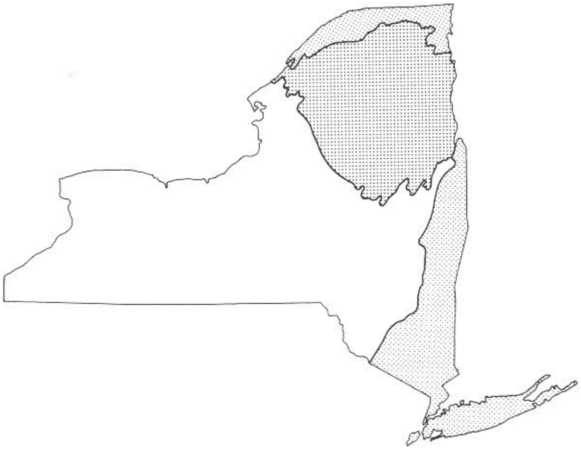

Underground Disposal of Liquid Waste in New York

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WILLIAM LYNN KREIDLER, 1911–1975

The author of this publication, W. Lynn Kreidler, died at his home in Loudonville, N. Y., September 27, 1975. Mr. Kreidler was born in Olean, New York, and joined the staff of the New York State Science Service — Geological Survey in 1949. He will be remembered for his contributions to the geology of oil, gas and salt deposits in New York and to the subsurface stratigraphy of the State.

Underground Disposal of Liquid Waste in New York[1]

by W. Lynn Kreidler, Senior Scientist, Geology, Geological Survey, New York State Museum and Science Service

ABSTRACT

Part I of this report brings to the attention of consultant geologists, engineers, and companies, some of the guidelines that should be followed for underground disposal of industrial liquid waste in New York State. Part II is a review of the subsurface geological formations in the Allegheny Synclinorium which may be suitable for liquid waste disposal. Other areas of New York less favorable for subsurface liquid waste disposal are briefly reviewed.

ACKNOWLEDGMENTS

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My thanks to William L. Kaschuble, Birdwell Division, Seismograph Service Corporation (a subsidiary of Raytheon Company) for permission to use the company's definitions of geophysical logs that came from two sales department publications.

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[1]Manuscript submitted for publication May 1975.

CONTENTS

ILLUSTRATIONS

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* Enclosure.

INTRODUCTION

The Geological Survey of the New York State Science Service, Department of Education, acts in an advisory capacity to other State agencies, on the geology of New York. In this role, advice is given to the Bureau of Industrial Programs of the Department of Environmental Conservation on geologic problems of a proposed disposal area. The Geological Survey also assesses the compatibility of underground liquid waste disposal with the following:

1. Fresh-water aquifers
2. Subsurface natural resources (oil, gas, gypsum, salt, etc.)
3. Existing mines (salt) and subsurface storage facilities (gas, oil and liquid petroleum gas [LPG])
4. Risk of seismic events.

The New York State Department of Environmental Conservation considers subsurface injection of industrial liquid waste as a solution to a disposal problem to be utilized only after all other methods have been explored by the company and determined to be impracticable. If other disposal methods would pollute the air, the land, or surface waters, the State will entertain the company's request to explore the possibility of using a subsurface rock unit for liquid waste disposal.

The New York State Legislature, in Article 17 of the Conservation Law, has given the Department of Environmental Conservation the authority to regulate the underground injection of industrial liquid waste. That authority includes the establishment and enforcement of standards and the issuing of State Pollutant Discharge Elimination System (S.P.D.E.S.) permits. The Bureau of Industrial Programs is the agency of the Department of Environmental Conservation that regulates underground injection of industrial liquid waste.

In general, pore space in subsurface rock units is filled with connate water or native fluids. Thus any liquid waste injected into these rocks forces back the connate water and/or mingles with it. Therefore, it is necessary to evaluate the physical, mechanical, and chemical characteristics of the subsurface rock units and the connate water to determine their compatibility with a liquid waste disposal program.

The term disposal will be used instead of storage of liquid waste. Storage implies that retrieval is possible at a later date. Disposal means it generally is not retrievable, but it should be emphasized that any liquid waste injected into the subsurface must be stored in perpetuity unless it breaks down in time.

PURPOSE

The purpose of this report is to describe in more detail than was previously done (Kreidler, 1968) procedures recommended for the development of an injection well and to describe appropriate geologic units that may have possibilities for liquid waste disposal.

Part I emphasizes the need for thorough study of the disposal program by the company or its consultants, utilizing a professional geologist to choose subsurface disposal units and to evaluate the risk factors of the proposed disposal well. Geological factors that should be considered before submitting a preliminary proposal for underground liquid waste disposal to the Bureau of Industrial Programs are emphasized.

Part II of this report discusses the possibilities for subsurface liquid waste disposal in the Allegheny Synclinorium of New York and other areas in the State. Some of the rock units of the Allegheny Synclinorium are illustrated by structure contour and isopach maps.

Part I

Guidelines for Subsurface Liquid Waste Disposal

Formations suitable for injection of liquid waste at safe pressures must be below the fresh-water aquifers, and must have suitable areal extent, thickness, porosity, permeability, and be confined above and below by impermeable beds. Subsurface data from wells drilled in the area or adjoining areas can be used to decide which beds have the best potential for disposal, but because porosity and permeability may differ from one area to another, it may be necessary to drill a test well to obtain rock and fluid samples and to run drill stem and injection tests on the formation or beds to be used for disposal to fully evaluate the suitability of the site.

A: WELL SITE SELECTION

Disposal Units

Most rocks suitable for subsurface disposal of liquid waste are sedimentary in origin. Their pore space is usually filled with connate (native) liquid which commonly is brine. Clean sandstones, or vugular type limestones or dolostones that are unfractured and have high porosity and permeability over a large area make the ideal disposal units. Such formations can receive large volumes of waste, if they have sufficient thickness and extend for some distance around the disposal well.

Confining Beds

Impermeable beds must overlie and underlie the injection zone to prevent the escape of liquid waste and the connate brine from the disposal units and thus protect the fresh-water aquifers and natural resources near the site. Suitable impermeable beds are unfractured shale, bentonite, anhydrite, gypsum, and marl. Unplugged wells, faults, joints, and fractures that penetrate the impermeable beds must be recognized in evaluating the disposal units. The minimum thickness of impermeable beds overlying and underlying the injection units that will effectively contain their fluids is difficult to define. In some cases 10 to 20 feet will confine oil and gas. To be effective seals for the disposal unit(s), the impermeable beds must extend some distance around the well.

Hydrology of the Disposal Units

The ability to receive liquid waste depends on the fluid viscosity of the liquid waste, pressure of injection, and the porosity and permeability characteristics of the disposal units. In sandstone, porosity commonly is part of the original space between the sand grains that is not filled by cement. Sorting and arrangement of the grains and the type of cementation influence pore space and permeability. Porosity is expressed in percent. Thus, a porosity of 10 percent indicates 10 percent of the total volume of the rock is void space. The porosity of limestone or dolostone commonly is caused by secondary solution by circulation of formation water. Permeability is the ability of a rock to transmit fluids under standard conditions. The higher the permeability (expressed in units called millidarcies), the lower the resistance to flow. An estimate of the porosity and permeability of the potential disposal units and the estimated pressure of fluids in the formation should be included in the preliminary report along with estimated wellhead pressure (pounds per square inch [psi]) required to inject the desired volume (gallons per minute [gpm]). A wellhead pressure that may fracture the disposal units is not permissible.

Folds

The structure of the bedrock can also have an important effect on the hydrology of the disposal zone. If the liquid to be disposed has a density greater than the connate water, the waste will tend to move to the structural lows. The reverse is true if the liquid to be disposed has a density less than the connate water; the waste will tend to migrate up-dip.

Seismicity

Injection of fluids into the subsurface can stimulate seismic activity under proper circumstances (see Sykes *et al.*, 1973). Thus it is important to know the past history of seismic activity within a 30- to 50-mile radius of a proposed well site (see figure 1). A comparison of the activity with geological structures and other geological and geophysical features should be made. It is recommended that natural seismicity be monitored several months before a disposal well is placed in operation to establish the normal background. Abnormal seismicity associated with the well operation could require shutting down the well, reducing the wellhead pressure and/or adjusting the rate of waste injection into the disposal horizon.

Natural Resources

The protection of natural resources, fresh-water aquifers, mining operations, and storage reservoirs is important in designing a waste-injection operation. Economic minerals such as gas, gypsum, oil, and salt may occur in the sedimentary sequence of the proposed disposal area. Natural gas may be stored in some of the depleted gas strata, or solution mining and other mining operations may exist. Fresh-water aquifers are in the upper sedimentary rock and its glacial covering and need to be protected from pollution.

Geohydrology of Fresh-Water Aquifers

The depth and thickness of the fresh-water aquifers should be determined in the area of the proposed disposal well site. Usage and well yield are important factors. Chemical analyses, indicating the salinity, hardness, specific conductance, etc., of water from the fresh-water aquifers, as well as chemical analyses of surface waters (streams, springs, and lakes) in the area should be determined before the disposal well becomes operational. This will give the necessary background to compare the changes, if any, of the surface and subsurface waters after the disposal well goes into use. It may also aid in locating sites for permanent wells to be used to monitor fresh-water aquifers.

Liquid Waste

The feasibility of liquid disposal requires knowledge of 1) the industrial process from which the liquid waste is derived; 2) daily rate of waste production; and 3) changes in daily rate throughout the year. Physical and chemical analyses of the liquid waste should be made, including any variations. This would include determination of the specific gravity, viscosity, acidity measured in pH, and total dissolved solids, and suspended solids in the liquid waste. The probable chemical and physical reactions of the liquid waste with the rock and native liquid of the disposal units should be determined.

Removal of Suspended Solids

All suspended solids need to be removed from the liquid waste that is to be injected because these tend to plug the pore spaces on the face of the well bore of the disposal units, and thus complicate or even defeat the project. Proper design of the filtration system will stop most solids from entering the disposal well.

Liquid waste may need to be chemically treated before it enters the filtration system, to avoid possible bacteriological plugging of the pore spaces.

Back-up Facilities

The company must have a contingency plan for unanticipated well failure during the disposal operation. The plan should include: 1) back-up facilities; 2) equipment available for storage of 15 to 20 days supply of liquid waste; 3) measures to prevent the well from reversing its flow; and 4) equipment to prevent blowouts.

Monitoring

The disposal of liquid waste in wells may cause well or formation failures that could create problems. Flow and pressure monitoring equipment must be installed on the wellhead, to record wellhead pressure and the volume of liquid waste injected into the disposal units. The wellhead pressure should not exceed a maximum pressure designated by the Bureau of Industrial Programs. Hydrofracture of the disposal units or the confining beds may cause leakage of industrial waste and the

Figure 1. EARTHQUAKE EPICENTERS and SEISMIC RISK ZONES in NEW YORK STATE and VICINITY

(Adapted from Smith 1962, 1964 and Algermissen 1969)

LEGEND

•	epicenters [1534 to 1968]		Seismic risk probability
□	cities	1	minor damage
— —	border between seismic risk zones	2	moderate damage
		3	major damage

JS

connate waters, thereby causing serious damage to the natural resources and fresh-water aquifers in the area. It is generally estimated that 1 pound per square inch (psi) or more of wellhead pressure per 1 foot of overburden may hydrofracture the disposal units. The State, in most cases, uses a factor of 0.65 psi of pressure per foot of overburden to prevent hydrofracturing of the disposal units. Local geological conditions may dictate the use of a different value.

