OHIO RIVER VALLEY WATER SANITATION COMMISSION

REGISTRY OF WELLS

for use in
UNDERGROUND INJECTION OF WASTEWATER
in the
OHIO VALLEY REGION

A compilation of data on the development, operation and characteristics of wastewater injection wells

developed by the
Ohio River Valley Water Sanitation Commission
sponsored by the
United States Geological Survey

March 1974

An Interstate Agency Representing: Illinois • Indiana • Kentucky • New York • Ohio • Pennsylvania • Virginia • West Virginia

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OHIO RIVER VALLEY WATER SANITATION COMMISSION
414 Walnut Street Cincinnati, Ohio 45202

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FOREWORD

In 1970, the Ohio River Valley Water Sanitation Commission (ORSANCO) established an Advisory Committee on Underground Injection of Wastewaters to provide guidance in the utilization of sub-surface disposal of industrial wastewaters. At the same time, efforts were initiated to establish a registry of wells that were constructed in the signatory states for the underground disposal of fluid wastes. Some 53 wells presently are documented in the registry of which 27 are located in the compact area.

The registry serves as a central repository of disposal well information that includes the owners name, location, geologic and geophysical logs, test results and operational characteristics. In addition to the above information, the type of wastes injected into the underground strata is classified according to chemical characteristics.

Another phase of these activities detailed in the report relates to an appraisal of the Mount Simon Sandstone which is a widely used injection zone for underground disposal. The effort represents a pilot project in characterizing the geological and physical properties of this zone.

In publishing this report, the Commission acknowledges with appreciation the efforts of those who contributed to its formulation, and to the United States Geological Survey for underwriting a substantial portion of the cost in developing the registry and associated appraisal of the Mount Simon Sandstone.

WILLIAM L. KLEIN
Acting Executive Director

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INTRODUCTION

This report covers the description, location, development and use of wells for the underground disposal of liquid waste materials in the ORSANCO states.

At the present time there are fifty-three underground wastewater injection wells within the borders of the eight states signatory to the ORSANCO compact. Twenty-eight of these wells are currently (as of mid-1972) receiving wastewaters -- fourteen are in the Ohio River drainage area and fourteen are in other portions of the ORSANCO states. Almost 1.4 million gallons of wastewater are being daily injected underground in the Ohio Valley, somewhat more in the remaining portions of the compact states.

With the cooperation and support of the U. S. Geological Survey, the state regulatory agencies, and help from the Advisory Committee on Underground Injection of Wastewaters, the ORSANCO staff has developed a Registry of all undergeound wastewater disposal wells in the ORSANCO states. Information for this report was obtained from this Registry.

OUTLINE OF REPORT

For ease of reading and to serve the range of interests of those using this report, it has been divided into three portions, each of which is essentially self-contained.

Part I summarizes the injection well information by various physical characteristics of the wells, their operating history, wastewater characteristics, and by state, including a division between Ohio basin and otherwise.

Part II contains a detailed description of each well by state. This portion includes state summaries and monthly operating records of individual wells when available.

Part III, prepared by Dr. Don L. Warner and Mr. John Reiss, Jr., of the University of Missouri, is a preliminary report on the Mt. Simon Sandstone formation, which is a very active zone for wastewater injection, particularly in Illinois, Indiana and Ohio.

ACKNOWLEDGMENTS

Advice and guidance was tendered in the development of the Registry, by the ORSANCO Advisory Committee on the Underground Injection of Wastewaters. This committee consists of the State Geologists of the eight member states and a representative from the U. S. Geological Survey, and is chaired by Dr. Don L. Warner, professor of Geology, Missouri State University, Rolla (see inside back cover). The various state administrators of underground disposal regulations have supplied or aided in obtaining operational data. Mr. Francis Kohout, geologist, U. S. Geological Survey supplied help and advice during the project. Mr. Rick Safford assisted the author during the summer of 1972 and was a valuable aid in organizing the information in the Registry file.

Mr. Thomas Andrews, Chief Project Engineer, Hammermill Paper Company, supplied substantial data on the development, operation and closing of injection wells at Erie. Similarly, Dr. George C. Smith, Technical Coordinator, Environmental Control Division of Jones and Laughlin rendered valuable assistance in obtaining operational data and history of the injection well at Aliquippa.

Personnel from the U. S. Geological Survey who served on the Advisory Committee at one time or another and rendered valuable assistance, including Joe L. Poole, Joseph Callahan and Leonard Wood. Beyond the advisory aspects from the U. S. Geological Survey Department of Interior that agency funded a substantial portion of the activities of the Committee and the costs of developing the ORSANCO Well Registry under U.S.G.S. grant No. 14-08-0001-G-42.

PART I

GENERAL SUMMARIES OF ORSANCO REGISTRY

Before presenting summary information from the Registry it is appropriate to discuss briefly how the Registry was developed and what it contains.

DEVELOPMENT OF THE REGISTRY

The Registry of injection wells for wastewaters developed in the following manner. Summaries of permit applications and actions in the files of the various state agencies were examined for data on: owner, location, well development and testing reports, wastes, and operational aspects of each wastewater injection well. Different approaches to keeping records were found. In some states a disposal well is developed under a water pollution control permit and is part of that permit. In other states, the underground injection constitutes a separate and unique permit, and information was sought from the permitting authority. No great difficulty in acquisition of information was experienced once the system was determined. The greatest effort was expended in reviewing correspondence that appended disposal well permit applications. Some of the permit requests were accompanied by feasibility reports or exploratory drilling reports or completion reports. When available, copies of such reports were obtained and included in the Registry.

All available logs are included in the Registry file; these include various geophysical logs such as electrical, temperature, sonic and gamma ray-neutron logs. Driller's logs, or geologist's lithologic logs, were found to be the only logging employed for some of the wells, but these appear restricted to a few of the older wells, less than 1,500 ft. depth, or where a closely spaced companion well had sophisticated logging.

More specifically this report on the Registry contains information of the following types:

1. Inventory of existing underground industrial waste-disposal operations, including logs of wells when available.

2. Indentification of chemical and thermal properties of injected fluids and, if possible, a judgement of their apparent compatibility with the native water and host formation.

3. Tabulation of similar information about injection wells that have been abandoned or are in disuse, and the reasons why.

4. Recommendation of specific matters that may qualify for further research and investigation.

LOCATION OF WELLS

Fig. 1 shows the approximate location of the fifty-three waste-water injection wells in the Ohio Valley states as of June 1972. The locations and identification follow.

Table 1. DISPOSAL WELLS BY GENERAL LOCATION AND STATUS (As of June 1972)

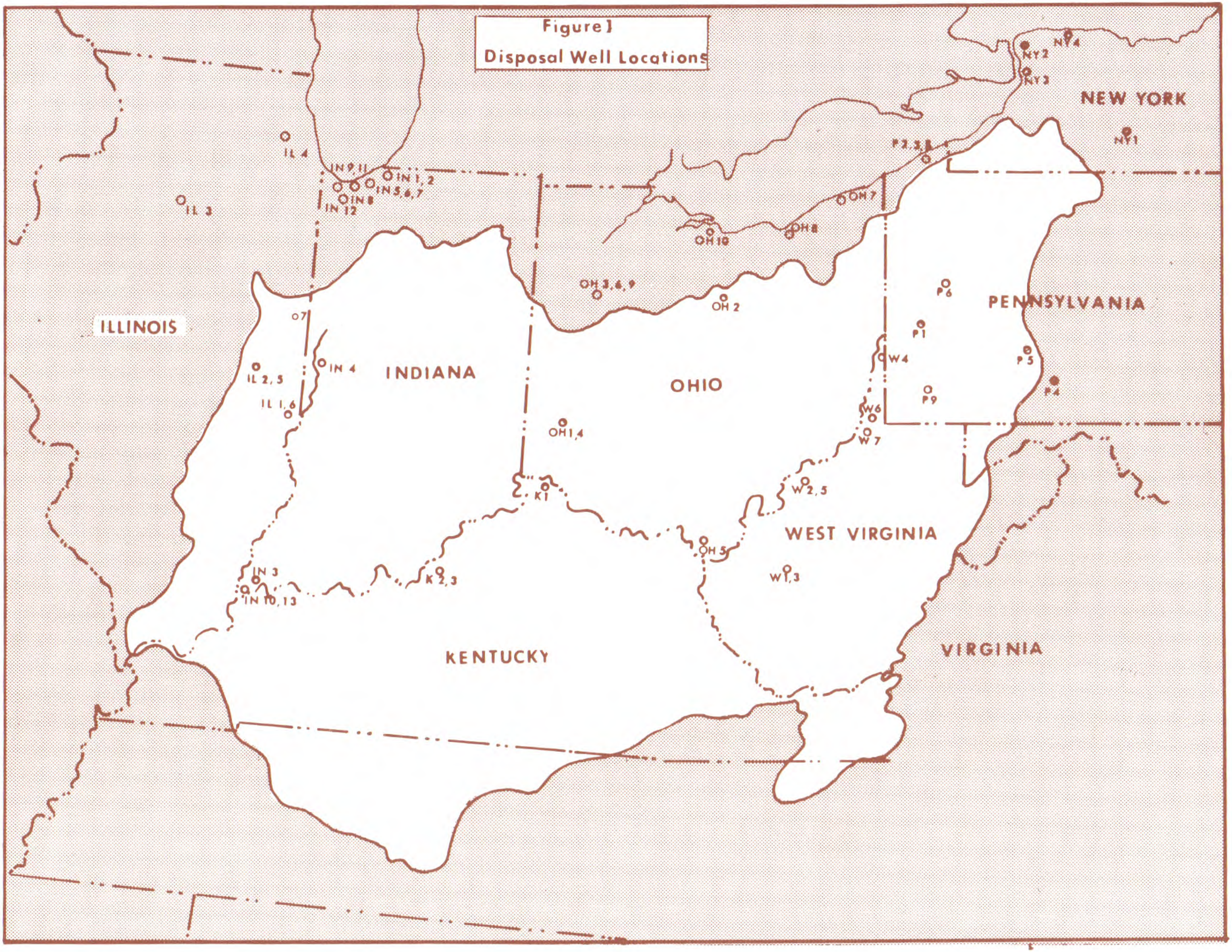
State	Registry Number	Operator	Location (City)	Status
Illinois	Il-1	Velsicol Chemical Company	Marshall	(1)
	Il-2	Cabot Corporation	Tuscola	(1)
	Il-3	Jones & Laughlin Steel Co.	Hennepin	(3)
	Il-4	American Potash and Chemical Company	West Chicago	(3)
	Il-5	U.S.I. Chemical Company	Tuscola	(1)
	Il-6	Velsicol Chemical Company	Marshall	(4)
	Il-7	Allied Chemical Company	Danville	(4)
Indiana	In-1	American Cyanamid Company	Michigan City	(1)
	In-2	American Cyanamid Company	Michigan City	(1)
	In-3	Indiana Farm Bureau	Mt. Vernon	(1)
	In-4	FMC Corporation	Newport	(1)
	In-5	Bethlehem Steel Company	Chesterton	(1)
	In-6	Bethlehem Steel Company	Chesterton	(1)
	In-7	Bethlehem Steel Company	Chesterton	(1)
	In-8	Midwest Steel Division	Portage	(1)
	In-9	U.S. Steel Company	Gary	(1)

(1) active (2) standby (3) abandoned (4) under development

Disposal wells by general location (continued)

State	Registry Number	Operator	Location (City)	Status
Indiana	In-10	General Electric Company	Mt. Vernon	(1)
	In-11	Inland Steel Corporation	East Chicago	(1)
	In-12	Indiana General Corporation	Valparaiso	(1)
	In-13	General Electric Company	Mt. Vernon	(1)
Kentucky	K-1	Sohio Petroleum Company	Latonia	(3)
	K-2	DuPont deNemours & Company	Louisville	(4)
	K-3	DuPont deNemours & Company	Louisville	(4)
New York	NY-1	International Salt Company	Schuyler County	(1)
	NY-2	Hooker Chemical Company	Niagara Falls	(2)
	NY-3	Bethlehem Steel Company	Lackawana	(2)
	NY-4	FMC Corporation	Middleport Village	(2)
Ohio	O-1	Armco Steel Corporation	Middletown	(1)
	O-2	Empire-Reeves Division	Mansfield	(3)
	O-3	Vistron Corporation	Lima	(1)
	O-4	Armco Steel Corporation	Middletown	(1)
	O-5	U.S.S. Chemical Company	Haverhill	(1)
	O-6	Vistron Corporation	Lima	(1)
	O-7	Calhio	Perry Village	(3)
	O-8	International Salt Company	Cleveland	(1)
	O-9	Vistron Corporation	Lima	(1)
	O-10	Ohio Liquid Disposal	Sandusky	(4)
Pennsylvania	P-1	Jones & Laughlin Steel Co.	Aliquippa	(3)
	P-2	Hammermill Paper Company	Erie	(3)
	P-3	Hammermill Paper Company	Erie	(3)
	P-4	Gulf Research & Development	Bedford County	(3)
	P-5	Bethlehem Steel Company	Franklin Boro	(3)
	P-6	Koppers Company, Inc.	Petrolia	(3)
	P-7	Peoples Natural Gas	Not developed	(3)
	P-8	Hammermill Paper Company	Erie	(3)
	P-9	Bethlehem Steel Company	Mariana	(3)
West Virginia	W-1	E.I. DuPont deNemours Co.	Belle	(2)
	W-2	E.I. DuPont deNemours Co.	Parkersburg	(2)
	W-3	E.I. DuPont deNemours Co.	Belle	(1)
	W-4	Weirton Steel Division	Weirton	(3)
	W-5	E.I. DuPont deNemours	Parkersburg	(1)
	W-6	PPG Industries	Proctor	(1)
	W-7	Allied Chemical Corp.	Moundsville	(1)

Figure 1
Disposal Well Locations



WASTEWATER INJECTION BY STATE

Somewhat more wastes are currently being injected in the ORSANCO states outside the Ohio basin than within the Ohio basin (about 1.65 million gallons/day vs. 1.4 million gallons/day) as can be seen in the following table. More Ohio Valley injection is now occurring in Illinois than in any other compact state, with West Virginia being a close second. Outside the Ohio basin, Indiana contains about 60 percent of the load followed by Ohio with about 30 percent (see table 3).

On an accumulative basis, Illinois again leads the list within the basin and Indiana outside, as the next table shows (see table 4).

TABLE 2 -- Current Underground Injection Rates
gallons/day

State	Ohio Basin Wells		Other Wells	
	Injection Rates	Number	Injection Rates	Number
Illinois	542,300	3	17,500	1
Indiana	61,700	2	965,800	9
New York	0	0	115,200	1
Ohio	310,300	3	553,200	3
West Virginia	483,700	6(1)	0	0
	1,398,000	14	1,651,800	14

(1) Two wells are recirculating and have no net injection volume.

TABLE 3 -- Accumulated Volumes of Wastes
Injected Underground -- by State
(millions of gallons)

State	Accumulated Volume Ohio Basin	Accumulated Volume Other
Illinois	421.4	11.3
Indiana	54.7	5,398.2
Kentucky	(1)	0
New York	0	15.0
Ohio	198.3	445.6
Pennsylvania	33.1	1,098.3
West Virginia	273.1	0
	980.1	6,968.4

(1) Relatively minor but unknown amounts injected into one well during World War II.

OPERATIONAL STATUS OF WELLS

For the purposes of this report injection wells are divided into four over-all classifications based on operational status: currently operating, standby, abandoned and under development. Abandonment is further divided into those which were once actively used for injection and those never used. Standby refers to those wells which were either once used, or at least once ready for use, and not now in use, but technically and legally still eligible for use.

Table 1 presents a summary of the fifty-three wells according to operational status and location.

ABANDONED WELLS

The category of abandoned wells needs further discussion because it may provide clues concerning what might be considered deficiencies in operation or design. Table 5 is a summary of reasons for abandonment. In but three of the twelve abandonments were equipment failures cited. A more detailed breakdown by individual abandoned wells is indicated in Table 6. Following Table 6 appears brief case histories of wells that were abandoned because of "Equipment Failures" and "Failure of Companion Wells." These wells are of particular interest since their failure occurred during actual injection of moderate amounts of wastewater.

TABLE 4 -- Operational Status of Underground Wastewater Injection Wells (1972)

Status	Number of Wells	
	Ohio Valley	Other
28 Currently operational	13	15
4 Standby	2	2
12 Abandoned - once operational	3	4
- never operational	4	1
9 Under development	5	4
	27	26

TABLE 5 -- Summary of Reasons for Abandonment of Injection Wells

Reason	Number of Wells
Wells didn't meet requirements for injection and were not utilized	5
Equipment failures	3
Failure of companion wells	2
Temporary use only	1
Unknown	1
	12

TABLE 6 -- Summary of Information on Abandoned Injection Wells

Identification Number	Operator	Operating History	Reason for Abandonment
I1-4	American Potash and Chemical Company	Completed 1967, never used for injection	Requirement for separation from 10,000 mg/1, TDS water could not be used
K-1	Sohio Petroleum Company	Used during World War II	Operated during war period only
O-2	Empire-Reeves Division of Cyclops Corporation	Operated Oct. 1968 to May 1970. Accumulated vol. 10.3 million gals. of spent pickle liquors	Excessive corrosion problems
P-1	Jones & Laughlin Steel Company	Operational 4/65 to 6/72. Accumulated vol. 33.1 million gals. of spent pickle liquors	Frequent tubing failures and excessive injection pressures needed.
P-2	Hammermill Paper Co.	Operated 1963 to 4/68. Accumulated vol. 446.4 million gals. of spent sulphite liquors	Casing and tubing lifted out of hole 4/14/68

Table 6 (Continued)

Identification Number	Operator	Operating History	Reason for Abandonment
P-3	Hammermill Paper Company	Operational 4/65 to 10/68. Accumulated vol. 297.9 million gals. of spent sulphite liquors	(Companion well to P-2)
P-8	Hammermill Paper Company	Operated 5/68 to 6/70. Accumulated vol. 354.0 million gals. of spent sulphite liquors	(Companion well to P-2)
P-4	Gulf Research and Development Company	Operated 1967-72, Accumulated vol. 15,500 gallons drilling fluids	Unknown
P-5	Bethlehem Steel Company	Was to be used for mine drainage; never operational	Tests proved unsatisfactory
P-6	Koppers Company	Never used for injection	Fell short of needs
P-9	Bethlehem Steel Company	Never used for injection	Found wanting in physical requirements
W-4	Weirton Steel Division of National Steel Co.	Never used for injection	Not suitable for injection purposes

EXAMPLES OF WELL FAILURES

OHIO

One well in Ohio was withdrawn from use after extensive injection tubing failure (O-2) resulting in excessive maintenance and was subsequently abandoned and plugged. Fluid escapes from the well were apparently minimal and no serious consequence was reported. The waste handled at this facility was spent sulphuric acid pickle-liquor consisting of up to 10 percent H_2SO_4 and about 10 percent Fe SO_4. Injection pressure for this well ranged initially 1,300 psig to 330 psig near the end of the injection period. (See Table 43,P.57 for injection record summary). The system was monitored for annulus pressure and specific conductance of the annulus fluid. The continued problem of injection tubing failure (corrosive) appears to be a problem common to the maintenance of other wells. An indication of the weakest link in the entire system appears to be this single element. This is not to say, however, that the other elements are invulnerable.

PENNSYLVANIA

The most dramatic failure in the region was that experienced at Erie, Pennsylvania, when on April 14, 1968, the No. 1 wastewater well of the Hammermill Paper Company (P-2) erupted its 7 inch casing string and the injection tube. Shut-down of the injection pumps was immediate but the well belched forth about 200,000 gallons per day of waste sulphite liquors which were directed into Lake Erie. Personnel and equipment were immediately summoned, the well was quieted with heavy media and electrical and mechanical surveys were made of the hole. Results indicated that leakage from the 4-1/2 inch injection pipe had allowed the escape of wastewater and severe corrosion had occurred at the 889 foot level of the 7 inch casing. The 7 inch casing was cemented to 830 ft. below top of hole. The pressure was sufficient to raise the upper approximately 890 ft. of the 7 inch tubing and head works over 30 ft. above the original casinghead elevation. Remedy was taken to stem the flow. The three wells of the system (P-2, P-3 and P-8) were all subsequently abandoned and plugged. The pressures utilized (1,250 psig at head) were well below critical pressures, approximately .6 of lithostatic. The annulus voids between casing runs were only partially cemented. The corrosion is attributed to either galvanic corrosion or escape of the corrosive fluids into the annular spaces. This case history may provide substance and support to a guideline that all casings be cemented from bottom to top of hole and the use of any annulus void be restricted to the one between the long string of casing and the injection tubing.

The Pennsylvania well at Aliquippa (P-1) was used to inject spent sulphuric acid waste pickle liquors. The well is unique in that it operated at sustained, relatively high pressures during its life (2,000/4,650 psig wellhead). Initially the well injected fluids at 5,252 ft. to 5,445 ft. in the Oriskany sandstone and later changed to 4,585 ft. to 4,635 ft. to include the Onondaga limestone. Records are not in sufficient detail to appraise fracturing effects. Corrosive failure of the injection tubing was common and was the basis of frequent shutdown and repair. The injection periods were preceded by an injection of fresh water to provide a "bubble" of lower reactivity than anticipated in the connate brine. The decision for shutdown abandonment and plugging of the well was made on the basis of the high pressure experienced. Criteria generally applied indicate the lithostatic pressure (about one pound per square inch per vertical foot of rock) was approached. This value approximates parting or fracturing pressures.

INJECTION PRESSURE

An important feature of an injection well is the pressure which must be applied to force the waste into the geologic formation. The following table indicates injection pressure for operating and standby wells. Most of the wells operate at pressures below 1,000 psi.

TABLE 7 -- Wells by Injection Pressure
(Operational and standby wells only)

PSIG* - Casinghead	Number of Wells	
	Ohio Valley	Outside
0 - 50	2	6
51 - 100	2	0
101 - 500	3	4
501 - 1,000	6	4
1,001 - 2,000	1	2
2,001 - 3,000	1	0
Not indicated	1	1
	16	17

* Pounds per square inch-gauge

One important measure of the magnitude of injection pressure is the ratio of the wellhead pressure to well depth.

