

2549

U.S. Geological Survey Research in
Radioactive Waste Disposal—
Fiscal Years 1983, 1984, and 1985

By G.A. Dinwiddie and N.J. Trask



U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 87—4009
1986

- Choquette, A. F., Colman, S. M., and Reynolds, R. L., 1986, Paleomagnetism of upper Cenozoic, coarse-grained red beds, Fisher Valley, southeastern Utah: *Catena*, in press.
- Colman, S. M., 1983, Influence of the Onion Creek salt diapir on the late Cenozoic history of Fisher Valley, southeastern Utah: *Geology*, v. 11, p. 240-243.
- Colman, S. M., and Hawkins, F. F., 1985, Surficial geologic map of the Fisher Valley-Professor Valley area, southeastern Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1596.
- Colman, Steven M., Choquette, Anne F., and Hawkins, Fred F., 1984, Age estimates from quantitative measures of secondary carbonate and clay in soils, Fisher Valley, Utah (abs.): American Quaternary Association, Program and Abstracts, Boulder, CO, 1984, p. 26.
- Colman, S. M., Choquette, A. F., and Hawkins, F. F., 1986, Physical, soil, and paleomagnetic stratigraphy of the upper Cenozoic sediments in Fisher Valley, southeastern Utah: U.S. Geological Survey Bulletin, in press.
- Colman, S. M., Choquette, A. F., Rosholt, J. R., Miller, G. H., and Huntley, D. J., 1984, Multiple dating methods applied to the upper Cenozoic sediments in Fisher Valley, Utah (abs.): Geological Society of America, Abstracts with Programs, v. 16, no. 6, p. 475.
- Colman, S. M., Choquette, A. F., Rosholt, J. R., Miller, G. H., and Huntley, D. J., 1986, Dating the upper Cenozoic sediments in Fisher Valley, Utah: Geological Society of America Bulletin, v. 97, in press.

Palo Duro Basin, Texas

Fluid Inclusions in Salt

By Edwin Roedder, Reston, VA

The storage of radioactive waste in natural salt was originally suggested, in part, because salt mines are dry. However, microscopic fluid inclusions are known to be present in most salt deposits. Most of these inclusions will migrate toward a source of heat such as a waste canister and bring in proximity to it an amount and composition of brine whose consequences must be assessed. In addition, the inclusions are fluids that either were present when the salt was deposited or moved in later and became trapped (due to recrystallization of salt); in the latter case, they provide information on the previous movement of fluids through the rocks.

Objective: Studies of fluid inclusions in salt at the USGS during the reporting period (October 1982-June 1985) have had a number of objectives. Most important among these are the following:

- 1) Develop and improve methods of obtaining quantitative data from inclusions and validate their geological and geochemical significance.

- 2) Determine what information can be obtained from fluid inclusions that may help in determining if, when, and how fluids have moved through the salt in the past and whether this may occur in the future.
- 3) Determine how much fluid is present in any given site and its distribution properties, and composition.
- 4) Determine what predictions can be made as to the behavior of known fluid inclusions, as well as other possible sources of migrating fluids (as indicated by fluid inclusion studies), during and following the storage of nuclear waste.

Approach: Specially prepared samples are examined by microscope for fluid inclusions and appropriately sized portions are removed for study and chemical analysis.

Progress:

1) Development of validation of methods

A wide variety of methods have been used in fluid inclusion study in the past, and new developments in many aspects of analytical instrumentation have been applied to fluid inclusion analysis. There is a need to integrate the very widely scattered world literature dealing with inclusion studies. Although some standard retrieval and abstract services such as Georef, Chemical Abstracts, Mineralogical Abstracts, etc., provide an introduction to the literature, these are far from adequate in coverage. The USGS fluid inclusion project has been preparing an annual abstract and citation summary of the world literature on fluid inclusions for 16 years (see, e.g., Roedder, 1985a). In each of the volumes issued during this reporting period, there has been an average of 25 entries specifically on inclusions in saline deposits. In this same connection, a general book on fluid inclusion study (Roedder, 1984a) has also been published.

The gases present in fluid inclusions can, at times, be very informative as to the origin and history of the fluids in a salt deposit. During the report period, several new developments in the use of high-sensitivity gas chromatography for the analysis of fluid inclusions were reported (Andrawes et al., 1984a,b). Similarly, the P-V-T-X properties of brines are essential in understanding the near-field effects of radioactive waste in salt. Several studies have provided important basic new thermodynamic data on the major system NaCl-H₂O (Bodnar, Chou, et al., 1985; Bodnar, Burnham, et al., 1985).