Well Annulus Monitoring: The annulus is the space between the injection tubing and casing. This space is usually filled with fluid and kept at a low positive pressure or zero. If the pressure increases, it usually indicates the well is not functioning properly and the malfunction should be corrected as soon as possible.

Another method for monitoring the annulus is to place a pair of electrodes in the annulus, one near the bottom and the other at mid-hole. If the electric conductivity changes between them, an alarm is triggered on the monitoring board to indicate the well is not functioning correctly.

Monitor or observation wells may be required for fresh-water aquifers. Under subheading "Geohydrology of Fresh-Water," the need for pre-operational chemical analysis of the subsurface and surface waters is indicated. Once the disposal well is in operation, water samples should be taken from the fresh-water aquifers at specific time intervals. Chemical analyses of these samples should be compared to the original chemical analyses.

Observation wells: It may be necessary to consider installing observation wells to the subsurface disposal units to check on movement of the liquid waste and pressure change in the disposal zone.

Proposed Operating Procedure

The proposed operating program indicates the planned average and maximum rate of injection of the liquid waste and the estimated annual total waste for each year through the projected well life. In addition, estimates of the proposed average and maximum wellhead pressure needed to inject the above volume of liquid waste have to be determined. The estimated bottom hole pressure should not exceed fracture pressure in the proposed disposal units.

Preliminary Reports

To apply for permission for underground disposal of liquid waste from the Bureau of Industrial Programs, Environmental Conservation Department, the company must submit a preliminary report. This report should document the guidelines previously discussed and include the data mentioned below.

A generalized map must be submitted, giving the location in feet to the nearest 5 minutes of latitude and longitude of the proposed disposal well site and its location by town and county. It must show the boundary lines of the property or lease, with the existing buildings, ponds, tanks, wells, etc. Also cultural and geographical features need to be described within a 5-mile radius of the proposed disposal well.

The company geologist will submit a report on the general geology of the area including a map that shows the strike and dip of the beds and other structural features, such as faults, joints, etc., within a 10-mile radius of the proposed well site. These structural features should be shown on surface and subsurface maps and cross-sections of the area. The subsurface maps and cross-sections should indicate the depth and thickness of the proposed disposal rock units and impermeable confining units.

A generalized geologic columnar section (1″=500′) should be included which shows rock units from the surface to the estimated total depth of the disposal well. This should indicate the anticipated formations in their correct sequence from the surface and give the general lithology, with estimated thickness and depth of each formation.

A search of the area should be made to identify the location of all wells. The wells should be documented showing their total depth, whether they have been properly plugged, and at what depths they were plugged.

In addition, any available data on an existing or former liquid waste disposal well in the same disposal rock units or from previous wells that penetrated the proposed disposal rock units should be included. This information may provide estimates of the distribution of the porosity and permeability of the disposal zone.

Where Does the Consulting Geologist Start

There are a number of geological conditions that a consulting geologist must consider in examining an area for subsurface liquid waste disposal. His first efforts should be directed to a search of the geologic literature. The logical place to begin the investigation is the State Geological Survey office in Albany, New York. Here he or she has an opportunity to discuss the geology with geologists familiar with the area. The consulting geologist can examine the State's geological files that contain data on most of the deep wells drilled in the State. This information includes drill cuttings, geophysical logs, lithic logs, determination of the major tops penetrated by the wells, and so forth. The above information is on open file except in a few cases where wells may be held on a confidential basis. From this geological data, the consultant will be able to begin compiling the data needed for his report.

Engineering Aspects

Another important aspect of the success or failure of a disposal well is the engineering design. The engineer's careful attention to the type of equipment and inspection of the installation of this equipment is vital. The engineer's responsibilities include the proposal of subsurface equipment; well-head equipment, above-ground facilities, and monitoring techniques. The contingency plan, in event of well failure during operation of the disposal well, is also the responsibility of the engineer. It is recommended that the design of operations and any engineering problems should be submitted to the Bureau of Industrial Programs.

B. DRILLING, COMPLETION, AND TESTING REPORTS

The Geological Survey requires reports on the drilling, completion, and testing of the disposal well. The reports will aid in evaluation of the reservoir capacity of the disposal rock units and will help determine if the confining beds are adequate. Necessary information includes accurately surveyed location and elevation of the disposal well, set of drill cuttings, description of the cored disposal zone, geologic correlation, well site stratigraphy, types and description of logs run, laboratory tests, chemical analyses, injection test evaluation, and other well tests.

Location and Elevation

The disposal well site must be located and described in feet to the nearest 5 minutes of latitude and longitude. The elevation of the ground and derrick floor or Kelly bushing of the well must be established. This is necessary to calculate the subsurface depths of the geological formations (penetrated by the drill) and the depth and thickness of the disposal zone.

Well Cuttings

The New York State Geological Survey has a standing request that the Bureau of Industrial Programs have the company furnish a complete set of well cuttings, collected at 5- to 10-foot intervals, from the surface to total depth of the well. The samples must be washed so that a clean set of well cuttings will be submitted to the State Geological Survey. The company geologist is responsible for a detailed microscopic study that describes the lithology of the well cuttings.

Coring of Disposal Units

The disposal unit must be cored. The cored intervals should be identified in feet according to the depth that coring started, depth that coring stopped, and the amount of core that was recovered in the interval. The cores are to be examined by the consulting geologist who makes a detailed description of the lithology of the cores. The cores should then be sent to a laboratory to be examined and tested for porosity, permeability, etc. After the cores have been studied and all other tests completed, a representative sample of the cored intervals will be turned over to the State Geological Survey.

Well Site Stratigraphy

Lithologic study of the well cuttings and cores by the consulting geologist shall identify the formations penetrated in the disposal well and establish the depth, thickness, and geological age of each formation. The drilling and completion report should contain a written description, in proper sequence, of the geologic formations at the disposal well site.

A geological columnar section (1″=500′) must be included in the drilling and completion report based on the lithologic study of the well cuttings and cores. From the drillers log, notations on fresh- or salt-water aquifers, gas and oil shows should be located on the columnar section.

Recommended Logs to Run in a Disposal Well

There are several kinds of logs that should be run in a disposal well. One is made by the drillers and is called the driller's log. The geophysical logs, usually run by a specialty company, are classified as electric (measuring spontaneous potential and resistivity, temperature), radioactive (natural and induced radiation), velocity (acoustics or travel of sound), and mechanical measurements.

Driller's Log:

The drilling log on a cable tool or rotary rig is compiled by the head driller. This log indicates in generalized terms the type of rock progressively penetrated by the drill, the rate of drilling, and amount of footage drilled per shift. In soft formations (shale), the drilling footage is more rapid than in hard formations (limestone). The driller's record should indicate the depth to potable and nonpotable waters and the presence of natural resources (oil, gas, and salt). The driller's record also indicates the time the rig is shut down for running casing, cementing, moving tools in and out of the hole, fishing for tools, cave-ins, testing, etc.

Geophysical Logs:

Good geophysical logs are extremely helpful to the geologist in his interpretation of the subsurface formations and analyzing the capabilities of the disposal rock units to act as a liquid waste reservoir. There are a number of, or combinations of, geophysical logs that are extremely useful in a liquid waste disposal program. These are listed below. (The geophysical definitions used here are those published by Birdwell Division, Seismograph Service Corporation.)

Electric:

Spontaneous potential log—is run in an uncased bore hole that is filled with fluid. "It is used for correlation, for fluid evaluation, for shaliness estimates, for 'net sand' estimates to determine subsurface formation pressures through 'salinity mapping' . . ." In an uncased hole the lithologic breaks are more easily identified on a spontaneous potential log than on a gamma ray log.

Temperature log—"temperature logs record the temperature of the fluid in the bore hole, which reflects thermal relationships between formations and their fluids . . . Present use includes the location of cement behind casings, determination of rock permeability in formations flowing gas into empty bore holes and location of permeability and fluid movements following hydraulic fracturing of low porosity formations."

Radioactive:

Gamma ray log—"The log is used for correlation of subsurface formations, for evaluation of shaliness and formation permeability, for the identification of many commercial minerals . . . for lithology studies and for environment of deposition exploration." In a cased hole, the subsurface lithology can be interpreted on a gamma ray log more accurately than on a spontaneous potential log. The gamma ray log may be run in uncased or cased holes, fluid filled holes, and empty holes.

Neutron log—"Neutron logs are used for geologic correlation, for evaluation of total porosity, for shaliness evaluation, for bulk lithology and mineral evaluation, for invasion and permeability studies, for gas-oil discrimination, for porosity type evaluation and in production logging."

Density log—"Density logs are used for correlation, for accurate porosity evaluation, for lithology and mineral identification, for formation fluid evaluation, for gas-oil discrimination and for quantitative evaluation of oil in oil shales. It provides the most accurate, almost shale-free porosities in sand-shale formations."

Acoustic:

3-D velocity or variable density log—". . . is used for amplitude investigation and cement bonding evaluation, and to determine rock porosities, fracture locations and gas and water contact zones. The 3-D Velocity Log can be operated in cased and uncased holes. The 3-D Velocity Log is the only acoustic log that detects cement bonding to both, or to either, the formation and/or casing."

Cement-bonding—". . . is based on the principle that amplitude (or signal strength) of the acoustic signal traveling along the casing is greatly reduced where the cement is well bonded to the pipe, compared to no bonding or poor bonding."

Mechanical:

Caliper log—". . . is a highly sensitive bore hole diameter measuring device for logging changes in bore hole size and variations in casing. Additional capabilities are locating packer seats, shot holes, washed out places and casing shoes."

Well Tests

The geologist should consider conducting other tests that will give him more data on the disposal zone while the drilling rig is still available. It is recommended that drill stem and injection tests be run on the disposal zone. A company that specializes in this type of work, primarily in the oil and gas field, can be contracted to do the testing.

Static water level should be determined before and after drill stem and injection tests.

Static Water Level:

The static water level in a well is the height to which water in the native aquifer rises and stabilizes. This is also called the pressure surface.

The depth to the water level below the surface of the ground should be measured several times before running a drill stem test (DST) or injection test in a well. The average value of the measurements will establish the static water level before the test. Commonly, the water does not reach static conditions for several days after drilling or testing is terminated.

Drill Stem Tests:

A drill stem test is a means of measuring formation pressure and permeability and for obtaining a sample of the formation water.

The instruments for a drill stem test are furnished and operated by an oil well service company. The instruments are attached to the end of the hollow drill stem with a rubber packer above and below the instruments. If the bottom part of the hole is being tested, only the top packer is needed. A typical operation of a drill stem test for bottom hole is described below as observed at Morton Salt Company's Disposal Well No. 4.

The assembled string of instruments is lowered to a few feet above the bottom of the hole. On the derrick floor, lengths of pipe (plumbing) are added to the top of the empty drill stem, terminating with a 1-inch rubber hose and located in a convenient place on the derrick platform. The drill stem is lowered another foot or two until the anchor pipe at the end of the drill stem takes the weight off the drill stem. This expands the rubber packer against the wall of the bore hole.

A valve at the top of the packer opens automatically by timer, 8 minutes after the packer was set, and allows any formation fluid to enter the drill stem through slots in the pipe. Fluid is allowed to enter into the drill stem for 10 minutes or so, a time in which it is expected that the formation exposed in that part of the hole below the packer will be flushed of drilling fluid.

