1817 Reference

11/1/74

ENTERED

Bulletin of the
Association of Engineering Geologists
Vol. XI, No. 1, 1974

HARLEY BARNES

Geologic and Hydrologic Background for Selecting Site of Pilot-plant Repository for Radioactive Waste

Abstract

The U.S. Geological Survey recently completed a series of studies designed to help the Advanced Research Projects Agency and the U.S. Atomic Energy Commission evaluate selected rock types and areas in the United States as potential sites for underground emplacement of noxious or radioactive wastes. The rock types selected were salt and impermeable argillaceous rocks. The areas investigated included the Permian salt basin (especially that part in southeastern New Mexico), the Paradox basin in Utah and Colorado, the Supai salt basin and Luke salt body in Arizona, and the northern Gulf Coast salt-dome province. Of these rock types and areas, the bedded salt deposits of southeastern New Mexico and the Paradox basin seem to be the most promising sites for underground emplacement of noxious or radioactive wastes.

Introduction

The studies summarized here were undertaken by the USGS (U.S. Geological Survey) in response to separate but similar requests from two governmental agencies. In April 1971 the Advanced Research Projects Agency of the U.S. Department of Defense, anticipating the difficulties the Department of Defense and its contractors might eventually face in finding safe underground sites for disposal of nonradioactive but chemically noxious wastes, contracted with the USGS to study salt deposits and certain other impermeable rocks in the conterminous United States with the purpose of evaluating the geologic and hydrologic suitability of those rocks for underground emplacement of noxious wastes. In March 1972, the AEC

Harley Barnes is with U.S. Geological Survey, Federal Center, Denver, Colorado.

9174

(U.S. Atomic Energy Commission) contracted with the USGS to help in the search for the most promising locations for a pilot-plant radioactive-waste repository. The USGS was to summarize the available geologic and hydrologic knowledge of selected areas and rock types, particularly salt, in regard to their suitability for the underground emplacement of radioactive wastes. Because the geologic and hydrologic factors involved in selecting sites for storage or disposal of wastes in subsurface salt deposits are much the same whether the wastes are highly radioactive or nonradioactive but highly toxic, the USGS was able to consolidate its investigations for the two agencies so that the investigations were more efficient and more comprehensive.

The urgent need for finding a safe method for managing radioactive waste has been so well established by the many recent articles on the subject that further documentation seems unnecessary. Some additional explanation, however, may help in specifying the type of radioactive waste for which the AEC is planning a pilot-plant repository.

A distinction must be made between the high-level radioactive wastes generated by the AEC and those generated by commercial reprocessing of fuel elements from nuclear reactor power plants. Over the last 30 years, AEC production, weapons, and reactor development programs have generated: (1) about 80,000,000 gallons [300,000 kiloliters] of neutralized aqueous high-level waste in the form of liquid, slurry, or wet salt cake now being stored in the AEC's Savannah River plant in South Carolina and the Hanford plant in the State of Washington, and (2) about 38,000 cubic feet [1,000 cubic meters] of calcined material stored in steel bins inside concrete vaults at the National Reactor Testing Station in Idaho.[1] This engineered storage is considered an interim phase during which time techniques for further treatment and permanent storage can be more fully investigated. By contrast, the high level waste generated by commercial reprocessing of fuel elements from nuclear reactor power plants will come to the AEC's pilot-plant repository in solid form within sealed canisters after having been stored several years at the reprocessing site.

[1] J. H. Rubin, speech at American Industrial Forum/American Nuclear Society International Conference, Washington, D.C., November 1972.

The search for a suitable repository site at first was focused on the extensive bedded salt deposits of central Kansas. Questions raised as to the long-term safety of that area, however, resulted in a search for an alternative site in bedded salt and a reassessment of the suitability of other geologic structures and rocks. As its contribution to this search and reassessment the USGS prepared summaries of available geologic and hydrologic information on the following topics and areas (fig. 1):

1. The Permian salt basin of Kansas, Oklahoma, Texas, and New Mexico.
2. That part of the Permian salt basin known as the Carlsbad potash area in southeastern New Mexico.
3. The Supai salt basin and Luke salt body in Arizona.
4. The Paradox basin in Utah and Colorado.
5. Salt domes of the Gulf Coast.
6. Impermeable argillaceous rocks—shales, mudstones, and claystones—in the conterminous United States.

The summaries were compiled from both published and unpublished data, from the personal knowledge of USGS geologists and hydrologists experienced in the specific areas and topics under study, and from fieldwork done specifically for this assignment. All six reports have been released in open file and are cited individually in the following discussion.

