 400 feet or less in the western portion to over 600 feet in the eastern portion of offshore Ohio. In Ohio most of the production has been oil from the Knox Dolomite in Morrow County. The producing section of the Knox in Morrow County is missing by erosion beneath the lake. Other Cambrian production in Ohio (summarized from Janssens, 1973) is listed below. This list includes only those Cambrian fields which produce from sections of the Cambrian which may be present under the lake. Locations of the pools are shown in figure 3.

Tiffin pool, Seneca County. Discovered 1938; produced from 3 wells in the lower Knox dolomite and sandstone; 21,282 barrels of oil from 1 well.

Hinckley pool, Medina County. Discovered 1959; produces gas from 1 well in lower Knox dolomite and sandstone; surrounded by 4 dry holes; produced 0.97 billion cubic feet of gas in 12 years.

Collins pool, Huron County. Discovered 1965; produces from Knox carbonate erosional remnant; 3 oil wells, 1 gas well, 1 combination well, 9 dry holes; cumulative production for 6 years: 164,543 barrels.

South Birmingham pool, Erie County. Discovered 1966; produces from thin sandstone in lower Knox ("B" zone); 5 oil wells, 7 dry holes; cumulative production to end of 1971: 533,752 barrels.

In addition to these pools, an abandoned well was reopened and completed with a reported initial production of 20 barrels of oil a day in Chatfield Township, Crawford County, probably from the "B" zone. No details are available.

Canadian production from the Cambrian is summarized below from Ontario Division of Mines (1974). The reserve figures for the pools are calculated by the Petroleum Resources Section.

Willey pool, Elgin County. Discovered 1964; produces from Cambrian sandy dolomite; proven recoverable primary reserves: 1,016,950 barrels of oil from 15 wells (average 67,797 barrels per well).

Clearville pool, Kent County. Discovered 1962; total primary reserves: 912,000 barrels of oil from 9 wells (average 101,333 barrels per well); secondary recovery potential.

Gobles pool, Oxford County. Discovered 1959; total primary reserves: 1,070,000 barrels of oil from 38 wells (average 28,158 barrels per well); secondary recovery potential; 10 small gas wells.

Innerkip pool, Oxford County. Discovered 1961; total primary reserves: 15,000 barrels of oil from 3 wells; 1,010 million cubic feet of gas from 3 wells.

East Innerkip pool, Oxford County. Discovered 1968; total primary reserves: 107 million cubic feet of gas from 2 wells.

There are at least 4 other producing Cambrian wells, but reserves from these are insignificant. One well drilled off Elgin County near the international boundary reported a good show of oil in the Cambrian. The well was not produced.

Most of the producing wells in the Cambrian on both sides of the lake have found oil. Cambrian primary reserves