On the derrick platform, the end of the rubber hose had been placed in a pail of water. Air bubbling out indicates that the zone tested produced a fluid and has significant permeability and that the apparatus was operating properly.

The drill stem string is rotated to close the valve on top of the packer. The valve is left closed for a specified time (1 hour or so) to allow formation pressure to build up. A pressure device suspended in the drill stem records formation pressure buildup. Afterwards, the valve is reopened allowing the native fluids of the rock unit to enter the drill stem. The valve is left open for approximately 1 hour. The native fluids are trapped in the drill stem by closing the valve. Then the plumbing is detached at the top of the drill stem and the drill stem is pulled out of the hole.

Samples of the native fluids of the rock units are taken for chemical analysis. Nitric acid is added to one sample bottle to keep iron and manganese in solution.

The two pressure-recording devices are removed. Inside of each cylinder is a thin metal sheet with the inside face carbon-coated. This had been marked by a stylus and measurements are taken of the lines to estimate the formation hole pressure.

Injection Test:

Injection tests are a means of estimating the rate and volume of fluid that can be injected into the subsurface disposal units. (Observed at Morton Salt Company Disposal Well No. 14.)

The maximum wellhead pressure for the test is decided before the injection test begins. The wellhead pressure is controlled, keeping it below the fracture point of the disposal rock units. The injection test is designed to be run continuously for a 48- to 72-hour period either at a constant injection rate or in progressively increasing rates based on the range of feasible wellhead pressures. The scheduling is flexible so that an apparent stabilized wellhead pressure is obtained at each injection rate.

Ideally the injection test would use recovered connate water or an artificial facsimile. For instance, in duplicating the connate formation water, one is strongly advised to avoid complicating the down hole environment and producing adverse chemical relations. Correction factors for using fluids differing from the planned waste fluid need to be applied. The fluid passes through a filtering system and then into the wellhead injection tubing. The filter system keeps solids from entering the well bore and plugging the face of the disposal unit. A flow meter, recording in gallons or barrels per minute, and a pressure gauge, recording in pounds per square inch (psi), are installed between the filter and the wellhead.

An oil well service company usually operates the pump, the flow meter recorder, the wellhead pressure recording, and performs the backflushing of the filters when required. Visual readings of gauges and recorders are logged to assure good records, giving time, flow rate, wellhead pressure, filter gauge pressure, and any remarks or unusual occurrences in the test to aid in evaluating the results.

Laboratory Tests

A report should be submitted on the laboratory tests run on the native fluids, the cores taken from the disposal zones, and on the waste liquid. Analysis of chemical and physical properties should be thorough, including chemistry, specific gravity, viscosity, pH, and total solids.

The cores should be tested for porosity and permeability. The cores must be examined for mineral composition and for the nature of the porosity, *i.e.*, vugular, jointed, cross-bedded, faulted, etc. The report should further indicate whether there are any adverse reactions between the waste liquid, disposal rock units, and native fluids, or if all three are compatible with one another.

If certain precautions are taken, the disposal well operations should run smoothly with no chemical or physical reactions occurring among the waste liquid, native fluids, and the disposal rock units. For instance:

1. Porosity and permeability of the disposal rock units might be affected by swelling clays which can block the passageways in the disposal rock units.
2. If gypsum is present, its chemical composition may be changed by reacting with the liquid waste to block or plug the passageways in the disposal rock units.

Testing, Evaluation, and Monitoring

The State will issue a S.P.D.E.S. permit authorizing operation of the disposal well after it is satisfied that all requirements have been met by the operating company. The permit will stipulate the requirements and conditions of operation of the disposal well. At specified times, monitoring reports and records listed below must be submitted to the proper State agency or agencies:

Monitoring Wellhead Pressure and Amount of Fluid Injected:

The monitoring equipment on the wellhead must give a continuous recording of the wellhead pressure which should not exceed the maximum pressure established by the State. The monitoring equipment will continuously record the rate of injection and volume of liquid waste injected into the disposal well.

Surface Water:

At specific intervals, surface-water samples should be taken in the area for chemical analysis.

The analyses should be compared to those run before the disposal well became operational to determine any changes.

Liquid Waste:

At specific times, the chemical and physical properties of the liquid waste should be analyzed. The analysis should closely agree with the original chemical analysis. A change in the type of waste may influence operating conditions.

Observation Wells:

If observation wells have been established in the fresh-water aquifers, water samples should be taken at specific times for chemical analysis. These analyses should be compared to the chemical analyses run before the disposal well became operational. Static water level in the observation well should be checked to determine if unusual levels are occurring in the aquifer.

Part II

Possible Areas for Subsurface Liquid Waste Disposal in New York

The Allegheny Plateau and the Erie-Ontario Lowlands occupy part of the Allegheny Synclinorium. From examination of the regional geology of the State for possible potential subsurface disposal rock units for liquid waste, it becomes apparent that the Allegheny Synclinorium has the best prospects. Even here, careful study must be carried out to be sure the area around the disposal well site does not have geological structures (faults, joints, and fractures) that could create problems for liquid waste disposal. The necessary qualifications that the rock units for disposal must have are:

1. Adequate areal extent and appropriate thickness for the volume to be stored around the disposal site.
2. Proper sealing by impermeable beds above and below.
3. Adequate porosity and permeability.
4. Position below usable ground water zones.
5. No unplugged wells entering or passing through the disposal rock units.
6. Location outside a major seismic risk area. If a disposal well has to be located in a major seismic risk area, the area should be monitored by seismic instruments before and during operation of the disposal well.

Following the discussion of the Allegheny Synclinorium is a brief review of other less favorable areas of New York and their possibilities for subsurface liquid waste disposal. They will be divided into two sections: areas that have questionable potential, where more detailed geological exploration must be carried out before recommending subsurface liquid waste disposal, and areas that have poor potential (see figure 2).

A more detailed description of the geology of New York can be found in other publications of the Geological Survey, New York State Museum and Science Service. In this report only those rock units that may have possibilities for subsurface liquid waste disposal will be discussed.

A. ALLEGHENY SYNCLINORIUM

The part of New York that is within the Allegheny Synclinorium is bounded on the north by Lake Erie, Lake Ontario, St. Lawrence River Valley, and the Adirondack Mountains. For convenience, the eastern boundary of the Allegheny Synclinorium in New York is considered to be the Catskill Front and the Hudson River Valley.

In western New York the regional dip of the surface bedrock is generally southerly, increasing from 20 to 25 feet per mile in the Buffalo area to 80 feet per mile in the Utica area. The regional southerly dip of the top of the Precambrian increases more rapidly from west to east than that of the surface beds (see plate III). Tabulated below is the southerly dip on top of the Precambrian basement between wells from west to east.

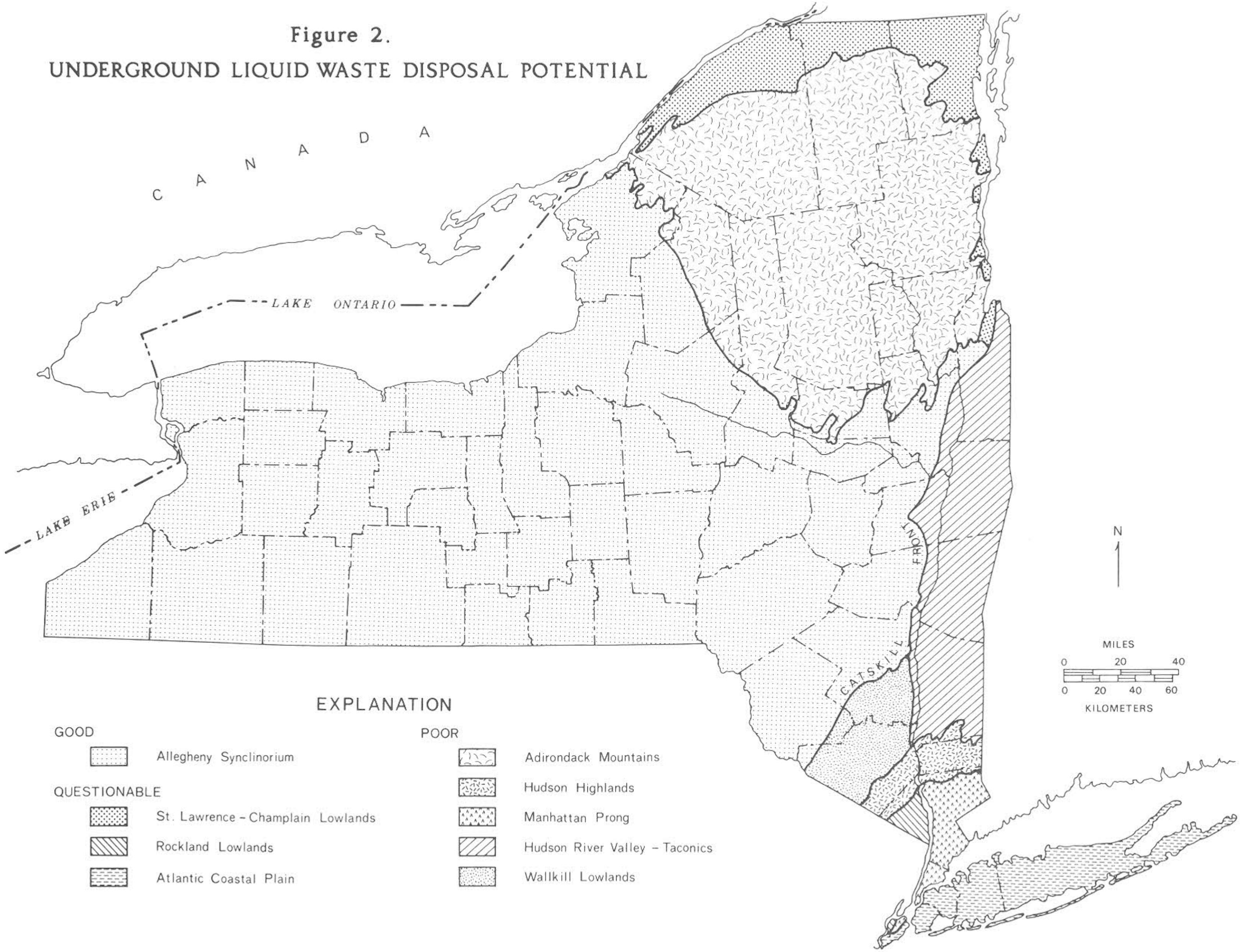
	Feet/Mile
Hooker Disposal (Niagara Co.)—Ellis (Cattaraugus Co.)	64
Wasielewski (Cayuga Co.)—Shepard (Tompkins Co.)	105
Lum (Otsego Co.)—Campbell (Delaware Co.)	181

The top of the Ordovician Queenston Formation that crops out south of Lake Ontario at an elevation of 300 feet is at a depth of 7,171 feet in the R. Olin 1 well near the New York-Pennsylvania line. This is due not only to the southerly regional dip of the rocks, but to increased elevations as one enters the Allegheny Plateau. The degree of folding increases to the south.

Cambrian System

The Cambrian System in the Allegheny Synclinorium of New York consists, from bottom to top, of the following formations: Potsdam

Figure 2.
UNDERGROUND LIQUID WASTE DISPOSAL POTENTIAL



Sandstone, the Galway (Theresa) Formation of interbedded dolostones and sandstones, and the Little Falls Formation of dolostones (see Fisher, 1962). According to deep well data, all three formations are present from Jamestown (Chautauqua County) east to the Delhi area (Delaware County). The Cambrian formations are absent from Lake Ontario east to the Adirondacks. In this region the Ordovician Trenton-Black River Group lies unconformably on the Precambrian basement complex. The Little Falls Formation is almost entirely absent in the Erie-Ontario Lowlands of New York.