PERMIAN SALT BASIN

Bachman and Johnson (1973) reviewed the tectonic history of the Permian salt basin of Kansas, Oklahoma, Texas, and New Mexico. They outlined the present structure of the basin, and the extent and thickness of salt within it. They also pointed out evidence of widespread subsurface dissolution of salt in the Permian salt basin, but concluded that the subsurface dissolution fronts of the thick-bedded salt deposits have retreated at a very slow average rate during the 230 million years since deposition of the salt.

The preservation of bedded salt from subsurface dissolution depends chiefly on the isolation of the salt from moving ground water

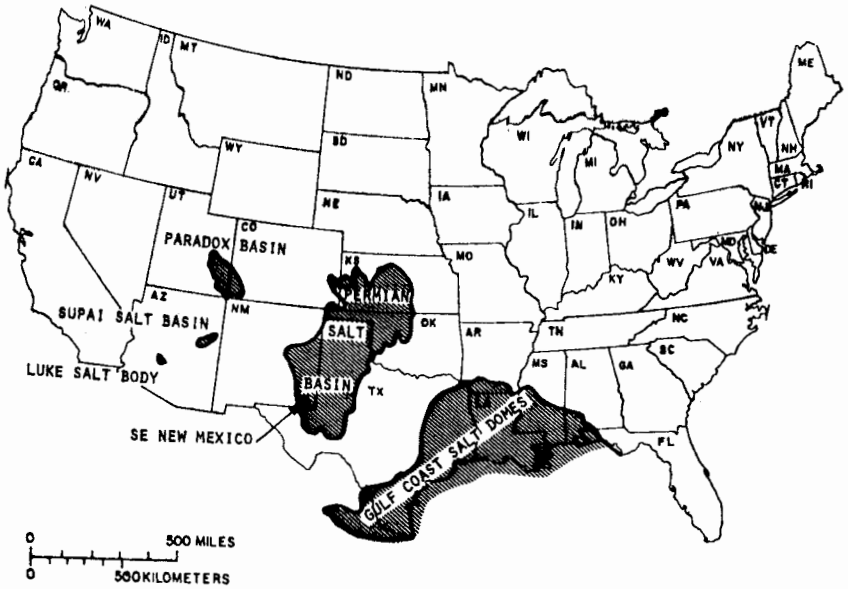

FIGURE 1. Geographic index of waste-emplacement studies in salt in the United States by U.S. Geological Survey, 1972–1973

that is not completely saturated with salt. Karst topography is a major criterion for recognizing areas where subsurface dissolution has been active in the past; therefore, the age of the karst development is needed to provide the most accurate estimate of the dissolution rate. The Ogallala Formation, generally of Pliocene age in the study area, is probably the most widespread deposit in the Permian salt basin that can be used as a point of reference for dating the development of recent topography. It is estimated that salt has been dissolved laterally in the vicinity of Carlsbad, New Mexico, at an average rate that did not exceed 6–8 miles per million years.

Areas in the Permian salt basin where the least dissolution of salt is apparent are those areas overlain by the Ogallala Formation. Unfortunately, over most of the Permian salt basin, thick salt deposits underlying the Ogallala may be at too great depth to be considered for waste disposal. Those parts of the Permian salt basin where thick salt deposits are reasonably near the surface and have been least disturbed by dissolution offer the greatest potential for safe emplacement of radioactive wastes.

In southeastern New Mexico a north-south belt of dissolution is present east of the Pecos valley. Salt deposits east of this belt should be considered for waste disposal. Care must be taken in this area, however, that a site is not selected so far to the east that it includes the San Simon Swale where some dissolution has taken place. In southeastern New Mexico the area where least dissolution is apparent is west of the San Simon Swale and east of Clayton Basin and Nash Draw.

In a discussion of dissolved salts in surface water, Swenson (in Bachman and Johnson, 1973) pointed out that large amounts of salt are carried by present-day rivers in the Permian salt basin. Using data compiled by the USGS on the quality of surface water in streams draining the salt basin, he divided major river basins into subbasins and estimated for each subbasin the tonnage of sodium chloride discharged by surface water each day. He also estimated the average incremental tonnage of sodium chloride discharged each year per square mile in each subbasin. Some of the salt in the surface water is derived from subsurface salt beds, but dissolution is relatively slow. Ground-water movement through the Permian salt basin is also relatively slow.

SOUTHEASTERN NEW MEXICO

Brokaw, Jones, Cooley, and Hays (1972) summarized the stratigraphy, structure, and ground-water hydrology of the Carlsbad potash area in southeastern New Mexico, with special attention to the geology of the Permian salt deposits of the Ochoan Series. They also reviewed the history and extent of potash mining and oil and gas production in the area.

They concluded that the geologic and hydrologic requirements for a pilot-plant radioactive-waste repository, as outlined by AEC, could be satisfied best in Townships 21, 22, 23, and 24 South, Ranges 31 and 32 East. They reported that, within southeastern New Mexico, the area of these four townships has the lowest density of drill holes for potash, oil, and gas, is farthest from the dissolution front in the salt section, and contains the maximum thickness of Salado Formation salt at reasonable depths below the surface.

