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ANNOTATED BIBLIOGRAPHY OF THE PHYSICAL DATA OF RAINIER MESA AND YUCCA MOUNTAIN

by
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The Nevada Agency for Nuclear Projects/Nuclear Waste Project Office was created by the Nevada Legislature to oversee federal high-level nuclear waste activities in the state. Since 1985, it has dealt largely with the U.S. Department of Energy's siting of a high-level nuclear waste repository at Yucca Mountain in southern Nevada. As part of its oversight role, NWPO has contracted for studies of various technical questions at Yucca Mountain.

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CONTENTS

SECTION 1
INTRODUCTION

Yucca Mountain, located on and adjacent to the Nevada Test Site (NTS) has been designated as the only site to undergo characterization to determine if it meets the criteria to become the Nation's first high-level nuclear waste repository. During this process, care must be taken to not compromise the site's integrity through excessive testing. In order to supplement the limited data to be gathered at Yucca Mountain, analog areas are to be considered. This annotated bibliography was compiled by the Desert Research Institute to help investigate ways in which Rainier Mesa could either be used as a supplemental repository test site or where existing Rainier Mesa data can be used either to support or refute test results from Yucca Mountain. Rainier Mesa, the location of numerous underground nuclear tests on the NTS, possesses some geologic characteristics similar to those of Yucca Mountain, which makes it a likely candidate for comparison.

Reports included within the annotated bibliography are predominantly those published by Sandia, Lawrence Livermore, and Los Alamos National Laboratories, the U.S. Geological Survey, EG&G, Fenix and Scisson, Desert Research Institute, and available refereed journal articles prior to June 30, 1987. Each of the reports contains data pertaining to some physical aspect of either Rainier Mesa or Yucca Mountain. The bibliography was compiled from three primary sources, the Desert Research Institute library, the U.S. Geological Survey, and from annotated bibliographies of published Yucca Mountain reports published yearly by the Nevada Nuclear Waste Storage Investigation project. It is possible that the search of these sources was not 100 percent complete, and that a few maps and/or reports are missing from the bibliography.

Almost 500 references regarding geology, hydrology, meteorology, biology, and archaeology were annotated and entered alpha-numerically into the bibliography. These references were categorized into 50 topics which are defined in Section 2 and presented in Section 3. Each reference is categorized as to whether it contains Yucca Mountain data, Rainier Mesa data, or both, and a final category consists of those reports that contain Rainier Mesa data that have already been applied to Yucca Mountain research. The annotated bibliography is presented in Section 4.

Only unclassified reports are included. Classified and sensitive (official-use-only) documents potentially contain useful data from Rainier Mesa, however, these must be re-classified prior to release. The majority of the documents in this bibliography may be found at:

NTIS Energy Distribution Center
P.O. Box 1300
Oak Ridge, Tennessee 37831

or

U.S. Geological Survey
Federal Center
P.O. Box 25425
Denver, Colorado 80225

SECTION 2
DEFINITIONS OF CATEGORIES AND KEY TOPICS

CATEGORIES

1. **Yucca Mountain**
   Reports that contain data or models of the existing physical parameters of Yucca Mountain and the impact of those parameters on the proposed repository performance, or the effect of the repository on those parameters.

2. **Rainier Mesa**
   Reports that contain data or models of the existing physical parameters of Rainier Mesa and the effect of nuclear testing on those parameters.

3. **Rainier Mesa Testing Directly Associated With Yucca Mountain**
   Reports that contain Rainier Mesa data and experiments that are in direct correlation with Yucca Mountain and the proposed repository to be located there.

KEY TOPICS

1. **Aeromagnetic and magnetic surveys**
   Reports that contain the results of borehole and or aeromagnetic surveys.

2. **Archaeology**
   Reports that deal with the archaeology of Yucca Mountain.

3. **Bibliographies**
   Reports that contain bibliographies relating to the hydrology, meteorology or geology of the two sites.

4. **Biology**
   Reports that assess species types and distributions on Rainier Mesa and/or Yucca Mountain.

5. **Climatology**
   Reports that deal with the meteorology or paleoclimate of the sites.

6. **Drillhole operation, construction and history**
   Reports that contain information or records of drillhole histories and operations.

7. **Effect of nuclear testing on tuff**
   Reports concerned with the effects of nuclear testing on the tuffs and groundwater within Rainier Mesa or how nuclear test-generated seismic pulses have been applied to seismic stability analysis of Yucca Mountain.

8. **Effect of repository on tuff**
Reports that are concerned with the effect that the proposed repository would have on the physical, chemical, and mechanical properties of the geologic units located there.

9. **Energy and mineral resources**
Reports that are summaries of the location and types of energy and mineral resources in a regional or local area.

10. **Environmental characterization**
Reports that contain summaries of the geologic, hydrologic, and meteorologic conditions of Yucca Mountain and/or Rainier Mesa.

11. **Flood potential**
Reports that assess flood potential in the area.

12. **Fracture data**
Reports that describe or contain any fracture data such as frequency, aperture, hydraulic conductivity, *etc*.

13. **Geochemistry**
Reports on the geochemical composition and reactions of the tuffaceous rocks found at Rainier Mesa and/or Yucca Mountain.

14. **Geologic history**
Reports that deal with the geologic history and age of various units and geologic events.

15. **Geophysics**
Reports that contain the methods and data derived from various borehole and surface geophysical methods.

16. **Groundwater geochemistry**
Reports that contain data on aspects of groundwater chemistry.

17. **Groundwater recharge**
Reports that contain data or models that estimate groundwater recharge rates and quantities.

18. **Groundwater travel/retention time**
Reports that document or estimate groundwater travel or residence time.

19. **Heater experiment**
Reports that are primarily concerned with the Tuff Water Migration/*In Situ* Heater Experiment conducted by Sandia National Laboratories at Rainier Mesa.

20. **Hydrogeologic parameters**
Reports that deal with any of the following data: hydraulic conductivity, water content, storativity, transmissivity, hydraulic head, water table elevation, matrix suction, pump test or tracer test results.

21. **Hydrogeologic units**
Reports that relate geologic units to hydrogeologic ones.

22. **Hydro-model sensitivity**
Reports that describe the sensitive parameters for local and regional hydrologic models that include Rainier Mesa and or Yucca Mountain.

23. **Imbibition and evaporation experiments**
Reports that document the flow paths and processes of wetting and drying fronts in porous media.

24. ***In situ* stress (measured)**
Reports that contain data on *in situ* stress fields as measured in geologic units.

25. ***In situ* stress (modeled)**
Reports that contain data on *in situ* stress fields as modeled through numeric simulation.

26. **Laboratory hydrothermal water-tuff interaction**
Reports that are concerned with the geochemical reactions between groundwater and tuff at elevated temperatures.

27. **Lithology**
Reports that contain lithologic information on Rainier Mesa and/or Yucca Mountain.

28. **Local flow system**
Reports that are concerned with the local flow system of the two mountain blocks.

29. **Mass transport**
Reports that relate either measured or modeled data to the transport of water, ions, or radionuclides through tuff.

30. **Mechanical properties (measured)**
Reports that contain actual measured data on any of the following: Poisson's ratio, bulk modulus, shear modulus, tensile strength, compressive strength, grain and bulk density, sonic properties, and other data related to geoengineering.

31. **Mechanical properties (modeled)**
Reports that contain modeled data on any of the following: Poisson's ratio, bulk modulus, shear modulus, tensile strength, compressive strength, grain and bulk density, sonic properties, *etc.*

32. **Mineralogy**
Reports that deal with the mineralogy of the formations contained within either of the two sites.

33. **Multiphase flow and transport**
Reports that deal with various aspects of liquid and/or vapor phase flow and transport in a porous media.

34. Nomenclature
Reports that document the changes in stratigraphic nomenclature for the units found in Rainier Mesa and Yucca Mountain.

35. Nuclide Field Migrations Experiment
Reports that are primarily concerned with the Radionuclide Migration Field Study conducted by Los Alamos National Laboratory at Rainier Mesa.

36. Petrology
Reports that list petrologic information concerning the formations of Rainier Mesa and/or Yucca Mountain.

37. Regional flow system
Reports that deal with the regional flow systems of Rainier Mesa and Yucca Mountain.

38. Regional geology
Reports that contain regional or reconnaissance geologic information.

39. Rock Mechanics Program
Reports that are primarily concerned with the Rock Mechanics Program conducted by Sandia National Laboratories at Rainier Mesa.

40. Rock properties (tunnel or outcrop)
Reports that contain data on the physical properties of the geologic units found in tunnels, outcrops and boreholes. This data consists of density, porosity, resistivity, induced polarization, sonic properties, magnetic properties, bulk and grain density, and radioactive surveys. Geoengineering parameters are generally excluded.

41. Seismic studies
Reports that deal with seismic profiles and reflections, seismicity, sonic velocities, and earthquake potential.

42. Soils
Reports that pertain to soil and soil physics and stability for the two sites.

43. Sorption and diffusion
Reports concerned with the adsorption and/or diffusion properties of tuffs.

44. Stratigraphy
Reports that contain stratigraphic information on Rainier Mesa and/or Yucca Mountain.

45. Structure
Reports that contain structural information for Rainier Mesa, Yucca Mountain, or the surrounding region.

46. Thermal studies
Reports that describe the effects of heat on tuffaceous rocks.

47. **Vadose zone flow**
Reports that contain data relating to unsaturated zone groundwater flow and transport properties.

48. **Volcanism risk assessment**
Reports on paleo-volcanism and risk assessment of future volcanism for Yucca Mountain.

49. **Water resources**
Reports that define the water resources for the local and regional flow systems of the two mountain blocks.

50. **Well location**
Reports that contain the location of wells for areas in and surrounding the two sites.

SECTION 3
CATEGORIES AND KEY TOPICS

bold	=	Yucca Mountain data
italics	=	Rainier Mesa data
underline	=	Pertains to both areas

CATEGORIES

1. **Yucca Mountain**
2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 32, 33, 35, 38, 39, 40, 41, 42, 45, 46, 47, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 68, 73, 74, 75, 76, 77, 78, 79, 84, 85, 86, 87, 88, 89, 91, 92, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 119, 121, 122, 130, 131, 132, 137, 142, 143, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 171, 174, 175, 176, 177, 178, 183, 185, 186, 187, 188, 189, 190, 193, 194, 196, 197, 198, 201, 202, 204, 207, 208, 211, 212, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 229, 230, 231, 232, 233, 235, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 248, 249, 250, 251, 254, 255, 262, 264, 265, 266, 267, 268, 269, 270, 272, 273, 274, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 288, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 354, 357, 358, 359, 360, 364, 365, 366, 367, 368, 369, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 409, 411, 412, 413, 414, 415, 416, 417, 418, 419, 421, 422, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 446, 447, 448, 449, 450, 451, 453, 455, 456, 457, 458, 462, 463, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 482, 486, 494,* 495*

2. **Rainier Mesa**
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3. **Rainier Mesa Testing Directly Associated With Yucca Mountain**
8, 31, 43, 90, 91, 92, 93, 120, 123, 144, 204, 205, 206, 207, 213, 228, 229, 231, 232, 234, 244, 275, 287, 297, 318, 408, 417, 447, 454, 456, 459, 460, 461, 481, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493

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*Contained in addendum.

1. Aeromagnetic and magnetic surveys
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2. Archaeology
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3. Bibliographies
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4. Biology
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5. Climatology
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6. Drillhole operation, construction and history
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7. Effect of nuclear testing on tuff
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9. Energy and mineral resources
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10. Environmental characterization
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12. Fracture data
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13. Geochemistry
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14. Geologic history
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15. Geophysics
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16. Groundwater geochemistry
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*Contained in addendum.

*Contained in addendum.

*Contained in addendum.

*Contained in addendum.

SECTION 4
ANNOTATED BIBLIOGRAPHY

1 Allingham, J.W., 1966, Remnant magnetism of rhyolitic tuffs at Rainier Mesa, Nevada Test Site: Geological Society of America, Special Papers, v. 101, p. 383.

The remnant magnetism of 65 samples of Tertiary ash-flows tuff was investigated as a possible aid in correlating volcanic units in the Nevada Test Site. Laboratory measurements showed significant differences in polarity and in direction of remnants, which are useful in stratigraphic studies in this area.

2 Anderson, L.A., 1981, Rock property analysis of core samples from the Calico Hills UE25a-3 borehole, Nevada Test Site, Nevada: U.S. Geological Survey open-file report 81-1337, 30 p.

Samples were measured for density, porosity, resistivity, induced polarization, compressional sonic velocity, and magnetic properties. The samples were similar to three distinct subunits of argillite underlain by a marble section. The relatively high remnant and induced magnetization of the altered argillite subunit is a distinguishing feature of that section of argillite. Most of the measurements were variable due to a complex history of formation and deformation.

3 Anderson, L.A., 1981, Rock property analysis of core samples the Yucca Mountain UE25a-1 borehole, Nevada Test Site, Nevada: U.S. Geological Survey open-file report 81-1338, 36 p.

Core samples from the UE25a-1 borehole (Yucca Mountain area) were measured for bulk density, porosity, resistivity, induced polarization, compressional sonic velocity, hydraulic conductivity, magnetic susceptibility and remnant magnetization as part of a large scale site evaluation of Yucca Mountain. The samples were taken from the following units, the Paintbrush Tuff, the Tuffaceous Beds of the Calico Hills and the Crater Flat Tuff.

4 Anderson, L.A., 1984, Rock property measurements on large-volume core samples from Yucca Mountain USW GU-3/G-3 and USW G-4 boreholes, Nevada Test Site, Nevada: U.S. Geological Survey open-file report 84-552, 39 p.

Core samples were selected to be representative of the major lithologic variations observed within the stratigraphy of the drill site. They were measured for electrical resistivity, induced polarization, porosity, bulk and grain density, and compressional sonic velocity. The results are intended to provide a means of rock property characterization that is not normally possible with conventional borehole techniques.

5 Ball, S.H., 1907, A geologic reconnaissance in southwestern Nevada and eastern California: U.S. Geological Survey Bulletin 308, 218 p.

A generalized geologic map of southwestern Nevada and eastern California is presented. Both Yucca Mountain and the area in the vicinity of Rainier Mesa are discussed.

6 Barr, G.E., 1985, Reduction of the well test data for test well USW H-1, adjacent to Nevada Test Site, Nye County, Nevada: Sandia National Laboratories report SAND84-0637, Albuquerque, NM, 41 p.

The drawdown and recovery data for three pump tests, three recovery tests, and six injection tests in well USW H-1 are reduced to determine hydraulic conductivity and storativity, assuming the medium is homogeneous, isotropic, and porous. Conductivity ranges from about 10^{-5} m/s in the upper zone to 10^{-10} m/s in the lower zone, and storativity ranges from 5×10^{-7} to about 0.5.

7 Bauer, S.J., and Holland, J.F., 1987, Analysis of *in situ* stress at Yucca Mountain: Sandia National Laboratories report SAND86-1808C, Albuquerque, NM, 11 p.

A method has been developed to initialize far-field finite element models such that the measured *in situ* stress state appears to be reproduced well. The method includes the use of the mechanical stratigraphy, mechanical effect of pore pressure, gravity loading, tectonic component of stress, and use of a jointed rock model to calculate the mechanical response. Topographic effects and effects related to the vertical variation in mechanical properties are predicted for repository depths. Gravity loadings with a small horizontal compression are used to calculate a minimum horizontal stress similar in magnitude to that measured *in situ*.

8 Bauer, S.J., Holland, J.F., and Parrish, D.K., 1985, Implications about *in situ* stress at Yucca Mountain: 26th U.S. Symposium on Rock Mechanics, Rapid City, SD, June 26-28, 1985, p. 1113-1121.

This paper uses the regional geologic studies that pertain to the stress state at the Nevada Test Site, stress measurements in Yucca Mountain, and stress measurements in nearby Rainier Mesa, in conjunction with finite element calculations to estimate the *in situ* stresses at Yucca Mountain. Based on these data, values of lateral earth-stress coefficients in the range of $0.3 < k_o < 0.8$ are reasonable for repository depths in thermomechanical analyses.

9 Bauer, S.J., Thomas, R.K., and Ford, L.M., 1985, Measurement and calculation of the mechanical response of a highly fractured rock: Sandia National Laboratories report SAND84-2020C, Albuquerque, NM, 8 p.

The first steps to validate a material constitutive model for a jointed rock mass have been completed. The continuum model, as utilized here within a finite element code, consists of a material constitutive description based on the linear elastic behavior of the matrix material and nonlinear normal and shear behavior of fracture planes.

10 Barton, C.C., 1986, Fractal geometry of two-dimensional fracture networks at Yucca Mountain, southwestern Nevada: in Proceedings of International Symposium on Fundamentals of Rock Joints, Bjorkliden, Lapland, Sweden, Sept. 15-20.

Fracture traces exposed on three 214 to 260 m^2 pavements in the same Miocene ash-flows tuff at Yucca Mountain, southwestern Nevada, have been mapped at a scale of 1:50. The maps are two-dimensional sections through the

three-dimensional network of strata-bound fractures. All fractures with trace lengths greater than 20 m were mapped. The distributions of fracture-trace lengths is log-normal. The fractures do not exhibit well-defined sets based on orientation. A fractal analysis was conducted for each network. Each network proved to be fractal and the fractal dimensions are tightly clustered.

11 **Bath, G.D., and Jahren, C.E., 1984, Interpretations of magnetic anomalies at a potential repository site located in the Yucca Mountain area, Nevada Test Site: U.S. Geological Survey open-file report 84-120, 40 p.**

In the Yucca Mountain area near the southwestern border of the Nevada Test Site, studies of the relation of magnetic properties to geologic features have provided structural information at and near the potential repository site. Interpreted features include a tabular mass of magnetized sedimentary rock beneath thick deposits of volcanics and 11 major faults that strike generally northward and displace magnetized volcanic rock.