Source of Cambrian Data:

Wells that penetrated into and through the Cambrian formations are the only source of data (see Appendix A—Cambrian Control Wells and locations on plates). The lithic logs of the above wells were furnished by the Geological Sample Log Co., Pittsburgh, Pennsylvania. The gamma ray tops on the Cambrian formations are those used by L. V. Rickard, New York State Museum and Science Service, Map and Chart Series Number 18. The presence of connate water reported in the wells came from Consolidated Gas Supply Corporation and other oil and gas companies.

Thickness:

In New York, the deepest part of the Appalachian Synclinorium is in Steuben, Chemung, and Tioga Counties. In the Olin well (map no. 40), Steuben County, the Cambrian is more than 2,100 feet thick and thins west and east from the central part of the basin. To the west, in Chautauqua County, the thickness is approximately 1,000 feet and eastward in Delaware County, it is 1,785 feet thick.

From the New York-Pennsylvania border the Cambrian thickness decreases up-dip toward Lake Ontario. The Searles well (map no. 26) in Orleans County has 31 feet of Potsdam underlying the Ordovician Trenton-Black River. The Little Falls, Galway, and Potsdam decrease in thickness and disappear to the north due to the long period of pre-Black River-Trenton erosion.

Porosity and Permeability:

Information is scant concerning porosity and permeability of the Cambrian formations. It can only be evaluated by the reports of connate water from wells drilled into the formations (see appendix A). The Galway Formation has 34 wells reported to have connate water, the Little Falls Formation seven wells and the Potsdam Formation seven wells. On this basis, the Galway has the better possibilities for underground disposal of liquid waste among the Cambrian formations.

Potsdam Formation

The Upper Cambrian Potsdam Sandstone lies unconformably on the eroded surface of the Precambrian Complex in New York State (see plate III). The only known exception is in the Olin well (map no. 40), where the basal sedimentary layers are thought to be Middle and Lower Cambrian in age. Therefore, only the Potsdam Formation in the Olin well was considered in isopach mapping the basal sandstone of New York (see plate I).

In the Shepard well (map no. 51), the thickness of the Potsdam Sandstone is 48 feet. To the west near Jamestown, the thickness is 185 feet and eastward 115 feet in the Campbell well (map no. 66) and 67 feet in the Lum well (map no. 78). Up-dip from the Shepard well, the Potsdam is absent in wells with the following map numbers: 22, 24 through 29, 44, 63 through 65, and 81.

Galway Formation

The Galway Formation in New York consists of interbedded dolostones and sandstones. The carbonates are light to dark in color and from dense to fine grained, medium to coarsely crystalline in texture and in part oolitic. The sandstones vary from fine through medium to coarse grained, quartz from angular to rounded and frosted, and from weakly cemented sandstone to orthoquartzites. A few beds of shale are not uncommon.

East of Cayuga County the Galway is predominantly carbonate with few interbedded sandstones. West and southwest of Cayuga and Tompkins Counties, the Galway has a predominance of sandstone with a few interbedded carbonates. In several wells in western New York, the upper bed of sandstone in the Galway has been reported as unconsolidated sand. This is believed to be the Rose Run Sandstone.

Indication of connate water in the Galway Formation does not necessarily mean that the water is from the Rose Run Member. The Ellis well (map no. 5) has six shows of connate water. Only the upper connate water show was in the Rose Run Member. This is also true of the Kennedy well (map no. 41) that has three shows of connate water. The Shepard well (map no. 51), in which the Rose Run Member is absent, has two shows of water in the Galway and was reported to have 12 barrels per hour. There are a number of shows of connate water in eastern New York. The largest reported is 20 barrels per hour of connate water in the Lum well (map no. 76), while in western New York, 35 barrels per hour of connate water from the Galway Formation was reported from the Tyler well (map no. 20).

In the Olin well (map no. 40), the thickness of the Galway Formation is 1,345 feet. To the west near Jamestown the thickness is 750 feet and eastward near Delhi, it is 1,405 feet. Up-dip from the Olin well, the Galway gradually decreases in thickness and is absent in wells with the following map numbers: 22, 24 through 33, 38, 47, 59 through 65, and 81. At the Bowerman well (map no. 44), the Galway Formation overlies unconformably the Basement Complex. This area was probably a high during the deposition of the Cambrian Potsdam Formation and, at a later date, was overlaid by the Cambrian Galway Formation.

Little Falls Formation

The Little Falls Formation in New York State is mainly dolostone with minor amounts of shale, sandstone, and siltstone. The dolostone ranges from light to dark gray and has very fine crystalline to dense texture.

In the Enterprise Transit Statewell (map no. 8) and Olin well (map no. 40), the Little Falls is over 330 feet thick. To the west near Jamestown, the thickness is 92 feet, and eastward, 265 feet in the Campbell well (map no. 66) and 210 feet thick in the Gans well (map no. 80). To the north or up-dip from the Enterprise Transit State and Olin wells, the Little Falls Formation is absent in and north of the following wells: Ellis (map no. 5), Werner (map no. 13), Frankish (map no. 42), Ripley (map no. 56) and Ainsworth (map no. 74).

Structure Map

The structure map on the Basement Complex (plate III) is generalized because of the lack of control wells. It displays the increase in southerly dip from west to east and the major structural feature, the Clarendon-Linden fault in western New York.

Isopach Mapping

In this report, the basal sandstone is not considered to be confined to the Potsdam Formation. Besides the Potsdam Sandstone, it includes the arkose and granite wash below the Potsdam and extends up into the basal Galway Formation wherever it is more than 50 percent sandstone. The Ordovician Black River basal sandstone overlying the Potsdam Formation south of Lake Ontario was not considered as part of the unit in isopach mapping.

The Basal Sandstone and Rose Run Sandstone are potential disposal units. Therefore isopach maps of them were constructed. The major problems in isopach mapping of the basal sandstone and Rose Run Sandstone were the lack of well control in central and southern New York, and identification of the sands in several of the wells in the northern part of the mapping area (see appendix A). Here some of the well logs indicated a thickening of the sandstone, and in some cases large sample gaps occurred between sandstone beds.

Basal Sandstone

Well data indicate that the basal sandstone extends north into Orleans, Cayuga, and Oswego Counties and that it is present as far east as Schoharie and Delaware Counties (see plate I). The basal sandstone in southwestern New York is more than 200 feet thick and to the east, in Delaware County, the Campbell well (map no. 66) indicates a possible thickness of 115 feet. This decrease in thickness is due to a facies change to carbonates in the east where the sandstone is interbedded with the carbonates. The basal sandstone, in the Allegheny Synclinorium, decreases in thickness to the north due to removal by erosion.

Rose Run Sandstone

The upper Galway Sandstone in western New York is believed to be correlative with the Rose Run

Sandstone reported in Ohio by A. Janssens (1973). In New York, the Rose Run Sandstone thins to the north because of erosion and is absent in the central part of Genesee, Monroe, and Wayne Counties and east to Cayuga and Tompkins Counties (see plate II).

The Rose Run Sandstone, in the Olin well (map no. 40) has a thickness of 265 feet, in the Kennedy well (map no. 12) 235 feet, and 170 feet in the Enterprise Transit State well (map no. 8). It is absent in the Kesselring (map no. 50) and the Shepard (map no. 51) wells (see plate II).

Recommendations

Potsdam Formation:

Seven wells drilled into or through the Potsdam Formation have logs that reported connate water in the Potsdam Sandstone in Chautauqua, Wyoming, Livingston, Orleans, and Wayne Counties. The best show was five barrels per hour from the Harrington well (map no. 1) with fair shows in two wells located in Wyoming County. This formation seems to have some possibilities for underground liquid waste disposal in southwestern New York.

Galway Formation:

Thirty-seven wells that penetrated or drilled through the Galway Formation have logs that reported the presence of connate water in the Galway sandstones and dolostones from the western counties of New York as far east as Greene County. However, there was no connate water reported in the Galway from wells drilled in Broome, Cortland, and Delaware Counties. If the presence of connate water is any indication of good porosity and permeability, the Galway Formation has the best possibilities of the Cambrian formations for underground liquid waste disposal in the Allegheny Synclinorium of New York.

Little Falls Formation:

Wells drilled through the Little Falls Formation that have reported water shows are located in eastern New York. The exceptions are the Kennedy well (map no. 41), which is a few miles south of where the Little Falls is absent, and the Harrington well (map no. 1) in Chautauqua County. The possibilities for underground disposal of liquid waste in the Little Falls are slim, as only minor amounts of connate water have been reported here. However, if one were to consider the Little Falls for underground liquid waste disposal, it would be better to look in eastern New York within a 40–50 mile radius south and southwest of the Adirondack Mountains. In this area, gas companies have reported shows of connate water from the Little Falls Formation.

Ordovician System

The Ordovician System in the Allegheny Synclinorium of New York consists, from bottom to top, of the following rocks: Beekmantown Group, Black River Group, Trenton Group, Utica Formation, Lorraine Group, Oswego Formation, and Queenston Formation (see Fisher, 1962). The Beekmantown Group is fully represented within the Allegheny Synclinorium. The Chazy Group of New York is confined to the Champlain Lowlands. In western and central New York the Knox unconformity is an erosion surface at the base of the Black River Group.

From the descriptions in the literature, the Ordovician groups and formations younger than the Beekmantown would be more suitable as cap rock (confining beds) to contain the upward movement of liquid waste placed in the Upper Cambrian formations than as waste receptacles. However, the presence of connate water in the Beekmantown of eastern New York and the presence of gas in the Trenton Group east of Lake Ontario to Rome and south of Oswego to Syracuse suggest natural permeability and may indicate potentially usable injection rock units. Connate water in the Queenston Formation is indicated in logs of several wells in south-central New York. These gas and water shows suggest that the Beekmantown, Trenton, and Queenston Groups may have potential for liquid waste disposal.

Beekmantown Group:

The Beekmantown consists predominantly of limestone and dolostone with some shale. It is often difficult to pick the Beekmantown in the subsurface as there are facies changes from limestone to dolostone in very short distances. This is true at the outcrop of the Beekmantown as well as in the subsurface.

In the Kesselring well (map no. 50) the Beekmantown has a thickness of 757 feet and thins west to 45 feet in the Enterprise Transit State well (map no. 8) and east to 345 feet in the Gans well (map no. 80). The Beekmantown thins to a feather edge north of the following wells: Enterprise Transit State (map no. 8), Fee (Richardson, map no. 52), Branagan (map no. 71), and the Danisevich (map no. 70).

The Beekmantown in wells in Chenango and Otsego Counties has reported shows of connate water as follows: Lobdell (map no. 69) 1,000 feet of fill-up, Burkard (map no. 75) 0.5 barrels per hour, and the Lum (map no. 76) with several shows.

These connate water shows do not prove that the Beekmantown is adequate for the disposal of large volumes of industrial liquid waste, but they do suggest an area for further exploration. A number of wells drilled in this area also have reported connate water in the Little Falls and Galway Formations. The possible combined use of the Beekmantown and the Little Falls or Galway Formations in this area may be adequate to handle the subsurface disposal of industrial liquid waste.