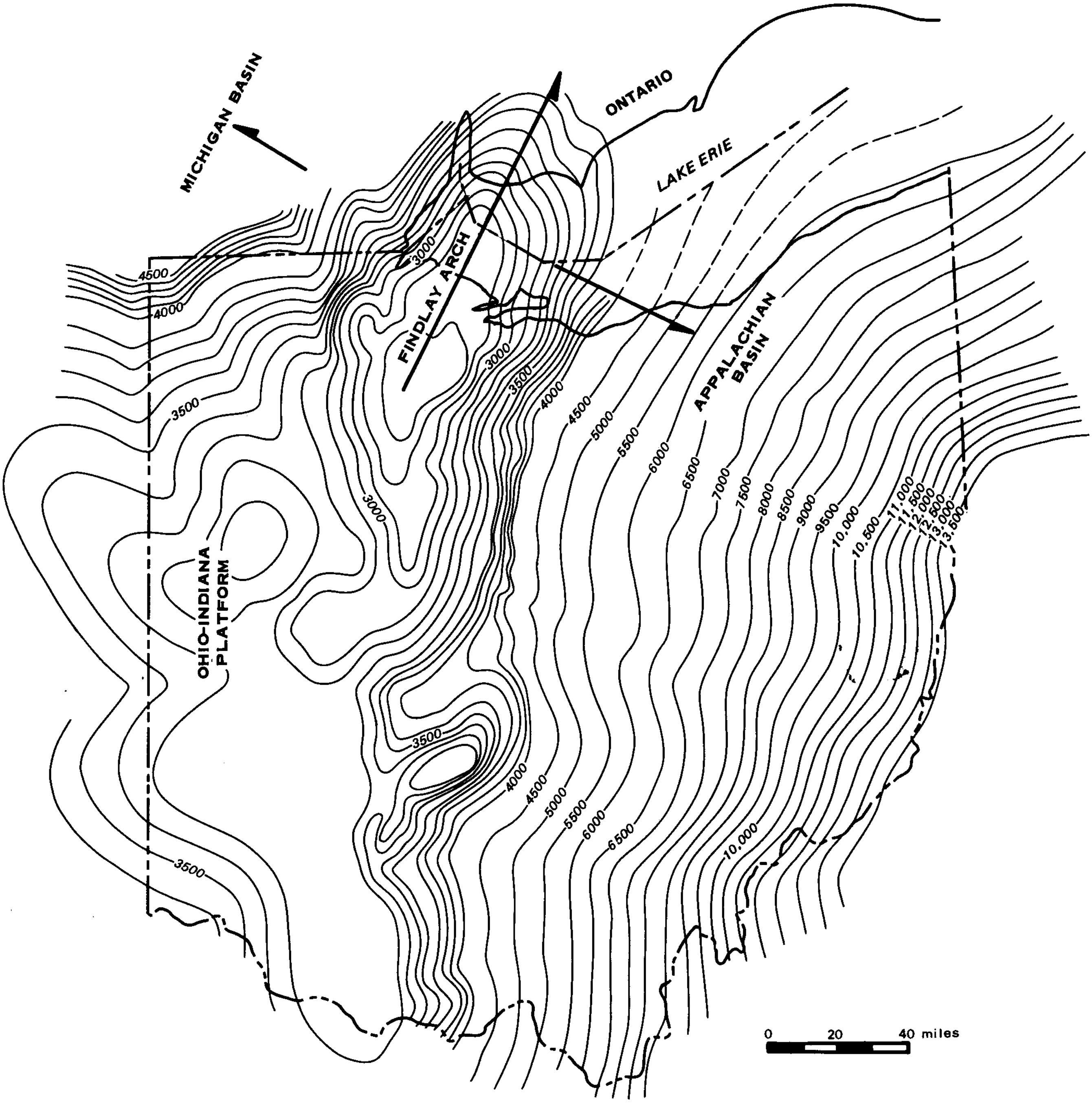

FIGURE 2.–Depths to the Precambrian basement in Ohio, contour interval 500 feet (after Hennington, 1972, fig. 3).

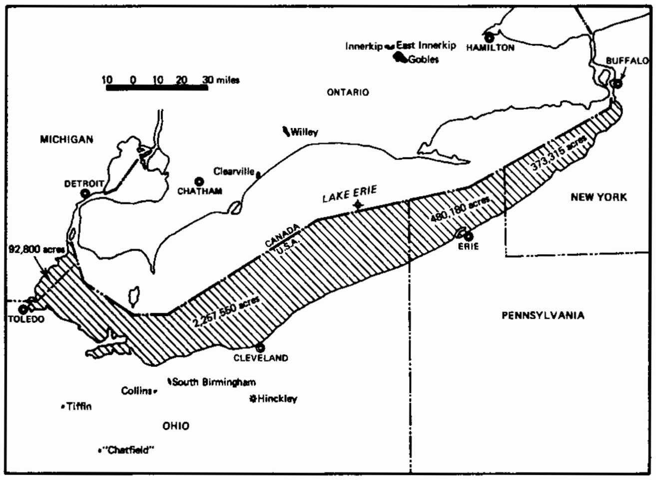

FIGURE 3.–Offshore acreage and Cambrian producing fields (base map after Bulmer and Bulmer, 1972).

