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GEOLOGY AND HYDROGEOLOGIC MODELING IN THE SALINA BASIN, NEW YORK AND OHIO

J. H. Peck, D. S. Pierce and L. W. Picking
Stone & Webster Enginnering Corporation

Geology

An extensive regional-reconnaissance study of the Salina basin has been made to evaluate the New York and Ohio portions of the basin for repository siting. An initial screening of the region was made to identify areas which warranted field study. The specifications used for the first-cut screening are discussed by Brunton and others.[1] Areas which contain an aggregate thickness of salt of at least 61 m, are underlain by salt at depths between 915 m and 305 m, and occur within regions having a seismic risk less than 3 (Algermissen, 1969)[2], were considered favorable.

Geologic information obtained from the literature and from public and private sources of unpublished data made it possible to evaluate these areas further.

A second screening was made based on data concerning faulting, oil and gas resources, salt mining, and brine-well locations. The specifications used were developed to allow concentration of effort during subsequent field programs in the most favorable parts of the study areas.

The results of the geologic screening are shown in Figure 1 for New York and Figure 2 for Ohio. The areas shown are considered favorable, from a geologic standpoint, for field study.

Results of the geologic studies also indicate that the geologic structure in the New York study area is complex. Folding and faulting within the salt section may make characterization of the salt geometry difficult. Ohio is less complex structurally, but has thinner salt deposits. Seismicity analysis shows that both study areas have had little earthquake activity.

Geohydrological Modeling

Two-dimensional salt-transport modeling techniques are being developed for use in the Salina basin investigations. The modeling goals are threefold, namely:

(1) To determine the relative importance (sensitivity) of the Salina basin geohydrologic parameters. This will aid in designing the field investigations.

(2) To provide a descriptive tool, for expressing the regional basin geohydrology, which can be continuously modified and upgraded as field data are collected.

(3) To aid in evaluating the long-term stability of the salt at specific locations within the basin considered for repository siting.

The modeling program is based on the finite-element method and was developed by Dr. E. O. Frind of the University of Waterloo. The program is formulated in the vertical plane so that the effective driving forces, which are the hydraulic gradient acting on the boundaries and gravity acting on differences in fluid densities, can be properly represented. The program, as yet, has not been qualified for Category I use.

Sensitivity analyses performed so far have concentrated on three salt-transport cases common to the Salina basin. These are: (1) an aquifer directly overlying the salt, (2) an aquifer directly underlying the salt, and (3) an aquifer overlying the salt but separated from the salt by an aquitard (Figure 3). Results to date indicate that velocity (hydraulic gradient and permeability) and aquifer thickness are the important parameters for Cases (1) and (2), and velocity, aquifer thickness, aquitard permeability, and aquitard thickness are the important parameters for Case (3). Dispersivity plays a relatively minor role in all three cases.

Several regional profile models have been created through the New York study area, based on scanty

data taken from the published literature and supplemented by well-log data from oil and gas explorations (Figures 4 and 5). Plots indicating salt concentrations, fluid pressures, and direction and velocity of fluid flow have been obtained from these models and appear realistic (Figures 6-8).

Qualification of the modeling techniques, the program, and the underlying assumptions is planned. This will be based on successful simulation of laboratory tank tests and controlled field dissolution experiments and reasonable duplication of well-known cases of salt dissolution and transport.