Knox Unconformity:

The Knox Unconformity at the base of the Black River Group occurs above the Ordovician Beekmantown of New York. In western New York, the Knox Unconformity from south to north progressively truncates the Beekmantown, Little Falls, Galway, and Potsdam Formations.

This is best illustrated on plate IV where a structure contour map of the Knox Unconformity is superimposed upon a paleogeologic map of the pre-Middle Ordovician. The Potsdam underlies most of the area under discussion except at the Bowerman well (map no. 44), where the Galway overlies the Basement Complex. The Potsdam Formation is absent also in several wells just south of Lake Ontario in Orleans and Niagara Counties where the Black River overlies the Basement Complex. The major structural feature is the Claredon-Linden fault in western New York.

Plate IV indicates the position of the various formations underlying the Knox Unconformity. This may be an essential factor in selection of the rock units the company wishes to test for possible underground liquid waste disposal because disposal must not be too close to the Knox Unconformity as the liquid waste may migrate into the zone of the unconformity and move laterally.

Black River Group:

The Black River Group overlies the Knox Unconformity. The drillers usually consider the Black River and the Trenton one unit and call the combination the Trenton Limestone. This is a misnomer as the Trenton Group is predominantly limestone in western New York, changing to shales and limestones in east-central New York. The Black River Group is limestone and dolostone in New York and overlies unconformably the Precambrian basement complex east of Lake Ontario. The Black River Group apparently has little potential for liquid waste disposal in New York because of lack of reported porosity and permeability.

Trenton Group:

In the Olin well (map no. 40) the Trenton Group has a thickness of 640 feet and 815 feet in the Schaffer No. 2 well (map no. 53) and to the west 512 feet in the Ellis well (map no. 5). East of Schaffer No. 2, the Trenton Group has a thickness of 220 feet in the Lobdell well (map no. 69) and 26 feet in the Gans well (map no. 80). The Trenton Group is absent in the Lanzilotta well (map no. 67). Well data indicate the Trenton Group is over 700 feet thick in the following counties: Cayuga, Monroe, Ontario, Seneca, and Wayne.

Old gas pools believed to have been in the Trenton Group are located east of Lake Ontario to Rome and south of Owego toward Syracuse. Recently, gas was found in the Trenton Limestone in Cayuga County in a field called the Blue Tail Rooster. In the above fields the gas occurred in fractured zones, joint planes, cavities, shale partings, and shale beds.

The Trenton Group should be considered for possible disposal of underground liquid waste in western and central New York, but it is believed that in this area, the deeper Cambrian formations are better suited. The abandoned Trenton gas field, east of Lake Ontario to Rome, in Oswego, Lewis, Oneida, and Onondaga Counties, may have possibilities for underground liquid waste disposal where drilling peripheral to the fields has indicated the absence of commercial gas.

Queenston Formation:

The Queenston Formation which crops out just south of Lake Ontario consists predominantly of friable red shale with some green shale and green sandstone. The Queenston Formation is the stratigraphic equivalent of the Juniata Formation of Pennsylvania. Eastward, the shales become silty and, south and east of Rochester, are difficult to distinguish from the overlying Silurian Medina in the subsurface. Further south in the Kesselring well (map no. 50), the Queenston is predominantly sandstone that is medium to coarse grained, with grains subangular to rounded, pink, red, and green in color, poorly consolidated and non-calcareous with minor amounts of shale that is fine-grained to sandy and light green-gray. There are some interbedded siltstones.

Well data indicate that the Queenston Formation is thickest in western New York and thins to the east. The nonmarine Queenston Formation is not found in wells in eastern Madison and eastern Chenango Counties. Here the Queenston Formation has been removed by pre-Silurian erosion.

The Queenston has thicknesses of 1,042 feet in the Wilson well (map no. 11), 945 feet in the Olin well (map no. 40) in central New York, 655 feet in the Kesselring well (map no. 50), and 76 feet in the Branagan well (map no. 71). The Queenston is absent in wells east and southeast of the Branagan well.

In the deeper part of the basin in the Corning and Binghamton area, the possibilities may be better for underground disposal of liquid waste in the Queenston, but very few wells have penetrated the formation in this area. In wells that have penetrated the Queenston here, the lithology is predominantly medium to coarse-grained sandstone, poorly consolidated and non-calcareous. Shows of connate water were reported in the Kesselring well (map no. 50) and the Richards well (map no. 82).

Silurian System

The Silurian System in the Allegheny Synclinorium of New York consists from bottom to top of the following groups: Medina, Clinton, Lockport, and Salina (see Fisher, 1960). The Salina Group is overlaid by the Rondout Formation in eastern and central New York and the Onondaga Formation in western New York.

Economic Minerals:

The presence of important economic minerals such as gas, gypsum, and salt in the Silurian System suggests that caution should be used for underground disposal of liquid waste in these beds. Commercial gas production has come from the Medina and Clinton Groups in western and central New York with the Medina Sandstone being one of the main gas producing horizons in the State. In 1932, some gas was discovered near Geneva, New York, in the Lockport Group apparently in coral reefs. In the past decade, commercial gas has been produced from the Lockport reefs in Michigan. As a result of the Michigan activity, there has been renewed interest in locating and drilling Lockport reef structures in New York. The Salina Group contains commercial salt beds in the Vernon and Syracuse Formations. The commercial gypsum beds occur in the Camillus Formation.

Porosity and Permeability:

The only evidence of porosity and permeability in these beds is the presence of water zones in the Medina and Lockport Groups. The connate water in the Medina is usually unrelated to the Medina gas fields. Several wells in Livingston County have logs that reported water shows of about one barrel per hour. The drillers in western New York often report a black-water zone that has a high sulphur content in the Lockport.

Recommendations:

If the Silurian formations are considered for underground liquid waste disposal, a thorough examination of the area under consideration for a disposal well must be made for unplugged wells, producing gas or storage fields, and the presence of commercial production of salt or gypsum. A disposal well must be far enough away from a gas or storage field so that the liquid waste will not invade it and destroy its usefulness.

Locally, the Medina and Lockport water zones might be considered for underground liquid waste disposal where there is assurance that no possibilities exist of harming any commercial mineral resources or fresh-water supplies in the area.

Devonian System

The Devonian System of the Allegheny

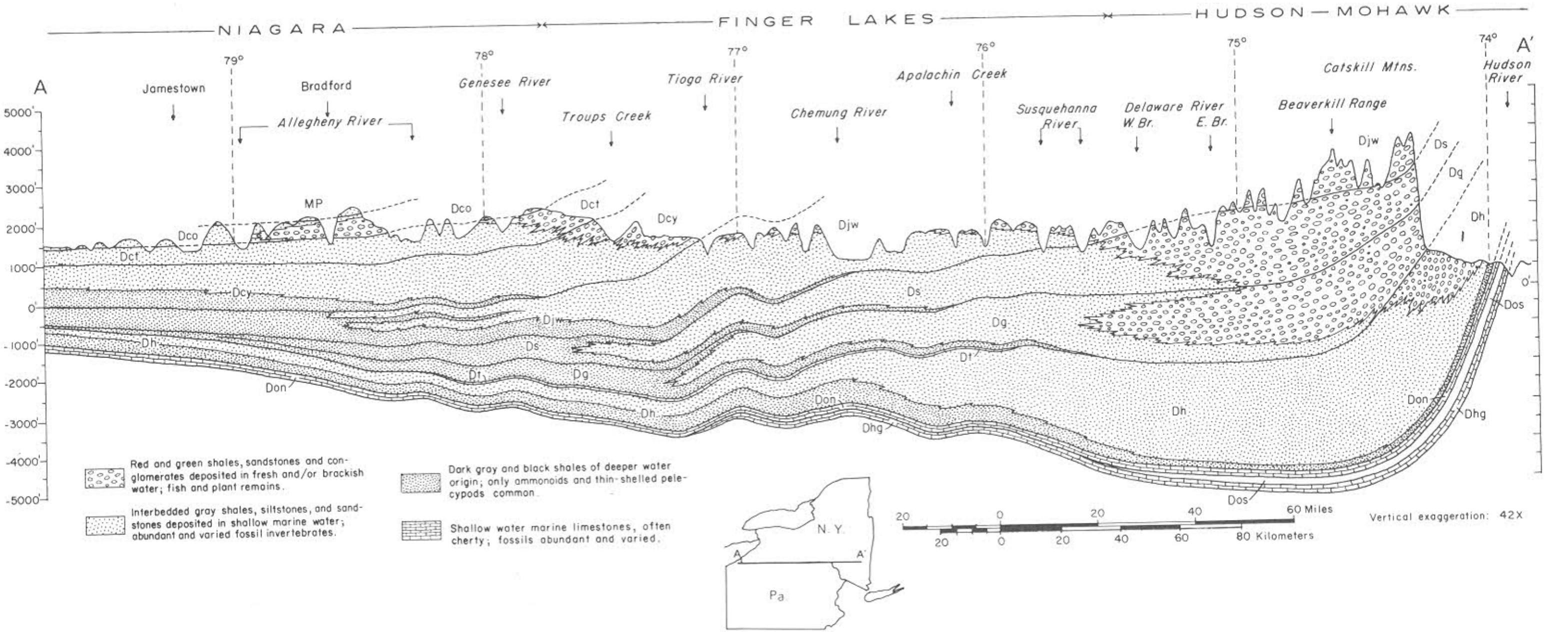


Figure 3. Cross Section of Devonian along New York - Pennsylvania Border

(BROUGHTON, J. G., *et al* 1961)

Synclinorium of New York consists from bottom to top of the following groups and formations: Helderberg, Tristates, Onondaga, Hamilton, Tully, Genesee, Sonyea, West Falls, Java, Canadaway, Conneaut, and Conewango (see Rickard, 1964, 1975). In the Olin well (map no. 40) the Devonian has a thickness of about 4,300 feet and a thickness of 4,800 feet in the Enterprise Transit State well (map no. 8) and 5,850 feet in the Campbell well (map no. 66).

Helderberg Group:

The Devonian rocks of New York are extremely diverse in extent, thickness, and lithology, and reflect the geological conditions which characterized that period. Marine shelf carbonate deposits are widespread in the Lower and Middle Devonian. The lowest is the Helderberg Group which is 230 feet thick in the Gans well (map no. 80). The Helderberg thickens somewhat southward and thins westward because of erosion, so that only the oldest units remain in the central part of the State (Kreidler, 1968). In the Finger Lakes Region, the Helderberg Group is being used for brine disposal. In the last day of a 3-day step-injection test, the Helderberg accepted 276 barrels per hour at an average wellhead pressure of 105 psi.

Oriskany Formation:

The Helderberg is succeeded by the Tristates Group of which the Oriskany Sandstone is the lowest formation. The Oriskany is found in the subsurface (thickness 0-50 feet) beneath much of the Allegheny Plateau area. In the central part of the State it has a thickness of more than 60 feet in the Kesselring well (map no. 50). In this well, there was a show of gas in the upper 2 feet of the Oriskany with connate water 55 feet lower. Suitable porosity and permeability are obviously present, but, as the Oriskany is a prolific gas producer to the west, it should probably not be used for underground liquid waste disposal. Eastward there is no record of gas production and if tests indicate suitable physical parameters, it may be ideally suited for underground liquid waste disposal. In the Tristates Group is the Glenerie Limestone of eastern New York, overlaid by shales and then by locally developed limestone.