12 **Bath, G.D., and Jahren, C.E., 1985, Investigations of an aeromagnetic anomaly on the west side of Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 85-459, 24 p.**

A prominent aeromagnetic anomaly of 290 nT on the potential repository site was further delineated through the use of ground magnetic traverses. The results indicate that the ground magnetic anomaly is caused by contributions from at least three sources. The elevated topography gives a terrain effect since the altitude is decreased between the airplane and the exposed Topopah Spring Member of the Paintbrush Tuff. Ground anomalies 300 m south of the air maximum indicate either an increase in magnetization or the presence of a small intrusive body.

13 **Bell, E.J., and Larson, L.T., 1982, Overview of energy and mineral resources for the Nevada nuclear waste storage investigation, Nevada Test Site, Nye County, Nevada: Reynolds Electrical and Engineering Co., Inc, NVO-250, Las Vegas, NV, Sept., 1982, 64 p.**

This report addresses energy resources including hydrocarbons, geothermal and radioactive fuel materials, mineral resources (including base and precious metals and associated minerals), industrial minerals and rock materials which occur in the vicinity of the NNWSI area. A generalized commentary is provided on past and present mining and exploration activity, with discussions of resource potential in a context of the regional resource base and projected future demands for these resources.

14 **Bell, E.J., and Larson, L.T., 1982, Annotated bibliography-overview of energy and mineral resources for the Nevada nuclear waste storage investigations, Nevada Test Site, Nye County, Nevada: Reynolds Electrical and Engineering Co., Inc., NVO-250, 73 p.**

References of this bibliography were selected in order to support the environmental characterization of Yucca Mountain.

15 **Benson, L.V., 1976, Mass transport in vitric tuffs of Rainier Mesa, Nye County, Nevada: Desert Research Institute Publication NVO-1253-10, 38 p.**

Chemical and physical analyses of reactant and product phases found in sub-aerially-exposed vitric tuffs of Rainier Mesa indicate that diagenetic alteration is occurring today. Variations within the fluid phase as a function of depth suggest a vertical transport system whereby the dissolution of metastable glass drives the sequential precipitation of montmorillonite, clinoptilolite, and possibly analcime.

16 **Benson, L.V., and McKinley, P.W., 1985, Chemical composition of groundwater in the Yucca Mountain area, Nevada, 1971-84: U.S. Geological Survey open-file report 85-484, 10 p.**

Fifteen test wells in the Yucca Mountain area have been sampled at least once for chemical analysis during 1971-84. Sodium was the most abundant cation, and bicarbonate was the dominate anion. Samples from the deep carbonate aquifer contained higher relative concentrations of calcium and magnesium than did samples from overlying volcanic tuffs. Concentrations of the stable isotopes of oxygen and hydrogen were relatively negative(light) and had deuterium-excess values ranging from -5 to -10. The distribution of uncorrected radiocarbon ages of water from the exploratory block on Yucca Mountain ranged from 12,000 to 18,500 years before present. A significant degree of lateral and vertical chemical inhomogeneity exists in the groundwater of the Yucca Mountain area.

17 **Benson, L.V., et al., 1983, Chemical composition of groundwater and the locations of permeable zones in the Yucca Mountain area, Nevada: U.S. Geological Survey open-file report 83-854, 19 p.**

Ten wells in the Yucca Mountain area have been sampled for chemical analysis. Sodium is the most abundant cation and bicarbonate the most abundant anion in all water samples. Differences were found in uncorrected carbon-14 and in inorganic and stable-isotope composition. Groundwater production is usually from one or more discrete zones of permeability.

18 **Bentley, C.B., 1984, Geohydrologic data for test well USW G-4 Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey open-file report 84-063, 48 p.**

This report presents data on drilling operations, lithology, borehole geophysics, hydrologic monitoring, core analysis, water chemistry, pumping tests, and packer-injection tests for test well USW G-4. This well is located on the eastern flanks of Yucca Mountain.

19 **Bentley, C.B., Robison, J.H., and Spengler, R.W., 1983, Geohydrologic data for test well USW H-5, Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey open-file report 83-853, 38 p.**

Data on drilling operations, lithology, borehole geophysics, water-level monitoring, core analysis, groundwater chemistry, pumping tests, and packer-injection tests for test well USW H-5 are presented.

20 **Bertram, S.G., 1982, Nevada nuclear waste storage investigations environmental area characterization report: The Mitre Corporation, Mclean, Virginia, SAND 83-7132, 123 p.**

The environmental area characterization report describes the southwestern corner of the Nevada Test Site, Nye County, Nevada, a potential site for a geologic repository for high-level nuclear waste. The characterization summarizes reports supplied by Sandia National Laboratories, which covers the following topics atmosphere, radiation background, hydrosphere, biosphere, energy, mineral resources, socioeconomics, and cultural resources.

21 **Bish, D.L., 1981, Detailed mineralogical characterization of the Bullfrog and Tram Members in USW-G1, with emphasis in clay mineralogy: Los Alamos National Laboratory LA-9021-MS, 21 p.**

This study characterizes the amounts and types of clay minerals in the tuffs and the possible effects clay minerals have on rock properties. Clay mineral formation occurred after zeolite crystallization and under conditions similar to those in the rocks today. It is also likely that the groundwater in the tuffs has inhibited the smectite-to-illite reaction.

22 **Bish, D.L., and Chipera, S.J., 1986, Mineralogy of drillholes J-13, UE-25A#1, and USW G-1 at Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-10764-MS, Los Alamos, NM, 23 p.**

The mineralogy of drillholes J-13, UE-25A#1, and USW G-1 was previously determined using qualitative and semiquantitative techniques, and most of the available data were incomplete and inaccurate. New quantitative x-ray diffraction data were obtained for rocks from all three of these drillholes. New findings of importance include better constraints on the distribution of the more soluble silica polymorphs.

23 Bish, D.L., Ogard, A.E., and Vaniman, D.T., 1984, Mineralogy-petrology and groundwater geochemistry of Yucca Mountain tuffs: in McVay, G.L., [ed], Proceedings of the Seventh International Symposia on the Scientific Basis for Nuclear Waste Management VII, Boston, MA, November, 1983.

This a study of the mineralogy of Yucca Mountain as a function of depth and lateral position to predict the horizontal and vertical distribution of these important potentially reactive and sorptive minerals. In addition the groundwater chemistry is studied along with the mineralogy to use as input to codes for calculating the transport rate of waste elements from the repository to the accessible environment.

24 Bish, D.L., et al., 1982, Summary of the Mineralogy-Petrology of tuffs of Yucca Mountain and secondary-phase thermal stability in tuffs: Los Alamos National Laboratory LA-9321-MS, 47 p.

This report describes the currently known range of lateral variability of the tuff units and the variation in mineralogy and petrology from unit to unit as determined through studies of drill core. The distribution of secondary phases, including clays and zeolites is also documented. The effects of temperature on these secondary phases and the resultant effects on a repository are also reviewed.

25 Bish, D.L., and Semarge, R.E., 1982, Mineralogic variations in a silicic tuff sequence: evidence for diagenetic and hydrothermal reactions: abstract, 19th Annual Clay Minerals Society Meeting, Hilo HI, August 8-14, 1982.

The mineralogy of clay and zeolite minerals in the vicinity of Yucca Mountain as a function of depth is discussed.

26 Bish, D.L., and Vaniman, D.T., 1985, Mineralogic summary of Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-10543-MS, Los Alamos, NM, 54 p.

A quantitative x-ray powder diffraction analysis of tuffs and silicic lavas, using matrix-flushing techniques, has been used to obtain a model of three-dimensional mineral distributions at Yucca Mountain, Nevada.

27 Bixler, N.E., and Eaton, R.R., 1986, Sensitivity of calculated hydrologic flows through multilayered hard rock to computational solution procedures: from Symposium of Groundwater Flow and Transport Modeling for Performance Assessment of Deep Geologic Disposal of Radioactive Waste, Albuquerque, NM, May 20, 1985.

Permeability and moisture content curves for partially saturated fractured, welded tuffs, such as those found near the site of a prospective nuclear waste repository at Yucca Mountain, Nevada, are highly non-linear. The authors illustrate, by means of a one-dimensional problem of infiltration into multilayered fractured tuff, the numerical instabilities that can arise when analyzing the flow in such porous materials. The results from two numerical schemes are compared.

28 Bixler, N.E., and Eaton, R.R., 1987, Drying analysis of a multiphase porous-flow experiment in fractured volcanic tuff: Sandia National Laboratories report SAND86-0722C, Albuquerque, NM, 20 p.

A submeter-scale drying experiment has been analyzed using a finite element, multiphase-flow code. In the experiment, an initially wet cylindrical core of fractured volcanic tuff was dried by blowing dry nitrogen over the ends. Results indicate that water is transported chiefly as liquid from the interior to the edges of the core, where it evaporates and escapes out the ends. Thus, liquid-phase transport controls the overall drying rate.

29 Blacic, J., 1982, Effects of long-term exposure of tuffs to high-level nuclear waste-repository conditions. Preliminary report: Los Alamos National Laboratory report LA-9174 -PR, Los Alamos, NM, 30 p.

Tests have been performed to explore the effects of extended exposure of tuffs from the southwestern portion of the Nevada Test Site to temperatures and pressures similar to those that will be encountered in a high-level nuclear waste repository. Tuff samples ranging from highly welded, nonzeolitized to unwelded highly zeolitized types were subjected to 80, 90, and 120°C temperatures, confining pore pressures of 0.5 to 19.7 MPa, and water pore pressures of up to 19.7 MPa for 2 to 6 months. Results indicate that depending on rock type and exposure conditions, significant changes in ambient tensile strength, compressive strength, grain density, and porosity were measured.

30 Blankennagel, R.K., and Weir, J.E., 1973, Geohydrology of the eastern part of Pahute Mesa, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey professional paper 712-B, 35 p.

The geologic setting, hydrogeologic units and their hydrologic parameters, regional and local groundwater flow paths, groundwater chemistry, and engineering hydrology of eastern Pahute Mesa is presented. This area is just to the north and northwest of Rainier Mesa.

31 Board, M.P., Wilson, M.L., and Voegele, M.D., 1987, Laboratory determination of the mechanical, ultrasonic and hydrologic properties of welded tuff from the Grouse Canyon Heated Block Site: Sandia National Laboratories contractor report SAND86-7130, Albuquerque, NM, 85 p.

The results of a laboratory testing program conducted to determine the mechanical, ultrasonic, and hydrologic properties of samples from the Grouse Canyon Member of the Belted Range Tuff exposed in the GTUF Heated Block Alcove, U12g Tunnel, Nevada Test Site are described.

32 Bowen, J.L., and Egami, R.T., 1983, Annotated bibliography for atmospheric overview for the Nevada Nuclear Waste Storage Investigations, Nevada Test Site, Nye County, Nevada: Desert Research Institute report NVO-268, Las Vegas, NV, 27 p.

This bibliography covers a number of aspects which will be incorporated environmental assessment on the effects of a nuclear waste repository on the air quality of the Nevada Test Site and environs. Literature was garnered for the following topics: 1) weather and climate of southern Nevada; 2) long-term climatology of the southwest; 3) climatology of the Nevada Test Site; 4) diffusion associated with the NRDS at Jackass Flats; 5) air quality of the southwest; 6) regional dispersion characteristics; 7) dispersion modeling over flat and complex terrain; 8) fugitive dust studies; 9) noise; and 10) regulations and recommended procedures.

33 Bowen, J.L., and Egami, R.T., 1983, Atmospheric overview for the Nevada Nuclear Waste Storage Investigations, Nevada Test Site, Nye County, Nevada: Desert Research Institute report DE84002818, Reno, Nevada, 75 p.

This report discusses the atmospheric considerations for a nuclear waste repository at Nevada Test Site. It presents the climatology of Nevada, and the Nevada Test Site in particular, including placoclimatology, average present climatology, and occurrences of extreme weather. It discusses air quality aspects, noise problems, and outlines a plan for an Environmental Impact Statement.

34 Bowers, W.E., 1964, Outline of the geology of the U12l and U12l.01 tunnels and lithology of the U12l.01 drillhole, Nevada Test Site: U.S. Geological Survey report TEI-842, 23 p.

The stratigraphy, chemistry, lithology, density, porosity, water content, and magnetic susceptibility are reported

for the tuffaceous units found within the U12I, U12I.01 drifts and U12I.01 drillhole. These drifts are located in the Aqueduct Mesa just to the northeast of Rainier Mesa.

35 Braithwaite, J.W., and Nimick, F.B., 1984, Effect of host-rock dissolution and precipitation on permeability in a nuclear waste repository in tuff: Sandia National Laboratories report SAND84-0192, Albuquerque, NM, 51 p.
A study has been conducted to determine whether thermally induced, host-rock mineral dissolution and precipitation processes could decrease the isolation capability of a potential high-level nuclear waste repository in tuff by significantly altering the permeability of the formation. Cumulative porosity changes were shown to be very small, and net decreases in porosity were shown to occur only in the vicinity of the repository horizon if the groundwater vaporizes. The differences in permeability for both matrix and fracture flow resulting from these small cumulative porosity changes should have no significant effect on the overall hydrologic patterns at Yucca Mountain.

36 Brethauer, G.E., and Magner, J.E., 1977, Analysis of the effect of a buried hemispherical excavation on the surrounding stress distribution: U.S. Geological Survey report USGS-474-237, 18 p.
An investigation of the stress around a buried hemispherical excavation, using finite element methods, was undertaken near the U12e.18 drift to analyze and compare the effect of orientation relative to an assumed *in situ* stress field. The most stable orientation of the hemispherical excavation is that in which the base is perpendicular to the direction of the minimum stress axis of the assumed *in situ* stress field.

37 Brethauer, G.E., Magner, J.E., and Miller, D.R., 1980, Statistical evaluation of physical properties in Area 12, Nevada Test Site, using the USGS/DNA storage and retrieval system: U.S. Geological Survey report USGS-474-309 (Special Projects-43), 94 p.
The U.S. Geological Survey/Defense Nuclear Agency Physical Properties Storage and Retrieval System was used to generate tables displaying the basic statistics of physical properties data sets sorted according to geologic identification and tunnel complex in Rainier and aqueduct Mesa. The results of this study indicate that no conclusive consistent relation exists between geologic identification and physical property average value.

38 Broxton, D.E., 1985, Chemical variability of zeolites at a potential nuclear waste repository, Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-UR-85-3933, Albuquerque, NM, 27 p.
The compositions of clinoptilolites and their host tuffs have been examined by electron microprobe and x-ray fluorescence, respectively, to determine their variability at a potential nuclear waste repository.

39 Broxton, D.E., Bish, D.L., and Warren, R.G., 1987, Distribution and chemistry of diagenetic minerals at Yucca Mountain, Nye County, Nevada: Clays and Minerals, vol. 35, no. 2, p. 89-110.
Beneath Yucca Mountain, four diagenetic mineral zones have been recognized that become progressively less hydrous with depth. The chemistry, mineral assemblages, location and thickness of these zones are described.

40 Broxton, D.E., and Carlos, B.A., 1986, Zeolitic alteration and fracture fillings in silicic tuffs at a potential nuclear waste repository, Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-UR-86-1413, Los Alamos, NM, 5 p.
This paper describes the distribution and chemistry of zeolites in tuffs and in fractures at Yucca Mountain. A variety of techniques were used to characterize the distribution and chemistry of zeolites in these samples.

41 Broxton, D., et al., 1982, Detailed petrographic descriptions and microprobe data for drillholes USW-G2 and UE25b-1H, Yucca Mountain, Nevada: Los Alamos National Laboratory LA-9324-MS, 168 p.
These drillholes penetrate a thick sequence of volcanic rocks consisting of voluminous ash-flows tuffs, intercalated with thin bedded tuffs and minor lavas. This report contains detailed petrologic descriptions. Microprobe analyses of feldspars and mafic phenocrysts as well as secondary feldspars are tabulated.

42 Broxton, D.E., et al., 1986, Chemistry of diagenetically altered tuffs at a potential nuclear waste repository, Yucca Mountain, Nye County, Nevada: Los Alamos National Laboratory report LA-10802-MS, Los Alamos, NM, 160 p.
This report describes the chemistry of diagenetically altered tuffs at a potential nuclear waste repository in Yucca Mountain. The degree of chemical variability within the diagenetically altered tuffs and within diagenetic minerals is described.

43 Bulmer, B.M., 1980, Pretest thermal analysis of the tuff water migration/*in situ* heater experiment: Sandia National Laboratories report SAND-79-1278, Albuquerque, NM, 43 p.
The pretest thermal analysis for the tuff water migration/*in situ* heater experiment to be conducted in welded tuff in G-Tunnel, Rainier Mesa, is presented. The parametric thermal modeling considers variable boiling temperature, tuff thermal conductivity, tuff emissivity, and heater operating power.

44 Bunker, C.M., Diment, W.H., and Wilmarth, V.R., 1960, Distribution of gamma-radioactivity, radioactive glass, and temperature surrounding the site of the Rainier underground nuclear explosion, Nevada: U.S. Geological Survey professional paper 400-B, p. 151-155.
The gamma radioactivity, temperature distribution, and radioactive glass distribution for the Rainier explosion conducted within U12b tunnel are briefly presented here.

45 Burchfiel, B.C., 1966, Reconnaissance geologic map of the Lathrop Wells 15-minute quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-474.
This map contains preliminary geologic investigations for southern Yucca Mountain and Lathrop Wells.