in Ontario are 46,368 barrels per well. Ohio reserves are probably similar. The average number of oil wells per field for the pools mentioned above is 10. For the most part, production from these pools is associated with folding or faulting, but because such structures are uncommon, there will probably not be many more pools encountered on land areas. Considering the size of the lake acreage in relation to the number of existing pools, it appears that 5 to 20 pools may be found beneath the Ohio waters. If there are 10 wells per pool and 46,368 barrels per well, then reserves could be between 2.3 and 9.3 million barrels of oil.

Because it is not certain that traps do exist beneath the lake or that the traps would be filled with hydrocarbons, the reserves are assigned a possible status.

In order to produce oil from beneath the lake, it appears that it will be necessary to erect permanent ice-resistant platforms. Aside from the fact that the small per-well reserves are not large enough to make such construction economically attractive under today's conditions, oil production carries a risk of environmental damage. Permanent platforms are considered to be hazardous to shipping and many consider them unsightly. Oil production is not now practiced in the lake.

Under present economic and technologic conditions it may prove difficult to realize the oil reserves under Lake Erie. Improvements in technology and changes in the economic climate could, however, make production of existing reserves feasible.

ORDOVICIAN SYSTEM–TRENTON LIMESTONE

Dolomitized Trenton Limestone has been a prolific producer in western Ohio. Oil production from the giant Lima-Indiana field (fig. 4) may exceed 500 million barrels. Production has been encountered near Lake Erie in Ohio and in and near the lake in Ontario. Figure 4 shows the producing areas and prospective acreage in Lake Erie off Ohio. Gas production has been encountered in a few areas, such as Hancock and Wood Counties, but this production seems to be related to structurally high areas (see fig. 2). The Lake Erie acreage appears to be structurally lower, therefore will probably yield oil.

Estimates of recoveries of oil in this trend have been made by Buehner (1971), who found that average recovery in Ohio was 840 barrels per acre. However, recovery in certain areas was much higher, ranging from 2,000 to more than 9,000 barrels per acre for a few wells. In Canada, Colchester field (fig. 4), a small field on and in the lake, produced 580,000 barrels of oil from 5 wells, or 116,000 barrels per well.

Because of the erratic nature of Trenton production, reserves are difficult to estimate. The following estimate, assigned a possible status, is based on the assumption that 5 percent of the approximately 300,000 prospective acres could be productive. Using 840 barrels per acre recovery, 12.6 million barrels could be produced. Oil from the Trenton does not appear to be economically producible under the lake at this time. Because of shallow depths, reservoir pressures will be low, and per-well recoveries may not be high enough to justify offshore completions.

SILURIAN SYSTEM

Silurian producing zones underlying the lake include the "Newburg" (also called Lockport and Guelph) and the "Clinton-Cataract" group.

The "Clinton" sandstones produce oil and gas in a broad band trending in a northeastward direction from Ohio across Ontario and Pennsylvania to New York. The hydrocarbons are situated in a large stratigraphic trap which is formed downdip from a change in facies from shale and carbonate rocks to sandstone. In general, gas production tends to be updip from oil production. Because of the discontinuous nature of individual sands and because of permeability variations there is no clearcut oil vs. gas delineation. Within the broad productive band, the sandstone is generally present and in almost every place yields hydrocarbons. Success ratios, as measured by well completions, are over 90 percent for wells on land in Ohio. In the Canadian portion of Lake Erie, over 50 percent of "Clinton" wells have been successful. The reason for the lower success ratio offshore probably is that only the better wells, wells which can repay the expense of lake-bottom completion and pipelines, are completed. Figure 5 shows the locations of "Clinton" production in and near Lake Erie.