The following table (8) is presented to show the pressure characteristics of the injection wells studied. This summary indicates that most of the wells operate pressures well below those considered to be critical. These values indicate only the head pressure and do not take into account hydrostatic head or fluid density.

TABLE 8 -- Well Depth and Head Pressure

Well identification No.	Injection formation & rock type	Depth to top/ thickness	Head press. (psig)	Ratio wellhead press. to depth
NY-1	Shale-limestone	1,300'/55'	300	.23
2	Sandstone-Dolomite	2,835'/191'	1,445	.23
3	Sandstone-Dolomite	3,794'/457'	1,938	.51
4	Sandstone-Dolomite	2,660'/105'	--	--
Pa-1	Sandstone (a)	5,385'/37'	2,000-4,650	.37-.86
	Limestone (b)	4,585'/50'	2,950-3,500	.63-.75
2	Dolomite (a)	1,611'/81'	1,220	.75
	Dolomite (b)	2,057'/245'	1,220	.59
3	Dolomite (a)	1,658'/74'	1,220	.73
	Sandstone (b)	5,914'/38'	1,220	.21
4	Dolomite	540'/13'	500	.94
5	Sandstone	--	--	--
6	Sandstone	1,903'/5'	--	--
	Sandstone	2,040'/6'	--	--
	Sandstone	2,145'/30'	--	--
8	Dolomite	1,586'/151'	1,220	.77
9	Sandstone	1,431'/86'	--	--
W-1	Sandstone	1,300'/200'	645	.50
2	Sandstone	1,300'/200'	744	.57
3	Dolomite	5,100'/100'	804-1,056	.20
4	Sandstone	1,086'/30'	--	--
5	Limestone	4,016'/89'	520	.12
6	Halite	6,820'/??	300	.04
7	Halite	6,623'/??	717	.11
KY-1	--	--	--	--
2	Dolomite	1,710'/2,590'	18-25	.01-.014
3	Dolomite	1,710'/2,590'	18-25	.01-.014
O-1	Sandstone	2,954'/282'	10-150	.003-.035
2	Sandstone	4,982'/82'	1,500-270	.3-.05
3	Sandstone	2,780'/352'	700-1,117	.25-.40
4	Sandstone	2,940'/339'	10-85	.003-.035
5	Sandstone	5,514'/66'	750-1,800	.13-.32
6	Sandstone	2,800'/382'	700-1,117	.25-.40
7	Sandstone	5,930'/??	--	--
8	Sandstone	1,335'/87'	--	--
9	Sandstone	(See 3 and 6) Not developed June 1972		

Table 8 (Continued)

Well identification No.	Injection formation & rock type	Depth to top/ thickness	Head press. (psig)	Ratio wellhead press. to depth
In-1	Dolomite	270'/397'	35	.13
2	Dolomite	255'/	35	.14
3	Sandstone	2,286'/100'	200	.09
4	Sandstone	5,286'/900'	1,000	.19
5	Sandstone	2,535'/1,700'	0	00
6	Sandstone	2,530'/1,415'	140-1,040	.055-.41
7	Sandstone	2,521'/1,744'	140-1,040	.055-.41
8	Sandstone	2,160'/2,100'	0	00
9	Sandstone	2,422'/2,100'	0	00
10	Sandstone	2,760'/46'	200-585	.07-.21
11	Sandstone	2,360'/1,980'	0	00
12	Sandstone	2,815'/1,733'	0-10	00
13	Sandstone	2,768'/74'	--	--
Il-1	Limestone	2,732'/250'	25-139	.01-.05
2	Dolomite	4,892'/426'	0	00
3	Sandstone	3,109'/1,734'	118-312	.04-.10
4	Not used			
5	Dolomite	5,015'/509'	2-22	.00026-.0025
6	Limestone	2,440'/283'	--	--

RATE OF INJECTION

The following table summarizes the rate of injection for the currently operational wells.

TABLE 9 -- Wells by Rate of Injection
(Currently operating wells only)

Gallons per minute	Gallons per day	Number of Wells Ohio Valley	Other
0 - 50	0 - 72,720	6(1)	7
51 - 100	72,721 - 144,720	5	3
101 - 150	144,721 - 216,720	2	1
151 - 200	216,721 - 288,721	0	2
201 - 250	288,721 - 360,721	0	1
251 - 300	360,721 - 432,720	1	0
Not available		1	0
		15	14

(1) Includes the recirculating wells with net injection rate of zero. Most operate in the up to 100 gallons per minute ranges.

The following table contains a classification of wells by depth of the top of the injection zone, which usually is the same as the top of the injection formation. Shallowest injection is 255 feet in a well at Michigan City (In-2). The top of the injection zone for nineteen of the Registry wells is between 2,000 and 3,000 feet below land surface.

TABLE 10 -- Classification of Wells by Depth Categories (depth to injection zone)

Depth	Number of Wells Ohio Valley	Number of Wells Outside
0 - 1,000	1	3
1,001 - 2,000	7-1/3*	4
2,001 - 3,000	7-2/3	11-1/2
3,001 - 4,000	0	2
4,001 - 5,000	3-1/2	0
5,001 - 6,000	5-1/2	1-1/2
6,001 - 7,000	2	0
Not indicated	0	4
	27	26

One reason why thickness of injection zone is important is because of storage potential. Porosity is also important, and it is included in Part II.

TABLE 11 -- Wells by Thickness of Injection Zone

Thickness (feet)	Number of Wells Ohio Valley	Number of Wells Outside
0 - 100	10	6-1/2*
101 - 200	2	3
201 - 300	3	1/2
301 - 400	1	3
401 - 500	1	1
501 - 1,000	3	0
1,001 - 1,500	0	1
1,501 - 2,000	1	5
2,001 - 2,500	1	1
2,501 - 3,000	2	0
Unknown	3	5
	27	26

* Fractions indicate wells with multiple injection zones

TIME PERIOD

The summaries of area-wide well characteristics follow. Most of the Registry wells were completed during 1966-70. Eleven wells were completed in 1968, 6 in 1967, and no more than 5 in any other single year.

TABLE 12 -- Well Completion by Time Periods

Years	Number of Wells
1940-45	2
1945-50	2
1951-55	2
1956-60	2
1961-65	6
1966-70	28
1971-72	11
	53

GEOLOGIC SYSTEMS USED

In broad terms virtually all of the geologic paleozoic systems in the region were used at one place or another. The following is a summary of the wells by geologic systems used. Interest in general is toward use of the formations of Cambrian age.

TABLE 13 -- Geologic Systems Used for Injection

System	Number of Wells
Pennsylvanian	3
Mississippian	5
Devonian	9
Silurian	5-1/2
Ordovician	6
Cambrian	24-1/2
	53

(1/2 well - injection into two zones in the same well)

The accumulation of injected fluids by injection zone is shown in the following table:

TABLE 14 -- Injections into Geologic Systems and Formation to Mid-1972

Geologic System Formation	Number of Wells	Volume accumulated (gals.) To June 1972
Pennsylvanian		
Pottsville (Salt Sands)	3	104,500,000
Mississippian		
Tar Springs	1	1,000,000
Bethel	2	98,000,000
Berea	1	Tests only
Burgoon	1	Tests only
Devonian		
Unspecified*	4	5,000,000,000 (approximate)
Warren, Queen & Speechly	1	Tests only
Marcellus	1	Partial
Onondaga**	1/2 ***	2,500,000
Oriskany	3-1/2	195,000,000
Silurian		
Bass Islands	1-1/3	932,000,000
Lockport	1/3	Unknown
Salina	2	Recycle of fluids
Williamsport	1	164,000,000
Ordovician		
Bellefonte	1	15,000
Knox	3	No injection as of June 1972
Cambrian		
Eminence-Potosi	2	352,000,000
Mount Simon	18-1/3	2,185,000,000
Potsdam/Theresa	3	Tests only

* Devonian and Silurian (2 wells) possibly basal Detroit River and Kenneth formations

** Well changed injection zones

*** **Fractions indicate wells with multiple injection zones**

CHEMICAL CHARACTER OF INJECTED WASTEWATERS

A discussion of the chemical character of injected wastewaters and attempts to classify these wastes in a set of simple groupings by chemical content is fraught with complexity. Most of the wastes may be characterized by a principal constituent or what may be generally expected. However, a NaCl brine from a plastic operation may contain, albeit small, quantities of the reactants and product; however small in load or concentration, effects may be accumulative over the long-term injection. Some wastes that are discharged to holding ponds will vary in character over time because of the effects of oxygen, sunlight, dilution, organism activity, and a different circumstance may be encountered with variability of such fluids than those delivered directly from the process line. Analyses are included to show the chemical character of the injected fluids.

Analyses are not always available in detail, but a general comparison may be made of waste composition. Spent petroleum catalyst wastes are known, for example, to contain sodium aluminates, thiophens, mercaptans, and mercaptides. And while the precise character is not known, sufficient knowledge of processes exists for evaluation purposes. Problems of waste character disclosure were found with the U. S. Army Arsenal disposal well at Newport, Indiana. The nature of most of the dissolved solids was disclosed but because of the usual associated secrecy provision, the precise nature of the fluids was never disclosed. The well is no longer used, but during the development assurances were given by the Department of the Army to the State of Indiana that the wastes would be properly contained.

Proprietary elements also exist in the area of complete disclosure. During the process of developing and confirming data some firms indicated that complete disclosure of the wastewater composition would invade the proprietary rights of the firm because the secret details or aspects of the process of the trade would be revealed to competitors.

In general, information on the chemical composition of the injected wastes is insufficient to judge compatibility with formation fluids, the nature of which are also often poorly known. One conclusion at this time however, is that no serious short-term effects have been reported. Long-term effects remain to be seen; most of the wells have operated for less than 10 years.

Part II will present detailed analytical information on individual injected wastewaters when available.

GENERIC TYPES OF WASTEWATER

Wastewaters contain numerous chemical constituents in varying concentrations. In the analysis of large amounts of information on wastewaters, such as in this report, there is utility in classifying wastewaters according to the generic type of the principal constituents. For the purposes of this report four generic types of wastewaters will be discussed: Steel pickling liquors, hydrochloric acid, chlorides and sulfates and organics (and combinations of each of these four types). Brief descriptions of each follow.

Steel Mill Spent Pickle Liquor -- These spent liquors are derived from surface treatment of steel with HCl or H_2SO_4 to remove scale. The resulting spent liquors contain a high concentration of ferrous chloride or sulphate and an accompanying residuum of acid. Other cations are present depending on the alloying ingredients of the steel. State summaries in Part II show wells used for spent pickle liquors and the resident formations. In at least one example the waste ($FeCl_2$,HCl) is used as raw material for a separate product. The processing results in a waste of NH_4Cl, which is disposed by injection.

Hydrochloric Acid Wastes -- A by-product of some of the chemical industries is concentrated hydrochloric acid. This is often accompanied by minor or trace amounts of the product or reactive raw materials. Most of the by-product is from a chemical replacement of Cl by fluorine in the preparation of fluorocarbon compounds. At times the by-product waste finds its way to use in steel pickling, but relatively large quantities in excess of needs is common.

Chloride and Sulphate Wastes (Predominantly Cl and SO_4 Salts of Ca and Na) -- A number of industries (other than steel) produce wastes with a predominately chloride or SO_4 content. Some of these are principally sodium chloride, but calcium and magnesium and ammonium chlorides are important. Organics are associated with some,and others are from inorganic chemical plants. This class of materials would generally seem to produce the least potential to intergranular porosity blockage. The exception would be possibly those materials which contain iron, sulphates, or reactive organics, although little or no effects are experienced at this point.

Organic Chemical Wastes -- These organics are usually associated with acid or brine effluent and constitute a low concentration. Usually the waste is the reaction medium or a small concentration of the product as well as the by-product. In terms of concentration the levels are generally low. The highest concentration noted of any organic chemical was that for phenol, estimated at 3 percent; this was followed by fluorocarbons at 1-1/2 percent. The fluids injected include fluorocarbons, acrylonitrile and acetyl nitriles, cumenes, phenols, chlorinated hydrocarbons, including chlordane, DDT, and others. Coke plant quench waters contain phenols, cyanides, thiocyanates and ammonia and are included in this category. Most organic wastes are present in small concentrations and are associated with brine or acid solutions. Therefore, they are listed under those readings as well.

All of the wells listed in the Registry that had received wastes at some time were classified in one or more of these four generic groupings.

Tables 15 and 16 show the volumes of currently injected wastewaters and accumulated volumes, respectively, for each generic waste according to whether within or without the Ohio basin. On a current basis, organic wastes, and organic wastes paired with HCl or chlorides and sulfates, comprise about one-half of the total amounts injected. On an accumulative basis, chlorides and sulfates are about 90 percent of the wastes outside the Ohio basin, but only about one-fourth that within. Organic wastes, separately or in combination, represent about 60 percent of the total accumulation in the Ohio basin.

TABLE 15 -- Chemical Characteristics of Currently-Injected Wastes (gallons/day)

Generic Type of Wastes	Ohio Basin Wells		Other Wells	
	Injection Rate	Number	Injection Rate	Number
Steel Pickling Liquors	285,200	3	161,700	4
Hydrochloric Acid	65,600	1	0	0
Chloride and Sulfate	0	2(1)	717,500	5
Organic	86,600	1	772,500	5
Organic and HCl	261,404	2	0	0
Organic and Cl/SO_4	317,296	3	0	0
Other	382,200	2	0	0
Totals	1,398,200	14	1,651,700	14

(1) Recirculating wells, no net injection volume.

TABLE 16 -- Accumulated Volume of Wastes Injected Underground -- By Generic Type (Millions of gallons)

Generic Type	Ohio Basin	Other
Steel Pickling Liquors	129.2	227.0
Hydrochloric Acid (HCl)	20.	0
Chlorides and sulfates (Cl/SO_4)	252.3	6,118.2
Organic	129.4	603.2
Organic and HCl	105.9	0
Organic and Cl/SO_4	342.1	0
Other	1.5	0
	980.4	6,968.4

GLOSSARY OF TERMS

Injection string . . . . . . The tubing that is used in the well for conducting fluids to disposal zone.

Long casing . . . . As used herein is the set of casing that extends from the surface and to or through the injection zone.

Annulus . . . . Space between casings or between the casing and the injection tubing.

Fracture porosity . . . . . Porosity that occurs in rocks that are otherwise impervious, except for the fractures.

Lithostatic . . . . Weight of column of rock; about one pound per square inch per foot of depth.

Drill-stem test . . . . . . Test performed in rotary drilling by introducing formation fluids into the drill-stem (hollow tube) to estimate flows and sample fluids.

Tight . . . . Not conducive to the flow of fluids, lacks permeability or ability to transmit fluid.

Basement complex . . . . . . Rocks upon which the sedimentary paleozoic rocks rest. May be granites, or schists in the basin.

Annulus void . . . . Non-cemented annular space between casings.

Porosity . . . . Amount of void space contained in a rock, indicated as a volumetric percentage.

Permeability . . . . Ability to transmit fluid, reported as millidarcies (md). A darcy is the equivalent of the passage of one cubic centimeter of fluid of one centipoise viscosity flowing in one second under a pressure differential of one atmosphere through a porous medium of one centimeter cross-section by one centimeter of length.

PART II

DESCRIPTION OF THE WELLS BY STATE

The sequence of wells described below is alphabetical by state. The description of the individual wells in a state includes a brief narrative followed by a series of tables. The first will contain a summary of current injection rates and accumulated volumes by generic type of wastewater; the second lists the physical characteristics of the individual wells; the third lists wastewater and other characteristics; and the remainder are monthly operating records, where available.

Illinois -- Of the seven wastewater injection wells in this state five are currently operating, one is under development (Il-7), and one was never operated but was abandoned (Il-4). The five Ohio basin wells consist of three of the operating wells and two under development. The abandoned well of the American Potash and Chemical Company at West Chicago (Il-4) was drilled for disposal service, but the requirement for separation from 10,000 TDS water could not be met; the well was plugged back and converted into a freshwater supply. The Allied Chemical Company completed and tested a well at Danville in 1972 (Il-7), but it is not in use as of mid-1972. In this well the top of the Mt. Simon is 5,144 ft. below the surface and 1,524 ft. thick.

The three currently operating Illinois wells in the Ohio basin, for which data is available, have accumulated about 43 percent of the total known amount of waste injected underground in the entire Ohio Valley. These same three wells contribute about 39 percent of the total current daily volume injected in the Ohio Valley.

Tables 17 - 19 contain summaries of current and accumulated injection volumes, physical characteristics, and wastewater characteristics, respectively, for the Illinois wells.

TABLE 17 -- Current Disposal Rates and Accumulated Volumes of Wastewaters Injected into Illinois Wells -- by Generic Type of Wastewater

	Current Disposal Rate (gallons per day)		Accumulated Volume (gallons)	
Generic Type	Ohio Basin	Outside	Ohio Basin	Outside
Pickling liquor	--	17,470	--	11,330,000
Hydrochloric acid	65,600	--	20,000,000(est.)	--
Chlorides and Sulfates	382,000	--	226,320,000	--
Organics and Cl/SO_4 (1)	95,040	--	175,000,000	--
	542,640	17,470	421,320,000	11,330,000

(1) Data not available for one well.

TABLE 18 -- Physical Characteristics of Injection Wells -- Illinois

Registry Number	Operator and Location	Injection Formation and Rock Type	Depth to Top/ Thickness (feet)	Porosity and Permeability	Injection Pressure Range (psig)
Il-1	Velsicol Chemical Corp. Marshall, Illinois Clark Co. T11N, R12W Section 12	Devonian Limestone	2,372/250		25-172
11-2	Cabot Corporation Tuscola, Illinois Douglas Co. T16N, R8W	Cambrian Eminence and Potosi Limestone-Dolomite	4,892/426	13% 20-100 md	0
11-3	Jones & Laughlin Steel Co. Hennepin, Illinois Putnam Co. T32N, R2W Section 3	Cambrian Mount Simon Sandstone	3,109/1,734		118-312
Il-4	American Potash and Chemical Company West Chicago, Illinois DuPage Co., T39N, R9E Section 9	Cambrian Mount Simon Sandstone	--		--
Il-5	U.S.I. Chemicals Company Tuscola, Illinois Douglas Co. T16N, R8W	Cambrian Eminence-Potosi Dolomite	5,015/509	25% est.	4-22
Il-6	Velsicol Chemical Company Marshall, Illinois Clark Co., T11N, R12W Section 12	Devonian Unnamed Limestone	2,440/283	N.A.	N.A.
Il-7	Allied Chemical Company Danville, Illinois	Mount Simon Sandstone	5,144/1,524	N.A.	--

TABLE 19 -- Wastewater and Other Characteristics of Injection Wells -- Illinois

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
Il-1	Yes	Currently operational	175,000,000 (est.)	95,040	NaCl - 140,000 ppm NaOH - 25,000 ppm NaOCl - 20,000 ppm pH - 10.5 to 11.5 Sp. gr. - 1.15 (Trace organics)
Il-2	Yes	Currently operational Completed 4/26/66 Operational 4/66	20,000,000 (est.)	65,600	HCl - 33% Sp. gr. 1.16 SiO_2 - Tr
Il-3	No	Currently operational Completed 8/12/66 Operational 12/67	11,328,876 (plus est. one million gals. of fresh water	17,470	HCl - 0.5% $FeCl_2$ - 24.0% $H_2Cr_2O_7$ - 1.0%
Il-4	No	Abandoned Completed 1967, but never used for injection	(Not permitted for wastewater but plugged back to potable water horizons and used for fresh water supply)		
Il-5	Yes	Currently operational Completed 5/9/70 Operational 8/4/70	226,320,000 (Incl. Aug. 1972)	382,000	$CaSO_4$ H_3PO_4 - 3% H_2SO_4 - 1.5% Fluorides - .7% pH - 1.0
Il-6	Yes	Not yet injecting (Classify as under development) Completed 12/28/71	--	--	(planned to be same as Il-1)
Il-7	Yes	Not in use (under development) Completed and tested in 1972	--	--	--

The following tables show monthly operating records for four Illinois wells (Il-1, Il-2, Il-3 and Il-5).

TABLE 20 -- VELSICOL Chemical Corp., Marshall Injection Well (Il-1)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
Nov. 1965		Well injection started			
July 1970	31	1,919,520		61,920	
Jan. 1971		3,080,160		99,360	71
March	31	2,410,560		77,760	105
June	30	2,246,400		74,880	123
Oct.	31	2,276,640		73,440	139
Dec.	31	2,232,000		72,000	154
Jan. 1972	31	2,232,000		72,000	156
Feb.	29	2,171,520		74,880	172
March	31	2,767,711		89,280	
May	31	2,410,560		77,760	25
June	30	2,851,200		95,040	59

TABLE 21 -- CABOT Corp., Tuscola Injection Well (Il-2)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
March 1972		2,267,104	2,267,104		0
April		2,276,543	4,543,647		0
May		2,412,917	6,956,564		0
June		2,370,902	9,327,466		0
July		2,227,142	11,554,608		0
Aug.		1,971,516	13,526,124		0
Oct.		1,968,042	15,494,166		0

TABLE 22 -- J & L Steel Corp. (Hennepin Works Div.)
Injection Well (I1-3)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
July 1970	3	329,174	329,174	109,724	187
Aug.	4	298,070	627,244	74,517	155
Sept.	3	306,536	933,780	102,178	210
Oct.	4	351,980	1,285,760	87,995	244
Nov.	3	210,880	1,496,640	70,293	118
Dec.	File missing, accumulated volume estimated as on standby				
Jan. 1971	3	475,640	1,972,280	158,546	225
Feb.	6	624,084	2,596,364	104,014	206
March	8	742,580	3,338,944	92,822	232
April	7	702,258	4,041,202	100,322	240
May	5	410,430	4,451,632	82,086	138
June	7	567,627	5,019,259	81,089	225
July	3	410,125	5,429,384	136,708	265
Aug.	1	131,346	5,564,730	131,346	270
Sept.	2	121,601	5,682,331	10,800	275
Oct.	3	376,292	6,058,623	125,430	312
Nov.	6	597,413	6,656,036	99,568	308
Dec.	6	653,514	7,309,550	108,919	124
Jan. 1972	4	511,650	7,821,200	127,912	129
Feb.	10	742,761	8,563,961	74,276	205
March	8	709,117	9,273,018	88,639	300
April	8	755,020	10,028,098	94,377	266
May	7	776,716	10,804,814	110,959	
June	9	524,062	11,328,876	58,225	294

TABLE 23 -- U. S. Industrial Chemical, Tuscola
Injection Well (I1-5)

Sept. 1970	30	16,203,000	16,203,000	524,000	6
Oct.	15	6,869,000	23,000,000	458,000	6
March 1971	16	6,520,000	29,520,000	524,000	22
April	16	12,488,000	42,008,000	292,100	20
May	30	13,378,000	55,386,000	432,000	16
June	30	12,312,000	67,698,000	397,000	16
July	29	12,112,000	79,810,000	361,000	16
August	30	13,153,000	92,963,000	438,000	13
September	13	5,460,000	98,423,000	182,000	8
October	27	10,969,000	109,392,000	392,000	4
November	23	8,747,000	118,239,000	370,000	12
December	29	11,683,000	129,922,000	448,000	8
Jan. 1972	30	12,686,000	142,608,000	423,000	7
Feb.	29	16,602,000	156,210,000	572,000	7
April	30	12,454,000	180,655,000	401,000	10
May	31	12,800,000	193,455,000	413,000	12
June	30	11,521,000	204,976,000	384,000	11
July	31	9,894,000	214,870,000	319,000	4
Aug.	30	11,450,000	226,320,000	382,000	8

Indiana -- Thirteen wells are used for underground injection of wastewaters from industrial sources in Indiana. Eleven are currently operating; one is on standby, and one is under development. Four of the wells are in the Ohio basin; the others are in the Lake Michigan watershed. Various geologic units are used for the injection; however, most of the disposal wells in the state are in the Mount Simon.