46 Bush, C.A., Bunker, C.M., and Spengler, R.W., 1983, Radioelement distribution in drillhole USW G-1, Yucca Mountain, Nevada: U.S. Geological Survey open-file report 83-847, 15 p.
The radioelement content (radium equivalent uranium (RaeU), thorium, and potassium) of samples collected from drillhole USW G-1 was measured to characterize the geologic units penetrated by the hole, to determine the homogeneity of the units, and to ascertain where redistribution of the radio elements may have occurred.

47 Byerlee, J., Morrow, C., and Moore, D., 1983, Permeability and pore-fluid chemistry of the Bullfrog Tuff in a temperature gradient: summary of results: U.S. Geological Survey open-file report 83-475, 26 p.
The purpose of this project is to investigate the changes that take place with time when groundwater comes in contact with heated rock, and to determine the ease with which potential radionuclide-bearing groundwater could be carried into the environment. The permeability and fluid chemistry of the Bullfrog Tuff is studied under conditions resembling a nuclear waste repository.

48 Byers, F.M., 1961, Porosity, density, and water content data on tuff of the Oak Spring Formation from the U12e tunnel system, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey report TEI-811, 37 p.
This report summarizes the porosity, density and water content of the tunnel beds found within U12e tunnel, Rainier

Mesa. The average porosity ranges from 25 to 40 % and generally increases stratigraphically upward. The natural-state bulk density ranges from about 2.10 g/cc in the oldest units to 1.85 g/cc in the youngest unit. The mineral density ranges from 2.3 to 2.5 g/cc and the average water content ranges from 14 to 21 % by weight. Frequency distributions and statistical parameters are shown graphically for each property and stratigraphic unit.

49 **Byers, F.M., Jr., 1985, Petrochemical variation of Topopah Spring tuff matrix with depth (stratigraphic level), Drillhole USW G-4, Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-10561-MS, 38 p.**

Core from hole USW G-4 was examined for petrochemical variation as a function of depth within the Topopah Spring Member of the Paintbrush Tuff. The results show that the petrographic textures and chemistry of the matrix vary systematically within recognizable lithologic subunits related to crystallization zones, welding zones, and compositional zones.

50 **Byers, F.M., Carr, W.J., Orkild, P.P., Quinlivan, W.D., and Sargent, K.A., 1976, Volcanic suites and related cauldrons of Timber Mountain-Oasis Valley Caldera complex, southern Nevada: U.S. Geological Survey professional paper 919, 70 p.**

A detailed geologic description of the tuffaceous units produced by the Timber Mountain-Oasis Valley Caldera complex is given. This descriptions include the occurrence and known areal extent of the formations and a summarized geologic history of the complex.

51 **Byers, F.M., and Moore, L.M., 1987, Petrographic variation of the Topopah Spring Tuff matrix within and between cored drillholes, Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-10901-MS, Los Alamos, NM, 73 p.**

This study extends the petrographic zonation of the devitrified rhyolitic tuff matrix of the Topopah Spring Member of the Paintbrush Tuff observed in USW G-4 to four other cored holes in the Yucca Mountain area of the Nevada Test Site: UE-25a#1, USW G-1, USW G-2, and USW G-3. Four petrographic zones are discussed.

52 **Byers, F.M. Jr., Warren, R.G.,1983, Revised volcanic stratigraphy of drillhole J-13, Fortymile Wash, Nevada, based on petrographic modes and chemistry of phenocrysts: Los Alamos National Laboratory LA-9652-MS, Los Alamos, NM, 23 p.**

The core and cuttings of water well J-13 below the lower contact of the Paintbrush Tuff at 1475 ft. to the total depth of 3498 ft. have been reexamined in the light of recent core drilling at Yucca Mountain. An updated stratigraphic log is presented, showing the position of cored intervals and sample locations. The units were identified by thin-section modal analysis and by electron microprobe analyses of the feldspar and biotite phenocrysts.

53 **Campbell, K., 1987, Lateral continuity of sorptive mineral zones underlying Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-11070-MS, Los Alamos, NM, 44 p.**

This report analyzes compositional data obtained by x-ray powder diffraction for several hundred samples from 14 drillholes in the vicinity of Yucca Mountain. Mineralization is compared with the functional stratigraphy for the region proposed by Ortiz, *et al.* (1985). Three major zeolitized intervals below the Topopah Spring Member of the Paintbrush Tuff are of particular interest because of their potential to retard the transport of dissolved radionuclides. No significant lateral trends in total zeolitization within these units are noted in the neighborhood of the exploration block, but there are trends in the abundances of the individual zeolites. Local variation is common.

54 **Caporuscio, F., et al., 1982, Petrologic studies of drill cores USW-G2 and UE25b-1H, Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-9255-MS, Los Alamos, NM, 111 p.**

Petrographic and x-ray diffraction studies of the two drill cores from these two wells are presented in this report and indicate that tuffs are partially recrystallized to secondary minerals. Correlations of stratigraphy are also made with previous drill cores from Yucca Mountain.

55 **Caporuscio, F.A., Warren, R.G., and Broxton, D.E., 1985, Detailed petrographic descriptions and microprobe data for Tertiary silicic volcanic rocks in drillhole USW G-1, Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-9323-MS, Los Alamos, NM, 78 p.**

This report contains detailed petrographic descriptions of 74 thin sections from drillhole USW G-1 at Yucca Mountain. These descriptions are keyed to the distinctions between devitrified, vitric and zeolitized intervals below the Topopah Spring Member repository horizon.

56 **Caporuscio, F.A., and Vaniman, D.T., 1985, Iron and manganese in oxide minerals and in glasses, preliminary consideration of Eh buffering potential at Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-10369 -MS, Los Alamos, NM, 29 p.**

The rock components that may affect the oxygen content of groundwater include Fe-Ti oxides, Mn oxides, and glasses that contain ferrous iron. The ability of these various minerals to affect the Eh of the groundwater is discussed. the results indicate that the minerals and glasses may have little or no capacity for reducing oxygen-rich groundwater at Yucca Mountain.

57 **Carlos, B.A., 1985, Minerals in fractures of the unsaturated zone from drill core USW G-4, Yucca Mountain, Nye County, Nevada: Los Alamos National Laboratory report LA-10415 -MS, Los Alamos, NM, 55 p.**

The mineralogy of fractures in drill core USW G-4, from a depth of nearly 800 ft. to the static water level at 1770 ft, was examined to determine the sequence of deposition and identity of minerals that might be natural barriers to radionuclide migration from a nuclear waste repository. Mordenite was found to be present, though not abundant, at the top of the lower lithophysal zone of the Topopah Spring Member of the Paintbrush Tuff. Heulandite occurs from about 1245 to 1378 ft, and clinoptilolite occurs alone or with mordenite below 1378 ft. Smectite in fractures is abundant only in the vitrophyre of the Topopah Spring Member of the Paintbrush Tuff and at the top of the Prow Pass Member of the Crater Flat Tuff. Similarities between fracture mineralogy and host-rock alteration in the nonwelded zeolitic units of the Topopah Spring Member suggest that this zone was once below the water table. The difference between microcrystalline (>= 0.01 mm) fracture coatings in the vitric zone and the mostly cryptocrystalline (<= 0.01 mm) fracture coatings in the zeolitic zone also suggests that the conditions under which these two types of linings formed were different. Nonwelded glass shards preserved in the host rock above the zeolite mineral transition in the fractures indicate that the water table was never higher than the lithic-rich base of the Topopah Spring Member in the vicinity of USW G-4.

58 **Carlos, B.A., 1986, Occurrence of fracture-lining manganese minerals in silicic tuffs, Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-UR-86-1412, Los Alamos, NM, 5 p.**

Drillhole USW G-4 was chosen for a detailed study of fracture filling minerals because it is closest to the planned NNWSI exploratory shaft site.

59 **Carlos, B.A., 1987, Minerals in fractures of the saturated zone from drill core USW G-4, Yucca Mountain, Nye County, Nevada: Los**

Alamos National Laboratory report LA-10927-MS, Los Alamos, NM, 32 p.

The minerals in fractures found in drill core USW G-4, from the static water level at 1770 ft. to the base of the hole at 3000 ft. were studied to determine their identity and depositional sequence and to compare them with those found above the SWL in the same drillhole.

60 Carr, M.D., et al., 1986, Geology of drillhole UE25p#1, a test hole into pre-Tertiary rocks near Yucca Mountain, southern Nevada: U.S. Geological Survey open-file report USGS-OF-86-175, 87 p.

The results of a geological investigation of drillhole UE25p#1 is presented. This drillhole is located on the eastern flank of Yucca Mountain.

61 Carr, W.J., 1974, Summary of tectonic and structural evidence for stress orientation at the Nevada Test Site: U.S. Geological Survey open-file report 74-176, 53 p.

A tectonic synthesis of the Nevada Test Site region, when combined with seismic data and a few stress and strain measurements, suggests a tentative model for stress orientation. This model proposes that the Nevada Test Site is undergoing extension in a N. 50° W.-S. 50° E. direction coincident with the minimum principal stress orientation. It is inferred that the stress episode resulting in the formation of deep alluvium-filled trenches began somewhere between 10 and less than 4 m.y. ago in the Nevada Test Site and is currently active.

62 Carr, W.J., 1984, Regional structural setting of Yucca Mountain, southwestern Nevada, and late Cenozoic rates of tectonic activity in part of the southwestern Great Basin, Nevada and California: U.S. Geological Survey open-file report 84-854, 109 p.

The regional structural setting of the southwestern Great Basin, with special emphasis on Yucca Mountain, is presented in detail.

63 Carr, W.J., 1982, Volcano-tectonic history of Crater Flat, southwestern Nevada, as suggested by new evidence from drillhole USW-VH-1 and vicinity: U.S. Geological Survey open-file report 82-457, 23 p.

New evidence for a possible resurgent dome in the caldera related to eruption of the Bullfrog Member of the Crater Flat Tuff has been provided by recent drilling of a 762 m hole in central Crater Flat. Although no new volcanic units were penetrated by the drillhole (USW-VH-1), the positive aeromagnetic anomaly in the vicinity of the drillhole appears to result in part from the unusually thick, densely welded tuff of the Bullfrog Member. Major units penetrated include alluvium, basalt of Crater Flat, Tiva Canyon and Topopah Spring Members of the Paintbrush Tuff, and Prow Pass and Bullfrog Members of the Crater Flat Tuff. In addition, the drillhole provided the first subsurface hydrologic information for the area. The water table in the hole is at about 180 m and the thermal gradient appears slightly higher than normal for the region.

64 Carr, W.J., Byers, F.M. Jr, and Orkild, P.P., 1986, Stratigraphic and volcano-tectonic relations of Crater Flat Tuff and some older volcanic units, Nye County, Nevada: U.S. Geological Survey professional paper 1323, 28 p.

The Crater Flat Tuff is herein revised to include a newly recognized lowest unit, the Tram Member, exposed at scattered localities in the southwestern Nevada Test Site region and in several drillholes in the Yucca Mountain area.

65 Carr, W.J., and Parrish, L.D., 1985, Geology of drillhole USW VH-2, and structure of Crater Flat, southwestern Nevada: U.S. Geological Survey open-file report 85-475, 41 p.

USW VH-2 was drilled into Crater Flat in order to delineate the geology and structure of the area. This drillhole penetrated a section of Timber Mountain, Paintbrush, and the upper part of the Crater Flat Tuffs.

66 Carrol, R.D., 1986, Shear-wave velocity measurements in volcanic tuff in Rainier Mesa tunnels, Nevada Test Site, Nevada: U.S. Geological Survey report USGS-474-3[illegible], 24 p.

Evidence indicates that in the geologic environment of the Rainier Mesa tunnels a shear wave is consistently generated and recorded on vertical geophones regardless of the energy source.

67 Carroll, R.D., 1983, Seismic velocities and postshot properties in and near chimneys: in Proceedings of the Monterey Containment Symposium, August 26-27, 1981, Los Alamos National Laboratory report LA-9211-C, Los Alamos, NM, 417 p.

Changes in the zeolitized tuff in Rainier Mesa, Nevada Test Site, resulting from a nuclear explosion suggest the presence of four regions at progressive ranges from the working point: 1) the chimney rubble, 2)a zone of pervasive microfailure immediately adjacent to the chimney, 3) a zone of pervasive microfailure, and 4) a zone of discrete or localized failure. Postshot seismic velocity measurements made at tunnel level for seven nuclear events indicate that the shear-wave velocity is definitive of three of these zones.

68 Carroll, P.I., Caporuscio, F.A., and Bish, D.L., 1981, Further description of the petrology of the Topopah Spring Member of the Paintbrush Tuff in drillholes UE25A-1 and USW-G1 and of the lithic rich tuff in USW-G1, Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-9000-MS, Los Alamos, NM, 26 p.

The purpose of this report is to provide a complete stratigraphic and petrologic description of the Topopah Spring Member and the lithic-rich tuff found in the Paintbrush Tuff unit as encountered in these two drillholes.

69 Carroll, R.D., and Cunningham, M.J., 1980, Geophysical investigations in deep horizontal holes drilled ahead of tunnelling: International Journal of Rock Mechanics Mineralogical Science and Geomechanics Abstracts, vol. 17, p. 89-107.

The U.S Geological Survey has developed geophysical logging techniques for obtaining resistivity and velocity data from horizontal exploratory drillholes drilled ahead of tunnelling. The purpose of the logging measurements is to define clay zones, because of the unstable ground conditions such zones present to tunnelling and to define zones of partially saturated rock, because of the attenuating effects such zones have on the shock wave generated by a nuclear detonation.

70 Carroll, R.D., and Kibler, J.E., 1983, Source-book of locations of geophysical surveys in tunnels and horizontal holes including results of seismic refraction surveys, Rainier Mesa, Aqueduct Mesa and Area 16, Nevada Test Site: U.S. Geological Survey open-file report 83-399, 85 p.

This report documents seismic refraction studies, both shear and compressional wave velocities and electrical surveys, that have been conducted in Rainier Mesa, Aqueduct Mesa, and Shoshone Mountain tunnel complexes since the 1950s. Synthesis of the seismic refraction data indicates a mean compressional wave velocity near the work point of 23 tunnel events of 2340 m/s with a range of 1876-2753 m/s. The mean shear wave velocity of 17 tunnel events is 1276 m/s with a range of 1140-1392 m/s. Experience indicates that these velocity variations are due chiefly to the extent of fracturing and/or the presence of partially saturated rock in the region of the survey.

71 Carroll, R.D., and Magner, J.E., 1986, Postshot seismic investigations in the vicinity of the Midas Myth event, U12t.04 drift, Nevada Test Site, Nevada: U.S. Geological Survey open-file report 86-98, 42 p.

Seismic velocity investigations were undertaken in an attempt to help explain ground-shock damage that occurred in an underground recording alcove as a result of the Midas Myth nuclear explosion. The results can be explained qualitatively in terms of the velocity theory of Crampin (1978) for wet and dry fracture sets and suggest the existence of a biplanar fracture system parallel and normal to the alcove orientation. Although the refraction data can be explained in terms of an apparent dipping low-velocity layer on the skin of the tunnel, it is felt that the results represent some as yet un-modelled fracture phenomenon resulting in detachments peculiar to the skin of the underground opening.

72 Cattermole, J.M., and Hansen, W.R., 1962, Geologic effects of the high-explosive tests in the USGS tunnel area, Nevada Test Site: U.S. Geological Survey professional paper 382-B, 31 p.

The pre- and postshot geology of the USGS explosive tests conducted in Rainier Mesa is documented as is the phenomenology of a 10 and 50 ton high explosive underground test. An equation relating amount of explosive to depth of containment was developed:

$$D = k\sqrt[3]{W}$$

where D=depth of cover in feet, k=constant, W=weight of explosive in pounds.

73 Christensen, R.C., and Spahr, N.E., 1980, Flood potential of Topopah Wash and tributaries, eastern part of Jackass Flats, Nevada Test Site, southern Nevada: U.S. Geological Survey Water Resources Investigations open-file report 80-963, 22 p.

Flood-prone areas for the three floods with present natural channel conditions were defined for the eastern part of Jackass Flats in the southwestern part of the Nevada Test Site. The effects of the 100, 500, and maximum flood hazards were determined for this area.

74 Church, H.W., Freeman, D.L., Boro, K., and Egami, R.T., 1984, Meteorological tower data for the Nevada Nuclear Waste Storage Investigations (NNWSI)-quarterly report, July-September, 1982 Yucca Alluvial (YA) Site: Sandia National Laboratories report SAND83-1912, Albuquerque, NM, 23 p.

The meteorological tower data for the Yucca alluvial site on Yucca Mountain are presented. The type of data presented are wind direction and speed, barometric pressure, temperature, relative humidity, solar radiation, ground IR radiation, precipitation and soil temperature.

75 Church, H.W., Freeman, D.L., Boro, K., and Egami, R.T., 1984, Meteorological tower data for the Nevada Nuclear Waste Storage Investigations (NNWSI)-quarterly report, October 1982-June 1983 Yucca Alluvial (YA) Site: Sandia National Laboratories report SAND84-1327, Albuquerque, NM, 65 p.

The meteorological tower data for the Yucca alluvial site on Yucca Mountain are presented. The type of data presented are wind direction and speed, barometric pressure, temperature, relative humidity, solar radiation, ground IR radiation, precipitation and soil temperature.

76 Church, H.W., Freemen, D.L., Boro, K., 1986, Meteorological tower data Yucca Ridge site January-June 1983: Sandia National Laboratories report SAND85-1053, Albuquerque, NM, 41 p.