Near the lake, production from the "Clinton" is mostly gas. In Lorain County, the production of all "Clinton" wells, as reported by the operators, was tabulated as follows: of 646 wells, 589 (91 percent) were gas wells, 53 (8 percent) were gas and oil wells, and fewer than 1 percent were oil wells. In Cuyahoga County, a 10-well "Clinton" field owned by East Ohio Gas Co. produces gas so dry that it can be fed directly into consumer lines. No oil and very little water are produced. Other area wells, now abandoned for the most part, were also gas wells, but no detailed data are available. In Ashtabula County, one operator reports that north of Interstate 90 "Clinton" production is gas, with oil not exceeding about 2 barrels per day. Ontario experience has shown the "Clinton" to be almost entirely gas productive. The structure contours in figure 5 show that the offshore acreage is updip from areas in Ohio which are oil productive in the "Clinton." It is concluded therefore that Ohio offshore production from the "Clinton" will be primarily gas, with little oil and water. A contrary opinion is held by

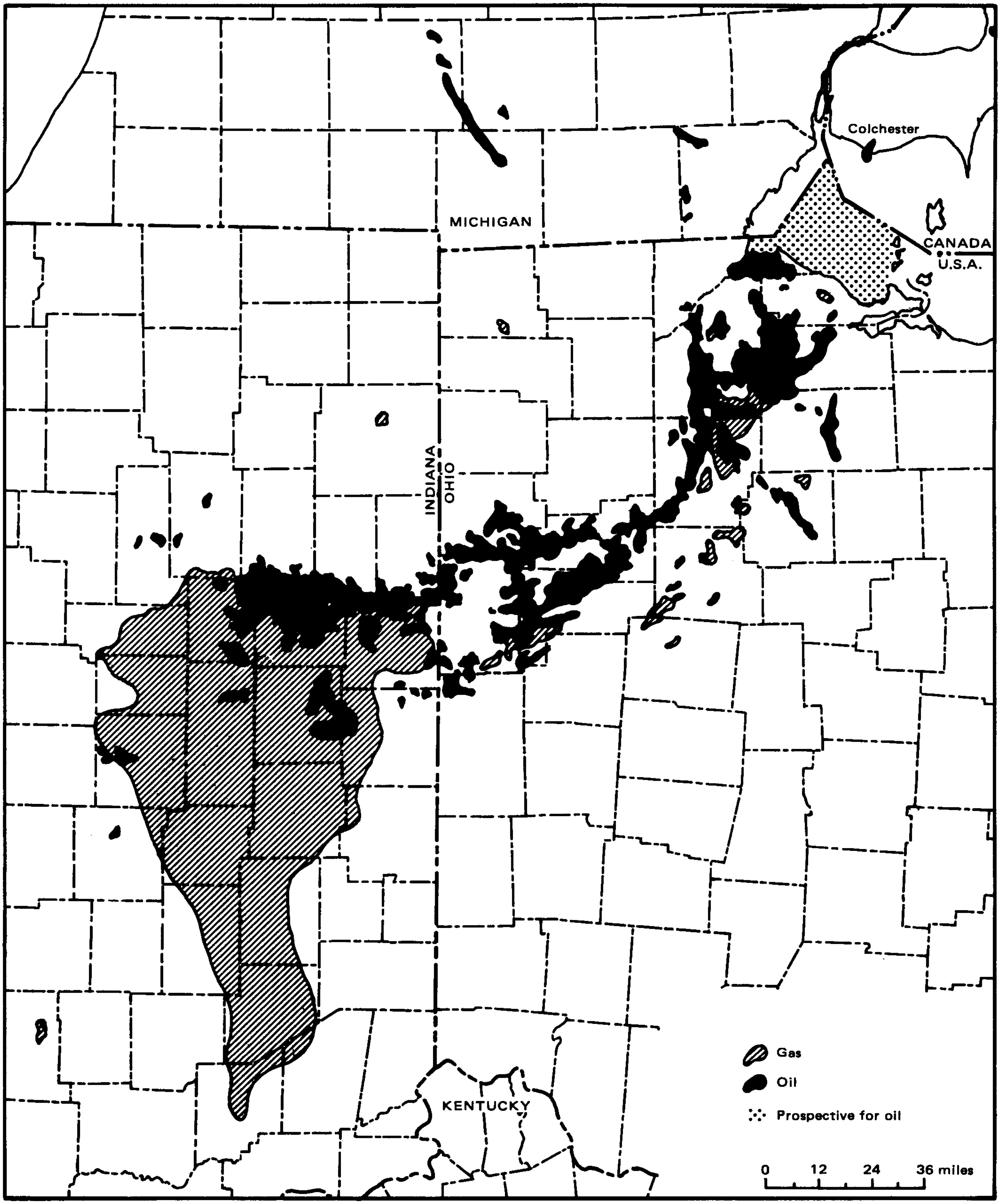

FIGURE 4.–Areas of Trenton-Black River production (after Buehner, 1971, fig. 2).