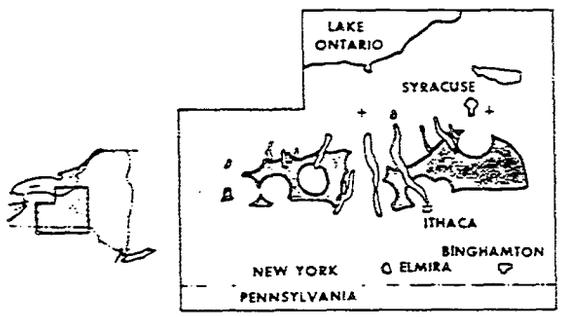

FIGURE 1. AREAS FAVORABLE FOR GEOLOGIC FIELD STUDY IN NEW YORK

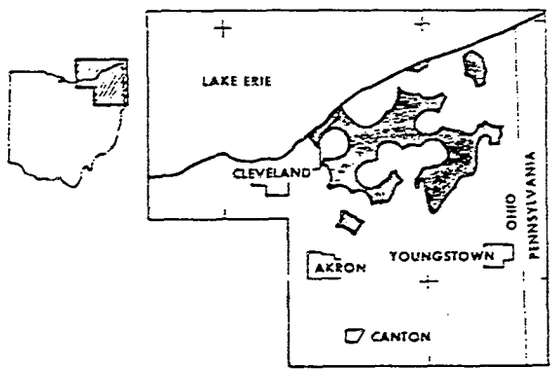

FIGURE 2. AREAS FAVORABLE FOR GEOLOGIC FIELD STUDY IN OHIO

REFERENCES

(1) Brunton, G. D., Laughon, R. B., and McClain, W. C. Screening Specifications for Bedded Salt, Salina Basin, New York and Ohio: Report No. Y/OWI/TM-54, Office of Waste Isolation, Union Carbide Corp. - Nuclear Div., 11 p., 1978.

(2) Algermissen, S. T., Seismic Risk Studies in the United States: U.S. Dept. of Commerce Reprint, 10 p, 8 figs., 1969.