This report is the first in a series of meteorological data summaries for the Yucca Ridge site.

77 Church, H.W., Freeman, D.L., Boro, K., and Egami, R.T., 1987, Meteorological tower data for the Yucca Alluvial (YA) site and Yucca Ridge (YR) site, Sandia National Laboratories, Sandia National Laboratories report SAND86-2533-UC-70, Albuquerque, NM, 12 p.

The purpose of the NNWSI meteorological data collection program was to support environmental evaluations of site suitability for a nuclear waste repository. This is the last of a series of data summaries for the NNWSI alluvial and ridge sites in southern Nevada, and covers the sixteen-month period of July, 1983 through October, 1984 for both sites.

78 Claassen, H.C., 1973, Water quality and physical characteristics of Nevada Test Site water-supply wells: U.S. Geological Survey report USGS-474-158, 145 p.

Chemical, radiochemical, and hydraulic data obtained from the water-supply wells at the Nevada Test Site are presented. Time variations in these parameters are discussed and evaluated. A diagrammatic representation of well construction and lithology penetrated is included for each well.

79 Claassen, H.C., 1983, Sources and mechanisms of recharge for groundwater in the west-central Amargosa Desert, Nevada— a geochemical interpretation: U.S. Geological Survey open-file report 83-542, 61 p.

Groundwater in the west-central Amargosa Desert, Nevada, was recharged primarily by overland flow of snowmelt in or near the present-day stream channels, rather than by subsurface flow from highland recharge areas to the north. Geochemical arguments, including reaction mechanisms, are used to support these findings. Carbon, hydrogen, and oxygen isotope data show that much of the recharge in the area occurred during the late Wisconsin time. Absence of groundwater recharged prior to late Pliestocene is considered to indicate that either climatic conditions were unfavorable for recharge or that groundwater velocities were such that this earlier recharge was transported away from the study area.

80 Claassen, H.C., and White, A.F., 1978, Application of geochemical kinetic data to groundwater systems— a tuffaceous-rock system in southern Nevada: in Jenne, E.A., [ed.], *Chemical Modeling in Aqueous Systems*, American Chemical Society, p771-791.

Kinetic modeling was used to estimate the effective surface area of an aquifer in contact with a unit volume of groundwater for Rainier Mesa. The results indicate that only a small part of the total interconnected pore space is available for transport of water. Laboratory and field data indicate that only the vitric phase has a significant influence on groundwater composition. Simulated mass transfer rates were significantly improved when the model was modified to account for precipitation of montmorillonite. Estimates of surface area per unit volume from the kinetic model are about 3 percent of those obtained using the Braunauer, Emmett, and Teller equation.

81 Clebsch, A., 1960, Groundwater in the Oak Spring Formation and hydrologic effects of underground nuclear explosions at the Nevada Test Site: U.S. Geological Survey report TEI- 759, 29 p.

Several zones of perched groundwater have been identified in tuff of the Oak Spring Formation near the U12b tunnel complex in Rainier Mesa. Approximately 30 acre-ft drained from this tunnel system in about seven weeks. This water has a relatively high concentration of silica and low TDS. A nuclear test increases fracturing within a few hundred feet of the test cavity, thereby affecting permeability and storativity in a localized area. Within this zone some fission products are taken into solution by percolating groundwater, however, the contaminants are thought to be retarded.

82 Clebsch, A., 1961, Tritium-age of groundwater at the Nevada Test Site, Nye County,

Nevada: U.S. Geological Survey professional paper p. 122-125.

Estimates of groundwater retention time are attempted utilizing tritium produced by fusion devices. The retention time for a seep within U12e.05 drift within Rainier Mesa and a spring just northwest of the mesa indicates a retention time ranging from 0.8 to 6 years.

83 Clebsch, A., and Barker, F.B., 1960, Analysis of groundwater from Rainier Mesa, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey Trace Elements report TEI-763, 22p.

Chemical and radiological analysis of groundwater collected from wells, springs, and tunnel seeps within Rainier Mesa during the period of September 1957 to December 1959 is presented.

84 Cohee, G.V., West, W.S., 1965, Changes in stratigraphic nomenclature by the U.S. Geological Survey 1964: U.S. Geological Survey Bulletin 1224-A, p. A44-51

This paper reviews and changes the names of Tertiary rocks in the Nevada Test Site. The Paintbrush and Timber Mountain Tuffs are named and the Fapi Canyon Formation is changed to a Group. In addition, other changes are made in the stratigraphic nomenclature of other rock units.

85 Collins, E., O'Farrell, T.P., 1981, Annotated bibliography for biologic overview for the Nevada Nuclear Waste Storage Investigations, Nevada Test Site, Nye County, Nevada: EG&G report EGG 1183-2419, Goleta, CA, 44 p.

This report is a compilation of relevant current literature that deals with the flora and fauna in the vicinity of the project area. The goals of the report were to: 1) evaluate whether information on flora and fauna habitat requirements, distribution, abundance, importance to the ecosystem, and sensitivity to perturbations is sufficient to support environmental impact analyses; 2) determine whether sensitive species might be located within the project area; 3) identify biological data gaps; and 4) recommend further studies to provide information for an EIS.

86 Collins, E., O'Farrell, T.P., and Rhoads, W.A., 1982, Biologic overview for the Nevada Nuclear Waste Storage Investigations, Nevada Test Site, Nye County, Nevada: EG&G report no. EGG 1183-2428, Goleta, CA, 55 p.

The NNWSI project study area includes five major vegetation associations characteristic of the transitional area between the Mohave and Great Basin Deserts. A total of 32 species of reptiles, 66 species of birds and 46 species of mammals are known to occur. Fourteen sensitive species exist within this area.

87 Collins, E., and O'Farrell, T.P. 1985, 1984 biotic study of Yucca Mountain, Nevada Test Site, Nye County, Nevada: EG&G report EGG 10282-2057, Goleta, CA, 28 p.

The results of field investigations into the Yucca Mountain mammals are presented. The vertebrate populations of Yucca Mountain are described and estimates of background dosimetry are given.

88 Collins, E., and Rhoads, W.A., 1981, Field surveys for Lathyrus hitchcockianus at the Nevada Test Site and Bullfrog Hills: EG&G report EGG-1183-2431, Goleta, CA, 8 p.

Surveys to determine the condition of Lathyrus hitchcockianus, a plant of limited distribution, as it occurs in the Bullfrog Hills and at Yucca Mountain was conducted during the weeks of May 25 and June 1, 1980.

89 Collins, E., Sauls, M.L., and O'Farrell, 1983, Surveys for desert tortoise on the proposed site of a high-level nuclear waste repository at the Nevada Test Site: EG&G report Goleta, CA, 10 p.

Preliminary field surveys indicated the presence of the desert tortoise, a sensitive species within the ecosystem. A more detailed study is presented that indicated the desert tortoise can be expected in small numbers over a wide range of Mojavean and transitional habitats.

90 Connolly, J.R., and Keil, K., 1985, Field, petrologic, and geochemical relations of the Grouse Canyon Member of the Belted Range Tuff in the GTUF mechanics test area, U12g tunnel, Nevada Test Site: Sandia National Laboratories report SAND84-7206, Albuquerque, NM, 65 p.

This report summarizes the results of petrochemical studies of welded tuff in the G-Tunnel Underground Rock Mechanics Facility (GTUF) carried out in support of thermomechanical testing.

91 Connolly, J.R., et al., 1983, Petrology and geochemistry of the Grouse Canyon Member of the Belted Range Tuff, Rock-Mechanics Drift, U12g tunnel, Nevada Test Site: Sandia National Laboratories report SAND81-1970, Albuquerque, NM, 78 p.

This report summarizes the petrology and geochemistry of the Grouse Canyon Member of the Belted Range Tuff as exposed in G-Tunnel complex beneath Rainier Mesa. The report also considers potential correlation of data from G-Tunnel and the Topopah Spring Member of the Paintbrush Tuff at Yucca Mountain.

92 Connolly, J.R., et al., 1984, Petrology and geochemistry of samples from bed-contact zones in Tunnel Bed 5, U12g tunnel, Nevada test site: Sandia National Laboratories report SAND84-1060, Albuquerque, NM, 43 p.

This report summarizes the detailed geologic characterization of samples of bed-contact zones and surrounding nonwelded bedued tuffs, both within Tunnel Bed 5, that are exposed in the G-Tunnel complex beneath Rainier Mesa. Original planing studies treated the bed-contact zones in Tunnel Bed 5 as simple planar surfaces of relatively high permeability. Detailed characterization indicates that these zones have finite thickness, are depositional in origin, vary considerably over short vertical and horizontal distances, and are internally complex. The similarity in composition of the clinoptilolites from Tunnel Bed 5 and those above the static water level at Yucca Mountain indicates that many of the results of nuclide migration experiments in Tunnel Bed 5 would be transferable to zeolitized nonwelded tuffs above the static water level at Yucca Mountain.

93 Costin, L.S., and Chen, E.P., 1988, An analysis of the G-Tunnel heated block experiment using a compliant joint rock mass model: Sandia National Laboratories report SAND87- 1938C, Albuquerque, NM, 8 p.

The results of two-dimensional finite element analyses of the G-Tunnel heated block experiment are presented. Good quantitative agreement between the experimental and numerical results was obtained in most cases.

94 Craig, R.W., and Johnson, K.A., 1984, Geohydrologic data for test well UE-25p#1, Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey open-file report 84-450, 63 p.

Test well UE25p#1 is located on the east flank of Yucca Mountain and is completed within the carbonates. The following data are presented for this drillhole: drilling operations, lithology, availability of borehole geophysical logs, water levels, water chemistry, pumping tests, borehole-flow survey, and packer injection tests.

95 Craig, R.W., Reed, R.L., and Spengler, R.W., 1983, Geohydrologic data for test well USW H-6, Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey open-file report 83-856, 39 p.

This report presents the following data for test well USW H-6: drilling operations, lithology, availability of borehole geophysical logs, water levels, future availability of core analyses, water chemistry, pumping tests, and packer injection tests.

96 Craig, R.W., and Robison, J.H., 1984, Geohydrology of rocks penetrated by test well UE-25p#1, Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey Water Resources Investigations report 84-4248, 57 p.

The results of hydraulic testing and hydraulic monitoring of test well UE-25p#1 are presented. This drillhole is located on the eastern flank of Yucca Mountain. The data presented are as follows: water levels for various strata, borehole-flow surveys, conceptual model of groundwater flow, pump tests, recovery tests, packer injection tests, and groundwater chemistry.

97 Crowe, B.M., and Carr, W.J., 1980, Preliminary assessment of the risk of volcanism at a proposed nuclear waste repository in the southern Great Basin: U.S. Geological Survey open-file report 80-357, 15 p.

This report is chiefly concerned with characterizing the geology, chronology, and tectonic setting of Pliocene and Quaternary volcanism in the Nevada Test Site region, and assessing volcanic risk through consequence and probability studies, particularly with respect to a potential site in the southwestern Nevada Test Site.

98 Crowe, B.M., Johnson, M.E., and Beckman, R.J., 1982, Calculation of the probability of volcanic disruption of a high-level radioactive waste repository within southern Nevada, USA: Radioactive Waste Management and the Nuclear Fuel Cycle, vol. 3, no. 2, Dec. 1982, p 167-190.

Calculations of the probability of disruption of a repository at the Nevada Test Site by basaltic volcanic activity have been completed as one of a number of approaches to assessing the risk of volcanism. The results indicate an annual probability of disruption of the repository site at Yucca Mountain that ranges from 10^{-8} to 10^{-10}. The numbers are limited in application by the geologic assumptions necessary to allow the calculations.

99 Crowe, B., et al., 1982, Aspects of possible magmatic disruption of a high-level radioactive waste repository in southern Nevada: Los Alamos National Laboratory report LA-9326-MS, Los Alamos, NM, 43 p.

This paper describes the processes of basaltic magnetism on the Nevada Test Site. Each stage in the evolution and dispersal of basaltic magma is described, and the disruption and potential dispersal of radionuclides is evaluated.

100 Crowe, B.M., and Sargent, K.A., 1979, Major-element geochemistry of the Silent Canyon-Black Mountain peralkaline volcanic centers, northwestern Nevada Test Site, applications to an assessment of renewed volcanism: U.S. Geological Survey open-file report 79-926, 25 p.

The major-element geochemistry of the Black Mountain-Silent Canyon volcanic centers differs in the total range and distribution of O_2, contents, the degree of peralkalinity, and in the values of total iron and alumina through the range of rock types. These differences indicate that the suites were unrelated and evolved from differing magma bodies. The Black Mountain volcanic cycle represents a renewed phase of volcanism following cessation of the Timber Mountain-Silent Canyon volcanic cycles. Consequently, there is a small but numerically incalculable probability of recurrence of Black Mountain-type volcanism within the Nevada Test Site. This represents a potential risk with respect to deep geologic storage of high-level radioactive waste at the Nevada Test Site.

101 Czarnecki, J.B., 1984, Simulated effects of increased recharge on the groundwater flow system of Yucca Mountain and vicinity, Nevada-California: U.S. Geological Survey Water-Resources Investigations report 84-4344, 33 p.

A study was performed to assess the potential effects of changes in future climatic conditions on the groundwater system in the vicinity of Yucca Mountain by simulating the groundwater system using a two-dimensional, finite-element groundwater flow model. The simulated position of the water table rose as much as 130 m near the area of the repository for a simulation involving a 100-percent increase in precipitation.

102 Czarnecki, J.B., and Waddell, R.K., 1984, Finite-element simulation of groundwater flow in the vicinity of Yucca Mountain, Nevada-California: U.S. Geological Survey Water-Resources Investigations report 84-4349, 38 p.

A finite-element model of the groundwater flow system in the vicinity of Yucca Mountain at the Nevada Test Site was developed using parameter-estimation techniques. The model simulated steady-state groundwater flow occurring in tuffaceous, volcanic, and carbonate rocks, and alluvial aquifers. Hydraulic gradients in the modeled area range from 0.00001 for carbonate aquifers to 0.19 for barriers in tuffaceous rocks. Three modeled parameters were used in estimating transmissivities in six zones. Simulated hydraulic head values range from about 1200 m near Timber Mountain to about 300 m near Furnace Creek Ranch. Model residuals for simulated versus measured hydraulic heads range from -28.6 to 21.4 m; most are less than -7 m. Sensitivity analyses conducted on the effect of boundary fluxes on model transmissivities indicated that varying the discharge at Franklin Lake and Furnace Creek had the greatest effect.

103 Daily, W., Lin, W., and Buscheck, T., 1987, Hydrological properties of Topopah Spring Tuff— laboratory measurements: Journal of Geophysical Research, vol. 92, no. B8, p. 7854-7864.

The purpose of this work is to study the transport of liquid and vapor water from the Topopah Spring welded unit under conditions expected in the near-field environment of a high-level nuclear waste container. A naturally fractured sample of the Topopah Spring Tuff and well J-13 water were used. During the more than 6-month experiment duration, water permeability decreased by approximately three orders of magnitude. The most likely mechanism is the redeposition of silica in the fracture. Results also indicate that the sample dehydrates and rehydrates nonuniformly.

104 Daniels, J.J., and Scott, J.H., 1980, Borehole geophysical measurements for hole UE25a#3, Nevada Test Site, Nuclear Waste Isolation Program: U.S. Geological Survey open-file report 80-126, 31 p.

Borehole geophysical measurements made in drillhole UE25a#3 are presented in this paper. Well logs are presented for dual detector density, normal resistivity, gamma ray, neutron neutron, induced polarization, and magnetic susceptibility measurements.

105 Daniels, J.J., and Scott, J.H., 1981, Interpretation of hole-to-surface resistivity measurements at Yucca Mountain, Nevada Test Site: U.S. Geological Survey open-file report 81-1336, 23 p.

Hole-to-surface measurements from drillholes UE25a-1, -4, -5, and -6 illustrate procedures for gathering, reducing, and interpreting hole-to-surface resistivity. Measurements conducted at Yucca Mountain indicate the presence of many near surface geologic inhomogeneities, with no definite indication of deep structural features. A resistive anomaly near drillhole UE25a-6 is interpreted as a thin, vertical, resistive body that nearly intersects the surface, and may be caused by a silicified or calcified fracture zone. A resistive anomaly near UE25a-7 is probably caused by a near-surface, horizontal, lens-shaped body that may represent a devitrified zone in the Tiva Canyon Member. Conductive anomalies to the southwest of UE25a-4 were interpreted to be caused by variations in the thickness of the surface alluvium.

106 Daniels, J.J., Scott, J.H., and Hag[illegible], J.T., 1981, Interpretation of geophysical well-log measurements in drillholes UE25a#4, #5, #6, and

#7, Yucca Mountain, Nevada Test Site: U.S. Geological Survey open-file report 81-389, 28 p.
Exploratory drillholes UE25a#4, UE25a#5, UE25a#6, and UE25a#7 were drilled to determine the suitability of pyroclastic deposits as storage sites for radioactive waste. Resistivity, density, neutron, gamma-ray, induced polarization, and magnetic susceptibility well log measurements were taken from these drillholes. Some mineralogic features in the drillholes can be identified on the gamma ray, induced polarization, and magnetic susceptibility well logs.

107 Daniels, W.R., et al., 1982, Summary report on the geochemistry of Yucca Mountain and Environs: Los Alamos National Laboratory report LA-9328-MS, Los Alamos, NM, 364 p.
This report addresses the various aspects of sorption by tuff, physical and chemical makeup of tuff, diffusion processes, tuff/groundwater chemistry, water element chemistry under expected repository conditions, transport processes involved in porous and fracture flow, and geochemical and transport modeling.