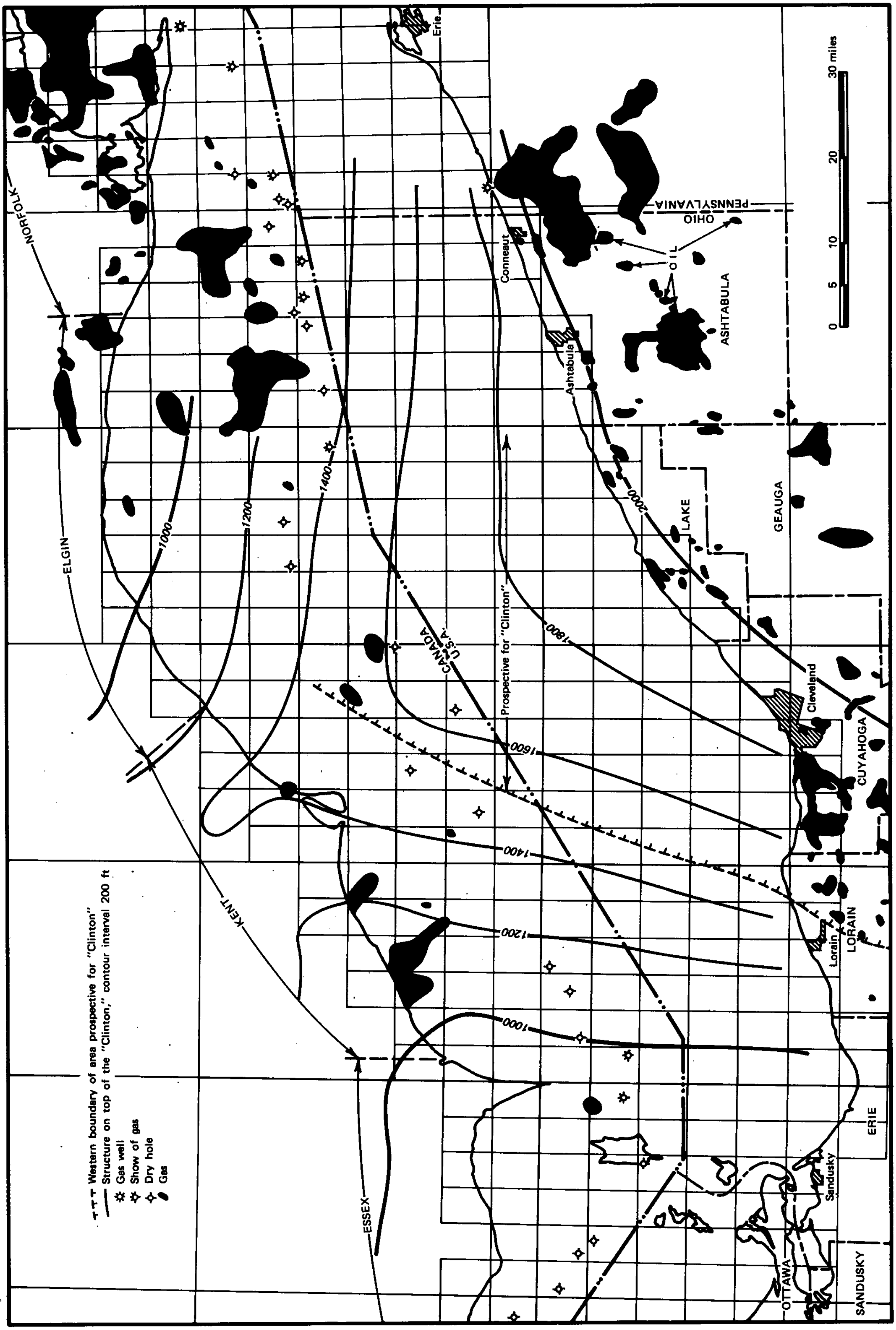

FIGURE 5.–Silurian and younger producing areas in and near Lake Erie and proposed lease blocks and structure on top of the "Clinton." Compiled from several sources.

some Ontario authorities (T. A. MacDougall, personal communication), who believe that most of the "Clinton" will be oil bearing in Ohio waters.

Detailed production data from which reserves estimates can be drawn are not available in Ohio because such data have not been required of operators in the past. Accurate reserves estimates will await detailed production data, but preliminary estimates based on data from Ontario and on intuitive generalizations can be made. The reserves here estimated are oriented to reflect that volume of gas which can actually be produced in the near future with existing technology.

Total production for the life of an average "Clinton" well in Lake Erie is considered to be 0.5 billion cubic feet of gas. This is based on informal estimates from various operators and on an article by Redic (1970).