Onondaga Formation:

The next major unit is the Onondaga Limestone formation which is found in the subsurface from the Catskill front to the western border of the State. It varies in thickness and averages about 100 feet. The Onondaga Limestone is the caprock in western New York for the Oriskany gas sand. However, in the past decade, the lower Onondaga (Edgecliff) reefs have produced commercial natural gas in western New York.

Hamilton Group:

After deposition of the Onondaga Limestone, a period of mountain building ensued in New England and the Canadian Maritime Provinces. This led to development of coalescing deltas and alluvial fans sloping westward (Catskill Delta) which had a profound effect on the thickness and lithology of all later Devonian formations. By the end of the Devonian, the Catskill Delta had restricted the seas to what is now the western part of the State. The Catskill Mountains are the eastern remnants of this delta's beveled remains (see figure 3).

The resulting picture in an east-west cross-section is a great wedge of rocks thinning to the west. The rocks in the east are mainly siltstone and muddy sandstones of continental origin. These change progressively westward to silty shales, shales, and minor sandstones. A few limy beds may be found in western New York as tongues thinning to the east. The Tully Limestone is a major unit of this type. Westward from the western Catskill area, the surface and subsurface rocks of the Devonian are mostly marine in origin. In contrast, the Herdman (Ulster County) well section shows about 2,000 feet of marine beds succeeded by an estimated 4,000 feet of continental beds.

The Hamilton Group overlies the Onondaga Formation and consists, from bottom to top, of the following formations: Marcellus, Skaneateles, Ludlowville, and Moscow. From the Kesselring well (map no. 50) west, the Hamilton Group is primarily shale with several interbedded limestones. East of the Kesselring well, the Hamilton Group consists of shale with some interbedded sandstones.

The above lithologies indicate that the Hamilton Group would be an excellent caprock. This is probably true for all the formations in the Hamilton Group except the Marcellus Formation that has some porosity and permeability in the Finger Lakes Region. Disposal wells in the Seneca Lake area, indicate that the Cherry Valley and Union Springs members of the Marcellus Formation will accept 7.1 barrels per hour. However, the Marcellus Formation, in other drilled areas in the State, has proven to be a tight impermeable shale.

Upper Devonian:

The Upper Devonian rocks are predominantly shales with interbedded sandstones. There are several possibilities in the Upper Devonian for liquid waste disposal in the sandstones with the shales acting as the caprock to seal in the liquid waste. For instance, from Tompkins County east toward the Catskill area, the Ithaca and Sherburne members of the Genesee Group may have suitable physical parameters for underground liquid waste disposal. Also, from the Genesee River east to Tompkins County, the Nunda and Wiscoy members of the West Falls and Java Groups may have porosity and permeability suitable for liquid disposal. Above the Java Group are the oil producing sands of the Canadaway and Conneaut groups. The overlying Conewango Group is too shallow for disposal use.

B. AREAS LESS SUITABLE FOR DISPOSAL

Outside of the Allegheny Synclinorium the subsurface rock units generally have less potential for liquid waste disposal than those within it. Below is a brief review of other areas in New York less suitable for underground liquid waste disposal. These areas will be divided into two sections: 1) questionable areas where more detailed geological exploration must be carried out, and 2) areas that have poor potential (see figure 2).

Questionable Areas

St. Lawrence-Champlain Lowlands of northeastern New York are underlaid by sandstone, dolostone, and limestone of the Cambrian and Ordovician systems. The beds in the St. Lawrence Valley dip gently (up to 10°) away from the Adirondack Mountains. The shoreline of Lake Champlain is largely controlled by north-south and east-west faults which have formed large fault blocks. The Morrisonville well, Clinton County, was drilled in 1899 to a depth over 1,350 feet. It penetrated 500 feet of Beekmantown, 50 feet of Galway, and stopped in the Potsdam after drilling 775 feet of sandstone. Only one stratum in the Potsdam was water bearing and this was not identified by the operator. More geological data are needed about the subsurface before evaluating the St. Lawrence-Champlain Lowlands for liquid waste disposal.

Rockland Lowlands: Early and Middle Triassic rocks are not known in New York, but Late Triassic rocks are present in Rockland County. These consist of red sandstone, shale, and conglomerate, with diabase flows. The sequence is thicker in the western part of the county. The sandstone rock units may have porosity and permeability and the diabase intrusive units may act as impermeable confining layers.

The Atlantic Coastal Lowlands are present in the southeastern part of New York and include Staten Island and Long Island. The area is covered with glacial drift which is underlaid by Cretaceous and possibly some Tertiary sediments. There is very little known about the subsurface in the Coastal Lowland, although numerous shallow wells have been drilled for ground water and some deep wells have been drilled in this area. More subsurface data is needed before evaluating this region. It is suggested that the local office of the U.S. Geological Survey, Water Resources Division, at Mineola, Long Island be contacted for more detailed information.

Poor Areas

The Adirondack Mountains are considered unsuitable for liquid waste disposal because the bedrock is highly metamorphosed crystalline rock with low porosity that is commonly faulted. Similar situations exist in the Hudson Highlands and Manhattan Prong in southeastern New York.

The Hudson River Valley and the Wallkill Lowlands are considered unsuitable for liquid waste disposal because the Cambrian-Ordovician rocks that underlie these areas are highly folded and faulted. The moderately metamorphosed Taconic rocks on the eastern border of the Hudson Valley are unsuitable for liquid waste disposal.

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Appendix A

CAMBRIAN CONTROL WELLS

Map No.	Well Name	Permit No.	County	Elevation (feet)	Rose Run (feet)	Thickness (feet)	Basal Sandstone (feet)	Thickness (feet)	Precambrian (feet)
1	Harrington	4437	Chautauqua	1760 G	6820-6900	80	7600-7690+	90+	
2	Gage	4561		1524 G	6272-6295+	23+	N.R.	—	
3	Shadle	4154		1617 D	6230-6280+	50+	N.R.	—	
4	Neihuas 2	1808		646 G	N.I.	—	N.R.	—	
5	Ellis	3868	Cattaraugus	1328 G	5622-5717	95	6230-6450	220	6460
6	Bethlehem Steel	6668	Erie	583 G	Abs.	0	4113-4300	187	4251
7	Hooker Chemical	6669	Niagara	579 D	Abs.	0	2900-3026	126	3026
8	Enterprise Transit St.	9235	Cattaraugus	2295 K	9720-9890	170	10860-11075	215	11025
9	Cook 2	3956		1672 D	7223-7337+	114+	N.R.	—	
10	Wolfer	4248		1572 G	7047-7247	200	N.R.	—	
11	Wilson	615	Wyoming	1483 D	6325-6465	140	6970-7144+	174+	
12	Veith	4092		1573 K	6325-6560	235	7105-7180+	75+	
13	Werner	4392		1609 D	5611-5722+	111+	N.R.	—	
14	Fisher	6073		1504 D	5516-5620	104	N.R.	—	
15	McClurg	4552	Livingston	986 D	4870-4955	85	5445-5550	105	5560
16	MacDonald	4069		881 G	4597-4652	55	N.R.	—	
17	Johnson	4567		795 D	N.I.	—	N.I.	—	4740
18	Klotzbach	5117	Genesee	862 G	Abs.	0	3810-3847	37	3857
19	Brundage	5115		733 D	Abs.	0	3543-3600+	57+	
20	Tyler	4593		712 D	Abs.	0	3743-3813	70	3813
21	Naylor	4806		666 G	N.I.	—	3322-3410+	88+	
22	Wolfe	4719	Niagara	329 G	Abs.	0	Abs.	0	1994
23	FMC Corp.	6667		549 D	Abs.	0	N.I.	—	2765
24	Weil	4753	Orleans	319 G	Abs.	0	Abs.	0	1995
25	Green	4873		277 G	Abs.	0	Abs.	0	1985
26	Searles	4752		350 G	Abs.	0	2177-2200	23	2208
27	Morrison	4764		335 D	Abs.	0	2160-2185	25	2185
28	Helfer	5007		297 G	Abs.	0	Abs.	0	2085
29	Brakenbury	4476		359 G	Abs.	0	Abs.	0	2193
30	Woolston	5091		364 G	Abs.	0	2252-2340	88	2340
31	Herman	4994		316 G	Abs.	0	2148-2190	42	2197
32	Nowak	5069		354 G	Abs.	0	2263-2313	50	2308
33	Malone	4912		434 G	Abs.	0	2435-2500	65	2518
34	Thaxter	5008		501 G	N.I.	—	N.I.	—	
35	Cook	4722		612 G	Abs.	0	2875-2980	105	2980
36	Domoy	5096		630 G	Abs.	0	2995-3095	100	3105
37	Kelley	4611		658 D	N.I.	—	2965-3020	55	3020
38	Hazen	4502	Monroe	309 G	Abs.	0	2148-2175	27	2178
39	Yantz	4724		644 G	Abs.	0	N.R.	—	
40	Olin	3924	Steuben	1645 D	11783-12048	265	12875-13095	220	
41	Kennedy	4630	Livingston	584 G	5640-5770	130	N.R.	—	
42	Frankish	6395	Ontario	1080 G	5520-5645	125	5690-6000+	40+	
43	Wyman	4760		597 G	4117-4202	85	N.R.	—	
44	Bowerman	4871		556 G	3915-3965+	50±	Abs.	0	4210
45	F. Smith	4754	Wayne	497	Abs.	0	N.R.	—	

Abbreviations Used:				
N.I. not identified	gals.	gallons	G ground	
N.R. not reached	hr.	hour	D derrick	
Abs. absent	min.	minute	K kelley bushing	

Map No.	Total Depth (feet)	Formation and Depth to Connate Water (feet), Amount Reported, Water Analysis and Other Comments	Gamma Ray Tops on Little Falls	Galway	Potsdam
1	7692	Little Falls 6838, Galway 7563, Potsdam substantial water 7692	6758	6850	7600
2	6292	Galway 6278, Water Analysis Yes	6222	6274	N.R.
3	6281	Galway 6281	6192	6250	N.R.
4	4510	Galway 4505	Abs.	4450	N.R.
5		Galway 5669-81, 5754-56, 5830, 5893, 6048, 6075	Abs.	5621	6280
6		Galway 3818, Precambrian 4300, Water Analysis Yes	Abs.	3794	4131
7		Galway 2846, Water Analysis Yes	Abs.	2835	2935
8		Galway 9800 (Top of fluid 9200), Water Analysis Yes	9380	9720	10910
9	7337	Galway 7322 (1200 fillup), 7337 (2000 fillup)	7103	7220	N.R.
10	7560		6900	7015	N.R.
11	7144	Galway 6375-95, 6397, 6391 (30 gals./hr.), Potsdam 7040 (rose 5500)	6195	6325	6968
12	7182	Galway 6375 (115 gals./hr.), Potsdam 7152-7180 (220 gals./hr.)	6260	6345	7020
13	5722	Galway 5646 (1200 of fillup)	Abs.	5568	N.R.
14	5718	Galway 5525, Water Analysis Yes	Abs.	5525	N.R.
15		Galway 5150 (10 bbls./hr.)	Abs.	4880	5460
16	5090	Galway 4815, 4887 (1000 fillup)	Abs.	4600	N.R.
17		Potsdam 4690 (1400 fillup), No lithic log	Abs.	4243	4677
18			Abs.	3553	3787
19	3600		Abs.	3320	3517
20		Galway 3722-24 (35 bbls./hr.)	Abs.	3520	3763
21	3410	Galway 3284-89 (675 fillup)	Abs.	3157	3357
22			Abs.	Abs.	Abs.
23		Precambrian slight flow of water 3130, no lithic log	Abs.	2660	N.I.
24			Abs.	Abs.	Abs.
25			Abs.	Abs.	Abs.
26			Abs.	Abs.	2177
27			Abs.	Abs.	2160
28			Abs.	Abs.	Abs.
29			Abs.	Abs.	Abs.
30			Abs.	Abs.	2252
31		Recovered 1200 feet of gas-cut salt water	Abs.	Abs.	2148
32			Abs.	Abs.	2263
33			Abs.	Abs.	2435
34	2664	No lithic log	Abs.	2604	N.I.
35			Abs.	2847	2875
36			Abs.	2965	3015
37		Potsdam 2972 (15-20 gals./hr.)	Abs.	2880	2967
38			Abs.	Abs.	2163
39	3274		Abs.	3137	N.R.
40	13500	Galway 11,933 (5 gals./hr.)	11405	11751	13065
41	13500	Little Falls 5555, Galway 5660-5690, 6085, 6183	5528	5623	6295
42	6000	Galway 5880	Abs.	5515	5960
43	4305		Abs.	4110	N.R.
44		Sample gaps	Abs.	3915	Abs.
45	3641		Abs.	3585	N.R.