108 Delany, J.M., 1985, Reaction of Topopah Spring Tuff with J-13 water: a geochemical modeling approach using the EQ3/6 reaction path code: Lawrence Livermore National Laboratory report UCRL-53631, Livermore, CA, 46 p.
EQ3/6 geochemical modeling code was used to investigate the interaction of the Topopah Spring Member and J-13 water at high temperatures. EQ3/6 input parameters were obtained from the results of laboratory experiments using USW G-1 core and J-13 water.

109 Dickey, D.D., 1960, Thermoluminescence of some dolomite, tuff, and granitic rock samples from the north-central part of the Nevada Test Site, Nye County, Nevada—a progress report: U.S. Geological Survey report TEI-765, 30 p.
Thermoluminescence was determined for tuff from Rainier Mesa, dolomite and a quartz vein from Dolomite Hill, and granitic rock from the Climax Stock in the northern part of the Nevada Test Site. The results of the study showed that dolomite, granitic rocks, and tuff are thermoluminescent, but further investigations are necessary before thermoluminescence can be proved useful in correlating rock units in this area or determining effects of nuclear explosions on the tuffaceous rocks.

110 Dickey, D.D., and Emerick, W.L., 1961, Interim report on on geologic investigations of the U12b tunnel system, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey report TEI-799: 13 p.
U12b tunnel is driven into the eastern flank of Rainier Mesa into the Oak Spring Formation. The chemistry, stratigraphy, and structure of the geologic units intercepted by the U12b tunnel complex are described.

111 Dickey, D.D., and Emerick, W.L., 1962, Interim geological investigations in the U12b.09 and U12b.07 tunnels, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey report TEI-797, 21 p.
U12b.09 and U12b.07 drifts of the U12b tunnel complex penetrate bedded tuff, welded tuff and tuffaceous sandstone of the Indian Trail and Piapi Canyon Formation. The stratigraphy, lithology, and structure of these units, as they occur within the two drifts, are described. The results of a gamma radioactivity survey within U12b.07 and U12b.09 drifts are also presented.

112 Diment, W.H., et al., 1958, Properties of Oak Spring Formation in Area 12 at the Nevada Test Site: U.S. Geological Survey report TEI-672.
Various physical parameters are reported for the Oak Spring Formation as it occurs in Rainier and Aqueduct Mesas. The parameters investigated are petrography, chemistry, porosity, density, fluid permeability, fracture permeability, water content, thermal and seismic properties, engineering properties, and radiochemical analysis.

113 Diment, W.H., et al., 1958, Geological survey investigations in the U12b.02 Tunnel, Nevada Test Site: U.S. Geological Survey report TEM-224, 34 p.
The geology, petrology, porosity, density and water content of the Oak Spring Unit 7 (Paintbrush Tuff) as it occurs within U12b.02 drift are reported. U12b tunnel is located on the eastern portion of Rainier Mesa and is located at an approximate altitude of 6650 ft.

114 Diment, W.H., et al., 1959, Geological effects of the Rainier underground nuclear explosion: U.S. Geological Survey report TEI-355,
The pre-shot stratigraphy, structure, physical properties, and hydrogeology are presented for U12b tunnel, the site of the detonation. The changes created by the Rainier event and its effect on structure, hydrogeology, chemistry, petrology, physical properties, and gravitational field are also discussed. The results of a survey of the gamma-radiation produced by the detonation of Rainier are also reported.

115 Diment, W.H., et al., 1959, Geological Survey investigations in the U12b.03 and U12b.04 tunnels, Nevada Test Site: U.S. Geological Survey report TEM-996, 75 p.
The stratigraphy, structure, petrology, porosity, density, water content, and groundwater occurrence and chemistry for the U12b.03 and U12b.04 drifts within Rainier Mesa are reported.

116 Diment, W.H., et al., 1959, Geological survey investigations in the U12e.05 tunnel, Nevada Test Site: U.S. Geological Survey report TEM-997, 70 p.
The stratigraphy, structure, petrology, porosity, density, water content and chemical nature of the area directly surrounding the shot chamber are described.

117 Diment, W.H., et al., 1959, Geological survey investigations in the U12b.01 tunnel, Nevada Test Site: U.S. Geological Survey report TEM-998, 39 p.
The stratigraphy, structure, petrology, porosity, density, and water content of the U12b.01 drift are described.

118 Dixon, G.L., Sargent, K.A., and Carr, W.J., 1975, Changes in stratigraphic nomenclature by the U.S. Geological Survey, 1975: U.S. Geological Survey Bulletin 1422-A, p. 49-54.
This report documents the abandonment of the Indian Trail Formation so that the individual units can be correlated to others of the Test Site.

119 Doyle, A.C., and Meyer, G.L., 1925, Summary of hydraulic data and abridged lithologic log of groundwater test well 6(J-13) Jackass Flats, Nevada Test Site, Nevada: U.S. Geological Survey Technical Letter NTS-50.
The hydraulic, geochemical, and lithologic data are presented for well J-13, which is located several miles east of Yucca Mountain.

120 Dulmstra, C.O., 1981, *In situ* water migration/heater experiment-hardware mechanical design definition: Sandia National Laboratories report SAND-81-1048, Albuquerque, NM, 116 p.
This report summarizes and documents the final design of the heater assembly, instrumentation placement, and packers used at the G-Tunnel site.

121 Eakin, T.E., Schoff, S.L., and Cohen, P., 1963, Regional hydrology of a part of southern Nevada, a reconnaissance: U.S. Geological Survey report TEI-833, 40 p.
The groundwater hydrology of a region of 11,700 mi^2 encompassing the Nevada Test Site is reviewed on the basis

of data that are limited except at the Test Site. The direction of movement of the groundwater is inferred from hydraulic gradients, relations of discharge to recharge areas, geologic conditions, and aqueous chemistry. These data suggest that the water moves generally southward or southwestward through the region but in a complex manner governed by differential primary and secondary permeabilities of Cenozoic volcanic and Paleozoic carbonate rocks and by multiple sources of recharge and discharge. The movement of groundwater through the bedrock between basins seems to be a significant element in the hydrologic system.

122 **Eaton, R.R., and Bixler, N.E., 1986, Analysis of a multiphase, porous-flow imbibition experiment in fractured volcanic tuff: Sandia National Laboratories report SAND86-1679C, Albuquerque, NM, 18 p.**

A sub-meter-scale imbibition experiment has been analyzed using a finite element, multiphase-flow code. In the experiment, an initially dry cylindrical core of fractured tuff was saturated by contacting the ends with pressurized water. The model used discretely accounts for three primary fractures that may be present in the core. Results show that vapor transport has a small (less than 5%) effect on the speed of the wetting front. By using experimental results to estimate apparent spatial variations in permeability along the core, good agreement with measured, transient, saturation data was achieved. The sensitivity of predicted transient wetting fronts to permeability data indicates a need for more extensive measurements. It is concluded that it will be difficult to characterize an entire repository, where inhomogeneities due to variations in matrix and fracture properties are not well known, solely from the results of sub-meter-scale laboratory testing and deterministic modeling.

123 **Eaton, R.R., et al., 1983, *In situ* tuff water migration/heater experiment post-test thermal analysis: Sandia National Laboratories report SAND81-0912, Albuquerque, NM, 71 p.**

This report describes post-test laboratory experiments and thermal computations for the *in situ* heater experiment conducted in G-Tunnel. Post-test laboratory experiments were designed to determine the accuracy of the temperatures measured by the rock wall thermocouples during the *in situ* test. The results indicate that the true rock wall temperatures were 10 to 20°C lower than the measured values.

124 **Ege, J.R., 1977, *In situ* stress measured at Rainier Mesa, Nevada, and a few geologic implications: PhD Dissertation, Colorado School of Mines, 172 p.**

Thirteen measurements of the three-dimensional stress field were obtained in several of the tunnels in Rainier Mesa. The maximum stress ranges from 117.2 to 65.8 bars, the intermediate stress ranges from 68.0 to 46.8 bars, and the minimum stress ranges from 42.6 to 13.8 bars. The maximum and intermediate principal stresses lie in a northeast trending plane that is vertical to 45° inclined. These stress field data were related to local geology, faulting, and tectonics.

125 **Ege, J.R., Carroll, R.D., 1980, Magner, J.E., and Cunningham, D.R., U.S. Geological Survey investigations in the U12n.03 drift, Rainier Mesa, Area 12, Nevada Test Site: U.S. Geological Survey open-file report 80-1074, 29 p.**

U12n.03 lies entirely within subunit 4 of the Miocene Tunnel beds. Parallel faults and clay rich tuff were encountered beneath the aqueduct syncline which created severe ground support and construction problems. This drift was eventually abandoned as a nuclear test site. Flows of up to 208 l/min were encountered initially. These flows have dropped to approximately 1.3 l/min.

126 **Ege, J.R., and Cunningham, M.J., 1976, Geology of the U12n.10 UG-1 horizontal drillhole, Rainier Mesa, Area 12, Nevada Test Site, Nevada: U.S. Geological Survey report USGS-474-218, 21p.**

The U12n.10 UG-1 horizontal exploratory hole was collared at Nevada State coordinates N. 895,008.84, E. 633,702.99 at an altitude of 1850.8 m within the tunnel beds of Rainier Mesa. This report contains stratigraphic, structural, geophysical and mechanical property data.

127 **Ege, J.R., Danilchick, W., and Feazel, C.T., 1980, Geology of the U12n.02 (Midi Mist) drift and Postshot observations, Rainier Mesa, Area 12, Nevada Test Site: U.S. Geologic Survey report USGS-474-229 (Area 12-45), 21 p.**

U12n.02 drift penetrates tunnel bed subunits 4AB, 4CD, 4E, 4F, 4G, 4H, and 4J. Two faults mapped on the surface of Rainier Mesa were identified as having cut the U12n tunnel complex at drift level. Visual inspection showed that shot-induced effects in the rock medium at the drift level extended for 237.7 m from the work point in the form of fractures and small shear displacements along bedding planes.

128 **Ege, J.R., Dodge, H.W., Miller, D.R., and Magner, J.E., 1976, Determination of *in situ* stress in U12t.02 SRI Alcove, Aqueduct Mesa, Nevada Test Site: U.S. Geological Survey report USGS-474-236 (Area 12-34), 16 p.**

Stress-relief borehole-deformation measurements were made in the U12t.02 drift. All stresses were found to be compressive. The calculated vertical-stress component of 65.6 bars is consistent with the estimated vertical stress attributed to overburden. The maximum principal stress (65.8 bars) trends N. 74° E. and is 4° off the vertical. The minimum stress (26.0 bars) trends S. 62° E. and is 3° below horizontal. These trends are similar to other stress measurements made at the Nevada Test Site

129 **Ege, J.R., Miller, D.R., and Danilchick, W., 1970, Schmidt hammer test method for field determination of physical properties of zeolitized tuff: U.S. Geological Survey open-File report 70-117, 23 p.**

This report documents the applicability of the L-type schmidt hammer on zeolitized tuff. Field testing of the device in Area 12 yielded rock strength values for Rainier Mesa.

130 **Eglinton, T.W., and Dreicer, R.J., 1984, Meteorological design parameters for the candidate site of a radioactive-waste repository at Yucca Mountain, Nevada: Sandia National Laboratories report SAND84-0440/2, Albuquerque, NM.**

A collection of meteorological information and data for the design and construction of an installation at the candidate location of a repository for radioactive waste at Yucca Mountain is presented. Climate and weather data provided in this summary that are essential to the proper architectural engineering of surface and subsurface facilities and scheduling of repository activities include: precipitation, lightning, temperature, relative humidity, solar radiation, cloud coverage, wind, and air pressure.

131 **Ehgartner, B.L., 1987, Sensitivity analyses of underground drift temperature, stresses, and safety factors to variation in the rock mass properties of tuff for a nuclear waste repository located at Yucca Mountain, Nevada: Sandia National Laboratories report SAND86-1250, Albuquerque, NM, 38 p.**

Preliminary two-dimensional thermal and thermal/mechanical sensitivity analyses of the design of the horizontal emplacement drift were performed for times out to 100 years after waste emplacement. The purpose of the analysis is to provide insight into the relative importance of the thermal and thermal/thermal mechanical properties that impact the stability of the emplacement drift, specifically: heat capacity, conductivity, thermal expansion, *in situ* thermal gradient, *in situ* stress, joint cohesion, and friction angle, elastic modules, Poisson's ratio, rock friction angle, and rock compressive and tensile strength. Results indicate that the design of the horizontal emplacement drift can tolerate the expected

variability in the thermal and thermal mechanical properties.

132 Ekren, E.B., 1968, Geologic setting of Nevada Test Site and Nellis Air Force Range: In Eckel, E.B., Nevada Test Site: Geological Society of America Memoir 110, p77-86.
The general stratigraphy, structure, geologic history and economic deposits of the Nevada Test Site are briefly discussed.

133 Ekren, E.B., Anderson, R.E., Rogers, C.L., and Noble, D.C., 1971, Geology of the northern Nellis Air Force Base Bombing and Gunnery Range, Nye County, Nevada: U.S. Geological Survey professional paper 651, 91 p.
The stratigraphy and structure of a 2,400 mi^2 area directly north of Rainier Mesa are described. The area is composed of dominantly Tertiary volcanic rocks. A brief description of several mines and prospects within the area is given as well

134 Ellis, W.L., and Ege, J.R., 1975, Determination of *in situ* stress in U12g tunnel, Rainier Mesa, Nevada Test Site, Nevada: U.S. Geological Survey report USGS-474-219, 18 p.
Stress relief borehole-deformation measurements utilizing the overcore technique were made at a depth of 442 m below Rainier Mesa. All stresses were compressive. The calculated vertical stress is 67 bars. The maximum principal stress (65 bars) trends N. 21° E. and the minimum principal stress (26 bars) trends N. 68° W.; both are nearly horizontal.

135 Ellis, W.L., and Kibler, J.D., 1983, Explosion-induced stress changes estimated from vibrating-wire stressmeter measurements near the Mighty Epic event, Nevada Test Site: U.S. Geological Survey open-file report 83-642, 25 p.
Explosion-induced compressive stresses have been predicted by computer calculations, but have never been confirmed by field measurements. Vibrating-wire stressmeter measurements made near the Mighty Epic nuclear detonation, however, qualitatively indicate that within 150 m of the working point, permanent compressive stress increases of several megapascals were present 15 weeks after the event. Variations between the calculated and measured value did occur. For the range of field measurements from the working point, the computer model predicted the largest stress change to be radial from the detonation point while field data indicate the transverse component of stress change to be the most compressive.

136 Ellis, W.L., and Magner, J.E., 1980, Compilation of results of three-dimensional stress determinations made in Rainier and Aqueduct Mesas, Nevada Test Site, Nevada: U.S. Geological Survey open-file report 80-1098, 27 p.
Since 1971, the U.S. Bureau of Mines overcore method has been used to determine stress at nine locations within Rainier and Aqueduct Mesa. Results indicate a generally consistent pattern of relatively high stress in a northeast southwest direction and relatively low stress in a northwest southeast direction within the mesas. The pattern is consistent with estimates of the regional stress orientation based on geological and geophysical evidence. The state of stress in Rainier and Aqueduct Mesas is probably tectonic in origin, with significant modifications in stress magnitude and orientation owing to the topography, elevations, and local geology of the measurement sites.

137 Ellis, W.L., and Swolfs, H.S., 1983, Preliminary assessment of *in situ* geomechanical characteristics in drillhole USW G-1, Yucca Mountain, Nevada: U.S. Geological Survey open-file report 83-401, 22 p.
Observations made during drilling and subsequent testing of the USW G-1 drillhole at Yucca Mountain provide qualitative insights into the *in situ* geomechanical characteristics of the layered tuff units penetrated by the hole.

138 Emerick, W.L., 1962, Interim Geological Investigations in the U12e.06 tunnel, Nevada Test Site, Nye County, Nevada, with a section on: Gamma-radioactivity: U.S. Geological Survey report TEI-773, 38 p.
The geology of the tunnel bed 4, as it occurs in U12e.06 drift is described. The structure, petrology, physical properties and chemical nature of the tuffs are described. A gamma radioactivity survey of the tuff was conducted within the drift. The results indicate that this method cannot be used for stratigraphic correlation, however it can determine radioisotope distribution resulting from nuclear tests. Anomalous radioactivity is apparently related to areas containing a higher degree of fracturing and faulting.

139 Emerick, W.L., and Dickey, D.D, 1962, Interim geological investigations in the U12e.03a and U12e.03b tunnels, Nevada Test Site, Nye County, Nevada, with a section on gamma-radioactivity survey of U12e.03a tunnel by C.M. Bunker: U.S. Geological Survey report TEI-806, 26 p.
The U12e tunnel complex is driven southwestward beneath Rainier Mesa. The geologic investigations examined the nonwelded, zeolitized tuffs of the informal tunnel bed units. A gamma-radioactivity survey showed very little variation in the tuffs with respect to gamma radiation.

140 Emerick, W.L., Dickey, D.D., and Mckeown, F.A., 1962, Interim geological investigations in the U12e.04 tunnel, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey report TEI-776, 27 p.
U12e.04 drift was mined entirely in the E and F subunits of the tunnel beds. The stratigraphy, structure, lithology, chemistry and physical properties of the units intersecting this drift are described.