The eight Mount Simon injection wells in Indiana were placed in operation over a period of eleven years. The first such well, owned by FMC, started operation in 1960 at Newport (In-4). The most recent Indiana Mount Simon well is the Indiana General Corporation well at Valparaiso (In-12) which went into operation in 1970. Rates of injection into the Mount Simon zone range from 32 to 275 gallons per minute into the thicknesses of Mount Simon ranging from 900 ft. to 2,100 ft. The porosities range from 6 percent to 20 percent and permeabilities from 6 to 427 millidarcys. All of the Mount Simon wells are active at present and have accumulated somewhat over 300,000,000 gallons of waste fluids.

The Mississippian Bethel formation and the Tar Sands formation are also utilized. Mount Vernon is the site for three wells, two of which were operational prior to 1972, and the third is being readied. The G. E. well No. 1 (In-10) at Mount Vernon has been in operation since August 1966, and has injected approximately 100,000,000 gallons of waste. The well has performed with minimum maintenance. A second well was drilled by G. E. at Mount Vernon to the St. Peter (In-13) but because of low porosity and permeability it was plugged back to the Bethel formation.

American Cyanamid wells (In-1 and 2) were developed in 1950 and 1951, and have operated continuously. It is estimated that approximately 5,000,000,000 gallons of wastewaters have been injected through mid-1972. The wells are monitored for flow and pressure (400 gpm at 35 psig). The formation is not clearly identified but the wells are 255 ft. and 270 ft. deep to the injection zone tops; thickness of injection zones are 40 ft. and 397 ft. These wells apparently utilize the basal Devonian and upper Silurian carbonate rocks for injection. The wastes contain sodium and ammonium sulphate with about 150 mg/l of acidity (titratable).

The Indiana Farm Bureau well (In-3) at Mount Vernon was completed in 1950 and plugged back to the Tar Springs (Mississippian) and has since injected spent petroleum catalysts. The amount is small and averages about 6,300 gallons per month. Estimated accumulation is 1,512,000 gallons.

The Newport well of the FMC Corporation (In-4) was drilled and put into operation in 1960. Injection is in the Mount Simon at 50 to 900 gpm at pressures of 1,000 to 1,500 psig. Detailed logs of injection do not appear in the records, but an estimate of accumulation of 26,000,000 gallons is made. The injection tubing collapsed in 1962 and the well was reworked and tested and put back on line. The well is not used at present.

Three Bethlehem Steel wells at Chesterton (In-5, In-6 and In-7) were drilled in November 1967, March 1968 and April 1968, respectively. All were put into operation soon after completion.

Two of these wells (In-6 and In-7) are operated alternately as companion wells for injection of ammonia liquors. Injection records for these two wells are maintained in a combined manner by the operator. The third Bethlehem Steel well operates as a separate unit for spent pickle liquors.

The Midwest Steel Division of National Steel Corporation well at Portage, (In-8), has an operational history that dates to August of 1965. By June of 1972, 111,378,620 gallons of spent pickle-liquors were injected. This well has a continuous operational history since its inception. The injection is into the Mount Simon.

U. S. Steel well at Gary, Indiana (In-9), was completed in 1965. Pressure and volume records presently available extend only from 1970.

A summary of current disposal rates and accumulated volumes for Indiana injection wells appears in Table 24 according to generic type of waste. Tables 25 and 26 contain physical and wastewater characteristics, repectively for the Indiana wells.

TABLE 24 -- Current Disposal Rates and Accumulated Volumes of Wastewaters Injected into Indiana Wells -- by Generic Type

	Current Disposal Rate (gallons/day)		Accumulated Volume (gallons)	
Generic Type	Ohio Basin	Outside	Ohio Basin	Outside
Pickling Liquor	61,480	144,260	27,208,154	215,673,107
Chlorides and Sulfates	0	580,740	26,000,000	5,004,269,827
Organics	0	240,880	0	178,222,998
Other	210	0	1,512,000	0
	61,690	965,880	54,720,154	5,398,170,932

TABLE 25 -- Physical Characteristics of Injection Wells -- Indiana

Registry Number	Operator and Location	Injection Formation and Rock Type	Depth to Top/ Thickness (feet)	Porosity and Permeability	Injection Pressure Range (psig)
In-1	American Cyanamid Co. Michigan City, Indiana Laporte Co. T38N, R4W, Sec. 22	Devonian Silurian Limestone and Dolomite	270/397		35
In-2	American Cyanamid Co. Michigan City, Indiana Laporte Co. T38N, R4W, Sec. 22	Devonian Silurian Limestone and Dolomite	255/40		35
In-3	Indiana Farm Bureau Coop. Association, Inc. Mt. Vernon, Indiana Posey Co. T75,R13W	Mississippian Tar Springs Sandstone	2,286/100	30% 200 md (est.)	200
In-4	FMC Corporation Newport, Indiana Vermillion Co. T16W, R6W, Sec. 9	Cambrian Mount Simon Sandstone	5,260/900	6% 6-8 md	1,000
In-5	Bethlehem Steel Corp. Chesterton, Indiana Porter Co., T37N, R6W Section 28	Cambrian Mount Simon Sandstone	2,535/1,700	9%	0
In-6	Bethlehem Steel Corp. Chesterton, Indiana Porter Co., T37N, R6W Section 30	Cambrian Mount Simon Sandstone	2,530/1,415	10-20% 20-100 md	140-1,1040
In-7	Bethlehem Steel Corp. Chesterton, Indiana Porter Co., T37N, R6W Section 29	Cambrian Mount Simon Sandstone	2,521/1,744	10-20% 10-100 md	140-1,1040

Table 25 (Continued)

Registry Number	Operator and Location	Injection Formation and Rock Type	Depth to Top/ Thickness (feet)	Porosity and Permeability	Injection Pressure Range (psig)
In-8	Midwest Steel Div. Portage, Indiana Porter Co., T37N, R7W Section 25	Cambrian Mount Simon Sandstone	2,160/2,100	18% 45 md	0
In-9	U. S. Steel Corporation Gary, Indiana Lake Co., T37N, R8W Section 29	Cambrian Mount Simon Sandstone	2,422/2,100	14.3% 427 md	0
In-10	General Electric Co. Mt. Vernon, Indiana Posey Co., T7S, R13W Section 18	Mississippian Bethel Sandstone	2,760/46	18% 100 md	200-585
In-11	Inland Steel Corporation East Chicago, Indiana Lake Co., T37N, R9W Section 14	Cambrian Mount Simon Sandstone	2,360/1,980	12% 316 md	0
In-12	Indiana General Corp. Valparaiso, Indiana Porter Co., T35N, R5W Section 16	Cambrian Mount Simon	2,815/1,733		0-10
In-13	General Electric Company Mt. Vernon, Indiana Posey Co., T7S, R13W Section 19	Mississippian Bethel Sandstone	2,768/74		--

TABLE 26 -- Wastewater and Other Characteristics of Injection Wells -- Indiana

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
In-1	No	Currently operational Completed and operational 1950	5,000,000,000 (est.) combined with In-2	576,000 Combined with IN-2	TDS - 14,000 mg/1 Na_2SO_4 - 6,500 mg/1 $(NH_4)_2SO_4$ - 5,000 mg/1 Acidity - 120 mg/1 Sp. gr. - 1.0 pH - 4.6
In-2	No	Currently operational Completed 1951 and operational 1952	See (In-1)	See (In-1)	Same as (In-1)
In-3	Yes	Currently operational Completed 4/1950 Operational 1950	1,512,000 (est.)	210	NaOH Na_2S Na mercaptide Sp. gr. - 1.12
In-4	Yes	Standby - completed 5/22/60 - operational 1960	26,000,000 (est.)	0	Ca - 22,000 mg/1 Fe - 9,000 mg/1 Mg - 3,000 mg/1 Cl -125,000 mg/1 SS - 10 ppm Sp. gr. - 1.09 pH - 4.9
In-5	No	Currently operational Operational 11/1967	11,754,788 (1/71 to 6/72)	11,160	Cl - 41,000 ppm Na_2O - 22,000
In-6	No	Currently operational Completed 4/4/68 Operational 1968	78,227,998 (1/71 to 6/72) Combined with In-7	217,700 Combined with In-7	NH_4 up to 9,800 mg/1 Phenols 400 - 5,600 mg/1 CN - 3 - 52 mg/1 CNS - 1,050 - 2,600 mg/1

TABLE 26 (Continued

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
In-7	No	Currently operational Completed 3/22/68 Operational 1968	See In-6	See In-6	Same as In-6
In-8	No	Currently operational Completed 8/64 Operational 7/65	111,378,620	65,200	H_2SO_4 - 6 to 10% $FeSO_4$ - 14 to 18% Sp. gr. - 1.14 $Na_2Cr_2O_7$ - Some
In-9	Yes	Currently operational Completed 1/7/65 Operational 1965	27,208,154 (12/70 to 6/72)	61,480	H_2SO_4 - 8 to 37% $FeSO_4$ - 18 to 25% $H_2Cr_2O_7$ - 2 to 6% HCl - 1% $FeCl_2$ - 15 to 20% Sp. gr. - 1.06 to 1.13
In-10	No	Currently operational Operational 8/1966	77,798,000 (to 12/1971)	23,180	Phenol - 3% Sp. gr. - 1.003 pH - 10 to 13
In-11	No	Currently operational Completed and operational 3/1968	92,539,699	67,900	H_2SO_4 - 8.5% $FeSO_4$ - 13.0% HCl - 0.5% $FeCl_2$ - 17.4% Sp. gr. - 1.1 to 1.2
In-12	No	Currently operational Operational 1970	4,269,827	4,740	NH_4 Cl - 5 - 10%
In-13	Yes	Under development	0	0	--

The following tables contain monthly operating records for eight (8) Indiana wastewater injection wells (In-5, In-6 and 7, In-8, In-9, In-10, In-11 and In-12), each of which is currently operating. Monthly data is not available for four other Indiana wells, three operating and one on standby. Two of these four wells (In-1 and 2) have accumulated an estimated 5 billion gallons of wastes, about 91 percent of all of the wastewater injected into Indiana wells.

TABLE 27 -- Bethlehem Steel, Burns Harbor
(Acid Well) (In-5)

Year Month	Volume	Accumulated Volume	Remarks
Jan. 1971	982,683	982,683	Wellhead pressure (vacuum)
Feb.	806,367	1,789,070	
March	386,876	2,175,946	
April	756,961	2,932,907	
May	1,049,110	3,982,007	
June	923,899	4,905,906	
July	771,923	5,677,829	
Aug.	303,646	5,981,475	
Sept.	328,624	6,310,099	
Oct.	203,150	6,513,249	
Nov.	282,222	6,796,471	
Dec.	457,321	7,253,792	
Jan. 1972	760,120	8,013,912	
Feb.	1,352,650	9,366,562	
March	963,065	10,329,627	
April	649,267	10,978,894	
May	440,948	11,419,842	
June	334,946	11,754,788	

TABLE 28 -- Bethlehem Steel Company, Chesterton, Indiana
Injection Wells
Burns Harbor (Ammonia Wells) (In-6, In-7)

Year Month	Volume	Accumulated Volume	Pressure Wellhead
Jan. 1971	3,712,773	3,712,773	360-650
Feb.	3,655,871	7,368,644	390-550
March	3,618,865	10,987,509	410-550
April	3,396,969	14,384,478	400-620
May	3,578,246	17,962,724	520-655
June	3,478,749	21,441,473	520-740
July	3,824,333*	25,265,806	140-280 No. 1 *
			150-750 No. 2
Aug.	3,525,829	28,791,635	140-290 No. 1
			150-800 No. 2
Sept.	3,467,168	33,258,803	290-300 No. 1
			710-770 No. 2
Oct.	3,873,424	36,132,227	650- 78
Nov.	3,198,634	39,330,861	550-720
Dec.	3,515,423	42,846,284	450-730
Jan. 1972	3,686,019	46,532,303	480-700
Feb.	5,368,990	51,901,293	450-780
March	7,004,523	58,905,816	595-980
April	6,207,782*	65,113,598	360-960
May	6,582,300	71,695,898	400-820
June	6,532,100	78,227,998	380-1,040

* No. 1 = In-6 -- No. 2 = In-7

TABLE 29 -- Midwest Steel Company, Portage, Indiana
Injection Well (In-8)

Year Month	Injected Volume	Accumulated Volume	Remarks Flow gpm	Remarks Annulus press.
Aug. 1965	25,100	25,000		
Oct.	1,153,080	1,178,180		
Dec.	1,202,770	2,380,950		
Jan. 1966	882,585	3,263,535		
Feb.	997,745	4,261,280		
March	1,454,535	5,715,815		

Table 29 (Continued)

Year Month	Injected Volume	Accumulated Volume	Remarks
			Flow gpm / Annulus press.
April 1966	1,269,009	6,984,824	
May	1,288,710	8,273,534	
June	1,049,780	9,323,314	
Aug.	1,035,810	10,359,124	
Sept.	1,335,060	11,694,184	
Oct.	1,484,145	13,178,329	
Nov.	1,158,750	14,337,079	
Dec.	1,301,805	15,638,884	
Jan. 1967	1,474,370	17,113,254	Annulus press. 40 lb. psi
Feb.	1,412,595	18,525,849	
March	1,479,375	19,996,224	Annulus press. 30 lb. psi
April	1,065,375	21,061,599	
May	1,341,000	22,402,599	
June	1,300,001 (est.)	23,702,600	
July	1,069,155	24,771,755	
Aug.	966,330	25,738,085	
Oct.	1,281,510	27,019,595	
Nov.	1,338,930	28,358,525	
Dec.	1,413,990	29,772,515	
Jan. 1968	1,292,400	31,064,915	
Feb.	1,635,930	32,700,845	
March	1,694,250	34,395,095	Annulus press. 45 lb. psi
April	1,546,200	35,941,295	Annulus press. 65 lb. psi
May	1,730,520	37,671,815	
June	1,477,680	39,149,495	
July	1,639,665	40,789,160	
Aug.	1,383,965	42,173,125	
Sept.	1,376,680	43,549,805	
Oct.	1,339,380	44,889,185	
Nov.	1,280,385	46,169,570	
Dec.	1,425,825	47,595,395	
Jan. 1969	1,275,180	48,870,575	Annulus press. 160 Flow gpm - 50 max.
Feb.	1,408,905	50,279,480	Annulus press. 160 Flow gpm - 51
March	1,749,820	52,029,300	Annulus press. 160 Flow gpm - 58
April	1,758,915	53,788,215	Annulus press. 160 Flow gpm - 55
May	1,796,310	55,584,525	Annulus press. 160 Flow gpm - 8-11
June	1,770,570	57,355,095	Annulus press. 160 Flow gpm - 61

Table 29 (Continued)

Year Month	Injected Volume	Accumulated Volume	Remarks	
			Flow gpm	Annulus press.
July 1969	1,659,555	59,014,650	63	160
Aug.	1,500,000	60,514,650	67	160
Sept.	1,352,700	61,867,350	62	160
Oct.	1,139,790	63,007,140	58	160
Nov.	1,431,610	64,438,750	54	160
Dec.	1,400,000 (est.)	65,838,750	58	160
Jan. 1970	1,689,050	67,527,800	73	160
Feb.	1,606,545	69,134,345	69	160
March	1,500,000 (est.)	70,634,345		160
April	1,591,065	72,225,410	61	160
May	1,495,350	73,720,760	59	
June	1,362,510	75,083,270		
July	1,380,195	76,463,465		
Aug.	1,675,980	78,139,445		
Sept.	1,667,145	79,806,590		
Oct.	1,495,395	81,301,985		
Nov.	1,263,870	82,565,855		
Dec.	1,662,180	84,228,035		
Jan. 1971	1,440,940	85,668,975	61 max.	160
Feb.	1,519,200	87,118,175	53	160
March	1,104,975	88,292,350	52	160
April	1,500,000	89,792,350		
May	1,641,240	94,433,590	53	160
June	1,368,495	92,802,085		160
July	985,950	93,788,035		
Aug.	328,725	94,116,760		
Sept.	1,072,215	95,188,975		
Oct.	1,705,315	96,894,290		
Nov.	1,646,325	98,540,615		
Dec.	1,362,465	99,903,080		
			Acid	
Jan. 1972	1,788,075	101,691,155	7-9%	
Feb.	2,110,860	103,802,015	7-10	(160)
March	2,009,430	105,811,445	6-10	
April	1,518,795	107,330,240	7-10	
May	2,091,875	109,422,115	6-11	
June	1,956,505	111,378,620	7-11	160

TABLE 30 -- U. S. Steel Company, Gary Indiana
Injection Well (In-9)

Year Month	Injected Volume	Accumulated Volume	Pressure (annulus)
Dec. 1970	2,258,445	2,258,440	40-210
Jan. 1971	1,641,430	3,899,375	90-200
Feb.	1,530,041	5,429,961	190-242
March	1,946,555	7,376,471	180-210
May	1,781,917	9,158,388	20-170
June	868,835	10,027,223	145-210
July	416,320	10,443,543	20-180
Aug.	296,510	10,740,053	130-150
Sept.	976,980	17,717,033	107-152
Oct.	1,306,080	13,023,113	77-203
Nov.	1,960,085	14,983,198	15-165
Dec.	1,927,590	16,910,788	107-195
Jan. 1972	1,188,700	18,099,488	80-230
Feb.	1,975,725	20,075,213	141-230
March	2,060,930	22,136,143	130-224
April	1,714,220	23,850,363	130-170
May	1,513,400	25,363,763	110-220
June	1,844,391	27,208,154	85-165

TABLE 31 -- General Electric Company, Mt. Vernon
Injection Well (In-10)

Year Month	Avg. Daily Injection G/D	Monthly Injection G/Mo.	Cumulative Injection	Plant Pressure Min-Max. psig
Aug. 1966	16,000	16,000	16,000	200-800
Sept.	15,900	190,800	207,000	660-950
Oct.	1,000	1,000	208,000	440-680
Nov.	15,600	156,000	364,000	400-550
Dec.	14,000	56,000	420,000	420-480
Jan. 1967	47,400	663,600	1,084,000	200-260
Feb.	39,800	756,200	1,840,000	160-210
March	40,400	1,090,800	2,931,000	160-300
April	40,000	1,200,000	4,131,000	160-210
May	42,700	1,323,700	5,455,000	340-410
June	48,600	1,458,000	6,913,000	450-500
July	28,800	892,800	7,806,000	440-480

Table 31 (Continued)

Year Month	Avg. Daily Injection G/D	Monthly Injection G/Mo.	Cumulative Injection	Plant Pressure Min-Max. psig
Aug. 1967	42,000	1,302,000	9,108,000	440-490
Sept.	51,800	1,554,000	10,662,000	440-490
Oct.	54,800	1,698,800	12,361,000	410-490
Nov.	55,900	1,677,000	14,038,000	350-410
Dec.	50,100	1,553,100	15,591,000	300-350
Jan. 1968	50,300	1,559,300	17,150,000	260-300
Feb.	55,900	1,621,100	18,771,000	340-410
March	49,560	1,536,360	20,307,000	370-440
April	51,270	1,538,100	21,845,000	440-550
May	52,200	1,618,200	23,463,000	560-650
June	50,500	1,410,000	24,978,000	650-720
July	38,900	1,205,900	26,184,000	500-600
Aug.	56,200	1,742,200	27,926,000	500-600
Sept.	52,500	1,575,000	29,501,000	500-580
Oct.	45,900	1,422,900	30,924,000	450-570
Nov.	47,800	1,434,000	32,358,000	420-490
Dec.	48,100	1,491,100	33,849,000	400-430
Jan. 1969	46,152	1,325,712	35,280,000	370-420
Feb.	48,850	1,367,800	36,647,000	400-420
March	50,000	1,550,000	38,197,000	400-420
April	49,900	1,546,900	39,744,000	420-500
May	48,400	1,500,400	41,245,000	500-700
June	52,700	1,581,000	42,826,000	280-580 (1)
July	51,000	1,479,000	44,305,000	300-400
Aug.	52,500	1,627,500	45,932,000	350-430
Sept.	53,526	1,605,780	47,538,000	360-400
Oct.	50,750	1,471,750	49,010,000	420-520
Nov.	47,296	1,418,880	50,429,000	440-560
Dec.	45,340	1,360,200	51,789,000	440-500
Jan. 1970	48,260	1,496,060	53,285,000	460-520
Feb.	47,888	1,340,864	54,626,000	410-480
March	50,464	1,564,384	56,191,000	410-480
April	49,543	1,486,290	57,677,000	430-490
May	48,800	1,464,000	59,141,000	450-520
June	36,017	1,080,510	60,221,000	465-510
July	32,944	1,021,264	61,243,000	510-550
Aug.	36,684	1,137,204	62,380,000	550-610
Sept.	32,845	985,350	63,365,000	580-610
Oct.	29,121	698,904	64,064,000	580-610
Nov.	37,746	1,132,380	65,196,000	580-610
Dec.	38,321	1,187,951	66,384,000	570-600

Table 31 (Continued)

Year Month	Avg. Daily Injection G/D	Monthly Injection G/Mo.	Cumulative Injection	Plant Pressure Min-Max. psig
				Wellhead Pressure
Jan. 1971	40,580	1,217,400	67,602,000	220-260
Feb.	37,562	1,051,736	68,653,000	220-260
March	38,197	1,184,107	69,837,000	260-320
April	27,081	812,430	70,650,000	300-360
May	32,269	1,000,339	71,650,000	460-510
June	29,115	873,450	72,524,000	565-580 (1)
July	28,829	893,699	73,417,000	315-330
Aug.	28,402	880,462	74,298,000	450-545
Sept.	34,102	1,023,060	75,321,000	470-575
Oct.	32,070	994,170	76,315,000	570-585
Nov.	25,482	764,460	77,079,000	430-530
Dec.	23,180	718,580	77,798,000	400-460

(1) Well was treated.