Calculation of the "Clinton" reserves was done as follows: The prospective area, less a 1-mile buffer zone near land, was planimetered to be approximately 1,300,000 acres (2,031 square miles). The drilling tracts in the lake are divided into 5-minute latitude and longitude blocks; each block is divided into 25 1-minute tracts. Because of northward convergence of longitude lines, the tracts differ slightly in size. The average tract size is about 630 acres. It is expected that the spacing of gas wells will be one well per

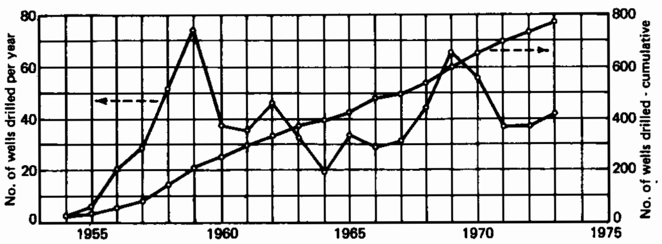

FIGURE 6.—Drilling history in the Canadian portion of Lake Erie.

tract. Therefore, there are about 2,063 locations for wells. If 65 percent are successful, 1,340 producers will result. If reserves per well are 0.5 billion cubic feet, 670 billion cubic feet, or 0.33 billion cubic feet per square mile, may be produced ultimately. This figure compares with gas reserves in the "Clinton" of 0.496 billion cubic feet per square mile estimated for offshore Norfolk County, Ontario (MacDougall, 1973, p. 53), and with 0.75 billion cubic feet per square mile estimated by Bulmer and Bulmer (1972) for the Ohio portion of Lake Erie.