2) Fluid movement through salt

Studies of fluid inclusions in salt from the Palo Duro Basin, Texas, in a cooperative program with the University of Texas, have shown that some are actual samples of Permian salt basin brines, trapped by the primary growth of salt crystals in very shallow brine pools, and even provide a record of the daily cycle of Permian day and night (Roedder, 1982a). Most other inclusions in salt represent fluids present during later recrystallization or diagenesis of the salt beds, and the major problem lies in deciding if these were trapped immediately following the primary crystallization, during diagenesis (perhaps millions of years later), or even in modern times

(Roedder, 1982b, 1984b). Studies of a seemingly trivial mineralogical oddity in the Palo Duro salt (Belkin and Libelo, 1985) may provide some useful evidence.

Study of the isotopes of hydrogen and oxygen in the H₂O in inclusions provide constraints on the possible origin of the fluid, but as many processes can affect the isotopic composition, interpretation of the data is usually ambiguous. This project has cooperated with several groups to provide valid samples for isotopic analysis. Work on Palo Duro samples in cooperation with L. P. Knauth of Arizona State University is still in progress, but that done some years ago on samples from the WIPP site in New Mexico is soon to be published (O'Neill et al., 1986; see also Roedder, 1984b).

3) The amount, distribution, properties, and composition of the fluids
Detailed petrographic and microthermometric studies of the fluid inclusions in salt can provide considerable geochemical data with a minimum of effort. During the report period, brief studies of this sort were made of a few samples from the Gibson Dome No. 1 bore, Paradox Basin, Utah (Roedder, 1984c). These revealed that a major diagenetic recrystallization of these salt beds had occurred, in the presence of very highly concentrated K-Mg brines, at surprisingly high temperatures (98-120°C).

The bulk of the effort during this report period has been in the development and use of procedures to extract and analyze chemically the fluid in inclusions, particularly those from the Palo Duro Basin, in cooperation with the University of Texas. The methods used for extraction are given by Roedder (1984a, 1985b), the analytical procedures by d'Angelo et al. (1984), and the results on a large number of inclusions from the Palo Duro Basin and elsewhere, with some geochemical interpretation, by Roedder et al. (1985, 1986).

4) Behavior of fluids during repository operation

Various aspects of the possible or probable behavior of the fluids in salt during repository operation have been considered during the report period. Some of these are summarized by Roedder (1982c). One of the project activities in this connection has been the review and evaluation of the work of others in the radioactive waste program in light of the data we have developed. Thus, there have been recurring discussions of the migration of fluid inclusions in a thermal gradient (e.g., Roedder and Chou, 1982; Chou, 1983), and numerous discussions and reviews have centered on the problems determining the specific origin of any given inclusion as evidenced by the criteria cited by Roedder (1984a, b, 1985a).

Reports

Andrawes, F., Holzer, G., Roedder, E., Gibson, E., and Oro, J., 1984a, Gas chromatographic analysis of volatiles in fluid and gas inclusions (abst.): Advances in Chromatography Meeting, New York, N.Y., April 1984, Program, p. 22.

Andrawes, F., Holzer, G., Roedder, E., Gibson, E. K., Jr., and Oro, J., 1984b, Gas chromatographic analysis of volatiles in fluid and gas inclusions: Jour. Chromatography, v. 302, p. 181-193.