TABLE 32 -- Inland Steel Company, East Chicago Injection Well (In-11)

Year Month	Injected Volume (gallons)	Accumulated Volume (gallons)	Remarks
March 1968	(Went into operation)		
April	2,111,447	2,111,447	Wellhead pressure
May	2,525,273	4,636,842	0 psig @ 50 gals. per min.
June	2,566,000	7,202,842	
July	2,416,250	9,619,092	
Aug.	1,663,708	11,252,800	
Sept.	1,096,362	12,339,162	
Oct.	1,412,357	13,751,519	
Nov.	1,719,450	15,470,969	
Dec.	1,785,800	17,256,769	
Feb. 1969	2,177,260	19,434,029	
March	2,306,624	21,740,653	
April	1,546,758	23,287,411	
May	2,192,370	25,479,781	
June	2,282,730	27,762,511	

Table 32 (Continued)

Year Month	Injected Volume (gallons)	Accumulated Volume (gallons)	Remarks
July 1969	2,107,104	29,869,615	
Aug.	2,115,142	31,984,757	
Sept.	2,307,940	34,292,697	
Oct.	2,181,080	36,473,777	
Nov.	1,931,810	38,405,587	
Dec.	2,131,937	40,537,524	
Jan. 1970	1,933,270	42,470,794	
March	2,023,378	44,494,172	
April	2,059,000	46,553,172	
May	2,181,000	48,734,172	
June	1,810,680	50,544,852	
July	2,052,460	52,597,312	
Aug.	1,767,580	54,273,892	
Sept.	1,865,920	56,139,812	
Oct.	2,196,345	58,336,157	
Nov.	1,845,920	60,182,077	
Dec.	2,047,150	62,229,227	
Jan. 1971	1,849,303	64,078,530	
March	2,315,950	66,394,480	
April	2,437,950	68,832,430	
May	2,608,720	71,441,150	
June	2,021,280	73,462,430	
July	1,589,168	75,051,598	
Aug.	603,856	75,655,454	
Sept.	1,144,700	76,800,154	
Oct.	1,672,990	78,473,144	
Nov.	770,122	79,243,266	
Dec.	1,073,914	80,317,180	
Jan. 1972	2,177,620	82,474,800	
Feb.	1,994,880	84,489,680	
March	2,306,550	86,526,230	
April	2,006,950	88,533,180	
May	1,969,450	90,502,630	
June	2,037,069	92,539,699	

TABLE 33 -- Indiana General Corp., Valparaiso
Injection Well (In-12)

Year Month	Injected Volume	Accumulated Volume	Pressure Wellhead	Pressure Annulus
Oct. 1970	30,170	30,170	Up to 10 psig @ 50 gpm	
Nov.	84,029	114,199		
Dec.	Not operating	114,199		
Jan. 1971	Not operating	114,199		
Feb.	Not operating	114,199		
March	Not operating			
April	647,686	761,885		
May	650,744	1,412,629		
June	358,518	1,771,147		
July	146,203	1,917,347		
Aug.	418,331	2,335,678		
Sept.	340,120	2,675,798		
Oct.	566,048	3,241,846		
Nov.	90,613	3,332,459		
Dec.	85,336	3,417,895		
Jan. 1972	Not operating	3,417,895		
Feb.	Not operating	3,417,895		
March	157,159	3,575,054		
April	259,326	3,834,380		
May	293,324	4,127,704		
June	142,123	4,269,827		

Kentucky -- Three wastewater injection wells are located in the Commonwealth of Kentucky and each is within the Ohio basin. Two of the three are not yet operational. The third well (K-1) was in operation during the 1940s and presumably used for disposal of spent refinery catalysts (alkalies and associated wastes), although no analytical data is available. The well, located at a refinery near Latonia, was drilled in 1941, and operated for the war period. No operational data is available from the Latonia well, but it may be assumed that only relatively small amounts of injection took place.

The other two wells are located at the Louisville Works of the duPont Company. These were drilled in 1971-72, and an additional well was also drilled for monitoring purposes. The system is not yet operational as of this writing. Detailed logs, drill-stem tests, cores and core analyses were made on these wells and when development phases are completed the data will be available for the Registry. The Mount Simon was "tight" and the Knox Dolomite was selected for testing and as a possible zone for hydrochloric acid waste disposal.

TABLE 34 -- Physical Characteristics of Injection Wells -- Kentucky

Registry Number	Operator and Location	Injection Formation and Rock Type	Depth to Top/ Thickness (feet)	Porosity and Permeability	Injection Pressure Range (psig)
K-1	Sohio Petroleum Company Latonia, Kentucky Kenton County	Cambrian-Ordovician Knox Dolomite	1,011/700		N.a.
K-2	E.I. DuPont deNemours Co. Louisville, Kentucky Jefferson County Section 10	Cambrian-Ordovician Knox Dolomite	1,710/2,590		18-25
K-3	E.I. DuPont deNemours Co. Louisville, Kentucky Jefferson County Section 10	Cambrian-Ordovician	1,790/2,590		18-25

TABLE 35 -- Wastewater and Other Characteristics of Injection Wells -- Kentucky

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
K-1	Yes	Abandoned Completed 1941 Operated 1941-45	Unknown - assumed to be small	Unknown	Thought to be spent refinery catalysts (alkalis and associated wastes) but no analytical data is available
K-2	Yes	Not yet operational (classified under development) Completed 3/10/71	0	0	Planned to be: HCl - 20% (wt.) Organics 100 ppm
K-3	Yes	Not yet operational (under development) drilled 1972	0	0	Same as K-2

New York -- Four wells were constructed for the underground consignment of waste fluids. Completion of three of the wells is in the Potsdam-Theresa interval (NY-3 and 4). These three wells are located in Niagara and Erie Counties (see Fig. 1) and are on standby at this time. A fourth well (NY-1) is for return of formation water which leaks into the shaft of a salt mine. This water is returned to the Tulley formation (shale), which contains the Cherry Valley limestone. This is apparently not the formation of brine origin but accepts the returned water with no apparent difficulty. These wells are all outside of the Ohio River basin. See Tables 36, 37 and 38.

Because of seismic conditions in the St. Lawrence region, including New York, the State Geological Survey placed seismometers down-hole with telemetry lines connected directly with Lamont-Doherty Observatory. The object was to monitor immediate seismic activity and to have a historical basis for measuring any increased activity that might be correlated with injection.

The following statement about Western New York State Seismic Stations was supplied by Dr. James Davis, State Geologist of New York.

> "In the summer of 1970, the New York State Geological Survey with the cooperation of Lamont-Doherty Geological Observatory started an experimental project with five movable seismic instruments in western New York. The objective was to establish permanent sites to detect earth movements and background count before allowing liquid waste disposal in the subsurface of western New York. This project was completed in the fall (1970) and eight permanent sites were established in 1971 with direct connections to the Lamont-Doherty Observatory in Palisades, New York. One of the above sites is located in an abandoned well approximately 1,000 feet below the surface, situated southeast of the Bethlehem Steel disposal well.
>
> "At a later date, one of the seismic sites picked up a disturbance near Dale, New York, where Texas Brine Corporation operates a brine field. The disturbance occurred due to the loss of brine water, apparently into the Clarendon-Linden fault zone. The brine field was shut down by the State until the background count became normal and was then allowed to continue operation at greatly reduced pressures."

TABLE 36 -- Current Disposal Rates and Accumulated Volumes of Wastewaters Injected into New York Wells -- by Generic Type of Wastewater

(All outside Ohio basin)

Generic Type	Current Disposal Rate (gallons per day)	Accumulated Volume (gallons)
Pickling liquors	0	0
Sulfates/chlorides	115,200	15,000,000 (est.)
HCl/Organics	0	0

TABLE 37 -- Physical Characteristics of Injection Wells -- New York

Registry Number	Operator and Location	Injection Formation and Rock Type	Depth to Top/ Thickness (feet)	Porosity and Permeability	Injection Pressure Range (psig)
NY-1	International Salt Company Schuyler County Reading Township	Devonian Marcellus (Shale) Cherry Valley member (Limestone)	1,300/55		300
NY-2	Hooker Chemical Company Niagara Falls, New York Niagara County	Cambrian Potsdam-Theresa Sandstone-Dolomite	2,835/191	4.3% 1-77 md	1,445
NY-3	Bethlehem Steel Company Lackawanna, New York Erie County Hamburg Township	Cambrian Potsdam-Theresa Sandstone and Dolomite	3,794/457	5%	1,938
NY-4	FMC Corporation Middleport Village Niagara County Royalton Township	Cambrian Potsdam-Theresa Sandstone and Dolomite	2,660/105		

TABLE 38 -- Wastewater and Other Characteristics of Injection Wells -- New York

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
NY-1	No	Currently operational Completed 6/1/70 Operational 12/3/71	15,000,000 (est.)	115,200	NaCl 358/000 mg/liter
NY-2	No	Standby Completed 8/5/68	0	0	HCl - 30% Phenol 1,440 lbs/day Chlorine 1,210 lbs/day Organics (soluble) 2,900 lbs/day
NY-3	No	Standby Completed 5/18/68	0	0	HCl - 0.5 - 5.0% $FeCl_2$ - 0-25.0% $FeCl_3$ - 0-0.5%
NY-4	No	Standby Completed 7/30/68	0	0	Na_2SO_4 - 4 to 8% $(NH_4)_2SO_4$ - 4-8% NaCl - 12% Na_2S - Unspecified Na trithio carbonate

Ohio -- There are reported to be ten injection wells in the State of Ohio. All except one (O-8) penetrate or utilize the Mount Simon Sandstone. Four of the wells are in the Ohio Valley; three of these are operating (O-1, O-4 and O-5) and one is abandoned (O-2).

Of the six wells outside the Ohio basin watershed three are in developmental or testing phases (O-7, O-9 and O-10), and three are operational (O-3, O-6 and O-8). One (O-8) is a return for brines that seep into the shafts at International Salt Mine in Cleveland. This water is returned to its source in the Oriskany sandstone.

A two-well system is operated by Armco Steel Company at Middletown, Ohio (O-1 and O-4). These were put into operation in May and June of 1969. Accompanying tables show the data on the injection characteristics. The wells at Middletown are for disposal of spent acids and resulting salts from steel pickling operations. These wells are operated alternately and on a short-term standby for any repairs or maintenance.

Another Ohio basin well, the Empire-Reeves Steel Division well (O-2)at Mansfield operated from November 1968 to May of 1970. The well was abandoned and plugged in the fall of 1972, after injecting 10,314,933 gallons of spent pickle liquors. The system had excessive corrosion problems, although the pressure and flow data do not reflect unusual characteristics. A variety of tubing materials was used including fibercast and penton lined steel. The annulus was filled with light oil, sealed and monitored for pressure. The characteristics of the injected materials (spent pickle-liquors and fresh water) remained essentially constant over the period of operation.

The fourth well within the confines of the Ohio basin is that of U.S.S. Chemicals at Haverhill, which started operation in October 1969 (O-5). This well, as of mid-1972, has injected 129,353,382 gallons of wastewater at average pressures of 1,250 to 1,800 psig.

Vistron Corporation at Lima, Ohio, operates two wells (O-3 and O-6) and is developing a third well for standby and maintenance relief (O-9). These wells penetrate the Mount Simon at 2,780 ft. and 2,800 ft., where the formation is 352 ft. to 382 ft. thick. Injection rate is about 15 million gallons per month. The waste is from acrylonitrile manufacture. The first well (O-3) has operated since July 1968; and the second well (O-6) since October 1970. The total accumulation to mid-1972 is 282,910,444 into the (O-6) well, and 162,082,571 gallons into the (O-9) well.

Monthly operating data are available only for wells (O-1 thru 6).

The three remaining Ohio wells not yet discussed are: Calhio Chemical Company in Lake County (O-7) -- not operational; International Salt Company, Cleveland (O-8) -- seepage water from shaft is returned to original formation (Oriskany); and an exploration well in the Sandusky area, which has been drilled and tested but permission has not yet been given to inject (O-10).

The following three tables present detailed information on the ten Ohio injection wells.

TABLE 39 -- Current Disposal Rates and Accumulated Volumes of Wastewaters Injected into Ohio Wells -- by Generic Type

	Current Disposal Rate (gallons/day)		Accumulated Volume (gallons)	
Generic Type	Ohio Basin	Outside	Ohio Basin	Outside
Pickling Liquor	223,750	0	68,925,895	0
Chlorides & Sulfates	0	21,600	0	648,000
Organics	86,579	531,645	129,353,382	444,993,015
	310,329	553,245	198,279,277	445,641,015

TABLE 40 -- Physical Characteristics of Injection Wells -- Ohio

Registry Number	Operator and Location	Injection Formation and Rock Type	Depth to Top/ Thickness (feet)	Porosity and Permeability	Injection Pressure Range (psig)
0-1	Armco Steel Corporation Middletown, Ohio Butler County, Lemon Twp. Section 8	Cambrian Mount Simon	2,954/282	7-14%	10-150
0-2	Empire-Reeves Div. Cyclops Corporation Mansfield, Ohio Richland County, Madison Twp. Section 16	Cambrian Mount Simon Sandstone	4,982/82	10% 24.5 md	270- 1,230
0-3	Vistron Corporation Lima, Ohio Allen County, Shawnee Twp. Section 16	Cambrian Mount Simon	2,780/352	14.4%	700-1,117
0-4	Armco Steel Corporation Middletown, Ohio Butler County, Lemon Twp. Section 8	Cambrian Mount Simon Sandstone	2,940/339		10-500
0-5	U.S.S. Chemicals Haverhill, Ohio Scioto County, Green Twp.	Cambrian Mount Simon Sandstone	5,514/66	11.9% 26.8 md	750-1,800
0-6	Vistron Corporation Lima, Ohio Allen County, Shawnee Twp. Section 11	Cambrian Mount Simon Sandstone	2,800/382		519-720

Table 40 (Continued)

Registry Number	Operator and Location	Injection Formation and Rock Type	Depth to Top/ Thickness (feet)	Porosity and Permeability	Injection Pressure Range (psig)
0-7	Calhio Chemicals Perry Village, Ohio Lake County, Perry Twp. Lot 47	Cambrian Mount Simon	5,930/?		--
0-8	International Salt Company Cleveland, Ohio Cuyahoga County, Brooklyn Twp. Lot 51	Devonian Oriskany Sandstone	1,335/87	11 Meinzer Units	135
0-9	Vistron Corporation Lima, Ohio Allen County, Shawnee Twp. Section 2	Cambrian Mount Simon	N.a.		--
0-10	Sandusky, Ohio				

TABLE 41 -- Wastewater and Other Characteristics of Injection Wells -- Ohio

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
0-1	Yes	Currently operational Completed 3/12/67 Operational June 1969	34,154,310	96,150	HCl - 1% $FeCl_2$ - 25% $FeCl_3$ - 1.5% Iron - 23.1 - 24.1 Total Dissolved solids -- 169,000 Specific Gravity - 1.12
0-2	Yes	Abandoned Completed 8/16/67 Operational 11/22/68 Plugged Fall 1972	10,314,933	0	Fe - 43,750 ppm Cu - 7.87 ppm Zn - 1.58 ppm Acid - 10.8% Particle - 20-200
0-3	No	Currently operational Completed 2/24/68 Operational 7/15/68	287,910,444	215,165	NH_3's - 395 mg/1 SO_4's - 768 mg/1 CN's - 324 mg/1 Nitriles: Acrylic 10.6 mg/1 Acetyl 62.0 mg/1 BOD - 3,000-10,000 mg/1 Sp. gr. - 1.06 to 1.12 Suspended solids 10 pH - 6.3
0-4	Yes	Currently operational Completed 4/24/68 Operational May 1969	24,456,652	127,600	Same as (0-1)

Table 41 (Continued)

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
0-5	Yes	Currently operational Completed 7/5/68 Operational Oct. 1, 1969	129,353,382	86,579	Phenolics - 44 mg/1 Acetone - 91 mg/1 Na_2SO_4 - 1,315 mg/1 $NaHCO_3$ - 24 mg/1 Na_2CO_3 - 218 mg/1 NaCOH - 22 mg/1 Cumene hydroperoxide - 50 mg/1
0-6	No	Currently operational Completed 7/15/69 Operational 11/14/69	162,082,571	316,480	Same as (0-3)
0-7	No	Not operational (classify under development) Completed 4/9/71	0	0	--
0-8	No	Currently operational Completed 8/3/71 Operational June 1972	648,000 (One month's operation)	648,000	Brines
0-9	No	Not operational (under development)	0	0	Same as (0-3)
0-10	No	Not operational (under development)	0	0	--

The following tables show monthly operating reports for six injection wells in the State of Ohio (0-1, 0-2, 0-3, 0-4, 0-5 and 0-6). All are currently operational except 0-2, which has been abandoned. Monthly reports are not available for the one other Ohio well that is currently operating, 0-8. The monthly injection rate for this well is thought to be 648,000 gallons.

TABLE 42 -- Armco Steel Company, Middletown, Ohio
Injection Well (0-1)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
May 1969	3	119,702	119,702	3,861	150
June	8	472,582	592,284	59,065	110
July	15	812,200	1,402,484	26,136	85
Aug.	6	124,135	1,526,619	4,004	60
Sept.	4	123,685	1,650,304	4,123	60
Oct.	4	235,732	1,886,036	7,604	15
Nov.			1,886,036		
Dec.			1,886,036		
Jan. 1970	8	535,905	2,421,941	66,988	60
Feb.	21	1,303,052	3,724,993	62,050	10
March	19	1,222,372	4,947,365	64,336	10
April	20	1,507,167	6,454,532	75,356	10
May	19	1,212,595	7,667,128	63,821	10
June	10	322,269	7,987,397	32,227	10
July	20	1,526,509	9,515,906	76,325	10
Aug.	24	1,396,801	10,912,707	58,200	10
Sept.	22	1,162,358	12,075,065	52,862	10
Oct.	25	1,435,182	13,500,247	57,407	10
Nov.	20	1,009,517	14,509,764	50,476	15
Dec.	22	1,099,103	15,608,867	49,959	15
Jan. 1971	23	1,416,910	17,025,777	61,605	10
Feb.			17,025,777		
March	1	95,011	17,120,788	95,011	80
April	10	669,542	17,790,330	66,954	30
May	11	752,148	18,542,478	68,377	40
June	10	593,640	19,136,118	59,364	80
July	18	1,569,103	20,705,221	87,172	80
Aug.	3	195,000	20,900,221	65,000	80
Sept.	24	731,760	21,631,981	30,500	80
Nov.	30	969,390	23,705,209	32,313	80
Feb. 1972	29	953,519	22,393,501	32,880	80
March	25	2,208,235	29,799,151	88,329	85
April	21	1,384,949	31,184,100	65,950	85
May	26	1,335,652	32,519,752	51,371	85
June	17	1,634,558	34,154,310	96,150	80

TABLE 43 -- Empire-Reeves, Mansfield, Ohio
Injection Well No. 1 (O-2)

Year Month		Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
Nov. 1968	(a)[1]	418,067			
	(b)[2]				1,300
Dec.	(a)	790,512	1,208,579		1,500
April 1969*	(a)	160,612	2,067,450	22,946	1,250
	(b)	62,570	62,570	8,940	1,750
May	(a)	783,240	2,850,715	26,108	1,230 (1,760*)
	(b)	402,510	465,080	13,420	450
June	(a)	697,056	3,547,771	34,853	1,150
	(b)	379,470	844,550	12,649	1,440
July	(a)	228,490	3,776,261	22,850	825
Aug.	(a)	436,048	4,212,309	18,169	425
	(b)	311,040		25,920	900
Sept.	(a)	289,159	4,499,468	11,486	500
	(b)	777,600	1,088,640	25,920	975
Oct.	(a)	342,313	4,841,781	14,883	275
	(b)	803,520	1,892,160	25,920	615
Nov.	(a)	423,538	5,265,319	14,118	270
	(b)	777,600	2,669,760	25,920	630
Dec.	(a)	876,694	7,392,151	28,280	330
	(b)	803,520	3,473,280	25,920	670
Jan. 1970	(a)	553,702	7,945,853	24,074	360
	(b)	803,520	4,276,800	25,920	595
Feb.	(a)	478,284	8,424,137	17,082	330
	(b)	725,760	5,002,560	25,920	585
March	(a)	739,866	9,164,003	23,867	330
	(b)	803,520	5,806,800	25,920	615
April	(a)	594,568	9,713,571	18,319	330
	(b)	777,600	6,583,680	25,920	615
May	(a)	601,362	10,314,933	20,737	330
	(b)	803,520	7,387,200	25,920	615