Two Arizona Salt Structures

In reporting on the Supai salt basin and Luke salt body in Arizona, Mytton (1973) pointed out that more detailed geologic and hydrologic information would be needed before either the Supai salt basin or the Luke salt body could be considered as a potential site for waste storage or disposal. Minimal requirements for both sites would include considerable core drilling and hydrologic testing. Too little is known of the detailed lithology to determine whether either site contains a potential disposal horizon in halite of the required purity and thickness, but the available drill-hole information is not encouraging in this respect. The Supai salt basin might also be unsuitable because of its hydrologic character. The salt-bearing rocks of the basin are overlain by the major aquifer of the region, the Coconino Sandstone, without the protection of a thick intervening impermeable sequence. The structure and physical extent of the Luke salt body are still matters of conjecture. In addition, the location of the salt body so near a large city, Phoenix, may rule out its consideration for immediate use. In summary, the scant data available on the two structures do not suggest a high potential for waste storage or disposal.

Paradox Basin

The appraisal of the Paradox basin is more favorable. The review by Hite and Lohman (1973) of the geology and hydrology of that part of southeastern Utah and southwestern Colorado suggested that, aside from southeastern New Mexico, the Paradox basin may be one of the most promising areas for subsurface waste storage or disposal.

Although the basin contains a widespread series of thick salt deposits, Hite pointed out that the number of potential sites is limited, because only in the salt anticlines of the region do the tops of the salt deposits come within 2,500 feet of the surface. The salt cores of the Paradox basin anticlines differ from typical Gulf coast salt domes. Instead of a nearly pure mass of halite, the cores of the Paradox anticlines are made up of multiple layers of salt and intervening layers of black shale, dolomite, and anhydrite. These

nonsalt layers are gas-bearing, but many individual halite beds are thick enough to provide a protective seal of halite between the gas-bearing beds and the openings mined for underground storage or disposal. The salt layers are not flat in the salt anticlines, so a detailed knowledge of the geometry of individual salt layers is needed to avoid undesirable layers in mining. In most of the larger anticlines the geometry of the salt layers is strongly influenced by diapirism. In nondiapiric anticlines, mine openings can stay well within specific salt layers if grades are planned that will follow the general dip of the anticlinal limbs. In diapiric anticlines it may be necessary to plan mine openings that conform with the axial plane of vertical to near-vertical folds. Of all the structures in the Paradox basin, Salt Valley anticline and Shafer dome are perhaps the best suited for further detailed investigation.

Gulf Coast Salt Domes

An extensive summary of data on salt domes compiled by Anderson, Eargle, and Davis (1973) provided the basis for their estimate that out of some 263 known or suspected onshore salt domes in the Texas-Louisiana-Mississippi-Albama portion of the Gulf Coast geosyncline, only 36 may prove to be acceptable sites for waste storage or disposal. Those 36 are the domes that are believed to be of adequate size, that are not being used by industry, and that have relatively shallow tops—no more than about 2,000 feet of overburden. The report provides a compilation of geologic and hydrologic background data divided into three parts: (1) summaries of the geology and hydrology of the salt-dome province as a whole; (2) summaries of the physiography, climate, geology, and hydrology of each of the five salt-dome basins that occur within the province; and (3) an appendix of background data for each of the potentially acceptable domes.

In order for the 36 selected salt domes to be proved acceptable, at least two critical factors must be examined: (1) the long-range stability of salt domes and (2) the long-range hydraulic isolation of salt domes. In regard to long-range stability Anderson, Eargle, and Davis (1973) inferred from limited geologic and hydrologic data that the diapiric rise of salt domes in the interior subprovince

tended to stop in Miocene time, but diapirism is still active in the coastal subprovince. They emphasized the need for much more data on rates of diapirism and suggested that detailed and integrated stratigraphic, microseismic, and leveling studies at carefully chosen locations might provide the needed data. In regard to long-range hydraulic isolation they reported that, in spite of the extensive exploration for petroleum along the flanks of salt domes, they found a notable lack of published information on the structural, lithologic, and hydrologic conditions that exist at the sides of salt domes. This deficiency of information precludes reliable evaluation of such factors as amounts and rates of dissolutioning and structural coupling or decoupling of the salt. Much more information from drilling and from geologic, hydrologic, and geophysical research is required, therefore, before any of these salt domes can be considered potentially safe sites for waste storage or disposal.

Impermeable Argillaceous Rocks

Merewether, Sharps, Gill, and Cooley (1973) outlined available geologic information on the argillaceous formations of the conterminous United States. They reviewed shale, mudstone, and claystone formations in terms of depth, dimension, composition, permeability, and structural and seismic history. They suggested that the most promising argillaceous rocks are shale, mudstone, and claystone of marine origin, in areas of little structural deformation, preferably in areas of low seismic risk.