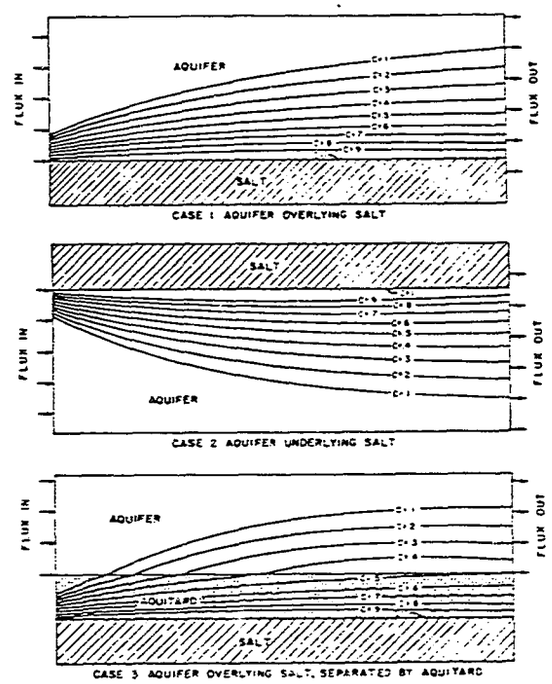

FIGURE 3. SALT DISSOLUTION, SALINA BASIN, NEW YORK

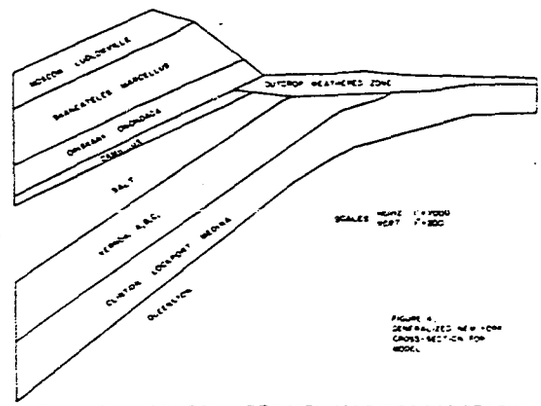

FIGURE 4. GENERALIZED NEW YORK CROSS SECTION FOR MODEL

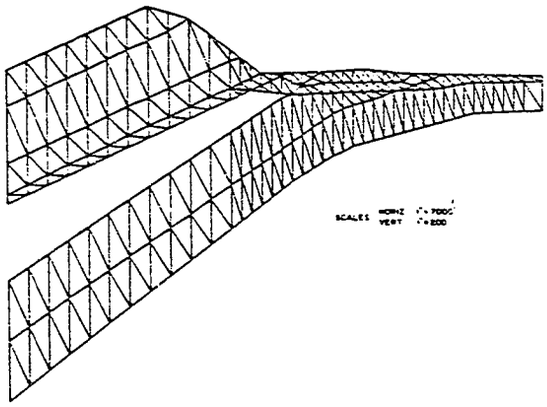

FIGURE 5. FINITE-ELEMENT MESH OF SECTION

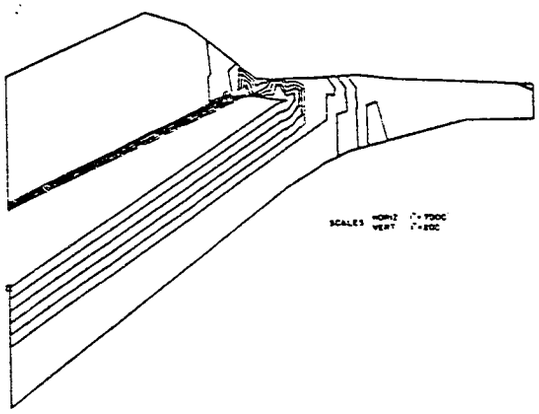

FIGURE 7. CONTOUR OF CONCENTRATIONS

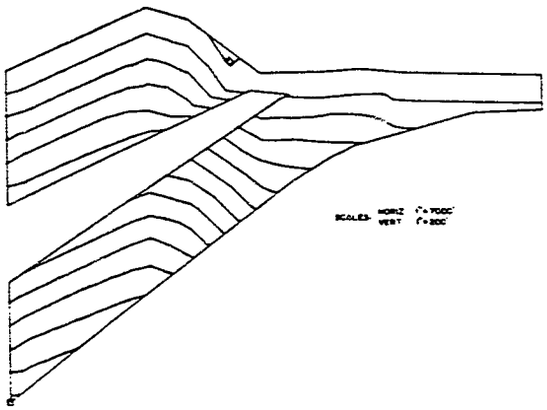

FIGURE 6. CONTOUR OF PRESSURES

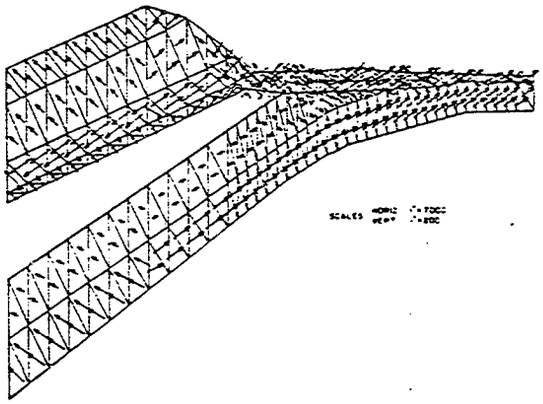

FIGURE 8. FLUX DIRECTION AND VELOCITY

SUMMARY OF STUDIES OF DEEP FORMATIONAL WATER ASSOCIATED WITH THE SALINA GROUP, OHIO AND NEW YORK

S. .E. Norris
U.S. Geological Survey (Columbus, Ohio)

Studies of the deep formational waters associated with the Salina Group in Ohio and New York were part of a general investigation of the Silurian salt deposits in the Appalachian and Michigan geological basins to determine their usefulness as repositories for radioactive wastes. The studies were related specifically to the search for potential repository sites in northeastern Ohio and western New York. They were funded by the Department of Energy (DOE).

The first phase of the work, which was started late in 1977, consisted of a review of the literature for information on the occurrence, composition, and origin of natural brines. The literature review was completed in late 1978. A manuscript report, now being reviewed, presents information on the occurrence of brines in basin environments, their chemical properties with emphasis on Ohio brines, and a review of hypotheses relative to the origin of brines. The review is arranged chronologically, ending with the more modern concepts based chiefly on isotope studies. The bibliography developed from the literature search is listed at the end of this summary statement.

Most early hypotheses on brine origin stated that brines originated as connate or "fossil" sea water that was retained in the pore spaces of the rocks after the seas retreated and the rocks were elevated. The chemical composition of the brine was changed and its salinity was increased to up to 10 times that of ocean water. These changes were believed to have resulted from chemical reactions between the water and the sediments.

More recent work, based on studies of stable isotopes of hydrogen and oxygen, has established that some of the water molecules in brines originated as meteoric water. This has led some investigators to believe that the brines are principally meteoric in origin and that the connate waters have been largely flushed from the sediments in the course of geologic time. Others believe that the brines represent principally the original waters of deposition, modified by mixing with meteoric waters. Advocates of both views agree that brines owe their high salinity to an "ion sieving" mechanism, or selective concentration of ions by passage of water through shales. The shales have acted as semipermeable membranes that retained the salts while allowing some of the water molecules and selected solutes to pass.

The second phase of the work, which was discontinued at the request of DOE, was to have been a field investigation of new commercial oil and gas wells, which were to be tested as they were being drilled. Plans had been made to measure heads, collect brine samples for analysis, and to determine the direction of fluid movement in the wells at various stages in the drilling. Preliminary arrangements had been made with drillers to obtain these data. Geophysical equipment, consisting of a logging truck and accessory components, had been assembled in the Ohio district office before the project was terminated. This phase had as its primary objective the collection of data upon which to base the choice of test drilling sites to determine the flow characteristics of deep-seated brines in areas being considered as possible repository sites. One such area, in northeastern Ohio, is the subject of a report by S. E. Norris (1979) entitled "The Silurian Salt Deposits in Eastern Lake, Northwestern Ashtabula, and Northeastern Geauga Counties, Ohio" (U.S. Geological Survey Open-File Rept. 79-269). The report gives the depths and thicknesses of five salt beds in a 250-square-mile area in northeastern Ohio in which further investigation, including test drilling, had been considered. Another report stemming from the studies is based on brine analyses collected in western New York by oil-and-gas drilling firms and state agencies. The report, now being reviewed, is entitled "Chemical Composition of Deep Groundwater (Brine) Within the Appalachian Basin, New York."