(a)[1] -- Acid injection

(b)[2] -- Fresh water injection

* -- Annulus pressure

TABLE 44 -- Vistron Corporation, Lima, Ohio
Injection Well No. 1 (0-3)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
July 1968	31	6,201,359	6,201,359	229,680	846
Aug.	24	6,634,136	12,834,495	214,004	745
Sept.	25	5,845,826	18,681,321	194,681	811
Oct.	28	6,266,351	24,947,672	202,140	828
Nov.	25	5,748,563	30,696,236	191,619	787
Dec.	26	6,428,300	37,124,535	207,364	713
Jan. 1969	29	7,345,304	44,469,839	236,945	733
Feb.	24	5,940,420	50,410,259	212,158	814
March	30	7,492,210	57,902,469	241,684	927
April	23	5,796,050	63,698,519	193,202	820
May	28	7,054,150	70,752,669	227,553	863
June	29	6,833,886	77,586,555	227,796	1,016
July	28	7,023,394	84,609,949	226,561	1,032
Aug.	29	7,742,245	92,352,194	249,750	1,117
Sept.	28	6,827,976	99,282,700	227,599	1,057
Oct.	24	5,002,000	104,284,700	161,355	981
Nov.	30	6,761,700	111,046,400	225,390	983
Dec.	31	7,552,600	118,599,000	243,632	1,010
Jan. 1970	28	7,223,100	125,822,100	233,003	963
Feb.	24	5,208,400	131,030,500	186,014	922
March	29	7,860,081	138,890,581	253,552	884
April	30	8,037,411	426,927,992	267,914	911
May	31	6,821,757	153,749,749	220,057	1,072
June	30	7,185,649	160,935,398	239,522	1,007
July	31	6,924,381	167,859,779	223,367	1,015
Aug.	31	6,545,449	174,405,228	211,144	992
Sept.	30	6,810,472	181,215,700	227,016	975
Oct.	31	8,444,427	189,660,127	272,401	944
Nov.	18	6,346,173	196,006,300	211,539	858
Dec.	31	8,660,500	204,668,800	279,371	879
Jan. 1971	31	8,639,800	213,306,600	278,703	876
Feb.	24	6,434,700	219,741,300	229,811	876
March	31	7,479,000	227,220,300	241,258	878
April	18	4,619,300	231,839,600	153,977	890
May	17	4,130,500	235,970,100	133,242	906
June	21	5,233,400	241,203,500	174,447	985
July	26	6,140,500	247,344,000	236,173	985
Aug.	24	4,931,871	252,275,871	205,495	958
Sept.	7	1,644,709	253,920,580	234,958	898
Oct.	12	2,281,170	256,501,750	215,098	938
Nov.	16	4,082,670	260,584,420	255,167	914
Dec.	16	4,009,540	264,593,960	250,596	836

Table 44 (Continued)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
Jan. 1972	10	2,195,818	266,789,778	219,582	726
Feb.	9	2,385,940	269,175,718	265,104	706
March	5	746,350	269,922,068	149,270	700
April	23	4,348,602	274,270,670	189,070	764
May	18	3,690,974	277,961,644	217,116	769
June	23	4,948,800	282,910 444	215,165	790

TABLE 45 -- Armco Steel Company, Hamilton, Ohio
Injection Well (O-4)

June 1969	2	79,543	79,543	39,772	165
July	3	55,700	135,243	18,567	65
Aug.	17	961,177	1,096,420	31,006	60
Sept.	15	936,964	2,633,348	31,232	60
Oct.	12	732,761	2,766,145	23,637	15
Nov.	23	1,646,243	4,412,388	71,576	60
Dec.	10	1,163,744	5,576,132	61,250	60
Jan. 1970	10	570,570	6,146,702	57,057	60
Feb.			6,146,702		60
June	12	877,398	7,024,100	73,116	10
July	3	172,409	7,196,509	49,457	20
Aug.			7,196,509		
Dec.	1	9,057	7,205,564	9,057	10
Jan. 1971	12	747,760	7,953,324	60,006	10
Feb.	23	1,662,097	9,615,421	72,265	10
March	25	1,698,896	11,314,317	67,956	60
April	19	1,233,911	12,548,228	64,942	60
May	14	1,075,257	13,623,485	76,804	80
June	15	975,240	14,598,725	65,016	80
July	7	438,184	15,036,909	62,598	80
Aug.	21	1,365,000	16,401,909	63,000	80
Sept.	17	828,137	17,230,046	51,400	80
Nov.	30	1,073,823	19,161,032	33,794	80
Dec.	22	1,143,443	20,304,477	51,975	80
Jan. 1972	24	1,135,505	21,439,982	47,313	80
Feb.	29	1,258,778	22,698,760	43,406	80
March	4	93,982	22,486,983	23,371	85
April	12	374,779	22,861,762	31,232	85
May	15	955,290	23,817,052	63,686	500
June	5	639,600	24,456,652	127,600	430

TABLE 46 -- U.S.S. Chemicals, Haverhills, Ohio
Injection Well No. 1 (0-5)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
Sept. 1969	20	1,948,740	1,948,740	144,000	750
Oct.	31	4,326,560	6,275,300	202,000	1,250
Dec.	31	3,747,800	13,073,800	121,000	1,250
Jan. 1970	31	4,545,200	17,619,000	147,000	1,100
Feb.	28	4,709,100	22,328,100	168,300	1,150
March	31	4,478,820	26,478,820	144,482	1,300
April	30	4,598,080	31,405,000	153,270	1,100
May	31	3,261,535	34,666,535	105,300	1,350
June	28	3,124,910	37,991,445	111,961	1,500
July	30	3,537,955	41,329,400	117,932	1,650
Aug.	31	3,460,600	44,790,000	111,632	1,650
Sept.	30	3,366,200	48,156,200	112,210	1,650
Oct.	31	3,871,070	52,027,270	124,873	1,700
Nov.	30	4,275,300	56,302,570	142,510	1,700
Dec.	31	4,533,084	60,835,654	146,228	1,750
Jan. 1971	31	3,735,855	64,571,509	120,511	1,750
Feb.	28	4,127,935	68,699,914	147,426	1,800
March	31	4,315,836	73,015,280	139,221	1,500
April	30	3,235,784	76,251,064	107,859	1,500
May	31	4,894,114	81,145,178	157,552	1,500
June	30	3,372,025	84,877,203	124,401	1,450
July	31	3,995,947	88,873,150	128,401	1,500
Aug.	31	3,584,255	92,457,405	115,621	1,560
Sept.	30	4,662,392	97,119,797	155,413	1,450
Oct.	31	4,300,105	101,419,902	138,713	1,540
Nov.	30	3,999,176	105,419,078	133,305	1,400
Dec.	31	3,888,284	109,307,362	129,086	1,400
Jan. 1972	31	3,418,758	112,726,120	110,283	1,350
Feb.	29	3,351,907	116,078,027	115,583	1,300
March	31	4,087,896	120,165,923	131,868	1,420
April	30	3,757,745	123,923,668	125,258	1,380
May	31	2,832,354	126,756,022	91,366	1,350
June	30	2,597,360	129,353,382	86,579	1,350

TABLE 47 -- Vistron Corp., Lima, Ohio
Injection Well No. 2 (O-6)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
Nov. 1969	18	4,890,700	4,890,700	257,405	801
Dec.	5	1,245,900	6,136,600	249,180	588
Jan. 1970	Standby		6,136,600		
Sept.	End of fresh water injections				
Oct.	17	4,882,686	4,882,686	287,217	571
Nov.	18	4,976,714	9,859,400	165,890	519
Dec.	31	8,515,000	18,374,400	274,677	540
Jan. 1971	31	8,822,200	27,196,600	284,587	524
Feb.	28	8,062,100	35,258,700	287,932	547
March	31	7,776,900	43,035,600	250,868	553
April	30	7,753,700	50,789,300	258,457	590
May	25	7,231,500	58,020,800	233,274	635
June	20	5,747,300	63,768,100	191,577	644
July	31	7,773,800	71,549,900	250,768	708
Aug.	29	7,606,880	79,148,780	262,306	720
Sept.	30	8,630,965	87,779,745	287,699	698
Oct.	25	7,396,033	95,175,778	295,814	707
Nov.	24	7,798,170	102,973,948	324,924	714
Dec.	29	9,402,410	112,376,358	324,221	670
Jan. 1972	31	9,226,928	121,603,286	297,643	622
Feb.	29	8,921,170	130,561,132	307,316	650
March	31	9,825,377	140,386,509	316,948	683
April	27	8,448,099	148,834,608	312,893	691
May	17	4,386,525	153,221,133	258,031	658
June	28	8,861,438	162,082,571	316,480	694

Pennsylvania -- Of the nine injection wells in Pennsylvania, eight are abandoned and one is under development (P-7). Five of the eight abandoned wells were previously operating. Of the four wells in the Ohio basin all have been abandoned (P-1, P-5, P-6, P-9). Operational pressures of the Aliquippa well (P-1) were considered to be too high for continued use. A well at Petrolia (P-6) was thoroughly tested but fell short of needs. The Marianna (P-9) and Franklin Boro (P-5) wells were experimental and abandoned without injection. Four additional wells have been drilled, tested and used for wastewater injection in the Lake Erie and the Susquehanna basins (P-2, P-3, P-4, P-8).

Three wells at Erie (P-2, P-3, P-8) constitute one system developed and maintained by Hammermill Paper Company. The first well was completed in the Bass Island formation, tested, and put into operation in 1964 (P-2). In 1964 a second well (P-3) was completed to the basement rocks, tested, and put into use. The injection intervals used were the Bass Islands Dolomite and the Mount Simon (Potsdam) -- the basal sandstone unit. In 1968 well No. 3 (P-8) was completed in the Bass Islands formation.

It is believed that Mount Simon received very little injection during the operational period, but 1,097,965,700 gallons were injected during the life of the system. On April 14, 1968, the casing and tubing of well P-2 were lifted out of the hole signalling the need for immediate repair and reconditioning of the well. The well returned fluids to the surface for several days while a drilling rig and other equipment and materials were brought into control the back flow. The system was never returned to full use and the three wells of the system were abandoned and plugged in the fall of 1972. Normal operational pressure values (1,250 psig) were experienced until a drop to near zero occurred. Much corrosion and corrosive failure was reported occurring at and above the top of the cemented part of the casing (approximately 800 ft. down hole).

The other significant disposal well system (P-1) in Pennsylvania is that of Jones and Laughlin Steel Company at Aliquippa. The well penetrated the Oriskany sandstone and later the Onondaga limestone (see summary sheet). The well went into operation in 1961 on a trial basis until 1965 when spent pickle liquors were injected into the Oriskany sandstone (5,385 ft. to 5,445 ft.) until July 1968. The injection zone was changed to 4,585 ft. to 4,635 ft. (this interval includes the Genessee, Marcellus shale, and the Onondaga limestone). This well was used from April 15, 1965, to June 9, 1972, when it was abandoned and plugged. The operational history shows frequent tubing failures. Another aspect of well operation was concern with respect to the injection pressures applied and the buildup of pressure to maintain the needed rates of injection. 33,087,000 gallons of pickle liquors and 77,600,000 gallons of fresh water were injected. At times the wellhead pressure was as high as .88 psi per foot of well, which would be approaching hydrofracture levels. As noted the well was withdrawn from use in 1972.

Other wells developed for disposal purposes have varied in depth but are generally shallower than are the above-mentioned wells. (See Table 49. The wells and formations tested were found less than satisfactory in one way or another even with small volumetric requirements (Gulf well in Bedford County, Table 49).

The following tables summarize a number of features of the nine Pennsylvania wells.

TABLE 48 -- Accumulated Volumes of Wastewater Injected into Pennsylvania Wells -- by Generic Type of Wastewater

Generic Type	Accumulated Volume (gallons)	
	Ohio Basin	Outside
Pickling liquors	33,087,000	0
Chlorides and Sulfates	0	1,098,260,700
Other	0	15,000
	33,087,000	1,098,275,700

TABLE 49 -- Physical Characteristics of Injection Wells -- Pennsylvania

Registry Number	Operator and Location	Injection Formation and Rock Type	Depth to Top/ Thickness (feet)	Porosity and Permeability	Injection Pressure Range (psig)
P-1	Jones & Laughlin Steel Co. Aliquippa, Pennsylvania Beaver County, Borough Twp.	Devonian Oriskany Sandstone Onondaga Limestone	5,385/37 4,585/50		2,275 to 4,650
P-2	Hammermill Paper Company Erie Pennsylvania Erie County	Silurian Bass Islands Dolomite Lockport Dolomite	1,611/81 2,057/245	8.5% 230 md	1,150 to 1,220
P-3	Hammermill Paper Company Erie, Pennsylvania Erie County	Silurian Bass Islands (Dolomite) Cambrian Mount Simon	1,658/74 5,914/38	8.5% 230 md	1,250
P-4	Gulf Research & Development Bedford County, Colerain Twp.	Ordovician Bellefonte Dolomite	540/13		500
P-5	Bethlehem Steel Company Franklin Boro, Pa. Cambria County	Mississippian Burgoon Sandstone	845/?		
P-6	Koppers Company, Inc. Petrolia, Pennsylvania Butler County, Fairview Twp.	Devonian Warren, Queen, Speechley Sandstone	1,903/5 2,040/6 2,152/30	6% 2.4% 2.15%	--

Table 49 (Continued)

Registry Number	Operator and Location	Injection Formation and Rock Type	Depth to Top/ Thickness (feet)	Porosity and Permeability	Injection Pressure Range (psig)
P-7	Peoples Natural Gas Company	Not developed			
P-8	Hammermill Paper Company Erie, Pennsylvania Erie County	Silurian Bass Islands Dolomite	1,586/151	8.5% 230 md	1,250
P-9	Bethlehem Steel Company Mariana, Pennsylvania Washington County, Mariana Boro	Pennsylvanian Salt Sands-Sandstone	1,431/86	4.5 - 10.0% 0 - 122 md	--

TABLE 50 -- Wastewater and Other Characteristics of Injection Wells -- Pennsylvania

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
P-1	Yes	Abandoned Completed 9/12/60 Operational 4/10/61 Plugged 1972	33,087,000	0	H_2SO_4 - to 10% $FeSO_4$ - to 10%
P-2	No	Abandoned Completed 3/28/63 Operational 10/64 Plugged 1972	446,422,700	0	Specific gravity - 1.02 pH - 5.3 Alkalinity to pH 4.5 1,500 mg/1 as Ca Acidity to pH - 8.3 1,900 mg/1 as Ca Suspended solids - 225 mg/1 NH_3 - NIL Total dissolved solids 5% Hardness total as $CaCO_3$ - 200 Ca as $CaCO_3$ - 80 MG as $CaCO_3$ - 100 Total sulphate - 1.75% Cl - 270 mg/1
P-3	No	Abandoned Completed 8/29/64 Operational 7/65 Plugged 1972	297,872,300	0	Same as (P-2)

Table 50 (Continued)

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
P-4	No	Abandoned Completed Dec. 1964 Operational Plugged 1972	15,000	0	Bentonite - variable
P-5	Yes	Abandoned Completed Jan. 1960 Operational Plugged 1972 (Never used - tests proved unsatisfactory)	0	0	(Was to be mine drainage)
P-6	Yes	Abandoned Completed 8/12/69 Operational Plugged 1972 (Never used)	0	0	--
P-7	No	Under development	0	0	--
P-8	No	Abandoned Completed 5/15/68 Operational 5/10/68 Plugged 1972	353,965,700	0	Same as (P-2)
P-9	Yes	Abandoned Completed 2/22/66 (Found wanting in physical requirements)	0	0	(Was to be used for mine drainage)

Of the five wells in Pennsylvania that have actually been used for injection, all are abandoned. Operating data from four of these (P-1, P-2, P-3 and P-8) are presented below although data from all but one (P-1) is very incomplete. The fifth well (P-4) is reported to have received only 15,000 gallons.

TABLE 51 -- Jones & Laughlin Steel Corporation
Aliquippa Works
Deep Well for Waste Pickling Acid
Disposal -- Operational History (P-1)

Period	Acid Injected (gallons)	Water Injected (gallons)	Pressure Initial	(psig) Final
4/15/65-6/24/65	2,450,000	7,088,000	2,600	3,825
6/25/65	Injection tubing failed			
6/26/65-7/18/65	0	4,313,000	3,875	3,650
	Replaced injection tubing			
7/22/65-7/2/66	7,238,000	21,251,000	2,000	4,150
7/66	Injection tubing failed			
7/24/66-9/30/66	0	3,272,000	2,275	4,000
	Replaced injection tubing			
5/15/67-8/26/67	2,690,000	5,419,000	2,950	4,450
8/26/67	Injection tubing failed			
8/26/67-10/23/67	0	6,113,000	--	4,000
	Replaced injection tubing			
10/28/67-6/1/68	5,507,000	8,059,000	4,100	4,650
6/1/68	Injection tubing failed			
6/1/68-7/20/68	0	5,824,000	2,850	--
	Replaced injection tubing -- opened new injection zone at 4,585 ft. - 4,635 ft.			
5/3/69-5/9/70	15,202,000	16,281,000	2,950	3,500
5/70	Final injection tubing failure			
6/5-6-7-8/72	Well cemented in			

TABLE 52 -- Hammermill Paper Company, Erie County, Injection Wells

Erie Well No. 1 (P-2)

	Injected volume	Accumulated volume	Avg. Press. psig
1963-1968		446,422,700	1,150

Erie Well No. 2 (P-3)

	Injected volume	Accumulated volume	Avg. Press. psig
April 1965- Oct. 1968		297,872,300	1,250

Erie Well No. 3 (P-8)

	Injected volume	Accumulated volume	Avg. Press. psig
May 1968 June 1970		353,965,700	1,250
		1,096,965,700	

West Virginia -- Seven disposal wells are located in West Virginia. All are in the Ohio basin and all are operating except one (W-4). The Weirton Steel Division of National Steel Company drilled this well (W-4) to the Berea sandstone, but it was not suitable for injection purposes and was abandoned.

Depth to top of injection zones ranges from 1,500 ft. to 6,720 ft. All of the wells except the one of the Weirton Steel Division (W-4) are in connection with either chemical or alkali plants.

One of the chemical operations produces hydrochloric acid together with organic and fluorinated organic compounds (W-2, W-5). These wastes were formerly discharged to the Pennsylvanian "Salt Sands" at a depth of 1,274 ft. but are now injected into the Onondaga limestone. At Belle, wastes containing chlorides, analine, ammonia, cyanides, HNO_3, organic acids and some mercury and other metal salts are injected into the Salt Sands (W-1) and the Williamsport (Silurian) W-3). See Table 55 for injection summaries.

PPG Industries, Inc., New Martinsville, uses a former input well (W-6) of the artificial brining operation in the Salina Salt, as does the Allied Chemical Company operation (W-7) at Moundsville. Return brines contain mercury or precipitates from pretreatment of the produced brines. The systems are closed circuits, hence the accumulative or rate values do not bear on a specific evaluation of ultimate displacements.

The following tables summarize salient features of the West Virginia injection wells.

TABLE 53 -- Current Disposal Rates and Accumulated Volumes of Wastewater Injected into West Virginia Wells -- by Generic Type of Wastewater

Generic Type	Current Rate (gallons/day)	Accumulated Volume (gallons)
Hydrochloric acid and Organics	261,404	105,911,510
Chlorides and Sulfates and Organics	222,276	167,166,350
	483,680	273,077,860

TABLE 54 -- Physical Characteristics of Injection Wells -- West Virginia

Registry Number	Operator and Location	Injection Formation and Rock Type	Depth to Top/ Thickness (feet)	Porosity and Permeability	Injection Pressure Range (psig)
W-1	E.I.DuPont deNemours & Co. Belle, West Virginia Kanawha County, Malden Dist. Section 33	Pennsylvanian Salt Sands (Sandstone)	1,300/200		492 to 643
W-2	E.I. DuPont deNemours & Co. Parkersburg, West Virginia Wood County, Lubeck District	Pennsylvanian	1,300/200?		744
W-3	E.I. DuPont deNemours & Co. Belle, West Virginia Section 1	Silurian Williamsport-Dolomite	5,100/100		801 to 1,050
W-4	Weirton Steel Division Weirton, West Virginia Hancock County	Mississippian Berea Sandstone	1,086/30		--
W-5	E.I. DuPont deNemours & Co. Parkersburg, W. Va. Wood County, Lubock District	Devonian Onondaga Limestone	4,016/89		520
W-6	PPG Industries, Inc. Proctor, West Virginia Marshall County, Franklin Dist.	Silurian Salina (Halite)	6,820/?	(Salt cavity)	0 - 300
W-7	Allied Chemical Company Moundsville, W. Va. Marshall County	Silurian Salina (Halite)	6,623/?	(Salt cavity)	717

TABLE 55 -- Wastewater and Other Characteristics of Injection Wells -- West Virginia

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
W-1	Yes	Currently operational Completed 1968	2,448,950	17,480	$NaCl$) $CaCl_2$) - 25%) Water soluble organics 5,000 ppm
W-2	Yes	Currently operational	103,470,710	108,604	HCl - 6-15% $HCOOH$) $HCOH$) - 2 to 5% Fluoro carbons - 10,000 ppm and other organics
W-3	Yes	Currently operational	164,717,400	204,796	Nitric acid - 1.5% Mono and dibasic Organic acids - 4.0% Cu & V 0.03%
W-4	Yes	Abandoned (Found not suitable for injection) Completed 2/15/68	0	0	--
W-5	Yes	Currently operational Completed 10/22/70 Operational 3/16/72	2,440,800	152,800	HCl - 6 to 15% Fluoro carbons and other organics 10,000

Table 55 (Continued)

Registry Number	Ohio Valley Well Yes/No	Operational Status	Accumulated Volume (gallons)	Current Injection Rate (gallons/day)	Wastewater Characteristics
W-6	Yes	Currently operational Completed 4/13/43 Operational 1972			Total solids - 5% $CaCO_3$ - 95.6% $Mg(OH_2)$ - 4.4% NaCl - 25% NaOH - 1,900 ppm Na_2CO_3 - 520 ppm Na_2SO_4 - 5,660 ppm Sp. Gr. - 1.20
W-7	Yes	Currently operational Completed June 1952 Operational 1972			NaCl) 1.040 sp. gr.) 57,529 mg/liter Ca -- 122 ppm Mg -- 7 ppm Fe -- 0.75 ppm SO_4 - 1,000 ppm Hg - 2-10 ppm