- Belkin, Harvey E., and Libelo, E. L., 1985, Whiskers of cryptomelane-hollandite in bedded salt, Palo Duro Basin, Texas; a natural example of solid-state diffusion growth (abst.): EOS, v. 66, p. 398.
- Bodnar, R., Chou, I-Ming, and Roedder, E., 1985, Chemistry of ore-forming fluids: U.S. Geol. Circular 949, p. 1-3.
- Bodnar, R. J., Burnham, C. W., and Blencoe, J. G., 1985, PVT properties of H₂O-NaCl mixtures at high temperatures and pressures (abst.): Geol. Soc. Am. Abstracts with Programs, v. 17, p. 526.
- Chou, I-Ming, 1983, Remarks on "Migration of brine inclusions in salt," Nuclear Technology, v. 63, p. 507-509.
- D'Angelo, W. D., Dorrzapf, A. F., Jr., and Doughten, M. W., 1984, Analysis of fluid inclusions by inductively coupled plasma atomic-emission spectroscopy and ion chromatography (abst.): 26th Rocky Mountain Conference, Denver, Colorado, Aug. 5-9, 1984, Rocky Mountain Section, Soc. for Applied Spectroscopy and the Rocky Mountain Chromatography Discussion Group, Program and Abstracts, p. 144.
- O'Neill, J. R., Johnson, C. M., White, L. D., and Roedder, E., 1986, The origin of fluids in the salt beds of the Delaware Basin, New Mexico and Texas: Applied Geochemistry (in press).
- Roedder, E., 1982a, Possible Permian diurnal periodicity in NaCl precipitation, Palo Duro Basin, Texas: The University of Texas at Austin, Bureau of Economic Geology Circular 82-7, p. 101-104.
- Roedder, E., 1982b, Application of studies of fluid inclusions in salt samples to the problems of nuclear waste storage: Acta Geologica Polonica, v. 32, no. 1-2, p. 109-113 (in English with Polish abstract).
- Roedder, E., 1982c, Fluid inclusion studies, p. 35-39 in R. Schneider and N. J. Trask, U.S. Geological Survey Research in Radioactive Waste Disposal--Fiscal Year 1980, U.S. Geol. Survey Open-File Report 82-509, p. 21-24.
- Roedder, E., 1984a, "Fluid Inclusions," Reviews in Mineralogy, V. 12, 644 p. Mineralogical Society of America.
- Roedder, E., 1984b, The fluids in salt: American Mineralogist, v. 69, p. 413-439.
- Roedder, E., 1984c, Final report on a study of fluid inclusions in core from Gibson Dome No. 1 bore, Paradox Basin, Utah: U.S. Geol. Survey Open-File Report 84-696, 16 p.
- Roedder, E. (ed.), 1985a, Fluid Inclusion Research--Proceedings of COFFI, v. 16, 1983; Ann Arbor, Mich., Univ. of Michigan Press, 365 p.
- Roedder, E., 1985b, Composition of fluid inclusions in salt beds (abst.): European Current Research on Fluid Inclusions, 8th Symposium Abstracts, p. 106.

Roedder, E., and Chou, I-Ming, 1982, A critique of "Brine migration in salt and its implications in the geologic disposal of nuclear waste," Oak Ridge National Laboratory Report 5818, by G. H. Jenks and H. C. Claiborne, U.S. Geol. Survey Open-File Report 82-1131, 31 p.

Roedder, E., d'Angelo, W. M., Dorrzapf, A. F., Jr., and Aruscavage, P. J., 1985, Progress report on studies of the chemical composition of fluid inclusions in Palo Duro Basin salt: Texas Bur. Econ. Geol. Project Report.

Roedder, E., d'Angelo, W. M., Dorrzapf, A. F., Jr., and Aruscavage, P. J., 1986, Composition of fluid inclusions in Permian salt beds, Palo Duro Basin, Texas, Chem. Geology (in press).

Waste Isolation Pilot Plant, New Mexico

The DOE has been investigating an area about 40 km east of Carlsbad, New Mexico, to determine its suitability as a site for the Waste Isolation Pilot Plant (WIPP), a geologic repository for nuclear wastes generated by defense activities. The geology and hydrology of the area have been studied in cooperation with Sandia National Laboratories to provide the DOE with information on which to base an assessment of the site, particularly with respect to geologic stability, long-term isolation of waste radionuclides, and the potential for the hydrologic system to provide a barrier to radionuclide transport. The potential host rock is bedded salt of the Salado Formation of Late Permian age.

Geology

By R. P. Snyder, Denver, CO

Objective: To evaluate the geologic setting of WIPP on a regional and site-specific basis with special regard to the dissolution history and past and possibly future movement (dissolution and flowage) of the evaporite sequence.

Approach: Acquire and refine data to define the geologic history of the evaporite rocks in the northern Delaware Basin using information from existing potash mines, drill holes (both commercial and WIPP-oriented), and surficial mapping. These data will be used to improve the understanding of the subsurface geology and will help in interpreting geologic processes such as dissolution and flowage of evaporite rocks (halite and anhydrite) at or near the repository site.

Progress: Samples from oil seeps that occur above the Permian Capitan Limestone (reef) in a potash mine and in two breccia pipes north of the WIPP site were analyzed by gas chromatograph, carbon isotope, and chemical analysis. Results of the analyses suggest the oil is similar to oil being extracted from wells drilled into the Permian Yates Formation a few miles to the north of the pipes and the mine (Palacas and others, 1982). The Yates also overlies the Capitan but was not deposited inside the Delaware Basin toward the WIPP site. It is believed that the oil moved upward along faults into the Salado Formation when the Salado and other rocks collapsed into cavities formed in the Capitan (Snyder and Gard, 1982).