The brine analyses collected in New York are noteworthy in that the brines do not appear to increase in salinity with depth, as they do elsewhere in the Appalachian basin. This could indicate relatively rapid circulation of the deep-seated waters in western New York.

Important questions in brine genesis involve the forces required to move brines through the semipermeable shale membranes. One concept is that brines circulate through the rocks as components of

regional flow systems, moving from potentiometrically high to potentiometrically low areas. Questions remain, however, as to the effects on such flow systems of the widespread deposits of bedded salt and anhydrite in the Michigan and Appalchian basins. Another concept concerning brine mobility involves osmotic forces which exist because of the presence of different salt concentrations on opposite sides of the shale membranes.

There are no plans to continue these studies beyond FY 1980.

BIBLIOGRAPHY

(1) Billings, G. K., Hitchon, Brian, and Shaw, D. R., 1969, Geochemistry and Origin of Formation Waters in the Western Canada Sedimentary Basin, 2. alkali metals: Chemical Geology, 4, p. 211-223.

(2) Bredehoeft, J. D., Blyth, C. R., White, W. A., and Maxey, G. B., 1963, Possible Mechanism for Concentration of Brines in Subsurface Formations: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 2, p. 257-269, 8 figs.

(3) Chave, Keith E., 1960, Evidence on History of Sea Water from Chemistry of Deeper Subsurface Waters of Ancient Basins: Am. Assoc. Petroleum Geologists Bull., v. 44, no. 3, p. 357-370, 8 figs., 7 tbls.

(4) Clayton, R. N., Friedman, I., Graf, D. L., Mayeda, T. K., Meents, W. F., and Shimp, N. F., 1966, The Origin of Saline Formation Waters: Jour. Geophysical Research, v., 71, no. 16, p. 3869-3882.

(5) Clifford, M. J., 1973, Silurian Rock Salt in Ohio; Ohio Dept. Nat. Resources, Div. Geol. Survey Rept. Inv. RI-90, 42 p., 21 figs., 4 pls., 5 tbls.

—1975, Subsurface Liquid-Waste Injection in Ohio: Ohio Dept. Nat. Resources, Div. Geol. Survey Inf. Circ. 43, 27 p.

(6) Craig, Harmon, 1961a, Isotopic Variations in Meteoric Waters: Science, v. 133, p. 1702-1703.

—1961b, Standard for Reporting Concentrations of Deuterium and Oxygen-18 in Natural Waters: Science, v. 133, p. 1833-1834.

—1963, The Isotopic Geochemistry of Water and Carbon in Geothermal Areas, In Proceedings of the Spolette Conference on Nuclear Geology and Geothermal areas, edited by E. Tongiorgi, p. 17, Consiglio Nazionale delle Recerche, Rome.

(7) Dansgaard, Willi, 1954, The O^{18}-Abundance in Fresh Water: Geochimica et Cosmochimica Acta, v. 6, p. 241-260.

(8) Degens, E T., Hunt, J. M., Reuter, J. H., and Reed, W. E., 1964, Data on the Distribution of Amino Acids and Oxygen Isotopes in Petroleum Brine Waters of Various Geologic Ages: Sedimentology, v. 3, p. 199-225.

(9) Desitter, L. U., 1947, Diagenesis of Oil-Field Brines: Am. Assoc. Petroleum Geologists Bull., v. 31, no. 11, p. 2030-2040, 4 figs.

(10) Dickey, Parke A., 1966, Patterns of Chemical Composition in Deep Subsurface Waters: Am. Assoc. Petroleum Geologists Bull., v. 50, p. 2472-2478.

—1969, Increasing Concentration of Subsurface Brines With Depth: Chemcial Geology, 4, p. 361-370.

(11) Engler, C., and Hofer, H., 1909, Das Erdol, Band 2: U. S. Geol. Survey Prof. Paper 117, p. 27.

(12) Epstein, S., and Mayeda, T., 1953, Variation of O^{18} Content of Waters from Natural Sources: Geochimica et Cosmochimica Acta, v. 4, p. 213-224.