In order to make a gross estimate of the volume of gas which may be delivered to shore from an active drilling program, the following projections are made: The Ontario drilling industry has, since 1957, drilled about 40 wells per year (fig. 6). On the basis of an estimate that two drilling rigs can be kept active in Ohio waters, it seems reasonable to assume that about 30 producing wells can be completed per year. The volume of gas delivered to shore depends on initial production rate and on the rate at which production declines. By use of a decline curve for an average "Clinton" well (Redic, 1970) and assuming an average initial deliverability of 800 thousand cubic feet per well per day, the curve in figure 7 was constructed to show the amount of gas which could be delivered. According to this model, maxi-

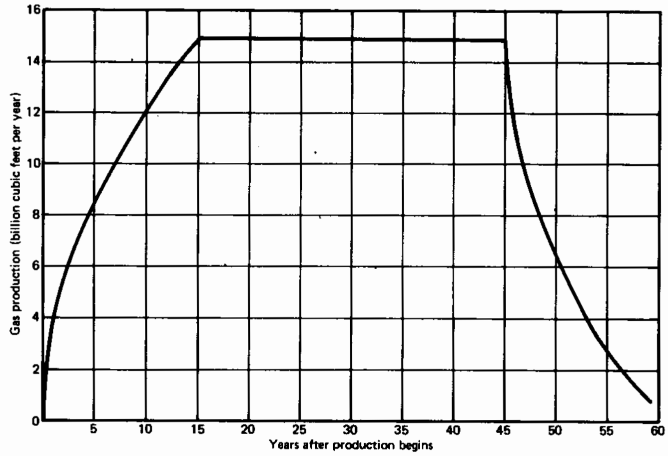

FIGURE 7.—Potential gas production from "Clinton" sandstone beneath the Ohio portion of Lake Erie (based on 30 completions per year; initial potential, 800 thousand cubic feet per day per well; decline rate for individual well after Redic, 1970).

mum deliverability, achieved 15 years after beginning of production, is about 15 billion cubic feet per year. That rate can be delivered for about 30 years, after which it declines. This rate is about one-third the amount of gas presently (1974) used for domestic purposes in the city of Cleveland and seven times that used in the city of Ashtabula. A graph of consumption, production, and potential "Clinton" production is shown in figure 8.

These reserves are classed as probable because the trap, a stratigraphic trap formed by updip loss of porosity in the sand, is known to be present beneath the lake. The trap is known to contain hydrocarbons because of the existence of production on both sides of the lake.

Another prospective zone in the Silurian System is the "Newburg" zone. This zone, a dolomite at or near the top of

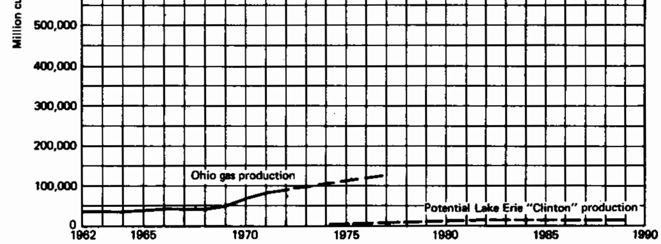

FIGURE 8.—Total gas consumption and production related to potential Lake Erie production in Ohio (after Lytle and others, 1973).

the Lockport Formation, appears to be dolomitized fossil reefs where productive. Structural expression of the reefs is as much as 200 feet in Ontario waters and just over 100 feet in Ohio. The productive areas are widely scattered and not readily predictable.

Most of the present "Newburg" fields were probably accidental—the result of deeper drilling to the "Clinton." Some reserves will possibly be discovered in the eastern Lake Erie basin by this method. In the western basin, however, other potential horizons are probably oil bearing and there may not be sufficient drilling to yield significant accidental "Newburg" reserves. However, reflection seismic techniques may serve to locate large high-relief reef-type fields if any are present.