Map No.	Well Name	Permit No.	County	Elevation (feet)	Rose Run (feet)	Thickness (feet)	Basal Sandstone (feet)	Thickness (feet)	Precambrian (feet)
46	Hammond	5116		587 G	N.I.	—	3662-3750+	88+	
47	Olson	5114	Wayne	487 G	Abs.	0	3615-3705	78	3705
48	Martin	6719		392 G	Abs.	0	3962-4050+	88+	
49	G. Reed	5095	Seneca	401 G	N.I.	—	N.R.	—	
50	Kesselring	443	Chemung	1081 D	Abs.	0	N.R.	—	
51	Shepard	3973	Tompkins	1295 D	Abs.	0	10250-10298	48	10278
52	Fee (Richardson)	4467		1051 D	9125-9175	50	N.R.	—	
53	Schaffer 2	4203	Seneca	542 D	4910-5000+	90+	5330-5420	90	5409
54	Alnutt	4715	Cayuga	515 D	N.I.	—	N.R.	—	
55	Parker	4999		589 D	Abs.	0	N.R.	—	
56	Ripley	5000		435 D	N.I.	—	N.R.	—	
57	Slayton 2	1003		476 G	N.I.	—	N.I.	—	3865
58	O'Neil	5011		404 K	N.I.	—	N.I.	—	3570
59	L. W. Smith	5031		441	Abs.	0	3310-3400+	90+	
60	Wasielewski	4624		447 G	Abs.	0	2948-3026	78	3026
61	Hall	5012	Oswego	318 D	Abs.	0	2461-2505	44	2505
62	Beckwith	1008		385 G	Abs.	0	2297-2317	20	2317
63	Heaphy	4209		465 D	Abs.	0	Abs.	0	2560
64	House	4208		504 D	Abs.	0	Abs.	0	2196
65	Kellogg	4357		745 D	Abs.	0	Abs.	0	1660
66	Campbell	4214	Delaware	1785 K	Abs.	0	10850-10965	115	10965
67	Lanzillotta	4379		1830 G	Abs.	0	Abs.	0	8920
68	Leslie	4455		1486 G	Abs.	0	7835-7878	43	7878
69	Lobdell	1160	Chenango	1373 D	Abs.	0	5476-5540	64	5548
70	Danisevich	4032	Madison	1506 G	Abs.	0	N.R.	—	
71	Branagan	3970		1549 D	Abs.	0	5635-5653	18	5661
72	Letts-Miller	1173		1255 D	Abs.	0	Abs.	0	4162
73	Keith	3928	Oneida	1319 G	Abs.	0	4309-4328	19	4316
74	Ainsworth	698		430 G	Abs.	0	2370-2403	33	2405
75	Burkhard	4547	Otsego	1252 G	Abs.	0	N.R.	—	
76	Lum	4055		1979 G	Abs.	0	5295-5355	60	5362
77	Skramko	3993	Herkimer	1515 G	Abs.	0	N.R.	—	
78	Puskeranko	4034		1590 G	Abs.	0	N.R.	—	
79	Fee (High Barney)	1001	Orange	600 G	Abs.	0	N.R.	—	
80	Gans	3904	Greene	1928 G	Abs.	0	N.R.	—	
81	Gould	4150	Lewis	1788 D	Abs.	0	Abs.	0	1766
82	Richards	5087	Broome	996 G	Abs.	0	N.R.	—	
83	Clough	4714	Cortland	1569 G	Abs.	0	N.R.	—	

Map No.	Total Depth (feet)	Formation and Depth to Connate Water (feet), amount reported, Water Analysis and Other Comments	Gamma Ray Tops on Little Falls	Galway	Potsdam
46	3750		Abs.	3565	3662
47		Potsdam recovered 75 feet of connate water	Abs.	Abs.	3615
48	4050		Abs.	3825	3962
49	4152	No lithic log	Abs.	3979	N.R.
50	11145	Galway 11145	10567	10915	N.R.
51		Galway 9514 and 9572 (510 gals./hr.)	9095	9388	10250
52	9390	Galway 9175 fillup to 8877	8720	9004	N.R.
53		Galway through Potsdam—All sandstone with large sample gaps in between	4820	4883	5340
54	4853	No lithic log	4444	4502	N.R.
55	4260		4168	4192	N.R.
56	3756	Large sample gaps	Abs.	3626	N.R.
57		Galway at 3713 rose to surface—Large sample gaps—Water Analysis—Yes	Abs.	3590	3760
58			Abs.	3376	N.I.
59	3402	Large sample gaps	Abs.	Abs.	3300
60			Abs.	Abs.	2948
61			Abs.	Abs.	2461
62			Abs.	Abs.	2297
63			Abs.	Abs.	Abs.
64			Abs.	Abs.	Abs.
65			Abs.	Abs.	Abs.
66			9180	9445	10850
67			7265	7505	8790
68			6755	7022	7823
69		Galway 5088 (300′ fillup), 5127 (1150′ fillup)—Water Analysis—Yes	4710	5000	5476
70	4889	Little Falls 4310, Galway 4650-62 (100 gals./hr.)	4273	4555	N.R.
71			4900	5210	5631
72		Little Falls 3540, Galway 4079-85 (fillup to 150′ from surface)	3535	3755	4155
73		Galway 4098 (30 gals./hr.)	3635	3887	4297
74			Abs.	2154	2372
75	5126	Galway 5040 (35 gals./hr.), 5093 (20 gals./hr.)	4690	4965	N.R.
76		Galway 5141 (fillup 400′/hr.), 5161 (20 bbls./hr.), Little Falls 4700-4875	4645	4925	5295
77	3581	Galway 3568 could not bail down, Little Falls 3360 (10 gals./hr.), 3466 (260 gals./hr.)	3258	3555	N.R.
78	2716	Galway 2644-72, Little Falls 2348 (fillup to 1250′), 2422-23	2260	2555	N.R.
79	6875	Galway 6862 (15 to 20 gals./min.)	5530	5800	N.R.
80	7185	Galway 6814 (fillup to 5500′)	6400	6610	N.R.
81			Abs.	Abs.	Abs.
82	9640		8815	9090	N.R.
83	8272		7765	8040	N.R.

Appendix B

NEW YORK STATE POLICY ON DEEP WELL INJECTION

Note: Because of the authority given the Department of Environmental Conservation in Article 17 of the Conservation Law, the following statement of Policy on Deep Well Injection is in effect.

Questions concerning the interpretation of "Statement of Policy" shall be addressed to the Director, Bureau of Industrial Programs.

New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233

Ogden Rei
Commissioner

DEEP WELL INJECTION

Statement of Policy

A. The injection of liquid wastes by deep wells is considered a last resort after all other methods have been evaluated; it is a method for gaining long-term storage rather than treatment. The applicant must demonstrate that this method (1) is the optimal approach, and (2) has the least effect to the total environment.

B. Fresh ground waters and potential mineral resources which may be subject to future development must be protected against any adverse effect by the disposal of wastes into the subsurface.

C. It is incumbent upon the applicant to obtain a competent geologist and a professional engineer for the necessary studies, design and preparation of reports and plans. This should include, but not be limited to the environmental, economical and technical implications.

D. Continuous injection at critical input (hydraulic parting) pressures is prohibited and will not be approved.

E. A permit must be issued prior to the construction and operation of any disposal of wastes through deep well injection.

F. Concurrence must be obtained from the Division of Oil and Gas of the Conservation Department and the office of the State Geologist of the Education Department.

May 29, 1969

Appendix C

COOPERATION WITH OTHER STATE, FEDERAL, AND CANADIAN AGENCIES

1. It is desirable to exchange data on subsurface disposal zones used for injection of liquid waste by bordering states and Canada.
2. It is desirable to have compatible subsurface liquid waste disposal regulations adopted by adjoining or bordering states and Canada.
3. The Federal agency concerned, Environmental Protection Agency, should be made aware of subsurface liquid waste disposal activities especially those close to state borders.
4. The State Department of Environmental Conservation has the regulatory authority and is the permit issuer.

Appendix D

STATE AGENCIES INVOLVED

New York State Department of Environmental Conservation:

Bureau of Industrial Programs
Division of Pure Waters
50 Wolf Road
Albany, New York 12201
(Telephone: 518-457-6716)

Bureau of Mineral Resources
Division of Quality Services
50 Wolf Road
Albany, New York 12201
(Telephone: 518-452-3967)

New York State Education Department:

The Geological Survey
Museum and Science Service
Education Building Annex
Albany, New York 12234
(Telephone: 518-474-5816)

NEW YORK STATE SCIENCE SERVICE
Hugo Jamnback, Director

THE UNIVERSITY OF THE STATE OF NEW YORK
THE STATE EDUCATION DEPARTMENT

GEOLOGICAL SURVEY
James F. Davis, State Geologist

Plate 1
ISOPACH MAP of the BASAL SANDSTONE

W. Lynn Kreidler

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Geological Survey, Map and Chart Series No. 26