(13) Ginter, Roy L., 1934, Sulphate Reduction in Deep Subsurface Waters: Am. Assoc. Petroleum Geologists Memoir 4, p. 907-925.

(14) Graf, D. L., Friedman, Irving, Meets, W. F., 1965, The Origin of Saline Formation Waters, II: Isotopic Fractionation by Shale Micropore Systems: Illinois Dept. Registration and Education, Geol. Survey Circ. 393, 32 p., 8 figs., 2 tbls.

(15) Graf, D. L., Meents, W. F., Friedman, Irving, and Shimp, N. F., 1966, The Origin of Saline Formation Waters, III: Calcium Chloride Waters: Illinois Dept. Registration and Education, Geol. Survey Circ. 397, 60 p., 14 figs., 6 tbls.

(16) Hanshaw, B. B., 1972, Natural-Membrane Phenomena and Subsurface Waste Emplacement; with Discussion by Wilson, E. N., Rold, J. W., Colburn, W. A., and Hanshaw, B. B.: Am. Assoc. Petroleum Geologist, Memoir 18, p. 308-315, 6 figs.

(16) Hanshaw, B. B., and Hill, G. A., 1969, Geochemistry and Hydrodynamics of the Paradox Basin Region, Utah, Colorado and New Mexico: Chemical Geology, 4, p. 263-294.

(17) Heck, E. T., 1940, Barium and Appalachian Salt Brines: Am. Assoc. Petroleum Geologist Bull., v. 24, no. 3, p. 486-493.

(18) Heck, E. T., Hare, C. E., and Hoskins, H. A., 1964, Appalachian Connate Water: West Virginia Geol. and Economic Survey Bull. 28, 42 p.

(19) Hem, John D., 1970, Study and Interpretation of the Chemical Characteristics of Natural Water: U. S. Geol. Survey Water-Supply Paper 1473, 358 p.

(20) Hitchon, Brian, and Friedman, Irving, 1969, Geochemistry and Origin of Formation Waters in the Western Canada Sedimentary Basin — I. Stable Isotopes of Hydrogen and Oxygen: Geochimica et Cosmochimica Acta, v. 33, p. 1321-1349.

(21) Hitchon, Brian, Billings, Gale K., and Klovan, J. E., 1971, Geochemistry and Origin of Formation Waters in the Western Canada Sedimentary Basin — III. Factors Controlling Chemical Composition: Geochimica et Cosmochimica Acta, v. 35, p. 567-598.

(22) Hoskins, Homer A., 1949, Interpretations of Salt Water Analyses: Appalachian Geol. Society Bull. v. 1, 10 p, 4 figs., 2 tbls.

(23) Hunt, T. S., 1875, Chemcial and Geological Essays: Boston, J. R. Osgood and Co., p. 117.

(24) Janssens, A., 1975, Catalog of Oil and Gas Wells in "Newburg" (Silurian) of Ohio: Ohio Dept. Nat. Resources, Div. Geol. Survey Infor. Circ. 42, 19 p.

(25) Lamborn, Raymond E., 1952, Additional Analyses of Brines from Ohio: Ohio Dept. Nat. Resources, Div. Geol. Survey Rept. Investigation 11, 56 p., 1 ill.

(26) McCann, T. P., Privrasky, N. C., Stead, F. L., and Wilson, J. E., 1968, Possibilities for Disposal of Industrial Wastes in Subsurface Rocks on North Flank of Appalachian Basin in New York in Subsurface Disposal in Geologic Basins — a Study of Reservoir Strata, edited by John E. Galley: Am. Assoc. Petroleum Geologists.

(27) Mills, R. Van A., and Wells, Roger C., 1919, The Evaporation and Concentration of Waters Associated with Petroleum and Natural Gas: U. S. Geol. Survey Bull. 693, 104 p., 4 pls., and 5 figs.

(28) Norris, Stanley E., 1956, Sand at the Top of the Niagara Group as a Source of Water in West-Central Ohio: Ohio Jour. Science, v. 56, no. 2, p. 93-100, illus.

(29) Norris, Stanley E., and Fidler, Richard E., 1973, Availability of Water from Limestone and Dolomite Aquifers in Southwest Ohio, and the Relation of Water Quality to the Regional Flow System: U.S. Geol. Survey Water Resources Invest. 17-73, 42 p.

(30) Orton, Edward, 1899, The Rock Waters of Ohio: U.S. Geol. Survey Nineteeth Annual Report, 1897-98, Part IV-Hydrography, p. 633-717.