Important "Newburg" fields in Ohio are Mayfield (Cuyahoga County) and Summit-Green (Summit County), which have reserves of 14 and 10 billion cubic feet, respectively. Similar fields in Canada are D'Clute (Kent County), with reserves of 20 billion cubic feet onshore and 16 billion cubic feet offshore, and Morpeth (Kent County), with 6 billion cubic feet onshore and offshore. In addition to these modest-sized fields there are several dozen smaller fields (scattered widely in Ontario and northern Ohio) and one very large field (onshore and offshore Kent County, Ontario). The large field, Tilbury, has reserves of about 260 billion cubic feet from about 160 wells.

In the area of offshore Ohio, there are possible reserves from 5 to 10 Summit-Green-type fields and 1 to 2 Tilbury-type fields; total reserves are 375 to 750 billion cubic feet.

The Bass Islands Dolomite, a carbonate unit at the top of the Silurian, has yielded gas in a few wells in Pennyslvania, but has not been productive in Canada or Ohio. A slight chance for gas from erosional, structural, or salt-collapse structures exists in this unit in the eastern portion of Ohio lake acreage, but no reserves are assigned to the unit at this time.

DEVONIAN SYSTEM

In northeastern Ohio at the base of the Devonian there is a widespread unit, the Oriskany Sandstone, which produces gas in small quantities in a few small fields in Ashtabula and Cuyahoga Counties and in Erie County in northwestern Pennsylvania. The Oriskany is as much as 70 feet thick along the Ohio lake front, yet it is absent (or very thin) updip in the Canadian portion of the lake. A possible stratigraphic trap is thus formed; such a trap could be productive, especially if combined with structural traps. However, the lack of prolific production onshore and lack of an impermeable shale confining bed prevent the assignment of reserves to the formation at this time.

Devonian carbonate rocks overlying the Oriskany produce in Ontario and have had a few shows of gas in Ohio. There has been no production in Ohio as yet; therefore no reserves are assigned.

The Devonian-age "Ohio shales" have produced low-volume gas along the lake front. This unit may yield shows of gas in Lake Erie, but probably not commercial quantities. The gas shows may prove troublesome in drilling operations, however.

SUMMARY OF RESERVES

The reserves of oil and gas beneath Lake Erie are summarized below:

Producing unit	*Probable reserves*	*Possible reserves*
"Newburg"		375-750 billion cubic feet gas
"Clinton-Cataract"	670 billion cubic feet gas	
Trenton Limestone		12.6 million barrels oil
Cambrian		1.5-6 million barrels oil

These estimates are preliminary, based on the best information currently available.

ECONOMIC INFLUENCES ON RESERVES

It must be emphasized that economic factors exert a strong influence on drilling activity, hence on reserves. One major factor will be the terms under which state acreage is leased. On land, the royalty to the landowner is commonly 12½ percent, and yearly rental in Ohio is in many cases $1.00 per year per acre. If the same or similar terms are applied to lake drilling, where costs are about 100 percent higher, incentive to drill wells will be reduced sharply. If the Lake Erie reserves are to be tapped it will be necessary to carefully balance royalty and rental income in order to maximize state income, yet provide enough incentive to drill. The history of drilling in Ontario makes it abundantly clear that offshore drilling is marginally profitable, thus industry activity is sensitive to royalty demands.

Some factors tending to increase or decrease effective reserves are listed below:

Reserves will be increased if

1. Price of product is increased or royalty is decreased, resulting in
   - A. More wells being drilled,
   - B. Wells being drilled closer together—gas wells could be drilled on 315-acre spacing instead of 630-acre spacing, with some increase in reserves,
   - C. Life of existing wells being increased—there would be greater incentive to "work over" wells and produce to lower yields before plugging;
2. Reserves per well are higher than estimated;
3. Other formations are found to be productive;
4. Improved technology is devised for drilling and production.

Reserves will be decreased if

1. Reservoirs are found to contain water or oil instead of gas;
2. Reservoirs are thin or absent;
3. Rigorous restrictions on drilling activity are made on the basis of environmental considerations;
4. Drillable acreage is reduced because of navigation rights-of-way, fishing areas, buffer zones near land, or other such considerations.

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