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COMPARATIVE EVALUATION AND USE OF PETROPHYSICALLY DERIVED AND LABORATORY-MEASURED CORE POROSITY DATA AT YUCCA MOUNTAIN, NEVADA

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I. INTRODUCTION

Volcanic rocks within the unsaturated zone at Yucca Mountain in southwestern Nevada are being considered by the U.S. Department of Energy as the host for a geologic repository for high-level nuclear waste. These rocks comprise a sequence of variably welded, nonwelded, and subaerially reworked tuffaceous deposits deposited, principally during Miocene time, as the result of regional silicic volcanism that produced thick pyroclastic-flow and air-fall deposits across much of southwestern Nevada.

The variable lithologic character of these volcanic rocks is well described by changes in the porosity of the units. Thick pyroclastic-flow deposits are generally densely welded and primary matrix porosity has been largely eliminated; welding compaction and secondary alteration by vapor-phase corrosion of these crystallized materials have produced generally low-porosity rock in these intervals. Less voluminous pyroclastic-flow deposits and air-fall tuff deposits that are relatively thin by comparison typically are only partially welded to completely nonwelded, and these rocks retain variable but generally large initial porosities. Thin reworked tuffaceous sediments that separate the major pyroclastic flow sequences from one another are also typically quite porous. Some of the nonwelded tuffs have been zeolitized at depth; this late-stage alteration process appears to have only minimal impact on the initial porosity of the rocks.

Although porosity, in and of itself, is of only minor importance in numerical modeling of ground-water flow and radionuclide transport, the physical processes that have affected this volcanic pile have induced relatively strong correlations between matrix porosity and a number of secondary rock properties (specifically bulk density, thermal conductivity, and matrix saturated hydraulic conductivity), understanding of which is crucial to modeling of the waste-isolation performance of a potential repository at Yucca Mountain. However, creation of rock-property models on the scale of the entire Yucca Mountain site requires the integration of observations and measurements acquired by numerous investigators over several decades.

II. DESCRIPTION OF ACTUAL WORK

We have evaluated three separate large suites of porosity data obtained from studies of the Yucca Mountain site. Two of these sets of data involve downhole petrophysical observations of rock density and water content that have been used to derive geologically reasonable estimates of the bulk porosity of the penetrated volcanic tuffs.[1,2] The third set of data comprises a large number of values, obtained by the direct measurement of matrix porosity on core samples in the laboratory.[3] Although the three suites of porosity data are distinctly separate and represent different approaches to the measurement of void space within tuffaceous rocks, sufficient overlap among the data sets combines with strong theoretical and physical justification to allow combination of the different porosity estimates as a single entity for use in rock properties modeling.[4]

III. RESULTS

Comparative evaluation of core-based and petrophysical measurements, as shown in figure 1, indicates that petrophysically derived porosity values can be used as reasonable estimates of both the matrix and bulk-rock porosity of the volcanic tuffs at Yucca Mountain. Discrepancies between two different petrophysical estimators of porosity allow delineation of intervals for which the presence of large (up to 1 m in diameter) lithophysal cavities increases the bulk-rock porosity with respect to the porosity of the tuff matrix. Identification of such "lithophysal porosity" allows a more detailed description of the extent and distribution of lithophysae-bearing welded tuff than has been possible heretofore. Differences between core porosity values obtained under two different laboratory drying conditions[3] allow a semiquantitative determination of late-stage, hydrous-phase alteration of the volcanic tuffs to clay and zeolite minerals. Similar differences are observed among several different petrophysical porosity estimators, and both alteration indicators can be compared successfully with independently determined X-ray diffraction studies of whole-rock mineralogy.[5]

In addition to providing an integrated, three-dimensional site-wide database for the geostatistical modeling of porosity and derivative rock properties,[4] the petrophysically derived porosity data were acquired on a rigorously systematic sampling pattern that allows evaluation of the degree of "representativeness" of laboratory-testing results for other rock properties. Specifically, sampling biases related to the loss of core during drilling and potentially to biased sampling of recovered core material, have been observed to exist in available measurements of hydraulic conductivity and thermal conductivity.