Two of the six West Virginia wells that have been used for wastewater injection are recirculating (W-6 and W-7), and have no net added volumes of wastes. Monthly operating records for the remaining four wells are included in the following:

TABLE 56 -- E. I. duPont deNemours & Company
Belle, West Virginia
Injection Well No. 1 (W-1)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
			231,636		
Oct. 1970	3	34,970	266,611	11,657	533
Nov.	Not in operation - no information between Nov. 70 and May 71				
June 1971	10	178,180	937,791	17,818	501
Dec.	12	188,000	1,277,400	15,666	492
Jan. 1972	10	201,508	1,478,900	20,151	523
Feb.	9		1,496,400		539
March	28	515,553	2,011,950	18,412	634
April	25	437,000	2,448,950	17,480	643

Injection Well No. 2 (W-3)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
Oct. 1970	31	6,961,600	89,458,200	233,300	864
Nov.	30	7,109,800	96,566,000	236,993	801
May 1971	31	7,521,089	127,741,600	242,616	957
June	30	7,237,800	135,262,700	211,260	1,002
Aug.	31	8,398,600	158,573,500	279,953	1,049
Sept.	30	6,143,900	164,717,400	204,796	1,056

TABLE 57 -- E. I. duPont deNemours & Company
Washington Works
Injection Well No. 1 (W-2)

Year Month	Days Oper.	Injected Volume	Accumulated Volume	Avg. rate per day	Avg. press. psig
Oct. 1970	31	3,311,840	55,183,580	106,834	583
Nov.	30	3,332,160	38,515,740	111,072	583
Dec.	31	3,345,060	41,860,800	107,906	639
Jan. 1971	31	3,363,840	45,228,640	108,511	655
Feb.	28	2,829,318	48,053,940	101,047	662
March	31	3,353,220	51,407,160	108,168	719
April	19	2,299,680	52,706,840	121,036	792
June	29	3,380,670	60,566,430	116,575	935
July	31	4,246,436	64,812,866	136,982	940
March 1972	23	2,736,000	97,221,190	118,956	980
April	21	2,882,800	100,103,990	137,276	980
May	31	3,366,720	103,470,710	108,604	744

Injection Well No. 2 (W-5)

March 1972	8	1,065,600	1,065,600	133,200	400
April	9	1,375,200	2,440,800	152,800	434

Abbreviations and Symbols Used in the Summary Tables for Fluids Injected and Operational Summary

Acid	Compounds with replaceable or ionizable hydrogen
Avg.	Average
Ca	Calcium
$CaCl_2$	Calcium chloride
$CaSO_4$	Calcium sulphate
$CaSO_4 . 2H_2O$	Gypsum
Chrome	Chromium compounds
Cr	Chromium
Cl, Cl_2	Chloride
Cu	Copper
CN	Cyanide
CNS	Thiocyanate
CO_2	Carbon dioxide
CO_3	Carbonate
Fe	Iron
$FeCl_2$, $FeCl_3$	Ferrous chloride -- ferric chloride
$FeSO_4$, $Fe_2 (SO_4)_3$	Ferrous sulphate -- ferric sulphate
fm	Formation
ft.	Feet
gal.	Gallon - 0.004 cubic meter
gpm	Gallons per minute 0.004 cubic meters per min.
HCO_3	Bicarbonate
H_2CO_3	Carbonic acid
HCl	Hydrochloric acid
H_2SO_4	Sulphuric acid
HCN	Hydrogen cyanide
HCOOH	Formic acid
HCHO	Formaldehyde
K	Potassium
mbr	Member
mg/l	Milligrams per liter
Mg	Magnesium
Na	Sodium
NaCl	Sodium chloride
Na_2SO_4	Sodium sulphate

Abbreviations and Symbols (Continued)

Na_2SO_3	Sodium sulphite
NH_3	Ammonia (usually is a reference to ammonium compounds)
NH_4	Ammonium
pH	Hydrogen ion concentration (activity)
ppm	Parts per million -- milligrams per kilogram
psi	Pounds per square inch -- 70.3 grams/cm^2
psig	Pounds per square inch gauge
pound	453.6 grams or .454 kilograms
press.	Pressure
ss	Suspended solids
T.D.S.	Total dissolved solids
V	Vanadium
Vol.	Volume

PROCEDURE FOR FUTURE MAINTENANCE OF ORSANCO INJECTION WELL REGISTRY *

The appropriate agency within each of the ORSANCO states should provide the Executive Director with:

1. A copy of the application for a construction permit for each new well.

2. A copy of each drilling or construction permit issued or notice of other action taken.

3. A copy of each well completion report filed.

4. A copy of each request for permission to operate a wastewater injection well.

5. A copy of each operating permit issued or notice of other action.

6. An annual summary for each operating well including the total volume of wastewater injected, the range of injection rates and pressures, and any change in wastewater character and well status.

7. A copy of the abandonment records for each abandoned well including the application for a permit to abandon, the permit to abandon, and the well plugging record.

Copies of each of the above listed documents should be sent to the Executive Director within 30 days of their receipt or issuance by the regulatory agency.

The Executive Director of ORSANCO should, in turn, periodically issue a report advising each of the member states of current activities in underground disposal and should make available to any interested party the information in the Registry.

* -- Recommendations to ORSANCO commissioners by the Advisory Committee on the Underground Injection of Wastewaters, January 11, 1973.

SOURCES AND REFERENCE FOR PARTS I & II

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3. Pennsylvania Department of Environmental Resources, Topographic and Geologic Survey, Harrisburg, Pennsylvania, Bureau of Water Quality Management.

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6. Kentucky Geological Survey, Lexington, Kentucky; Kentucky Stream Pollution Control Commission, Frankfort, Kentucky.

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PART III

PRELIMINARY REPORT ON THE POROSITY, PERMEABILITY AND INJECTION CHARACTERISTICS OF THE MOUNT SIMON SANDSTONE FORMATION

INTRODUCTION

The purpose of this investigation is to provide values of the reservoir parameters of the Mount Simon sandstone to determine the feasibility of utilizing it for the disposal of liquid waste by deep well injection systems. The criteria for disposal wells is governed by the presence of suitably permeable and porous formations to receive the wastes, and the presence of confining formations to prevent other resources -- mainly potable ground water -- from being damaged by the wastes. Reservoir parameters of interest, such as, porosity (ϕ), permeability (K), and transmissibility (T), as well as depth and thickness of the reservoir and depth and thickness of confining formations can be determined by the proper interpretation of geophysical well logs that are obtainable from existing drilled wells. Once this data is gathered over a large area, in this case, an eight-state area ϕ contour maps, K contour maps, structure contour maps, and isopachous maps can be prepared. Regional trends can then be observed regarding reservoir characteristics of the sandstone formation,its areal extent and that of the confining formation.

This report deals with the preliminary study of the Mount Simon sandstone within the State of Illinois and the data generated from logs of selected wells throughout the state.

LITHOLOGY AND POROSITY

The Mount Simon sandstone is dominately a fine to coarse grained sandstone. and contains beds of shale and siltstone. The porosity and permeability of the Mount Simon are affected by the amount of clay deposited with the sand grains. A small amount of clay may have only a small effect on the porosity whereas the effect of clay on permeability is large -- the greater the amount of clay present, the smaller the value of permeability of the sandstone. Likewise, beds of laminae of shale, or even thin micaceous partings greatly reduce the permeability of a sand body to fluids. One of the more important logs used in this investigation has been the gamma-ray log. This log is a measurement of the natural radioactivity of the formation. Because radioactive elements tend to concentrate in clays and shales, the log normally reflects the shale content of a formation. In order to generate effectively reliable values of porosity and permeability this log was utilized to define these shale beds or lenses in the formation. In doing so, values obtained for porosity and permeability are representative only for the sand intervals.

Shale occurrences as beds or lenses are essentially eliminated from these calculations. This method is important when a porosity-permeability correlation is attempted. Another important application of this log was in determining at what shale content the reservoir becomes ineffective. In most of the wells investigated, the distinction between the sand and shale occurrences were readily apparent, whereas in others it became more difficult to distinguish between them. These shaly sand or "dirty" sand intervals were evaluated by determining the shale content using the following linear relationship:

$$V_s = \frac{(GR-GR_1)}{(GR_2-GR_1)}$$

Where GR = Actual Gamma-Ray Reading

GR_2 = Reading Opposite Clay Beds (Max.)

GR_1 = Reading in Clean Intervals (Min.)

The St. Peter sandstone was used for the gamma-ray readings in a clean interval and the Eau Claire shale was used for the readings opposite a clay bed. Three different wells were studied at 10 foot intervals and their values were compared to core values of permeability. An arbitrary value of 10 millidarcies was used as a minimum for an effective reservoir. Statistically it was shown that a shale content of 30 percent or more constituted an ineffective reservoir. A refinement of this method would be to include the density of the sand and shale in the calculations as well as the volume of silt and its radioactive background readings, if it is contributing to the natural radioactivity of the formation. This was not done in the present study because this information was not readily available.

The Mount Simon in Illinois is everywhere overlain by a varying thickness of shale, the Eau Claire. By analyzing the gamma-ray log, the formation boundaries and thickness of the Eau Claire were adequately defined.

In a few selected cases, the Precambrian basement was also defined by the response of the gamma-ray log.

Porosity determinations were made using four basic logs: the neutron log, the formation density log, the sonic log and the Synergetic log. Not all of these logs were available for every well selected for the study.

The neutron log responds primarily to the amount of hydrogen present in a formation and is used primarily for determination of porosity. Where the neutron log and core analysis data were available, the determination of porosity values was as follows: (1) the shale occurrences were defined and eliminated from consideration; (2) the average neutron deflection for the sand intervals were recorded; (3) the average porosities for the sand intervals as found in the core analysis were then calculated; (4) these values were then plotted on semi-log paper (the neutron curve response diminishes in an approximately logarithmic manner as the porosity increases) and a best fit line was determined by linear regression analysis to fit this data. In most cases, the core analysis data did not cover the entire sequence of the formation. The total formation could then be evaluated by referring to this porosity-neutron deflection curve. In areas where it was deemed feasible, this same graph could be utilized to determine the porosities of wells within nearby areas which did not have core analysis data available. The uniformity of the Mount Simon over large areas justified this approach. This same method was applied to the other porosity logs (FD, S SYN.) when appropriate. When core analysis data was not available or the area did not justify the extension of the porosity plots to nearby wells, the analysis was performed by the usual geophysical interpretation principles.

A point to be made here is that when the sand occurrences were defined, they would range in thickness from two (2) feet to one hundred (100) feet or more. Where the intervals were small enough the average deflection on any of the porosity logs was determined by drawing a line through the response such that equal areas of deflection were taken above and below it. The corresponding value of the line was taken as average. Where the intervals were large, actual values of deflection were defined for every two feet of response and these values were subsequently averaged over the interval.

Another radioactive log for porosity determination is the formation density log. The response of the density tool is determined essentially by the electron density of the formation (number of electrons per cubic centimeter). Electron density is related to the true bulk density, ρ , in gms/cc, which in turn depends on the density of the rock matrix material, the formation porosity and the density of the fluids filling the pores.

The sonic log is a recording of the time, Δt, required for a compressional sound wave to traverse one foot of a formation. Known as the interval transit time, Δt, is the reciprocal of the velocity of the compressional sound wave and is dependent upon the formation lithology and porosity.

Within the shaly sand sequences of the Mount Simon it was often necessary to generate cross plots of the above log responses, (density-neutron or sonic-density). These plots provided more accurate porosity values in accordance with standard log practice.

The Synergetic log is a computer printout of porosity values of the formation developed from input values derived from the above-mentioned cross plots. Although limited to only five wells within the study area, they provided reliable porosity values as well as shale content on a percent basis as a standard output. They were also helpful as a comparison of the interpretation techniques developed with other logs and wells.

The porosity values are weighted average values derived by the following method: (1) the sand intervals were picked from the gamma-ray log and the thickness determined; (2) average porosity values were then determined with the appropriate logs; (3) a value of 0-ft. was then calculated and summed over the entire formation and (4) this value was then divided by the sum of all the sand intervals within the formation.

Other type logs used in this study such as: induction logs, laterologs, micrologs, electric logs, porosity logs, and sidewall neutron logs when used in conjunction with the afore-mentioned logs aided in the porosity and lithologic determinations.

Permeability -- Unlike porosity, there is no direct logging method for measuring permeability in the hole. Although, in many instances a fair measure of the average value of permeability can be deduced with sufficient accuracy to permit a correct reservoir evaluation from established logging techniques. One such method requires that correct values of porosity and irreducible water saturation be obtained from the appropriate logs. Permeability can then be calculated using the following equation:

$$K^{\frac{1}{2}} = \frac{250\phi^3}{S}$$

Where K = Permeability

ϕ = Porosity

S = Irreducible water saturation

This method, of course, requires that the appropriate logs are available for the particular well under investigation to generate these values, and that the zone in question is at irreducible water saturation which is not always the case.

Another approach involves the use of electron logs and the associated formation factor calculated from them. A relationship was found to exist among formation factors, grain size, and permeability, the latter two parameters being determined from laboratory analysis. Unfortunately, lack of this data often precludes the utilization of the method. The approach has been found to apply to fresh water deposits with but little accuracy realized under other conditions.

Still another method was mentioned under porosity determination techniques. This technique involves the use of the gamma-ray log to determine the amount of clay present within the sandstone formation. Gamma radiation levels are then compared to core analysis derived permeability values. In the present study, the method was found pertinent only in determining reservoir effectiveness of shaly sand occurrences. In future studies, however, it may prove valuable in determining strict permeability values.

At present, core analysis is one of the most important tools in the determination of reservoir rock characteristics. Absolute values of permeability obtained from core analysis are questionable in that such measurements are generally made on dry cores, that is, under conditions that do not duplicate fluid conditions of mineral hydration and of over-burden pressure. It is believed, however, that the relative magnitudes of permeability derived from core analysis are of value for defining the regional trends of the sandstone unit under investigation.

An attempt was made to find a correlation between porosity and permeability from the core analysis data and geophysical logs of wells within the study area. Finding a correlation, if one exists, would be invaluable in projecting permeability values from wells that have data available to those judged similar and that do not have data available. This first attempt, with No. 1 Feinhold in Livingston County, proved to be a success. Subsequent studies of wells in adjacent McLean County and one in Putman County, proved less than satisfactory. The method employed was to take the sand intervals that were delineated by the gamma-ray log and calculate average porosity and permeability values for each interval. This data was plotted on various types of log paper. It was found that a semi-logarithmic relationship existed between these parameters, with porosity plotted on the abscissa and permeability on the ordinate. A definite trend was apparent with higher values of porosity and permeability. A best fit line was obtained by first order linear regression analysis using the UMR-IBM 360 compute. Lower values of ϕ and K was essentially a perpendicular line indicating little or no correlation. When, however, a cut-off value of $<$ 10 millidarcies was used to define an effective reservoir, the plot provided a reliable indicate of average values of porosity and permeability. Extending this technique to other wells provided plots which were much less defined than the original one, one reason being that the values of porosity were essentially uniform throughout the sandstone formation. Another reason was the lack of core data available as well as the sampling technique of those performing the analysis. This, of course, is understandable in that core will be lost and not all sections of core analyzed are, of necessity, truly representative of the formation. Various statistical models were applied to the data in an attempt to see if a non-linear model might not be more applicable to the data. Higher linear order regression analysis (up to order 7), correlation analysis and multiple linear regression programs were obtained and run with the data available. To date, no obvious relationship can be predicted, although with more data from other locations a correlation might still be obtainable.

Conclusions -- The results of this preliminary study indicate the feasibility of continuing this type of investigation to other states. Suites of logs have already been obtained of selected wells within an eight-state area which should provide data to aid in the assessment of the Mount Simon for utilization as a waste disposal unit. The maps generated by this study, such as porosity trend, permeability trend, structure-contour, and isopachous should provide a better understanding of this subsurface formation and its associated cap rock. In regard to the Eau Claire, its gradation to a carbonate series in southeast Illinois was readily apparent through the interpretation of geophysical logs that were available. Likewise, the extension of this type of interpretation over a large area will reveal pertinent information regarding regional changes in characteristics of not only the cap rock but also the reservoir itself. Future work will involve refinement of methods and techniques which can only provide more reliable data for analysis.

It is hoped that, as in the permeability determination, results can be better realized with statistical application as was attempted in the preliminary investigation.

Geophysical well logging techniques present a plethora of information regarding the subsurface. All possibilities shall be pursued in future investigation to present as reliable a picture as is possible.

APPENDIX

TABLE 58 -- Selected Wells in Illinois

County	Well	Sec.	T.	R.	Log Suites*
Champaign	#1 Flessner	17	21N	7E	GR-N, M
Cook	#1 Geiger	31	40N	12E	GR-N, E
DeWitt	#1 Lamb	1	20N	4E	GR-N, L, FD, M, S, E
Douglas	#1 Bristow	4	16N	8E	M, IL
DuPage	#1 W. D.	9	39N	9E	GR-N, IE, FD, P, M, S
Fayette	#1 Weaber Horn	28	8N	3E	S, ML, L, IE
Hamilton	#1 Cuppy	6	6S	7E	GR-N, I, FD, S, DI-L, M
Henry	#1 South	30	16N	IE	S
Kankakee	#6 Karcher	32	30N	10E	E, M
Kankakee	#7 Schwark	32	30N	10E	E, M

Table 58 (Continued)

County	Well	Sec.	T.	R.	Log Suites*
LaSalle	#1 Butler	5	34N	1E	FD, S, SYN
LaSalle	#1 Mathesius	32	35N	1E	E
LaSalle	#1 Miller	1	36N	4E	E
LaSalle	#1 Swenson	1	36N	5E	GR-N
Livingston	#3 Cullen	29	30N	3E	FD, S, SYN
Livingston	#1 Feinhold	33	28N	6E	GR-N, M, L
Livingston	#16 Feinhold	32	28N	6E	SYN
Madison	#1 Kircheis	27	3N	6W	GR-N, S,E,IE,M
Marion	#1 Johnson	6	IN	2E	GR-N, FD, S
McLean	#1 Dady	14	25N	3E	GR-N, FD, S, SYN
McLean	#2 Furrow	31	26N	3E	L-GR,N,FD,SYN,M
McLean	#1 Grimes	1	24N	2E	GR-N, SYN
McLean	#1 Moore	22	25N	3E	GR-N, L,M,SYN
Mercer	#1 Fullerton	19	13N	4W	E
Monroe	#A-15 Theobald	35	1S	10W	GR-N, E
Morgan	#7-15 Whitlock	15	13N	8W	M, DI-L
Moultrie	#1 Harrison	22	15N	5E	E
Pike	#1 Harrison	15	4S	5W	E
Pike	#1 Mumford	21	5S	4W	E
Putnam	#1 W. D.	3	32N	2W	L-GR-N, FD, S, P, M, DI-L
Union	#1 Pickel	21	13S	2W	IL, IE, S
Wayne	#1 Cisne Comm.	3	1S	7E	FD, DI-L, SNP
Will	#1 McCoy	20	35N	9E	IE

Log Suites*

GR-N -- Gamma Ray Neutron
M -- Micrlog
E -- Electric
L -- Laterolog
FD -- Formation Density
S -- Sonic
IL -- Induction-Laterolog
IE -- Induction-Electric
P -- Porosity
DI-L -- Dual Induction-Laterolog
SNP -- Sidewall Neutron Porosity
SYN -- Synergetic

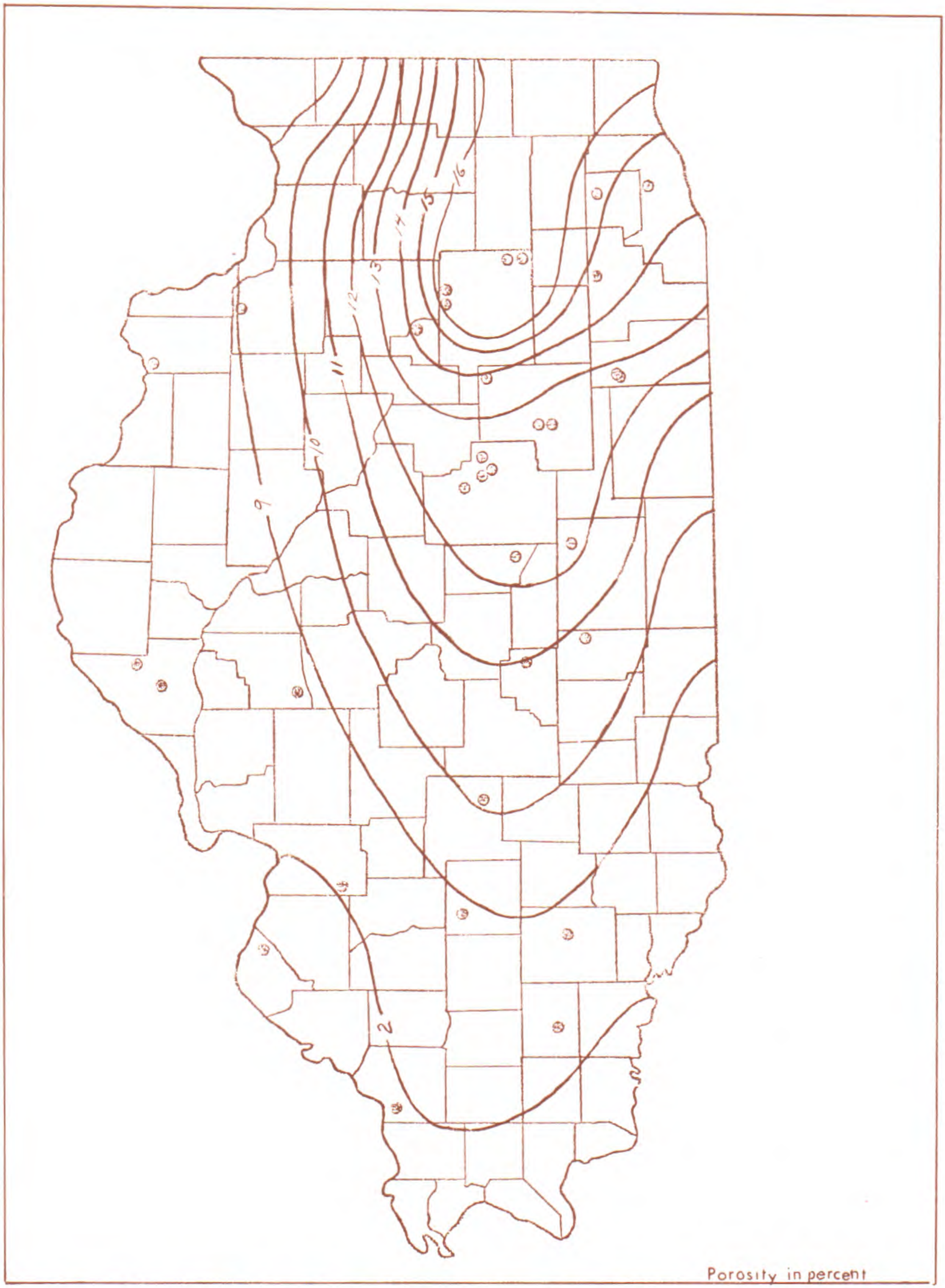

Fig. 2 Porosity map of the Mt. Simon Sandstone formation. (in percent,%)