141 Emerick, W.L., and Houser, F.N., 1962, Interim geological investigations in the U12b.08 tunnel, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey report TEI-814, 23 p.
U12b.08 drift is part of the U12b tunnel complex driven into the eastern flank of Rainier Mesa within the Survey Butte Member of the Oak Spring Formation. The stratigraphy, structure, mineralogy, chemistry, and physical properties of the units intersected by the U12b.08 drift are presented

142 Erdal, B.R., et al., 1978, Sorption and migration of radionuclides in geologic media: Los Alamos National Laboratory report LA-UR-78-2746, Los Alamos, NM
The interactions of a quartz monzonite, an argillite, an alluvium, and several tuffs with various radionuclides in selected phreatic waters have been studied.

143 Erdal, B.R., et al., 1980, Parameters affecting radionuclide migration in geologic media: In Northrup, C.J.M., [edt], *Scientific Basis for Nuclear Waste Management*, Plenum Publishing Corporation, New York, NY, p. 609-616.
Studies conducted by Los Alamos National Laboratory on quartz monzonite porphyry (Climax stock), an argillite (Eleana Formation), and rhyolitic tuff (Jackass Flat) are presented. These studies are primarily concerned with sorption ratios and the parameters which affect it.

144 Erdal, B.R., et al., 1981, Nuclide Migration Field Experiments— Program Plan: Los Alamos National Laboratory report LA-8487-MS, Los Alamos, NM, 71 p.
A description of Los Alamos nuclide migration field studies is given. The field studies are an attempt to determine the parameters that control radionuclide migration in a tuffaceous environment similar to Yucca Mountain. The field experiments will be located within U12g tunnel in Rainier Mesa.

145 Erdal, B.R., et al., 1982, Some geo-chemical considerations for a potential repository site in tuff at Yucca Mountain: Los Alamos National Laboratory report LA-UR-83-1304, Los Alamos, NM, 20 p.

Geochemical considerations from Yucca Mountain are presented in order to show some of the geochemical factors that must be considered before any "guarantee" can be made that potential releases of radioactive contaminants will not affect the health and safety of present and future generations. Site specific tuff geochemical information that is important for site selection and repository performance is discussed.

146 Erickson, J.R., Waddell, R.K., 1985, Identification and characterization of hydrologic properties of fractured tuff using hydraulic and tracer tests: Test well USW H-4, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Water-Resources report 85-4066, 30 p.

The test well penetrates volcanic tuffs through which water moves primarily along fractures. Data collected from hydrologic and tracer tests and an acoustic-televiewer log, were used to quantify intrawell-bore flow directions and rates, permeability distribution, fracture porosity, and orientations of the hydraulic conductivity ellipsoid for the test well. This report also presents results and interpretations of hydrologic and tracer tests used to identify and characterize fractures contributing to groundwater flow in the well.

147 Fenix and Scisson, 1986, NNWSI hole histories UE-25a#1, UE-25a#3, UE-25a#4, UE-25a#5, UE-25a#6, UE-25a#7: Fenix and Scisson report DOE/NV/10322-9, Tulsa, OK, 63 p.

Data presented in this document includes the hole histories, locations, daily activities, coring records, review of hole conditions, and geophysical logs of drillholes UE-25a#1, UE-25a#3, UE-25a#4, UE-25a#5, UE-25a#6, UE-25a#7. These wells are located in Drillhole Wash, on the east flank of Yucca Mountain.

148 Fenix and Scisson, 1986, NNWSI hole history UE-25b#1: Fenix and Scisson report DOE/NV/10322-13, Tulsa, OK, 37 p.

Data presented in this document includes the hole histories, locations, daily activities, coring records, review of hole conditions, and geophysical logs of drillholes UE-25b#1.

149 Fenix and Scisson, 1986, NNWSI hole histories UE-25c#1, UE-25c#2, and UE-25c#3: Fenix and Scisson report DOE/NV/10322-14, Tulsa, OK, 59 p.

Data presented in this document includes the hole histories, geophysical log and video tape listings, and microfiche copies of all geophysical logs run in drillholes UE-25c#1, UE25c#2, UE25c#3 by Fenix and Scisson. These wells are located on Yucca Mountain.

150 Fenix and Scisson, 1986, NNWSI hole history UE-25h#1: Fenix and Scisson report DOE/NV/10322-15, Tulsa, OK, 14 p.

This borehole was drilled to provide continuous core samples for the geologic investigation of the Topopah Spring Member as a possible site for an adit in which to conduct nuclide migration field experiments. Data presented include location, daily activities, review of hole conditions, geophysical log listings, video tape listing and microfiche copies of all geophysical logs run by the F&S subcontractor.

151 Fenix and Scisson, 1986, NNWSI hole histories UE-25p#1: Fenix and Scisson report DOE/NV/10322-16, Tulsa, OK, 39 p.

Data presented include locations, daily activities, reviews of hole condition, geophysical log listings, video tape listings, and microfiche copies of all geophysical logs run by F&S subcontractors. This drillhole is located on the eastern flank of Yucca Mountain.

152 Fenix and Scisson, 1986, NNWSI hole histories UE-25 RF#1, UE-25 RF#2, UE-25 RF#3, UE-25 RF#3B, UE-25 RF#4, UE-25 RF#5, UE-25 RF#7, UE-25 RF#7A, UE-25 RF#8, UE-25 RF#9, UE-25 RF#10, UE-25 RF#11: Fenix and Scisson report DOE/NV/10322-11, Tulsa, OK, 60 p.

The 12 holes were drilled to provide samples and alluvial thickness determinations for the repository surface facilities, especially with respect to foundation conditions. Data presented in the hole histories include all locations, daily activities and review of hole conditions.

153 Fenix and Scisson, 1986, NNWSI hole histories UE-25 WT#3, UE-25 WT#4, UE-25 WT#5, UE-25 WT#6, UE-25 WT#12, UE-25 WT#13, UE-25 WT#14, UE-25 WT#15, UE-25 WT#16, UE-25 WT#17, UE-25 WT#18, USW WT-1, USW WT-2, USW WT-7, USW WT-10, USW WT-11: Fenix and Scisson report DOE/NV/10322-10, Tulsa, OK, 112 p.

Data presented include locations, daily activities, reviews of hole conditions, geophysical log listings, video tape listings, and microfiche copies of all geophysical logs run by F&S subcontractors.

154 Fenix and Scisson, 1986, NNWSI hole histories UE-29a#1, UE-29a#2: Fenix and Scisson report DOE/NV/10322-12, Tulsa, OK, 23 p.

Data presented in this document includes the hole histories, locations, daily activities, coring records, review of hole conditions, and geophysical logs of drillholes UE-29a#1 and UE29a#2. These wells are located in Fortymile Canyon, just east of Yucca Mountain.

155 Fenix and Scisson, 1986, NNWSI hole histories USW VH-1 and USW VH-2: Fenix and Scisson report DOE/NV/10322-17, Tulsa, OK, 57 p.

These boreholes were drilled to obtain hydrologic, geologic, and geophysical data to help determine the volcanic eruption rate in Crater Flat, the aeromagnetic anomalies east of Red and Black volcanic cones, and to help define the rate of vertical tectonism in western Crater Flat. Data presented include locations, daily activities, review of hole conditions, geophysical log listings, video tape listings, and microfiche copies of all geophysical logs run by F&S subcontractors.

156 Fenix and Scisson, 1987, NNWSI drilling and mining summary: Fenix and Scisson report DOE/NV/10322-24, Tulsa, OK, 45 p.

A summary report for all boreholes drilled prior to July 1, 1987 in support of the NNWSI is presented. The boreholes were drilled in Areas 1, 5, 16, 17, 25, 26, 29, and 30 of the Nevada Test Site and in the Bureau of Land Management land adjacent to the Nevada Test Site.

157 Fenix and Scisson, 1987, NNWSI hole histories; unsaturated zone-neutron holes; 76 boreholes drilled between May 1984 and February 1986: Fenix and Scisson report DOE/NV/10322-21 Tulsa, OK, 310 p.

This is a compilation of data from 74 shallow alluvial exploratory core holes and two shallow calibration core holes. The boreholes were drilled to obtain undisturbed alluvial cores, to determine vertical distribution of moisture content and water potential, and to run neutron moisture logs. Data presented in the hole histories include all locations, daily activities and review of hole conditions.

158 Fenix and Scisson, 1987, NNWSI hole histories USW G-1, USW G-2, USW G-3, USW G-4, USW GA-1, USW GU-1: Fenix and Scisson report DOE/NV/10322-19, Tulsa, OK, 187 p.

This is a compilation of data from six exploratory boreholes drilled to characterize the geologic, geophysical and hydrologic data for the Yucca Mountain block. The information presented includes locations, daily activities, core records, mud records, review of hole conditions, geophysical log listings, video tape listings, and microfiche copies of all geophysical logs run by F&S subcontractors.

159 **Fenix and Scisson, 1987, NNWSI hole histories USW H-1, USW H-3, USW H-4, USW H-5, USW H-6: Fenix and Scisson report DOE/NV/10322-18, Tulsa, OK, 43 p.**
This is a compilation of data from five boreholes drilled within the Bureau of Land Management lands adjacent to the Nevada Test Site. The information presented includes locations, daily activities, review of hole conditions, geophysical log listings, video tape listings, and microfiche copies of all geophysical logs run by F&S subcontractors.

160 **Fenix and Scisson, 1987, NNWSI hole histories USW UZ#1, USW UZ #4, USW UZ #5, USW UZ#6, USW UZ#6s, USW UZ#7, USW UZ#8, USW UZ#13: Fenix and Scisson report DOE/NV/10322-20, Tulsa, OK, 84 p.**
This is a compilation of data from five boreholes drilled within the Bureau of Land Management lands adjacent to the Nevada Test Site. The information presented includes locations, daily activities, review of hole conditions, geophysical log listings, video tape listings, and microfiche copies of all geophysical logs run by F&S subcontractors.

161 **Fenske, P.R., and Carnahan, C.L., 1975, Water table and related maps for Nevada Test Site and central Nevada test area: Desert Research Institute Publication #45009, Reno, NV, 18 p.**
Water Table Maps, water table gradient maps, and depth-to-water maps have been constructed for the Nevada Test Site and the Central Nevada Test Area by empirical simulation using a digital computer.

162 **Flanigan, V.J., 1981, A slingram survey at Yucca Mountain on the Nevada Test Site: U.S. Geological Survey open-file report 81-980, 37 p.**
The purpose of this study is to determine whether or not various EM methods could determine the location of fault zones within northwest-trending valleys in the Yucca Mountain area. The methods tried included slingram, turam and VLF. The data suggest that some of the northwest-trending valleys contain EM conductors that may be related to fracturing and faulting.

163 **Flood, T.P., Schuraytz, B.C., and Vogel, T.A., 1986, Magma mixing due to disruption of a compositional interface: Lawrence Livermore National Laboratory report UCRL-15821, Livermore, CA, 44 p.**
The chemical compositions of glassy pumices are used to investigate the relationship between two ash-flows sheets that were erupted from the same volcanic center. The first ash-flows sheet, the large volume Topopah Spring Member, represents an eruption from a magma body that contained a sharp compositional interface between a high-silica rhyolite and a lower-silica quartz latite. The second ash-flows sheet is the smaller volume Pah Canyon Member. It represents an eruption of a relatively homogeneous magma that is intermediate in composition to the compositions of the Topopah Spring Member.

164 **Fouty, S.C., 1984, Index to published geologic maps in the region around the potential Yucca Mountain nuclear waste repository site, southern Nye County, Nevada: U.S. Geological Survey open-file report 84-524, 20 p.**
A series of index maps are presented in this report to provide an up-to-date reference of published geological maps covering the candidate area. The published maps range in scale from 1:1,200 through 1:700,000 and include maps published by the USGS, state and commercial organizations, universities, and professional societies.

165 **Freeze, R.A., et al., 1987, report of the Technical Advisory Committee on "Uncertainties in groundwater travel time calculations at Yucca Mountain, Nevada": Technical Advisory Committee report, Sandia National Laboratories, Albuquerque, NM, 19 p.**
This report summarizes the meeting of the Technical Advisory Committee held at the Ramada Classic Inn in Albuquerque, NM, on June 15-16, 1987. The relative influence of the uncertainty of various parameters on the groundwater travel time and the cumulative density function are expressed.

166 **French, R.H., 1983, Precipitation in southern Nevada: Journal of Hydraulic Engineering, vol. 109, no. 7, p. 1023-103a.**
The distribution of precipitation in both time and space in the southern Nevada area is examined. It is concluded that this area can be divided into two zones of precipitation separated by a transition zone on the basis of annual average precipitation. One region, relative to the other, is defined to to be a deficit annual average precipitation region. In addition, precipitation records at two stations in the southern Nevada area were examined and point intensity/duration relationships were derived.

167 **French, R.H., Elzeftawy, A., Bird, J., Elliot, B., 1984, Hydrology and water resources overview for the Nevada Nuclear Waste Storage Investigations, Nevada Test Site, Nye County, Nevada: Desert Research Institute report DE85001350, Las Vegas, NV, 51 p.**
A summary is presented of the literature and available unpublished data regarding hydrology and water resources utilization in the Nevada Test Site area is presented.

168 **French, R.H., Elzeftawy, A., Elliot, B., 1984, Hydrology and water resources overview for the Nevada Nuclear Waste Storage Investigations, Nevada Test Site, Nye County, Nevada— annotated bibliography: Desert Research Institute report DE85001349, Las Vegas, NV, 79 p.**
The literature available regarding hydrology and utilization of water resources in the southwestern Nevada Test Site area is reviewed.

169 **Galloway, D.L., and Erickson, J.R., 1985, Tracer test for evaluating nonpumping intra-borehole flow in fractured media: Transaction of the American Nuclear Society, vol. 50, p. 192.**
A short-term tracer test using 131_I was conducted in USW H4 under non-pumping conditions to determine intra-borehole flow directions, magnitudes, points of groundwater borehole ingress and egress, and to correlate these movements with the occurrence and properties of fractures.

170 **Gibbons, A.B., 1958, Geologic effects of the Rainier underground test— preliminary report: U.S. Geological Survey report TEI-718, 35 p.**
The geologic effects of the Rainier nuclear test conducted at Rainier Mesa are documented. The area of study includes the U12b portal and adits and surficial expression of the area above the blast.

171 **Gibbons, A.B., Hinrichs, E.N., and Botinelly, T., 1960, The role of impermeable rocks in controlling zeolitic alteration of tuff: U.S. Geological Survey professional paper 400-B, B473-B475.**
This report documents the effects impermeable rocks, welded tuff, rhyolite, and pre-volcanic rocks have had on the zeolitization of more permeable, overlying tuffaceous units.

172 **Gibbons, A.B., Hinrichs, E.N., Hansen, W.R., and Lemke, R.W., 1963, Geology of the Rainier Mesa Quadrangle Nye County, Nevada: U.S. Geological Survey Map GQ-215.**
A geologic map of Rainier Mesa is presented.

173 **Glanzman, V.M., 1985, Bibliography of reports by U.S. Geological Survey personnel on studies of underground nuclear test sites and on waste**

management studies at the Nevada Test Site and the Waste Isolation Pilot Plant Site, NM, January 1, 1983, to December 31, 1984: U.S. Geological Survey open-file report 85-363, 24 p.

reports within this bibliography include information on underground nuclear testing and waste management projects at the Nevada Test Site and radioactive waste projects at the WIPP site in NM.

174 Guzowski, R.V., Nimick, F.B., Siegel, M.D., and Finley, N.C., 1983, Repository site data report for tuff: Yucca Mountain, Nevada: Sandia National Laboratories report SAND82-2105, Albuquerque, NM, 312 p.

Site specific data concerning the high level repository at Yucca Mountain are integrated as part of the NRC risk assessment methodology development program. The tectonic setting, seismicity, igneous activity, geothermal gradient, surface geologic processes, natural resources, stratigraphy, structure, and nomenclature and classification of tuffs are discussed. Also discussed are the hydrology and geochemistry of Yucca Mountain.

175 Hadley, G.R., 1984, Water transport through welded tuff: Sandia National Laboratories report SAND82-1043, Albuquerque, NM, 32 p.

Water transport through welded tuff was studied with the aid of three drying experiments and one imbibition experiment performed on a single 0.15-m-long core. The specimen was saturated using a novel technique which measures the volume of water imbibed as a function of time in order to insure complete saturation. Profiles of saturation vs. axial position along the core were provided by measuring the intensity of a beam of 662 KeV gamma ray photons after passing through the sample in a direction normal to the axis of the cylinder. Results indicate that the drying process is, in general, not characterized by a receding evaporation front as has been previously assumed, but rather by evaporation throughout the sample.

176 Hadley, G.R., and Turner, Jr., J.R., 1980, Evaporative water loss from welded tuff: Sandia National Laboratories, Albuquerque, NM, SAND report 80-0201, 19 p.

This paper reports the measurement of water loss rate for welded tuff at various temperatures due to the action of evaporative drying. The resulting data show that the water loss rate declines monotonically with time at a given temperature and increases with increasing temperature as expected. Surprisingly 90% of the sample moisture was lost to evaporation within 72 hours at room temperature.

177 Hagstrum, J.T., Daniels, J.J., and Scott, J.H., 1980, Analysis of the magnetic susceptibility well log in drillhole UE25a-5, Yucca Mountain, Nevada Test Site: U.S. Geological Survey open-file report 80- 1263, 35 p.

An analysis was conducted to determine the factor(s) responsible the variation in magnetic susceptibility measurements from drillhole UE25a#5 at Yucca Mountain. Results indicate a correlation between magnetite grain size and susceptibility variation. The association of magnetic susceptibility anomalies with the crystal-rich zones of the welded tuffs will aid in the identification and correlation of the eruptive sequences at the Nevada Test Site.