(31) Poth, Charles W., 1962: The Occurrence of Brine in Western Pennsylvania: Pennsylvania Geological Survey Bull. M 47, 53 p., 11 figs., 7 tbls.

(32) Richardson, G. B., 1917a, Note on Appalachian Oil-Field Brines: Econ. Geology, v. 12, p. 37-41.

—1917b, Note on the Diffusion of Sodium Chloride in Appalachian Oil-Field Waters: Washington Acad. Science Jour., v. 7, p. 73-75.

(33) Rightmire, C. T., Young, H. W., and Whitehead, R. L., 1976, Geothermal Investigations in Idaho, Part 4, Isotopic and Geochemical Analyses of Water from the Bruneau-Grand View and Weiser Areas, Southwest Idaho: Idaho Dept. Water Resources Water Inform. Bull. 30, 28 p., 11 figs., 6 tbls.

(34) Rittenhouse, Gordon, 1964, Discussion, Possible Mechanism for Concentration of Brines in Subsurface Formations: Am. Assoc. Petroleum Geologist Bull. v. 48, no. 2, p. 234-236. 1 fig., 1 tbl. with reply by Bredehoeft, J. D., White, W. A., and Maxey, G. B., p. 236-238.

(35) Rittenhouse, Gordon, Fulton, Robert B., III, Grabowski, Robert J., and Bernard, Joseph L., 1969, Minor Elements in Oil-Field Waters: Chemical Geology, 4, p. 189-209.

(36) Rogers, G. Sherburne, 1919, The Sunset-Midway Oil Field California: U.S. Geol. Survey Prof. Paper 117, 103 p.

(37) Russel, William L., 1933, Subsurface Concentration of Chloride Brines: Am. Assoc. Petroleum Geologists Bull., v. 17, no. 10, p. 1213-1228.

(38) Stout, Wilber, Lamborn, R. E., Schaaf, Downs, 1932, Brines of Ohio: Ohio Geol. Survey Fourth Series, Bull. 37, 123 p., 2 figs.

(39) Torrey, Paul D., 1934, Composition of Oil-Field Waters of the Appalachian Region in Wrather, W. E., and Lahee, F. H., Problems of Petroleum Geology (Sidney Powers memorial volume): Am. Assoc. Petroleum Geologist p. 841-853.

(40) Washburne, Chester W., 1914, Oil-Field Brines: Am. Inst. Mining Metal. Petroleum Engineers Trans., v. 65, p. 269-294.

(41) Washburne, C. W., and Lahee, F. H., 1934, Oil-Field Waters in Wrather, W. E., and Lahee, F. H., Problems of Petroleum Geology (Sidney Powers memorial volume): Am. Assoc. Petroleum Geologist, p. 833-840.

(42) White, Donald E., 1957, Magmatic, Connate, and Metamorphic Waters: Geol. Society of America Bull., v. 68, p. 1659-1682, 1 fig.

—1965, Saline Waters of Sedimentary Rocks: Am. Assoc. Petroleum Geol. Memoir 4, Fluids in Subsurface Environments, Young, Addison and Galley, J. E., eds., p. 342-366.

(43) White, D. E., Hem, H. D., and Waring, G. A., 1963, Chemical Composition of Subsurface Waters: U. S. Geol. Survey Prof. Paper 440F, p. F1-F67.

(44) Wrather, W. E., and Lahee, F. H., 1934, Problems of Petroleum Geology (Sidney Powers memorial volume): Am. Assoc. Petroleum Geologist, 1073 p.

(45) Young, Allen and Low, Phillip F., 1965, Osmosis in Argillaceous Rocks: Am. Assoc. Petroleum Geologist Bull., v. 49, no. 7, p. 1004-1008, 2 figs.