IV. CONCLUSIONS

Integration of core-based and petrophysically derived porosity measurements taken from throughout the Yucca Mountain site area provides a single coherent set of rock-properties data of vastly larger areal and volumetric extent than that provided by any of the three suites of measurements taken individually. In addition to providing effectively compatible quantitative measurements of matrix porosity, well-documented cross-property correlations with saturated hydraulic conductivity, thermal conductivity, and bulk density measurements can be used to generate coherent, quantitative models of these secondary rock properties as well.[4] With proper care, the core- and petrophysically derived porosity measurements can be used to model lateral as well as vertical heterogeneity in lithology and rock material properties, including semiquantitative modeling of significant hydrous-phase mineral alteration. Additionally, the systematic regular spacing of the petrophysical porosity measurements allows quantification of the extent of sampling bias in the measurement of other material properties caused both by core loss during drilling and selective sampling of recovered drill core.

V. ACKNOWLEDGMENTS

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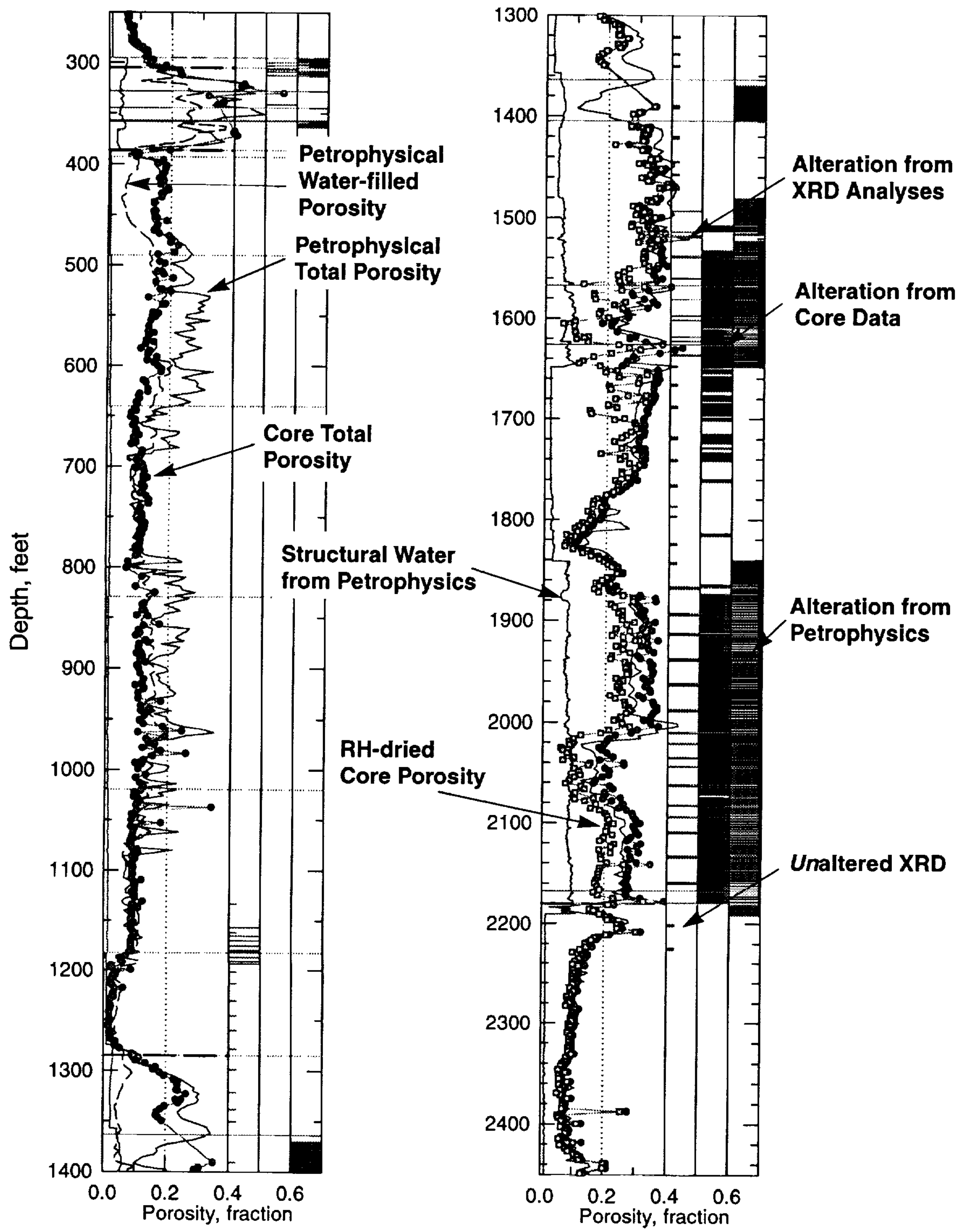

Figure 1. Comparison of core and petrophysically based porosity data for the USW SD-7 drillhole at Yucca Mountain.