178 Hagstrum, J.T., Daniels, J.J., and Scott, J.H., 1980, Interpretation of geophysical well-log measurements in drillhole UE25a#1, Nevada Test Site Radioactive Waste Program: U.S. Geological Survey open-file report USGS- OFR-80-941, 36 p.

This report deals with the interpretation of physical properties for the tuff units from geophysical well-log measurements. To characterize these units, resistivity, density, neutron, gamma ray, induced polarization, and magnetic susceptibility geophysical logs were made.

179 Haimson, B.C., 1982, A comparative study of deep hydrofracturing and overcoring stress measurements at six locations with particular interest to the Nevada Test Site: in Zoback, M.D., and Haimson, B.C., [eds], 1982, Proceedings of workshop 17, workshop on hydraulic fracturing stress measurements, vol. 1: U.S. Geological Survey open-file report 82-1075, p. 277-304

Six case histories, including 12 from Rainier Mesa, are described in which deep hole hydrofracturing stress measurements were compared with independently conducted overcoring tests. All the comparisons show good to excellent agreement with respect to both stress magnitudes and directions.

180 Hansen, W.R., and Lemke, R.W., 1958, Geology of the USGS and Rainier tunnel areas, Nevada Test Site: U.S. Geological Survey report TEI-716, 110p.

In 1957, the Rainier and USGS tunnels were the sites of experimental explosions designed to test the feasibility of deep-underground detonation as a method of testing nuclear devices. The geology of these areas was mapped in detail so that the geologic effects of the blasts could be fully evaluated.

181 Hansen,, W.R., Lemke, R.W., Cattermole, J.M., and Gibbons, A.B., 1963, Stratigraphy and structure of the Rainier and USGS tunnel areas, Nevada Test Site: U.S. Geological Survey professional paper 382-A, 48p.

In 1957, the Rainier and USGS tunnels were the sites of experimental explosions designed to test the feasibility of deep-underground detonation as a method of testing nuclear devices. The geology of these areas was mapped in detail so that the geologic effects of the blasts could be fully evaluated.

182 Hasler, J.W., 1963, Interim geological investigations in the U12e.07 tunnel, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey report TEI-834, 19 p.

U12e.07 drift was driven into the eastern flank of Rainier Mesa into the nonwelded tuff of the lower member of the Indian Trail Formation. The stratigraphy, lithology, structure, petrology, chemistry, and physical properties of this unit as it occurs in the vicinity of the U12e.07 drift are described.

183 Hawkins, D.B., 1981, Kinetics of glass dissolution and zeolite formation under hydrothermal conditions: Clays and Clay Minerals, vol. 29, no. 5, p. 331-340.

The kinetics of the dissolution of rhyolitic glass and the resultant diagenesis of minerals are investigated.

184 Hazlewood, R.M., 1961, Interim report on seismic velocities of the Oak Spring Formation U12e and U12b tunnel systems, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey report TEI-795, 12p.

A summary of seismic velocity profiles taken in U12b and U12e tunnels within Rainier Mesa is presented. The seismic surveys were done to determine the average velocity for the mapped lithologic units in the tunnels and to set seismic stations in each tunnel system for which velocity data are known or can be computed.

185 Healy, J.H., Hickman, S.H., Zoback, M.D., and Ellis, W.L., 1981, report on televiewer log and stress measurements in core hole USW G-1, Nevada Test Site, December 13-22, 1981: U.S. Geological Survey open-file report 84-15, 47 p.

This document describes the operations and preliminary results of televiewer logging and stress measurements conducted in USW-G1 drillhole on the eastern flank of Yucca Mountain.

186 Healey, D.L., Clutsom, F.G., and Glover, D.A., 1984, Borehole gravity meter surveys in drillholes USW G-3, UE-25p#1 and UE-25c#1,

Yucca Mountain area, Nevada: U.S. Geological Survey open-file report 84-672, 16 p.

The primary purpose of the study was to measure the *in situ* bulk densities of the lithostratigraphic units penetrated by these drillholes using borehole gravity meter surveys.

187 **Healey, D.L., Clutsom, F.G., and Glover, D.A., 1986, Borehole gravity meter survey in drillhole USW G-4, Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey open-file report 86-205, 23 p.**

Drillhole USW G-4 was logged with a borehole gravity meter in order to obtain a more accurate estimate of the *in situ* average bulk density of the geologic units. This data should be helpful for planning the construction of the proposed shaft.

188 **Healey, D.L., Wahl, R.R., and Currey, F.E., 1981, Principal facts, accuracies, sources, and base station descriptions for gravity stations in the Nevada part of the Goldfield and Mariposa 2° sheets: U.S. Geological Survey report USGS-474-311, 12 p.**

More than 12,000 gravity observations have been taken since 1958 in the Nevada part of the Goldfield and Mariposa 2° sheets. Numerous reports are available that present discrete parts of the data. This report is a compilation of all these data after conversion to the International Gravity Standardization Network. The report provides descriptive information and offers a source for principal facts.

189 **Healey, J.H., Hickman, S.H., Zoback, M.D., and Ellis, W.L., 1984, report on televiewer log and stress measurements in core hole USW G-1, Nevada Test Site, December 13-22, 1981: U.S. Geological Survey open-file report 84-15, 50 p.**

The operations and the preliminary results of televiewer logging and stress measurements in USW G-1 at Yucca Mountain, carried out on December 13 and 22, 1981 are discussed. USW G-1 is located on the eastern flank of Yucca Mountain.

190 **Heiken, G.H., Bevier, M.L., 1979, Petrology of tuff units from the J-13 drill site, Jackass Flats, Nevada: Los Alamos National Laboratory LA-7563-MS, Los Alamos, NM, 55 p.**

The purpose of this report is to provide basic petrologic data for the tuff encountered in the J-13 drill site. It describes zonation of authigenic minerals with depth and compares the zonation to other areas of the Test Site and west Texas. The zonation is developed by leaching of glass phases and deposition of authigenic minerals in open hydrologic systems.

191 **Henne, M.S., 1982, The dissolution of Rainier Mesa volcanic tuffs, and its application to the analysis of the groundwater environment: University of Nevada, Reno Masters Thesis, Reno, NV, 113 p.**

Dissolution studies of Rainier Mesa volcanic glass were conducted to determine the time-dependency of various silicate reactions. These studies yielded the following relationship between silica concentrations in the groundwater (Q), time (t), and the tuff surface area to water volume ratio, (σ):

$$Q = 3.5 \times 10^{-4} \sigma^{1.656t}$$

With this relationship the retention time of water in the tuffs was estimated to be about three months.

192 **Hinrichs, E.N., and Orkild, P.P., 1961, Eight members of the Oak Spring Formation, Nevada Test Site, Nye and Lincoln Counties, Nevada: U.S. Geologic Survey professional paper 424-D, p. 96-103.**

The Oak Spring Formation is divided into seven formal members and an informal lower member. These members are: Tub Spring, Grouse Canyon, Survey Butte, Stockade Wash, Topopah Spring, Tiva Canyon, and Rainier Mesa.

193 **Ho, D.M., Sayre, R.L., and Wu, C.L., 1986, Suitability of natural soils for foundations for surface facilities at the prospective Yucca Mountain Nuclear Waste Repository: Sandia National Laboratories report SAND85-7107, Albuquerque, NM**

The natural soils of Yucca Mountain are evaluated for the purpose of assessing the suitability of the soils for the foundations of the surface facilities at the prospective repository.

194 **Hoffman, L.R., and Mooney, W.D., 1984, A seismic study of Yucca Mountain and vicinity, southern Nevada: U.S. Geological Survey open-file report 83-588, 57 p.**

Seismic refraction studies were conducted at the Nevada Test Site to aid in the investigation of the regional crustal structure near Yucca Mountain. Results indicate that Paleozoic rocks lie at a minimum depth of 3 km beneath part of Yucca Mountain. These results confirm earlier estimates based on the modeling of detailed gravity data. A mid-crustal boundary at 15 ± 2 km beneath Yucca Mountain is evident as are ones identified at 24 and 30 km.

195 **Holcomb, D.J., and Teufel, L.W., 1982, Acoustic emissions during deformation of intact and jointed welded tuff: Sandia National Laboratories report SAND-82-1003, Albuquerque, NM, 41 p.**

As an aid to understanding and monitoring the behavior of jointed rock masses, a series of experiments on intact and artificially jointed samples of Grouse Canyon tuff have been done. The tuff was selected because it is similar to units under consideration as a disposal medium for nuclear wastes. The samples were instrumented to measure axial and transverse displacements and AE rates.

196 **Hoover, D.B., Chornack, M.P., and Broker, M.M., 1982, E-field telluric traverses near Fortymile Wash, Nevada Test Site, Nevada: U.S. Geological Survey open-file report 82-1042, 15 p.**

E-field ratio telluric traverses have identified abrupt changes in resistivity at several places along the Fortymile Wash drainage. These resistivity changes have been interpreted to result from Basin and Range normal faulting along the wash. East of the Yucca Mountain site, four north-south trending faults have been identified.

197 **Hoover, D.L., 1968, Genesis of zeolites, Nevada Test Site: In Eckel, E.B., 1968, Nevada Test Site: Geological Society of America Memoir 110, p275-284.**

The geology, hydrology, mineralogy and chemistry indicate that zeolitization at the Nevada Test Site took place in an unsaturated environment in which vitric rocks were altered by leaching and deposition. Zeolites were formed just above permeability barriers where the cation content of the groundwater and the saturation of vitric rocks were high enough to produce zeolites. Zeolite zoning took place after the formation of clinoptilolite and consisted mostly of a replacement of calcium and magnesium by sodium.

198 **Hoover, D.L., Swadley, W.C., and Gordon, A.J., 1981, Correlation characteristics of surficial deposits with a description of surficial stratigraphy in the Nevada Test Site region: U.S. Geological Survey open-file report 81-512, 26 p.**

Surficial deposits in the Nevada Test Site region have been correlated between valleys employing topography, drainage, topographic relationships, soils, desert pavement, depositional environment, and lithology as correlation characteristics. Areas with detailed mapping are centered around the southwest portion of the Nevada Test Site including Yucca Mountain and the Lathrop Wells quadrangle.

199 **Houser, F.N., 1962, Outline of geology of the U12k and U12k.01 tunnels, Area 12, Nevada**

Test Site: U.S. Geological Survey report TEI-817, 32 p.

The U12k tunnel complex was mined into Aqueduct Mesa which is to the northwest of Rainier Mesa. The stratigraphy, structure, mineralogy, chemistry, and physical properties of the Grouse Canyon and Survey Butte Members of the Oak Spring Formation are described as they occur in this tunnel complex.

200 **Houser, F.N. and Poole, F.G., 1960, Structural features of pyroclastic rocks of the Oak Spring Formation at the Nevada Test Site, Nye County, Nevada, as related to the topography of the underlying surface: U.S. Geological Survey professional paper 400-B, p. B266-B268.**

The structural features of the former Oak Spring Formation in the general area of Rainier Mesa is related to pre-Tertiary topography.

201 **Iman, R.L., et al., 1979, Sensitivity study on the parameters of the regional hydrology model for the Nevada Nuclear Waste Storage Investigations: Sandia National Laboratories report SAND79-1197C, Albuquerque, NM, 31 p.**

Statistical techniques including Latin Hypercube sampling were used to perform a sensitivity analysis on a two-dimensional finite-element code of 16 hydrogeologic zones used to model the regional groundwater flow system. From the results it was found that (1) the ranking of the relative importance of input variables between locations within the same hydrogeologic zone was similar, but not identical; and (2) inclusion of a correlation structure for input variables had a significant effect on the ranking of their relative importance. The significance of these results is discussed with respect to the hydrology of the region.

202 **Johnson, M.S. and Hibbard, D.E., 1957, Geology of the Atomic Energy Commission Nevada Proving Grounds Area, Nevada: U.S. Geological Survey Bulletin 1021-K, p. 333-384.**

The stratigraphy, lithology, and structure of the Nevada Test Site is compiled and documented in a comprehensive manner for the first time. Since its publication, numerous revisions to stratigraphy have been published.

203 **Johnson, G.W., Higgins, G.H. and Violet, C.E., 1959, Underground nuclear detonations: Journal of Geophysical Research, vol. 64, no. 10, p. 1457-1470.**

The major experimental data from several early nuclear tests conducted within Rainier Mesa are presented here. The data are primarily concerned with the location, yield, phenomenology and radiochemical effects of the devices and the chemical, mechanical, thermal, and physical properties of the tunnel bed tuffs surrounding the work points.

204 **Johnson, R.L., and Bauer, S.J., 1987, Unit evaluation at Yucca Mountain, Nevada Test Site, near-field thermal and mechanical calculations using the SANDIA-ADINA code: Sandia National Laboratories report SAND83-0030, Albuquerque, NM, 48 p.**

The results of a comparative study of the Topopah Spring Member and the Tuffaceous Beds of the Calico Hills are presented. The mechanical and thermomechanical response of these two horizons were assessed using a two-dimensional version of SANDIA-ADINA. A comparison is made with a similar underground opening geometry located in the G-Tunnel complex within Rainier Mesa. The unit under investigation there is the Grouse Canyon Member of the Belted Range Tuff.

205 **Johnstone, J.K., 1980, *In situ* tuff water migration/heater experiment-experimental plan: Sandia National Laboratories report SAND-79-1276, Albuquerque, NM, 166 p.**

The experimental plan describes an *in situ* experiment intended as an initial assessment of water generation [illegible]tion in response to a thermal input. The experiment will be conducted in the Grouse Canyon Member of the Belted Range Tuff in U12g tunnel within Rainier Mesa. While this unit is not a potential repository medium, it has physical, thermal, and mechanical properties very similar to those tuffs currently under consideration and is accessible at depth in an existing facility. The experimental layout is discussed in detail.

206 **Johnstone, J.K., Hadley, G.R., and Waymire, D.R., 1985, *In situ* tuff water migration/heater experiment, final report: Sandia National Laboratories report SAND81-1918, Albuquerque, NM, 106 p.**

A summation is presented of the results of the *in situ* tuff water migration/heater experiment operated in the welded portion of the Grouse Canyon Member of the Belted Range Tuff in U12g-tunnel at Rainier Mesa. The experiment was designed to provide an initial assessment of the thermally induced behavior of the potentially large volumes of water available in near saturated tuffaceous rocks. The results indicate that the pore water in these rocks was highly mobile, probably by a vapor diffusion/condensation process.

207 **Johnstone, J.K., and Wolfsberg, K. [eds], 1980, Evaluation of tuff as a medium for a nuclear waste repository; interim status report on the properties of tuff: Sandia National Laboratories report SAND80-1464, Albuquerque, NM, 134 p.**

The interim status of studies of tuff properties determined on samples obtained from Yucca Mountain and Rainier Mesa (G-Tunnel) located on the Nevada Test Site is discussed

208 **Kane, M.F., and Bracken, R.E., 1983, Aeromagnetic map of Yucca Mountain and surrounding regions, southwest Nevada: U.S. Geological Survey open-file report 83-616, 78 p.**

Magnetic anomalies over Yucca Mountain and surrounding areas are largely caused by variations in magnetic properties and shapes including structural offsets of the extensive volcanic units that underlie the region. In a few places, the anomalies are caused by intrusions. Three major boundaries are indicated by contrasts in regional magnetic expressions

209 **Keller, G.V., 1960, Physical properties of the Oak Spring Formation, Nevada: U.S. Geological Survey professional paper 400-B, p. B396-B400.**

A brief presentation of the porosity, density, permeability, water content, acoustic velocities, thermal properties and electrical properties are given for the Oak Spring Formation as it occurs within Rainier Mesa.

210 **Keller, G.V., 1962, Electrical resistivity of rocks in the Area 12 tunnels, Nevada Test Site, Nye County, Nevada: Geophysics, vol. 27, no. 2, p. 242-252.**

Electrical resistivity measurements were made in U12b tunnel within Rainier Mesa in order to determine water content of the tuffaceous units found there. The results of this early experiment proved the usefulness of resistivity measurements for this task.

211 **Kelmers, A.D., 1985, Concerns relative to the applicability of the Yucca Mountain sorption information for site performance assessment purposes: Oak Ridge National Laboratory ORNL WS-41250, 10 p.**

Outline of concerns about the amount of data available and the timeliness of the data being released on sorption experiments are presented.

212 **Kerrisk, J.F., 1987, Groundwater chemistry at Yucca Mountain, Nevada, and vicinity: Los Alamos National Laboratory report LA-10929-MS, Los Alamos, NM, 118 p.**

The chemistry of groundwater at Yucca Mountain and vicinity has been reviewed and compared with the chemistry of water from the Nevada Test Site and surrounding areas such as Amargosa Valley and Oasis Valley. Sodium is the primary cation and carbonate is the primary anion in water from the saturated zone of the tuffaceous aquifer at Yucca Mountain. Other major cations present are calcium, potassium, and magnesium: other major anions are sulfate and chloride, with lesser quantities of fluoride and nitrate. Aqueous silica is also present. Major cation concentrations are controlled by rock dissolution and mineral precipitation reactions as well as by cation exchange with existing minerals. Aqueous carbonate initially comes from atmospheric and soil-zone CO_2, but there is evidence at Yucca Mountain that CO_2 in the gas phase of the unsaturated zone supplies additional carbonate to saturated zone water in the tuffaceous aquifer as mineral dissolution and precipitation reactions raise the pH of the water. A carbon model for this process is discussed; one conclusion of the model is that the true age of water that has obtained significant amounts of carbonate from the gas phase of the unsaturated zone is older than its apparent age. The primary source of aqueous chloride and sulfate is probably precipitation; there does not appear to be any mineralogical controls on these species at Yucca Mountain. There is some evidence that the water in the deep saturated zone may be reducing. Water near the static water level is oxidizing. Water in the western part of Yucca Mountain is lower in calcium than water to the east. Carbonate and fluoride tend to be more concentrated in the water in the southwestward part of the mountain.