Those authors concluded that most of the shales, mudstones, and claystones in the conterminous United States are probably not suitable as host rocks for the underground emplacement of waste. Many shale bodies are too thin or too deeply buried and have mineral constituents that may be unacceptable. The argillaceous strata of Mesozoic and Cenozoic age, which are widespread in the Pacific and Rocky Mountain Systems and the Atlantic Plain, generally contain large amounts of montmorillonite that may release water when heated. Many of the Devonian, Mississippian, and Pennsylvanian shales in the eastern half of the nation contain large amounts of organic matter; when heated, these shales may yield carbon compounds. In the Atlantic Plain and elsewhere many shale

bodies that are underlain or overlain by significant aquifers have lost their hydraulic isolation through the drilling of oil and gas wells. Strata in the orogenic belts of the United States—the Appalachian Mountains, Ouachita Mountains, Rocky Mountains, and other regions—are largely unacceptable because of abundant fractures that increase the permeability and decrease the strength of the rocks.

The argillaceous sedimentary rocks in a few areas of the United States fulfill many of the geologic requirements for repository strata and more detailed investigations may indicate that some of these sequences are acceptable. The Devonian-Mississippian Ellsworth Shale and Mississippian Coldwater Shale in Michigan are promising potential host rocks. In central and northern Ohio, parts of the Devonian Ohio Shale seem to have the necessary characteristics. The thick Upper Cretaceous shale bodies in the Rocky Mountain System would probably be suitable host rocks if the problem posed by montmorillonite could be solved.

Additional Studies

On the basis of the above series of studies the AEC asked the USGS to conduct more detailed investigations in southeastern New Mexico. These supplemental geologic and hydrologic studies (Jones, 1973; Bachman, 1973) strengthen the earlier conclusion that the southeastern New Mexico target area of Brokaw and others (1972) constitutes a very promising location for a pilot-plant repository for radioactive waste.

References*

Anderson, R. E., Eargle, D. H., and Davis, B. O., 1973, Geologic and hydrologic summary of salt domes in Gulf Coast region of Texas, Louisiana, Mississippi, and Alabama: U.S. Geol. Survey open-file report, 294 p., 110 text figs., 5 tables, 3 pl. in pocket. Released in open file June 25, 1973.

* For information on how to examine or obtain copies of these open-file reports write to: Public Inquiries Office, U.S. Geological Survey, Room 1012, Federal Building, Denver, Colorado 80202.

Bachman, G. O., 1973, Surficial features and late Cenozoic history in southeastern New Mexico: U.S. Geol. Survey open-file report, 32 p., 5 figs., 2 tables. Released in open file May 29, 1973.

Bachman, G. O., and Johnson, R. B., 1973, Stability of salt in the Permian salt basin of Kansas, Oklahoma, Texas, and New Mexico, *with a section on* Dissolved salts in surface water, by Swenson, F. A.: U.S. Geol. Survey open-file report, 62 p., 12 text figs., 1 table, 1 pl. in pocket. Released in open file March 30, 1973.

Brokaw, A. L., Jones, C. L., Cooley, M. E., and Hays, W. H., 1972, Geology and hydrology of the Carlsbad potash area, Eddy and Lea Counties, New Mexico: U.S. Geol. Survey open-file report, 86 p., 12 text figs., 5 tables, 8 pl. and 1 table in pocket. Released in open file September 28, 1972.

Hite, R. J., and Lohman, S. W., 1973, Geologic appraisal of Paradox basin salt deposits for waste emplacement: U.S. Geol. Survey open-file report, 75 p., 15 text figs., 2 tables, 1 pl. in pocket. Released in open file June 25, 1973.

Jones, C. L., 1973, Salt deposits of Los Medaños area, Eddy and Lea Counties, New Mexico, *with sections* on Ground water hydrology, by M. E. Cooley, *and* Surficial geology, by G. O. Bachman U.S. Geol. Survey open-file report, 67 p., 5 text figs., 13 pl. in pocket, 4 tables. Released in open file May 29, 1973.

Merewether, E. A., Sharps, J. A., Gill, J. R., and Cooley, M. E., 1973, Shale, mudstone, and claystone as potential host rocks for underground emplacement of waste: U.S. Geol. Survey open-file report, 44 p., 13 text figs., 1 table, 7 pl. in pocket. Released in open file September 28, 1973.

Mytton, J. W., 1973, Two salt structures in Arizona—The Supai salt basin and the Luke salt body: U.S. Geol. Survey open-file report, 40 p., 14 figs., 4 tables. Released in open file April 11, 1973.