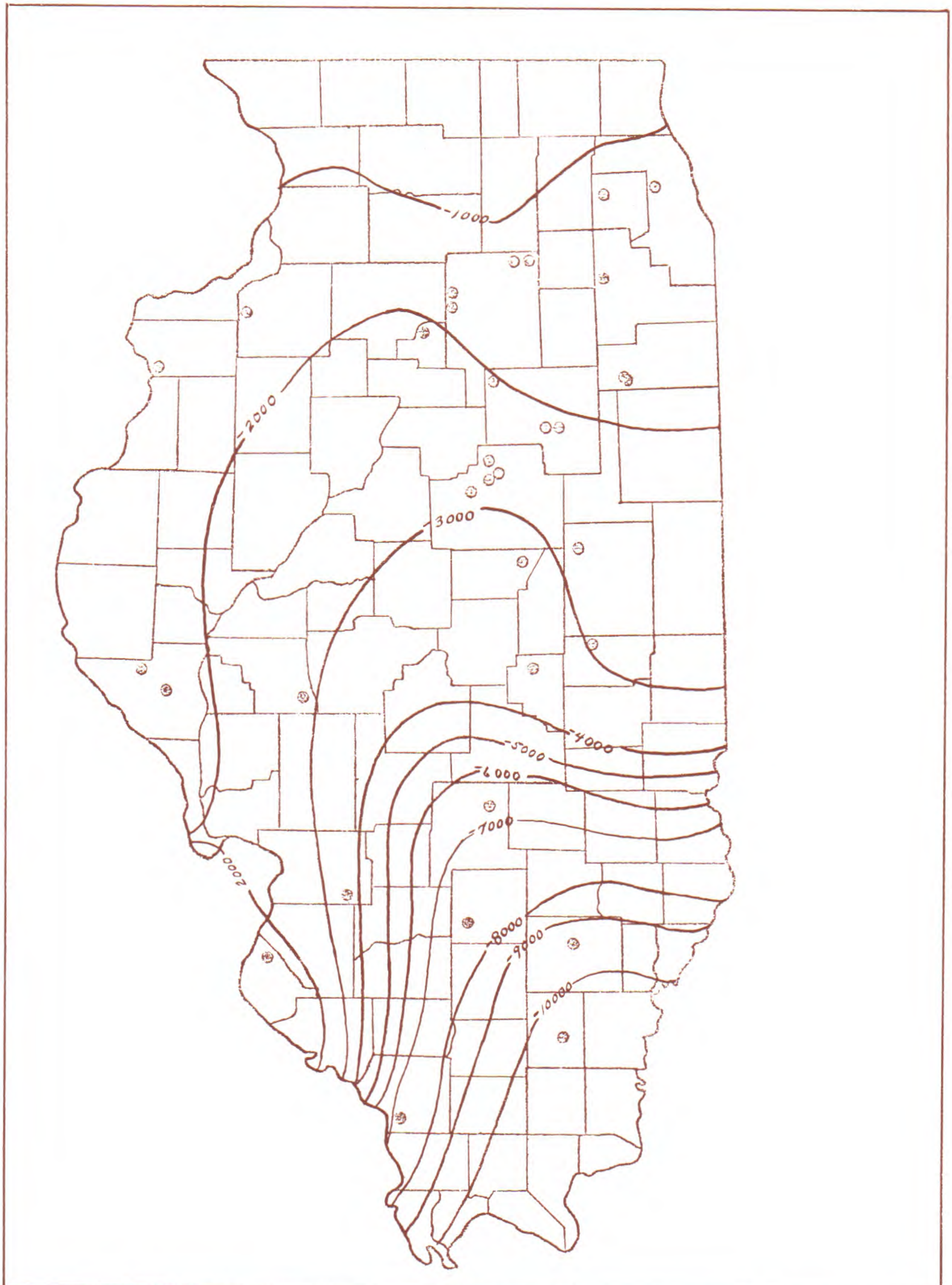

Fig. 3 Structure contour map of the Eau Claire shale formation. Sea level datum (feet)

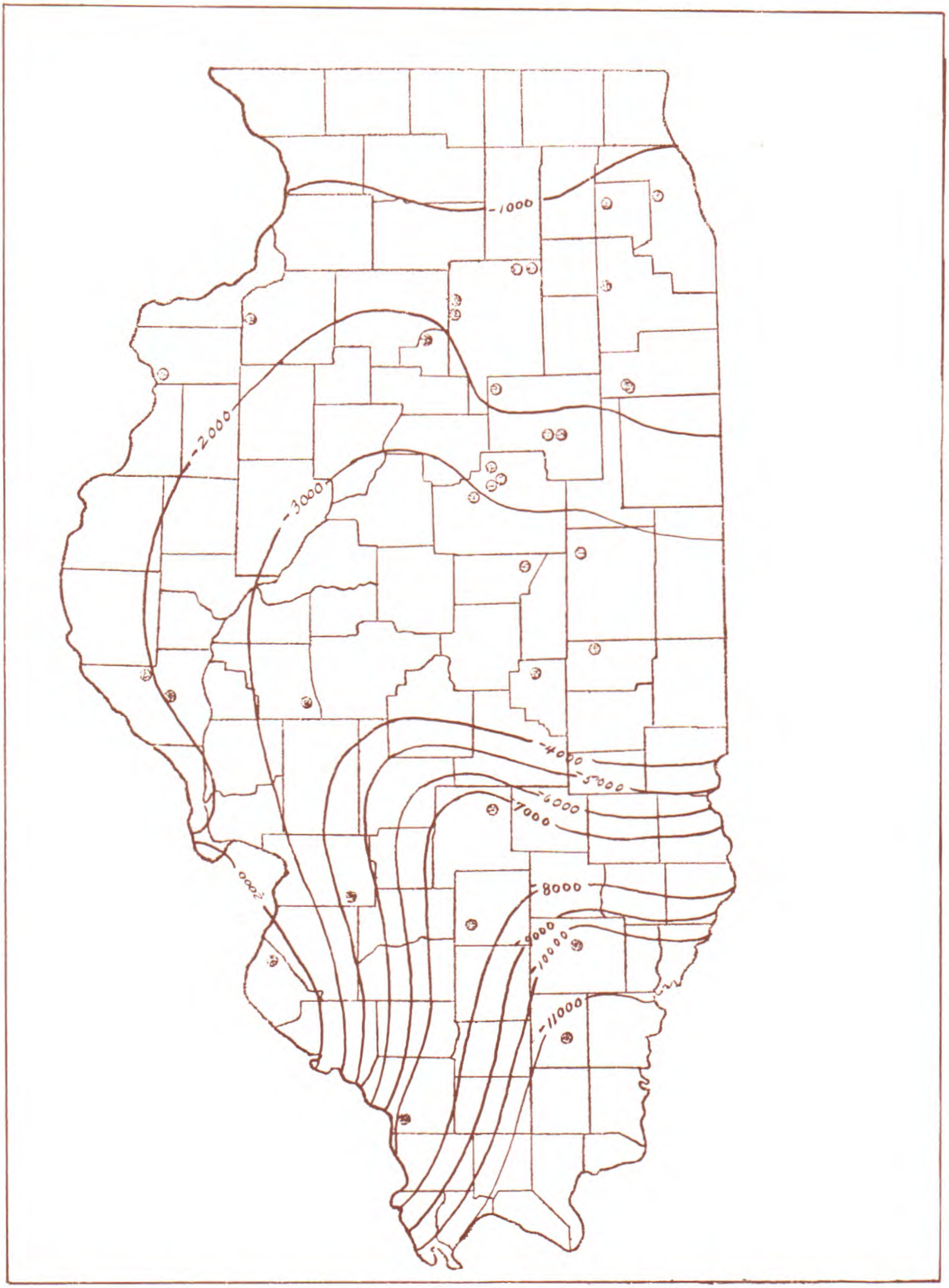

Fig. 4 Structure contour map of the Mt. Simon Sandstone formation. Sea level datum (feet)

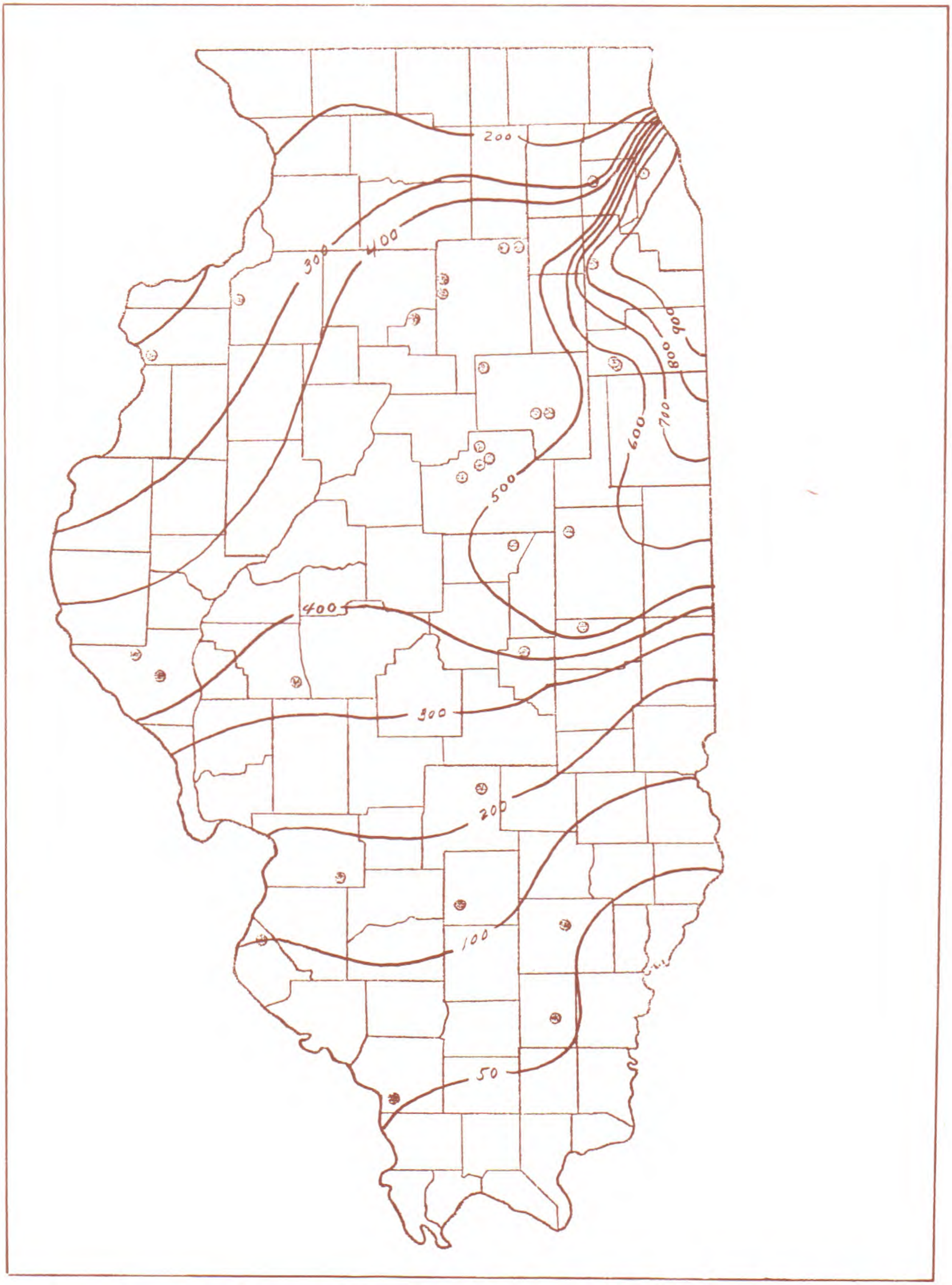

Fig. 5 Isopachous map of the Eau Claire shale formation. (in feet)

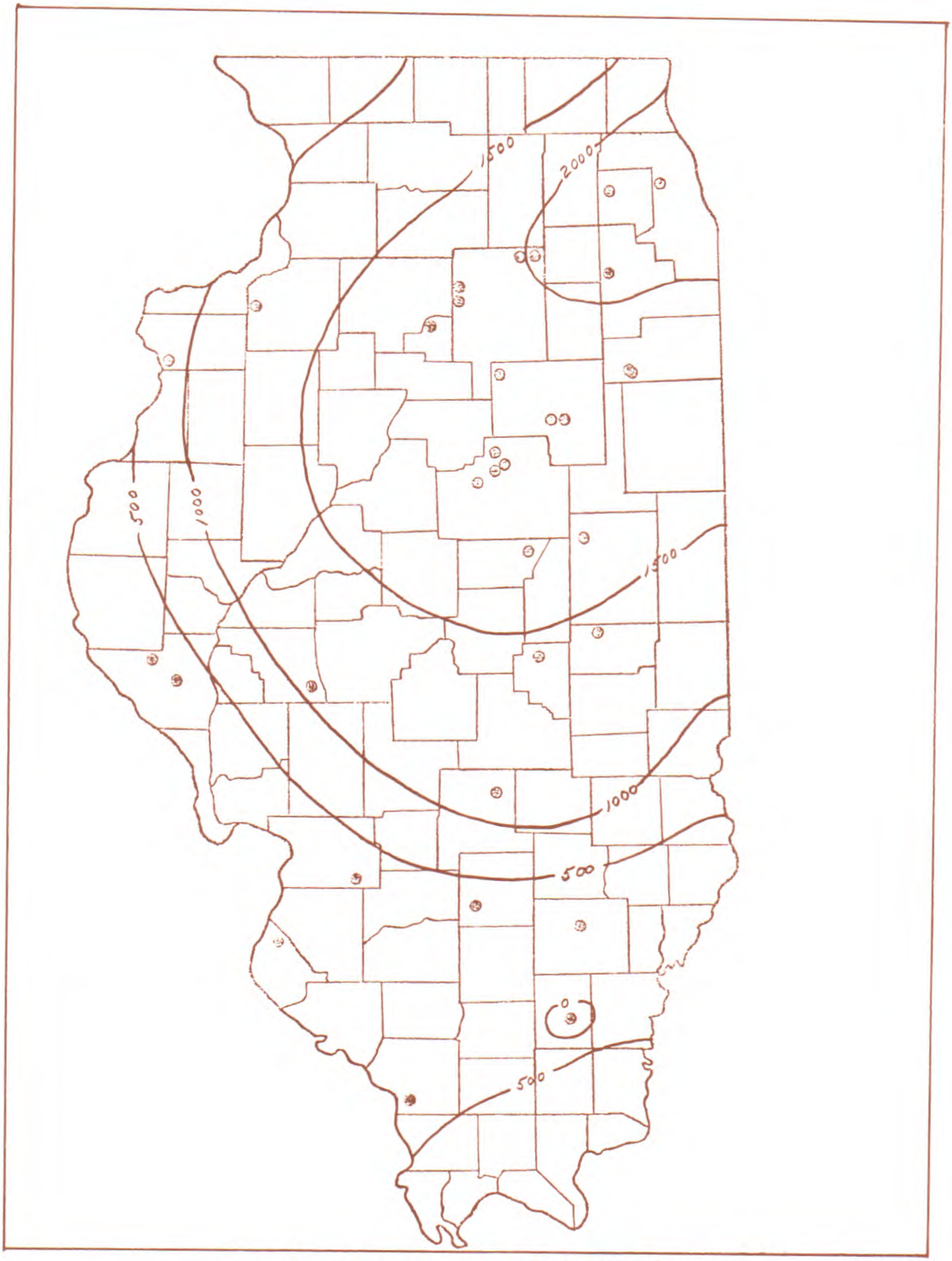

Fig. 6 Isopachous map of the Mt. Simon Sandstone formation. (in feet)

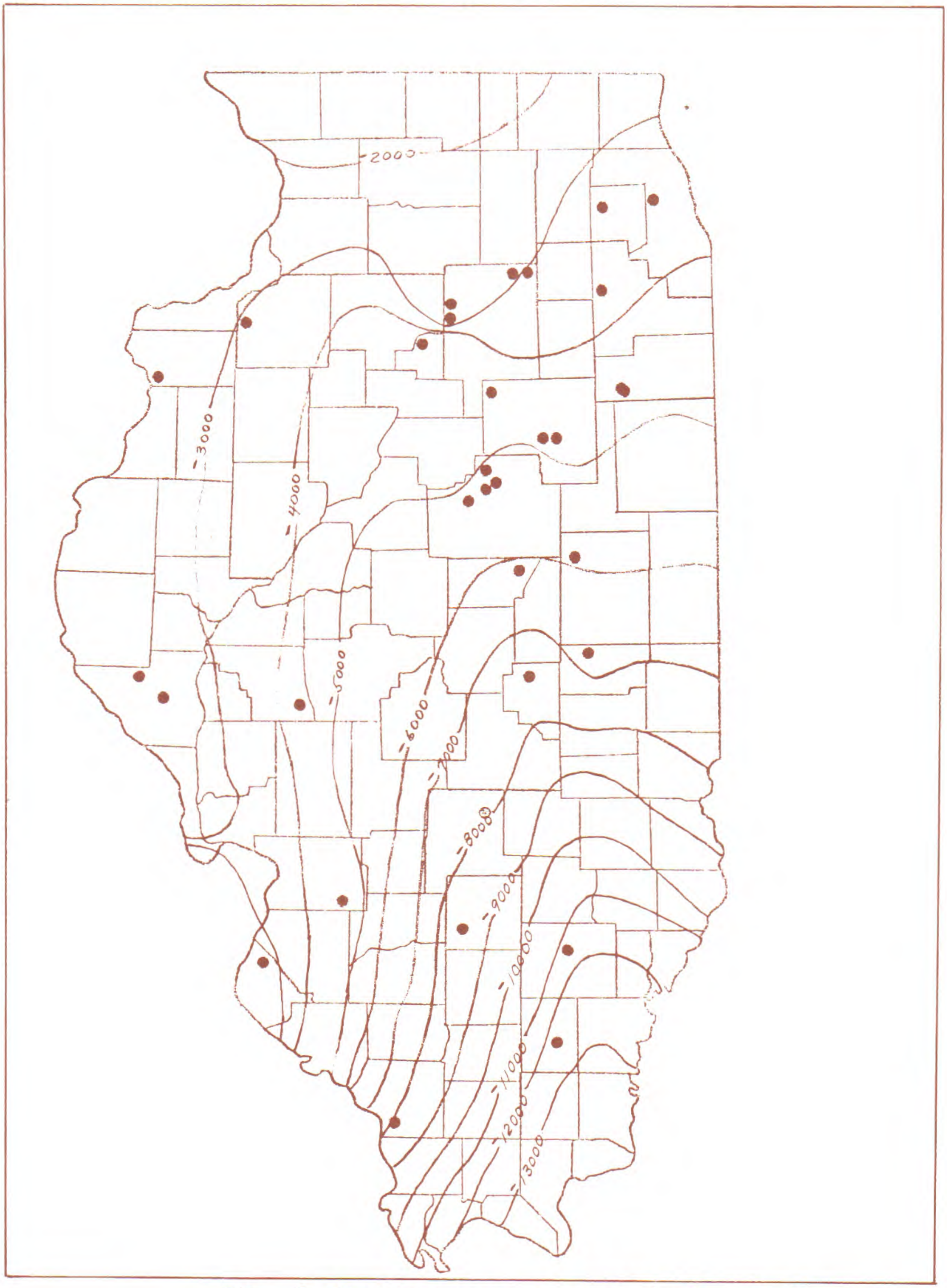

Fig. 7 Structure contour map of the Precambrian surface. Sea level datum (feet)

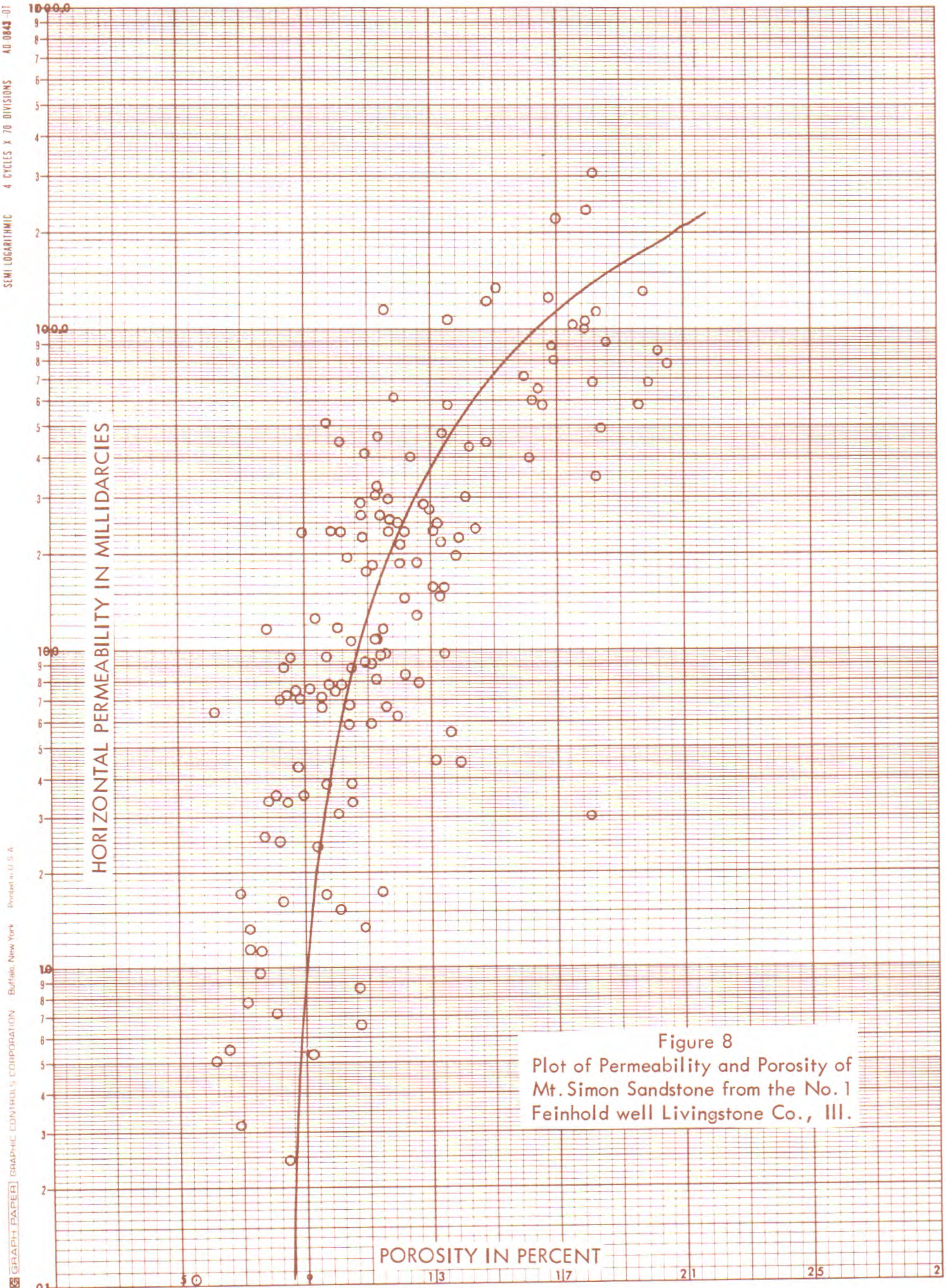

Figure 8
Plot of Permeability and Porosity of Mt. Simon Sandstone from the No. 1 Feinhold well Livingstone Co., Ill.