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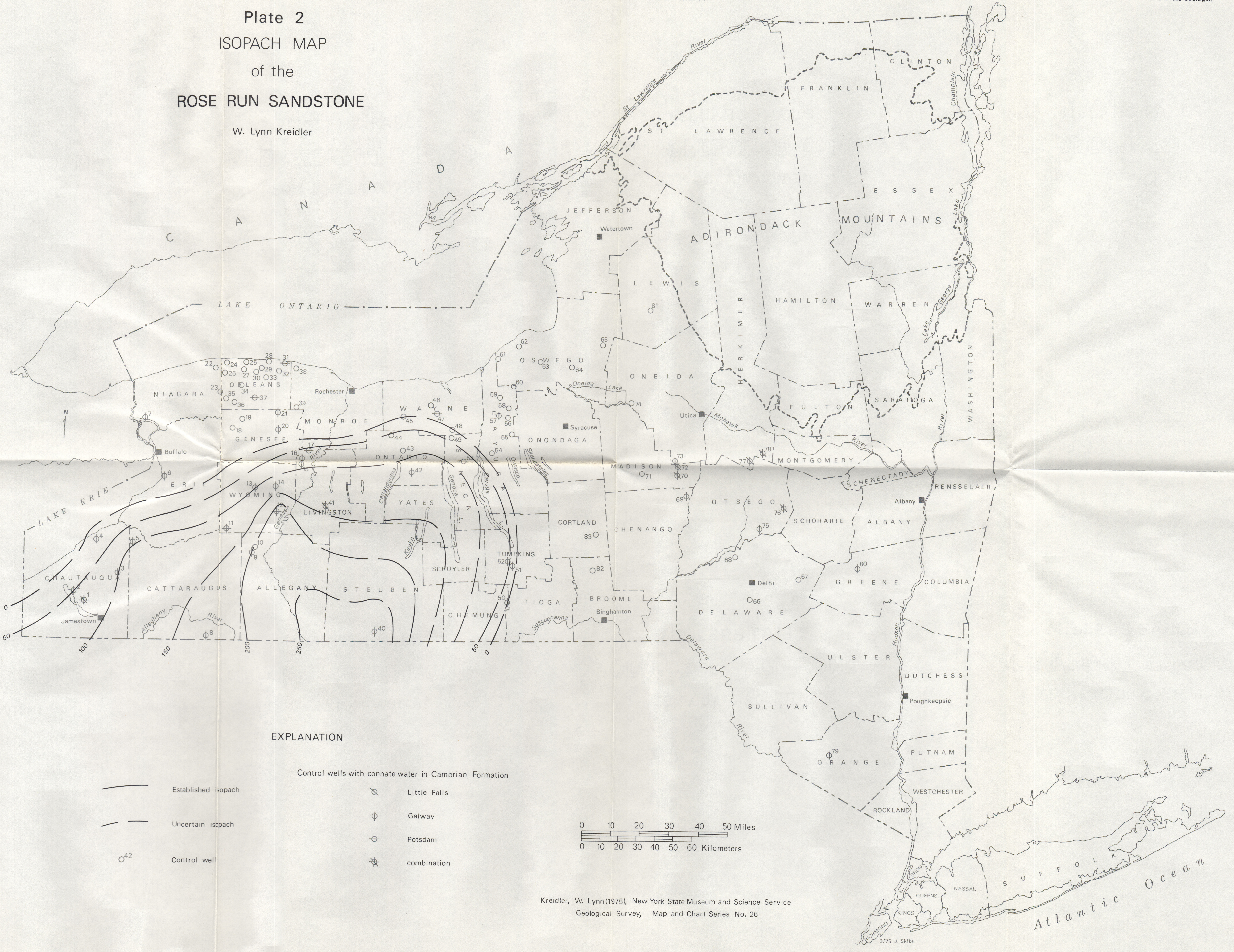
Hugo Jamnback, Director

THE UNIVERSITY OF THE STATE OF NEW YORK
THE STATE EDUCATION DEPARTMENT

GEOLOGICAL SURVEY
James F. Davis, State Geologist

Plate 2
ISOPACH MAP of the ROSE RUN SANDSTONE

W. Lynn Kreidler



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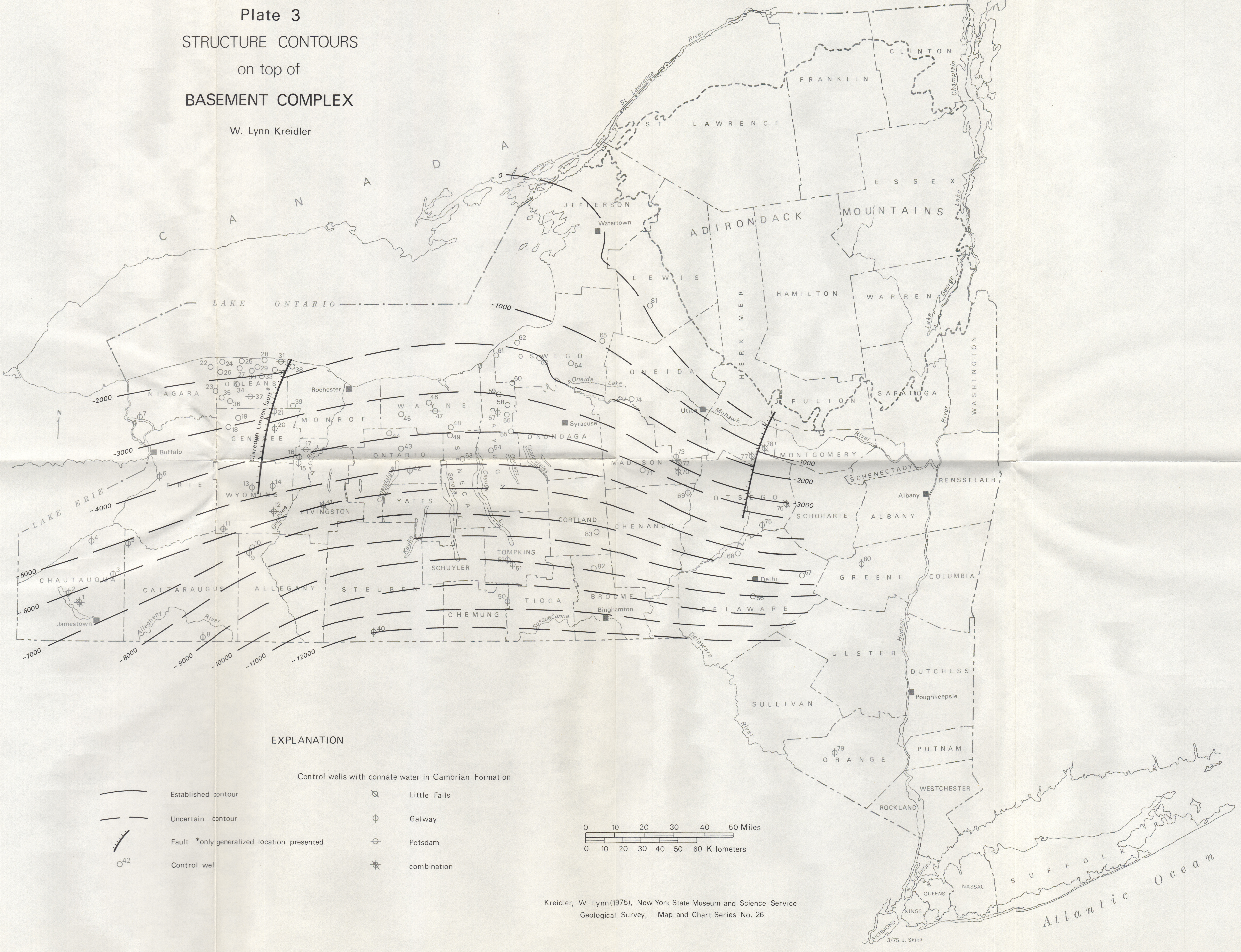
GEOLOGICAL SURVEY
James F. Davis, State Geologist

Plate 3
STRUCTURE CONTOURS on top of BASEMENT COMPLEX

W. Lynn Kreidler



EXPLANATION

Control wells with connate water in Cambrian Formation

(solid line)	Established contour	(symbol)	Little Falls
(dashed line)	Uncertain contour	(symbol)	Galway
(hachured line)	Fault *only generalized location presented	(symbol)	Potsdam
○42	Control well	(symbol)	combination

0 10 20 30 40 50 Miles
0 10 20 30 40 50 60 Kilometers

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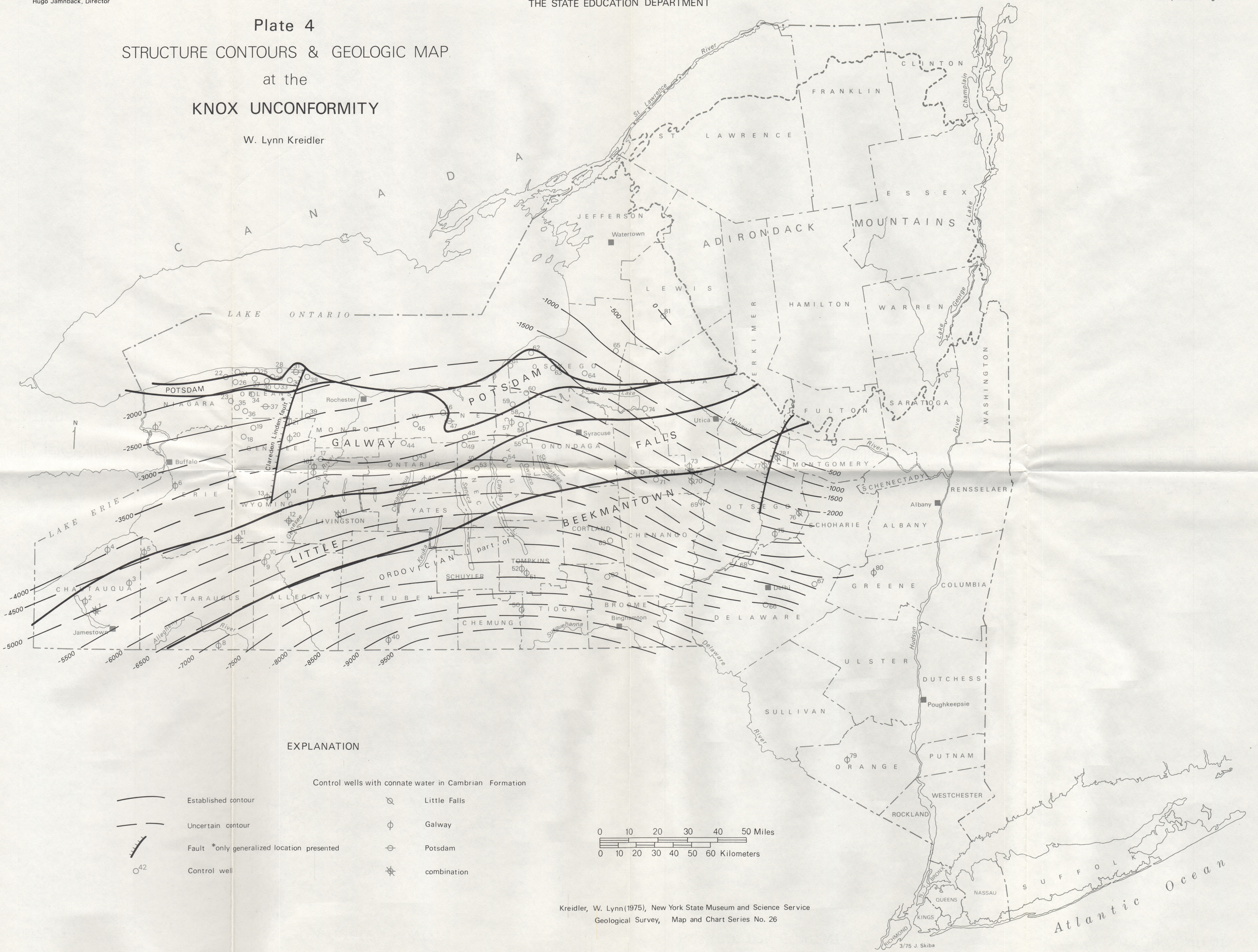
GEOLOGICAL SURVEY
James F. Davis, State Geologist

Plate 4
STRUCTURE CONTOURS & GEOLOGIC MAP at the KNOX UNCONFORMITY

W. Lynn Kreidler



EXPLANATION

Control wells with connate water in Cambrian Formation

- Established contour
- Uncertain contour
- Fault *only generalized location presented
- Control well
- Little Falls
- Galway
- Potsdam
- combination

0 10 20 30 40 50 Miles
0 10 20 30 40 50 60 Kilometers

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