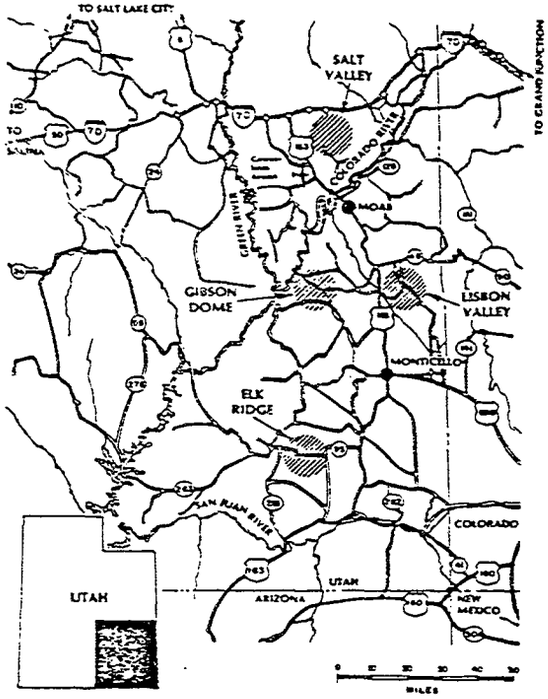

FIGURE 3. AREAS OF INTEREST IN THE PARADOX BASIN SALT DEPOSIT

ENVIRONMENTAL SURVEYS OF THE PERMIAN AND SALINA BASINS

J. J. DiNunno
NUS Corporation

D. A. Waite and W. H. McIntosh
Office of Nuclear Waste Isolation

NUS Corporation, under contract with ONWI, is serving as one of the Regulatory Program Managers in support of the NWTS/ONWI site qualification and licensing program.The purpose of the work undertaken by NUS is to conduct environmentally related studies and prepare environmental/safety-related reports as required for review and licensing of an underground waste repository. The objectives of these studies are to ensure that the construction and operation of the waste repositories will be in full compliance with the requirements of the National Environmental Policy Act (NEPA) of 1969, the Code of Federal Regulations (CFR), and all other applicable federal, state, and local guidelines and regulations.

The basic studies to be performed include:

- TASK A: Regional characterization of the Permian rock-salt formation and the Salina salt formation*
- TASK B: Area studies within the Permian and Salina basins
- TASK C: Location studies within the Permian and Salina basins
- TASK D: Preparation of a complete Preliminary Draft Environmental Impact Statement (PDEIS) for a specific site

- TASK E: Preparation of a complete Environmental Report (ER) and Preliminary Safety Analysis Report (PSAR) for a specific site
- TASKS F AND G: Licensing support as required. including expert testimony related to the PDEIS, ER, and PSAR
- TASK H: Contribute to preparation of a Preliminary Information Report, using a reference repository site and and reference repository design.

*Presently Inactive.

The environmental studies under the RPM assignment are being focused by geologic investigations for potentially suitable geohydrological settings for repository locations. These geologic investigations are being performed separately from the RPM effort.

Regional Studies

Formation-wide, reconnaissance-level environmental characterization studies have been completed for both the Permian and Salina basins. The Permian and Salina basins are regions of bedded salt. The outlines of these regions are shown by Figures 1 and 2. Results of these efforts have been published as ONWI-27, "Environmental Characterization of Bedded Salt Formations and Overlying Areas of the Permian Basin", May, 1979, and ONWI-16, (Draft) "Environmental Characterization of Bedded Salt Formation and Overlying Areas of the Salina Basin", March, 1979.

In these characterization reports, the nature and use of the resources and overlying land areas of the bedded-salt regions are described in terms of environmental media (the geosphere, hydrosphere, and atmosphere) and natural background radiation. Also included is coverage that pertains to human (socio-economic and land use) activities and natural (ecological) settings. The following represents a selection of interesting environmental observations extracted from the report summaries:

(1) Permian Basin

- The region encompasses approximately 189,000 square miles.
- The Permian region experienced a complex tectonic history during the Pennsylvanian period some 310 to 280 million years ago. Structural readjustments since that time have had little effect on the post-Permian rock units, including the salt sequences. The entire Permian region is seismically stable (seismic Zone 1).
- The Permian region has long been one of the major oil-and gas-producing regions of the United States.
- Groundwater represents a major resource in the region. Greater than 60 percent of the water withdrawn comes from groundwater. The largest single use of water in the region is for agriculture, which accounts for approximately 84 percent of the total consumption.
- Glaciers did not extend to the Permian region.
- Data indicate the national ambient air quality secondary standards for particulates are being exceeded throughout the western portions of the region and in some eastern areas.
- The Permian region is relatively sparsely populated. Only three urban areas in the region support a population of more than 100,000 inhabitants.
- Total earnings in 1970 were approximately 11 billion dollars. Agriculture, forestry, and fisheries accounted for approximately 14 percent; mining and extractive industries, 5 percent; retail, wholesale trade, government, and institutions accounted for 68 percent.
- The major land use is agricultural with 98 percent of the area classified as range or pasture (58 percent) and cropland (40 percent).
- A large portion of the region is semiarid with intermittent streams as the only aquatic habitat.