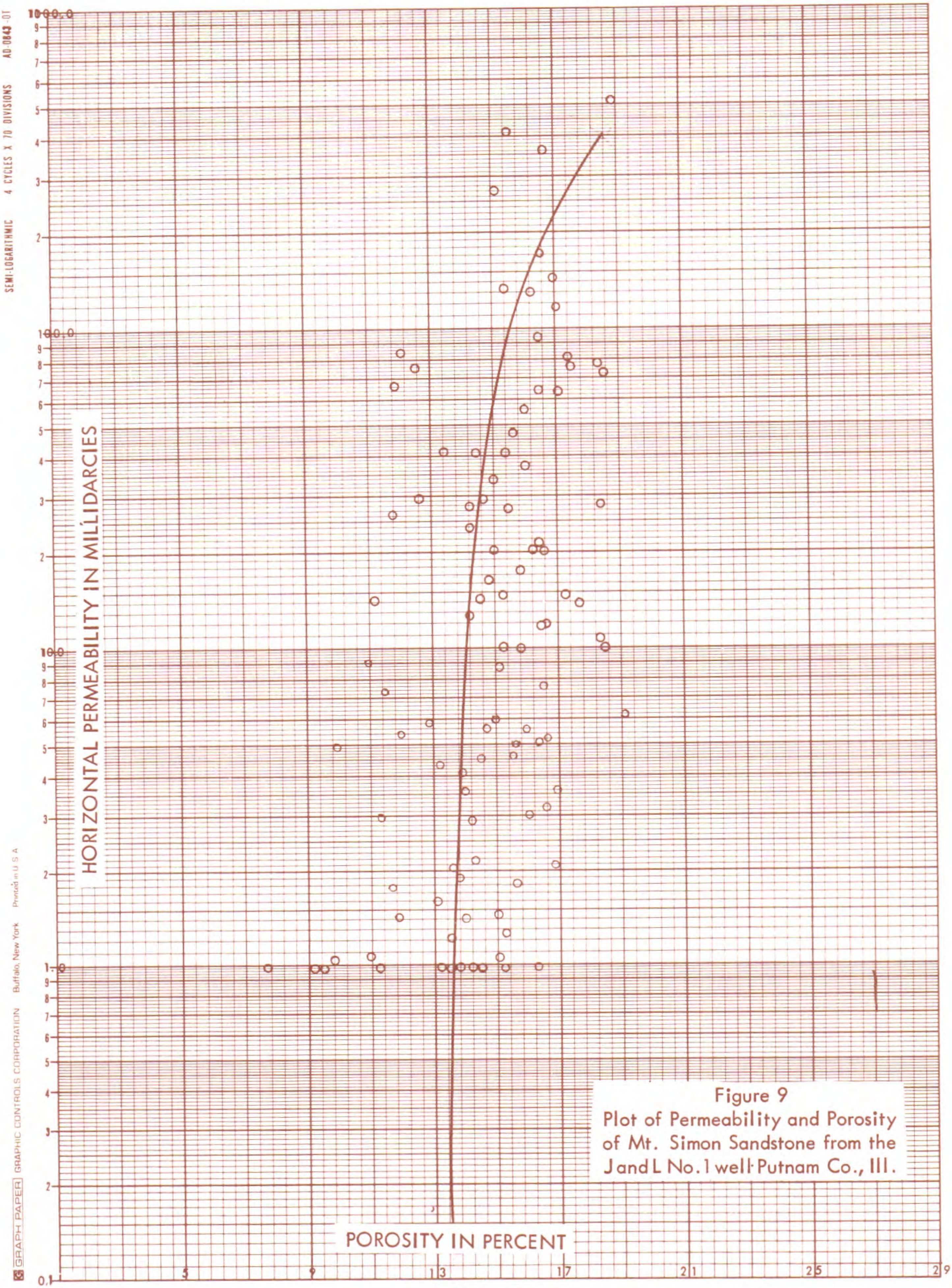

Figure 9
Plot of Permeability and Porosity of Mt. Simon Sandstone from the J and L No. 1 well · Putnam Co., Ill.

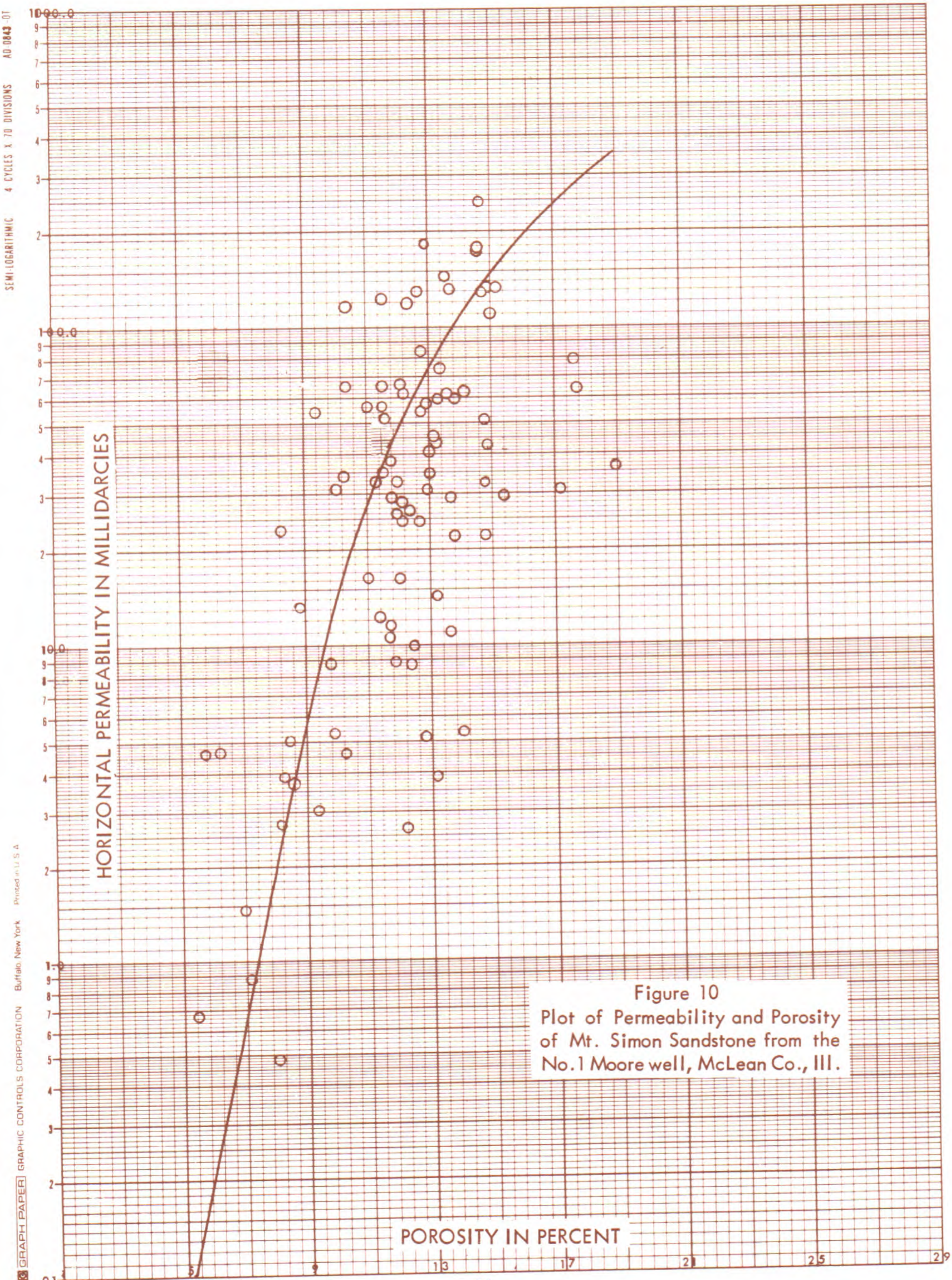

Figure 10
Plot of Permeability and Porosity of Mt. Simon Sandstone from the No.1 Moore well, McLean Co., Ill.

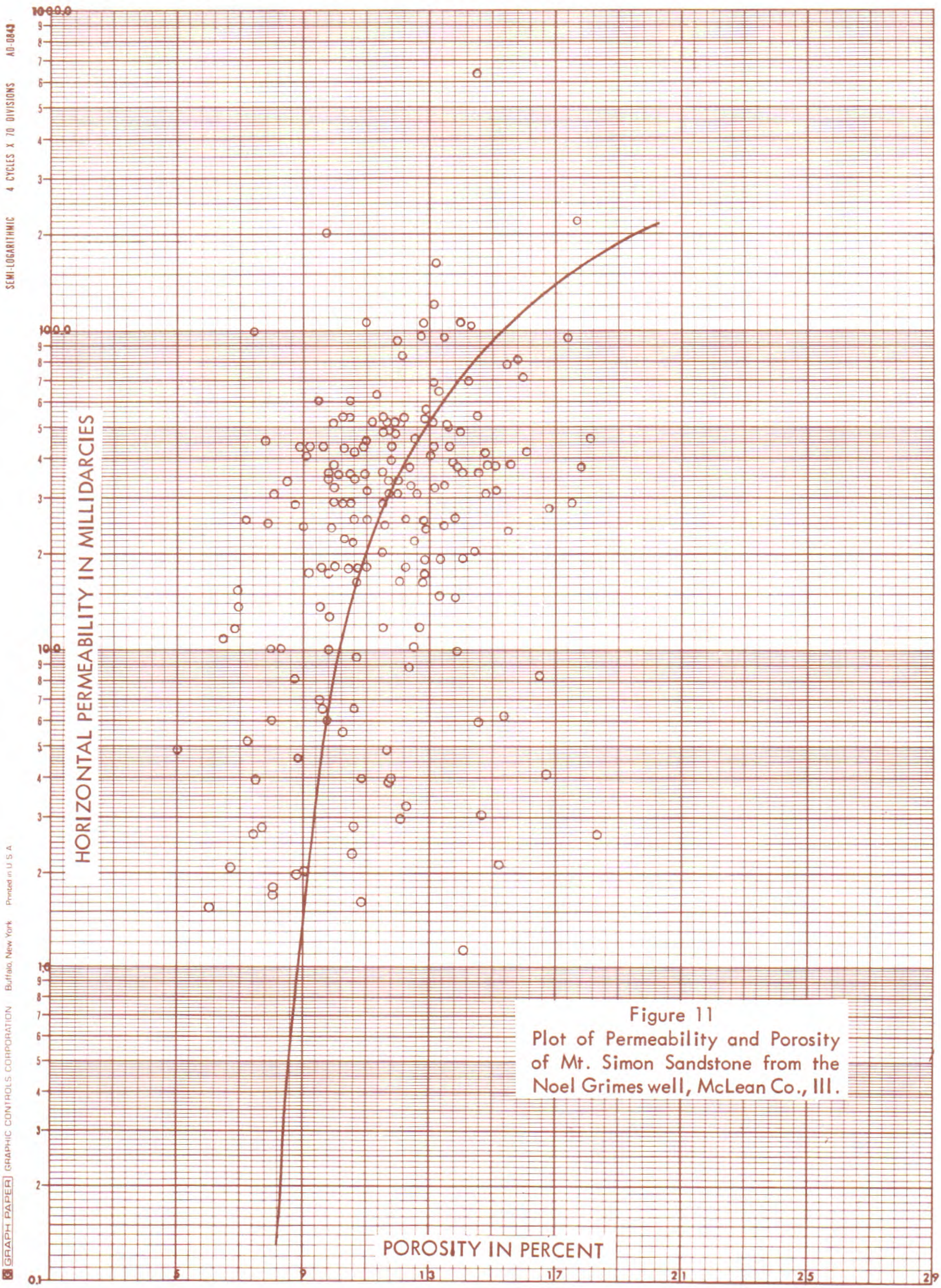

Figure 11
Plot of Permeability and Porosity of Mt. Simon Sandstone from the Noel Grimes well, McLean Co., Ill.

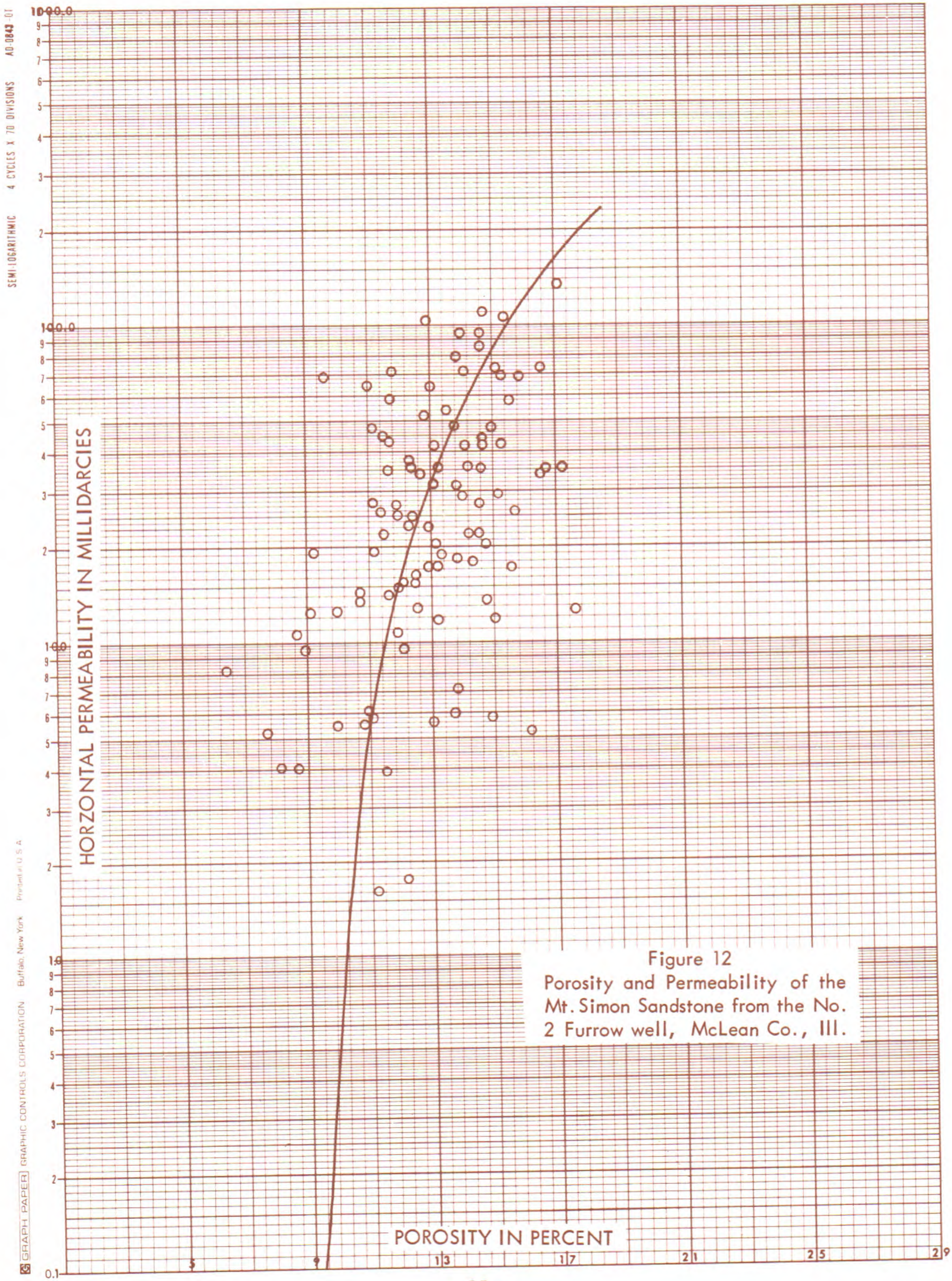

Figure 12
Porosity and Permeability of the Mt. Simon Sandstone from the No. 2 Furrow well, McLean Co., Ill.

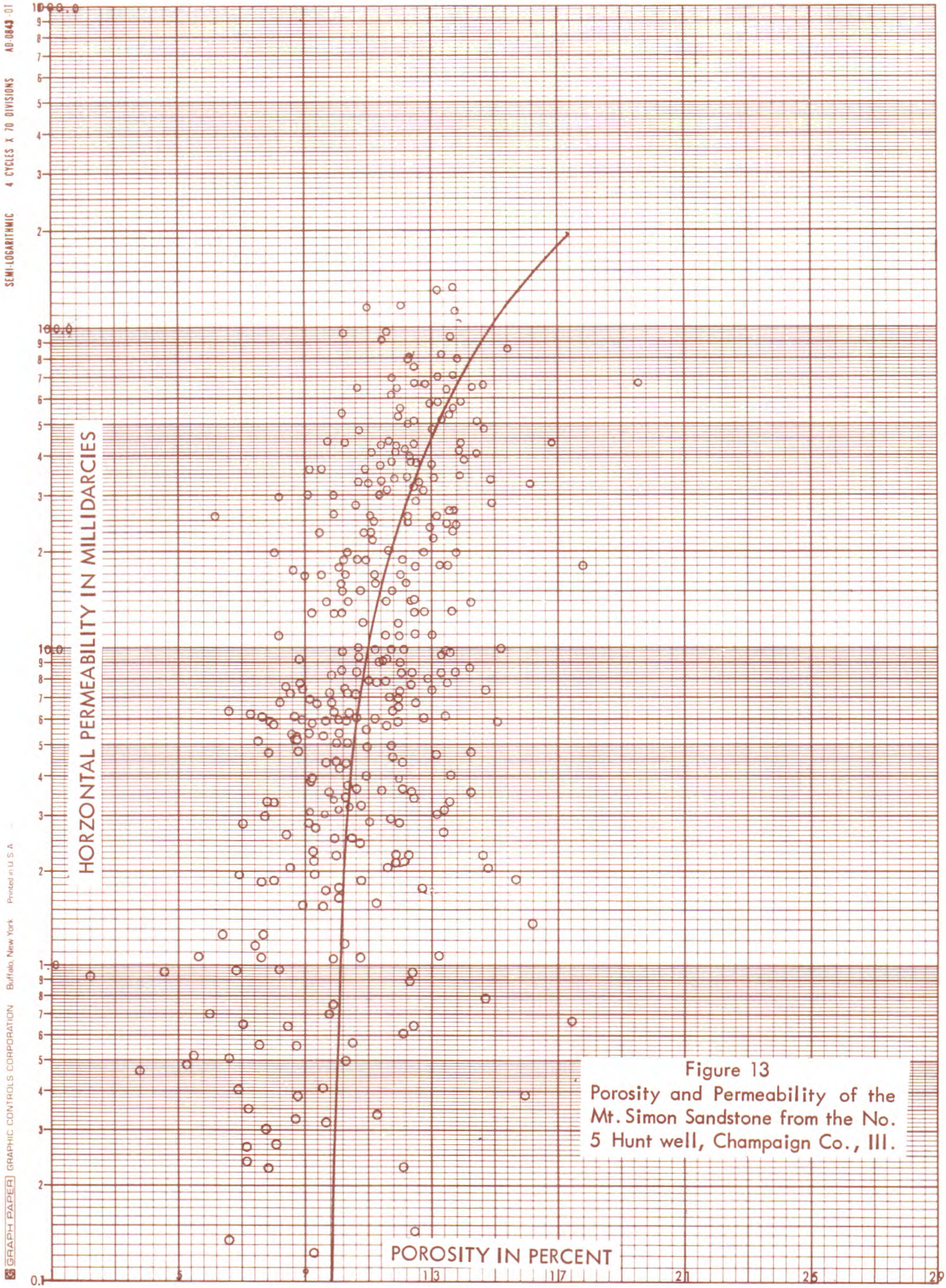

Figure 13
Porosity and Permeability of the Mt. Simon Sandstone from the No. 5 Hunt well, Champaign Co., Ill.

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