(2) Salina Basin

- The region encompasses approximately 80,000 square miles.
- Salt beds of the Salina basin were formed during the Paleozoic Era (400 million years ago).
- Major geologic structures of the region are extremely old; there have been no major movements in the earth's crust for approximately 180 million years.
- The region is one of low seismicity. Such earthquakes as have occurred in the Eastern region are attributed to readjustment of the earth's crust after the most recent ice age.

- Oil and gas fields have been developed in many parts of the region. Major bituminous coal fields occur throughout several of the states in the region.
- The region encompasses major hydrologic resources, both surface and groundwater. Surface water uses predominate due to a rainfall that ranges from 28 to 45 inches annually.
- Wind and precipitation patterns indicate low erosion potential in the region.
- Fundamental changes in climate have occurred over the last million years. During this period there have been four ice ages during which glaciers covered much of the region. The most recent ice age ended about 10,000 years ago.
- Many areas within the region are highly urbanized.
- Major land classifications of the region are forest land (44 percent), cropland (31 percent), pastureland (6 percent), and other rural land (6 percent).
- Total earnings in the region for 1970 are reported as 66 billion dollars. Manufacturing accounted for 41 percent of this amount. Retail and wholesale trade and government, institutional, and other services account for 56 percent.
- The Great Lakes and other regional surfacewater resources represent significant habitats for fish and other aquatic life forms.

Area Studies

Regional reconnaissance-level geological and environmental studies have been completed in both the Permian and Salina basins. Areas having features of particular interest were identified for further, more detailed studies. Area environmental-characterization studies in the Palo Duro and Dalhart subbasins portions of the Permian basin were initiated in August, 1979. The following provides a brief scope of the Environmental Study Program to be conducted in these subbasins.

The desired information will be obtained from the existing literature and by consultation with specialists/experts in the local areas. Information of interest includes.:

(1) A description of the physical characteristics of the hydrosphere, including surface water and river basins

(2) A general characterization of the climate in the study area, including temperature range, precipitation, general air quality, and the occurrence of various weather events such as thunderstorms and hurricanes

(3) Demographic, socioeconomic, and land-use information to provide a characterization of the areas in terms of population densities, urban place locations, major transportation routes, and land-use patterns

(4) Terrestrial and aquatic ecosystems data, including rare and endangered species, unique habitats, major agricul tural crops, and recreation areas.

Area environmental-characterization studies in the Salina basin have been delayed, pending resolution of federal/state questions on the site-search program.

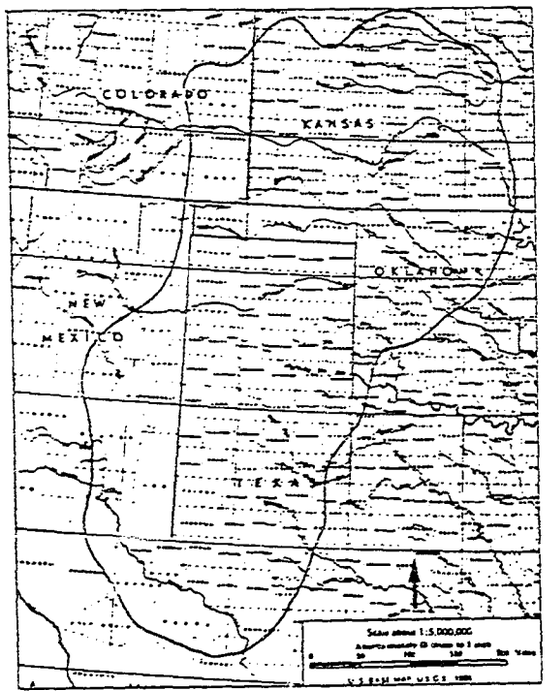

FIGURE 1. THE PERMIAN BEDDED-SALT REGION

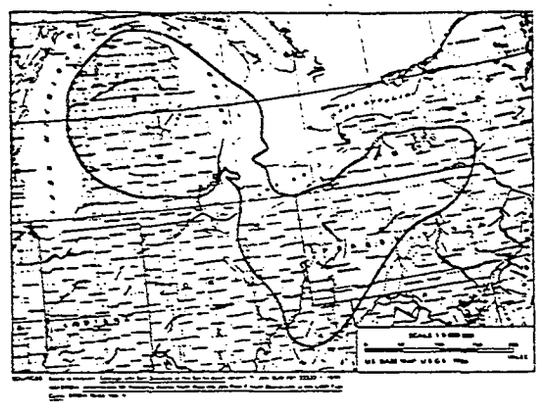

FIGURE 2. THE SALINA BEDDED-SALT REGION