213 **Kerrisk, J.F., 1983, Reaction-path calculations of groundwater chemistry and mineral formation at Rainier Mesa, Nevada: Los Alamos National Laboratory report LA-9912-MS, Los Alamos, NM, 41 p.**

This paper studies reaction-path calculations of groundwater chemistry and mineral formation at Rainier Mesa. This was done using a model of volcanic glass dissolution by water that is initially saturated with CO_2. Groundwater chemistry is related to the relative dissolution rates of species from the glass and the minerals that precipitate during the dissolution process. A sequence of mineral evolution has been defined in this study. The results will be used in support of geochemical models of Yucca Mountain.

214 **Kerrisk, J.F., 1985, An assessment of the important radionuclides in nuclear waste: Los Alamos National Laboratory report LA-10414-MS, Los Alamos, NM, 28 p.**

The relative importance of the various radionuclides contained in nuclear waste has been assessed by consideration of: 1) the quantity of each radionuclide present; 2) the Environmental Protection Agency's release limits for radionuclides; 3) how retardation processes such as solubility and sorption affect radionuclide transport; and 4) the physical and chemical forms of the radionuclides in the waste. Three types of waste were reviewed: spent fuel, high level waste, and defense high level waste. Conditions specific to the NNWSI project's proposed site at Yucca Mountain were used to describe radionuclide transport. The actinides Am, Pu, Np, and U were identified as the waste elements for which solubility and sorption data were most urgently needed. Other important waste elements were identified as Sr, Cs, C, Ni, Zr, Tc, Th, Ra, and Sn. Under some conditions, the radionuclides of C, Tc, and I may have high solubility and negligible sorption. The potential for transport of some waste elements (C and I) in the gas phase must also be evaluated for the Yucca Mountain site.

215 **King, K.W., and Engdahl, E.R., 1984, Southern Great Basin seismological data report for 1980 and preliminary data analysis: Sandia National Laboratories report SAND83-2625, Albuquerque, NM**

Earthquake data for the calendar year 1980 are presented for earthquakes occurring within and adjacent to the southern Nevada seismograph network. Locations, magnitudes, and selected focal mechanisms for these events and events from prior years of network operation are presented and discussed in relation to the geologic framework of the region. The principal results are that (1) earthquakes concentrate in fault zones having a northeast orientation, (2) fault zones having a northwest orientation are quiescent or nearly so, and (3) no earthquakes have been detected closer than 12 km to the proposed Yucca Mountain nuclear waste repository area.

216 **Klavetter, E.A., and Peters, R.R., 1986, Estimation of hydrologic properties of an unsaturated, fractured rock mass: Sandia National Laboratories, Albuquerque, NM, report SAND 84-2642, unlimited release, UC-70, 49 p.**

This document presents a general discussion of (1) the hydrology of Yucca Mountain and the conceptual hydrologic model currently being used for the Yucca Mountain site, (2) the development of models that may be used to simulate flow in a fractured porous medium, and (3) comparison of these models.

217 **Knauss, K.G., 1983, Petrologic and geochemical characterization of the Bullfrog Member of the Crater Flat Tuff-outcrop samples used in waste package experiments: Lawrence Livermore National Laboratory report UCRL-53470, Livermore, CA, 21 p.**

This report summarizes the characterization done on samples of the Bullfrog Member of the Crater Flat Tuff. Experiments include hydrothermal water/rock interactions, corrosion, thermomechanics, and geochemical modeling.

218 **Knauss, K.G., 1984, Hydrothermal interaction studies of Bullfrog Member tuff core wafers in J-13 water at 150°C: quantitative analyses of aqueous and solid phases: Lawrence Livermore National Laboratory UCRL-53521, Livermore, CA, 24 p.**

This paper describes the work conducted to understand the water chemistry in the near-field surrounding a nuclear waste repository in the Bullfrog Member of the Crater Flat Tuff and to study any changes in the rock itself due to hydrothermal alteration. Samples were collected from the southwestern portion of Yucca Mountain. Static hydrothermal experiments with polished core wafers were run for 60 days. Solution chemistry for both crushed tuff and the core wafers are in good agreement. Extent of the reaction over the 60 days is minor, even though solution effects were observed.

219 **Knauss, K.G., 1984, Petrologic and geochemical characterization of the Topopah Spring Member of the Paintbrush Tuff, outcrop samples used in waste package experiments: Lawrence Livermore National Laboratory report UCRL-53558, Livermore, CA, 36 p.**

Characterization studies conducted with outcrop samples of Topopah Spring Member of the Paintbrush Tuff are summarized.

220 **Knauss, K.G., 1987, Zeolitization of glassy Topopah Spring Tuff under hydrothermal conditions: Lawrence Livermore National Laboratory report UCRL-94664, Livermore, CA, 10 p.**

Solid wafers of glassy tuff were reacted with a dilute groundwater for several months at 150 and 250°C at 100 bars pressure in Dickson-type, gold-bag rocking autoclaves. The *in situ* chemistry of the hydrothermal fluids were modeled and the chemical affinities for all possible mineral precipitation reactions were calculated using the EQ3/6 program. In general, the observations are in relatively good agreement with the geochemical model calculations.

221 **Knauss, K.G., and Beiriger, W.B., 1984, report on static hydrothermal alteration studies of Topopah Spring Tuff wafers in J-13 water at 150°C: Lawrence Livermore National Laboratory report UCRL-53576, Livermore, CA, 29 p.**

Static hydrothermal alteration experiments were run for four months using polished wafers either fully submerged in an appropriate natural groundwater or exposed to water-saturated air with enough excess water to allow refluxing. The results predict relatively minor changes in water chemis-

try, very minor alteration of the host rock, and the production of slight amounts of secondary minerals.

222 **Knauss, K.G., Beiriger, W.J., and Peifer, D.W., 1985, Hydrothermal interaction of crushed Topopah Spring Tuff and J-13 water at 90, 150, and 250°C using Dickson-type, gold bag autoclaves: Lawrence Livermore National Laboratory report UCRL-53630, Livermore, CA, 27 p.**

The data, derived from hydrothermal interaction of crushed Topopah Spring Member samples and well J-13 water, can be used to: assess the ability to use "accelerated" tests based on the surface area/volume parameter and temperature; allow the measurement of chemical changes due to reaction phases present in the tuff before reaction; and permit the identification and chemical analysis of secondary phases resulting from hydrothermal reactions.

223 **Knauss, K.G., Beiriger, W.J., Peifer, D.W., Piwinski, A.J., 1985, Hydrothermal interaction of solid wafers of Topopah Spring Tuff with J-13 water and distilled water at 90, 150, and 250°C, using Dickson-type, gold-bag rocking autoclaves: Lawrence Livermore National Laboratory report UCRL-53645, Livermore, CA, 55 p.**

The NNWSI project has conducted experiments to study the hydrothermal interaction of rock and water representative of a potential high-level waste repository at Yucca Mountain. The results obtained from the experiments have been used to evaluate the modeled results produced by calculations using the geochemical reaction process code EQ3/6.

224 **Knauss, K.G., Beiriger, W.J., and Peifer, D.W., 1987, Hydrothermal interaction of solid wafers of Topopah Spring Tuff with J-13 water at 90° and 150°C using Dickson-type gold bag rocking autoclaves; long-term experiments: Lawrence Livermore National Laboratory report UCRL-53722, Livermore, CA, 21 p.**

The experiment was designed to augment shorter term hydrothermal interaction experiments. Results indicate that a kinetic inhibition exists for the precipitation of zeolites in hydrothermal waters.

225 **Knauss, K.G., et al., 1984, Hydrothermal interaction of Topopah Spring Tuff with J-13 water as a function of temperature: Lawrence Livermore National Laboratory report UCRL- 90853, Livermore, CA, 9 p.**

Experiments were conducted to study the hydrothermal interaction of rock and water representative of a potential repository in tuff. Crushed tuff and polished wafers were reacted with a natural groundwater in Dickson-type gold-bag rocking autoclaves. Results were compared with predictions based on the EQ3/6 geochemical modeling code.

226 **Knauss, K.G., and Peifer, D.W., 1986, Reaction of vitric Topopah Spring tuff and J-13 groundwater under hydrothermal conditions using Dickson-type gold-bag rocking autoclaves: Lawrence Livermore National Laboratory report UCRL-53795, Livermore, CA, 39 p.**

Experiments were conducted to study the effects of repository-generated heat on glassy tuff present at Yucca Mountain. The *in situ* chemistry of the hydrothermal fluids was modeled for several temperatures, and the chemical affinities for all possible mineral precipitation reactions for species contained within the database were calculated using EQ3/6. For the 250°C experiment, the calculations predicted the precipitation of a zeolite mineral. Analysis of the run showed that the wafer had been extensively corroded, the glass shards were replaced by clinoptilolite, and pure clinoptilolite precipitated from solution. Modeling of the 150°C experiment indicated that, although clay minerals were more highly supersaturated than zeolites in the first half of the experiment, by the end of the run a zeolite was also predicted to precipitate. Analysis of the run showed no well crystallized secondary minerals had formed. In the 90°C run, the degree of supersaturation for both clays and zeolites was lower than at either of the higher temperatures. The relative change in supersaturation for any one mineral was lower as the run progressed. Slow precipitation kinetics may preclude the formation of the minerals of interest during the time span of the experiment.

227 **Lahoud, R.G., Lobmeyer, D.H., and Whitfield, M.S. Jr., 1984, Geohydrology of volcanic tuff penetrated by test well UE-25b#1, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Water Resources Investigations report 84-4253, 44 p.**

Average hydraulic conductivity was measured along with hydraulic head on the water in the well. Chemical analyses indicated the water is a soft sodium bicarbonate, slightly alkaline, with large concentrations of dissolved silica and sulfate. Carbon-14 age dates of the water were 14,100 and 13,400 years.

228 **Langkopf, B.S., and Eshom, E., 1982, Site exploration for rock mechanics field test in the Grouse Canyon Member, Belted Range Tuff, U12g Tunnel Complex, Nevada Test Site: Sandia National Laboratories report SAND-81-1897, Albuquerque, NM, 62 p.**

This report describes site exploration work completed in support of planned rock-mechanics field tests in the Grouse Canyon Member of the Belted Range Tuff at the Nevada Test Site, G-Tunnel. As part of this work, the rock mechanics drift and the rock mass property alcove were mined and three coreholes were drilled. The results of the mapping and coring are displayed, described and analyzed.

229 **Langkopf, B.S., and Gnirk, P.R., 1986, Rock-mass classification of candidate repository units at Yucca Mountain, Nye County, Nevada: Sandia National Laboratories report SAND82-2034, Albuquerque, NM, 136 p.**

Available site-specific information from drillholes, supplemented by the needed information from tuff units at other locations, was used in conjunction with two rock-mass classification systems to evaluate the relative excavation stability of these units. The four units within Yucca Mountain which were evaluated were the welded, devitrified portion of the Topopah Spring Member; the zeolitized, nonwelded portion of the Tuffaceous Beds of the Calico Hills; the welded, devitrified portion of the Bullfrog member; and the devitrified portion of the Tram Member. Two other units located at Rainier Mesa, the welded portion of the Grouse Canyon Member of the Belted Range Tuff and the nonwelded Tunnel Bed 5 were also evaluated. The welded, devitrified portion of the Topopah Spring Member and the welded portion of the Grouse Canyon Member ranked highest in stability.

230 **Langkopf, B.S., and Mallory, L.H., 1984, Natural language solution to a tuff problem: Sandia National Laboratories report SAND84-0704C, Albuquerque, NM, 12 p.**

The Tuff database, is being created for use by scientists and engineers investigating the feasibility of locating a high-level radioactive waste repository at Yucca Mountain. This paper gives a brief description of the Tuff database and its associated systems.

231 **Lappin, A.R., 1980, Preliminary thermal expansion screening data for tuffs: Sandia National Laboratories report SAND78-1147, Albuquerque, NM, 34 p.**

A major variable in evaluating the potential of silicic tuffs for use in geologic disposal of heat-producing nuclear wastes is thermal expansion. Results of ambient-pressure linear-expansion measurements on a group of tuffs that vary greatly in porosity and mineralogy are presented. Samples were taken from UE-25a#1 at Yucca Mountain, well J-13 on the western edge of Jackass Flat, and the G-Tunnel complex beneath Rainier Mesa.

232 **Lappin, A.R., 1981, Thermal conductivity of silicic tuffs, predictive formalism and compari-**

son with preliminary experimental results: Sandia National Laboratories report SAND80-0769, Albuquerque, NM, 46 p.

The available thermal conductivity data for silicate phases within tuffaceous units are summarized and several grain density and conductivity trends which may result from post emplacement alteration are described. A formalism for the prediction of tuff thermal conductivity is discussed. A bounding curve is drawn that predicts the minimum theoretical matrix (zero porosity) conductivity for most tuffs as a function of grain density. Comparison of experimental results with this curve shows that experimental conductivities are consistently lower at any given grain density. Samples were taken from drillhole UE-25a#1 at Yucca Mountain and the G-Tunnel complex at Rainier Mesa.

233 Lappin, A.R., and Nimick, F.B., 1985, Bulk and thermal properties of functional tuffaceous beds in holes USW G-1, UE-25a#1, and USW G-2, Yucca Mountain, Nevada: Sandia National Laboratories report SAND82-1434, Albuquerque, NM, 55 p.

A possible emplacement horizon, known as the tuffaceous beds, is delineated in three boreholes below Yucca Mountain. Physical parameters measured are grain densities, thickness, porosity, and thermal conductivity and expansion.

234 Lappin, A.R., and Nimick, F.B., 1985, Thermal properties of the Grouse Canyon Member of the Belted Range Tuff and of Tunnel Bed 5, G-Tunnel, Nevada Test Site: Sandia National Laboratories report SAND82-2203, Albuquerque, NM, 47 p.

Thermal conductivity and thermal expansion data for tuffs of the devitrified welded Grouse Canyon Member and for the zeolitized nonwelded Tunnel Bed 5 are presented. Thermal properties have been found to be a function of mineralogy and saturation. Thermal conductivity results also are affected by matrix and fracture porosity, and thermal expansion behavior is a function of confining and fluid pressures.

235 Lappin, A.R., et al., 1982, Thermal conductivity, bulk properties, and thermal stratigraphy of silicic tuffs from the upper portion of Hole USW-G1, Yucca Mountain, Nye County, Nevada: Sandia National Laboratories report SAND81-1873, Albuquerque, NM, 46 p.

Thermal-conductivity and bulk property measurements were made on welded and non-welded silicic tuffs from the upper portion of Hole USW-G1, located at Yucca Mountain. Extrapolated measurements suggest that matrix thermal conductivity of both zeolitized and devitrified tuffs is independent of stratigraphic position, depth, and location.

236 Laraway, W.H., and Houser, F.N., 1962, Outline of geology of the U12j and U12j.01 tunnels, Nevada Test Site: U.S. Geological Survey report TEI-828, 12 p.

The U12j tunnel complex is located within Aqueduct Mesa to the northeast of Rainier Mesa. The tunnel is driven entirely into the Survey Butte Member of the Piapi Canyon Formation. The stratigraphy, structure, lithology, chemistry, and physical properties of the units intersected by this tunnel are presented.

237 Levy, S.S., 1984, Petrology of samples from drillholes USW H-3, H-4, and H-5, Yucca Mountain: Los Alamos National Laboratory report LA-9706-MS, Los Alamos, NM, 82 p.

The petrology of altered volcaniclastic rocks and associated secondary minerals was studied from samples obtained from drillholes USW H-3, H-4, H-5 in Yucca Mountain. Products of zeolitization were analyzed in the Paintbrush Tuff, tuff of Calico Hills, and Crater Flat Tuff.

238 Levy, S.S., 1984, Studies of altered vitrophyre for the prediction of nuclear waste repository-induced thermal alteration at Yucca Mountain, Nevada: Los Alamos National Laboratory: In Scientific Basis for Nuclear Waste Management VII: Symposium held November 1983 in Boston, Massachusetts: Materials Research Society Symposia Proceedings, vol. 26, pp.959-966.

The susceptibility of a 50 ft-thick vitrophyre to thermal alteration by examining alteration that occurred in the rock as it cooled after deposition is evaluated. An increase of 60°C or more is likely to result in alteration and formation of zeolites and smectites. Alteration will be concentrated near the top of the vitrophyre and along fractures. Zeolites and smectite, newly-crystallized along fluid flow paths below the waste repository, could provide an enhanced sorptive barrier to radionuclide migration.

239 Lin, W., and Daily, W., 1984, Transport properties of Topopah Spring Tuff: Lawrence Livermore National Laboratory report UCRL-53602, Livermore, CA, 20 p.

Electrical resistivity, ultrasonic P-wave velocity and water permeability were measured simultaneously on both intact and fractured Topopah Spring Tuff samples at a confining pressure of 5.0 MPa, pore pressure to 2.5 MPa, and temperatures to 140°C. Results indicate that the fractured sample dehydrates and rehydrates nonuniformly, whereas the intact sample does so uniformly. The wetting front moved 100-times faster within the dry fractured sample relative to that of the dry intact sample. The wetting and drying cycle decreased the fracture permeability as a result of fracture healing caused by silica dissolution and redeposition.

240 Lipman, P.W., and Christiansen, R.L., 1964, Zonal features of an ash-flows sheet in the Piapi Canyon Formation, southern Nevada: U.S. Geological Survey professional paper 501-B, p. B74-B78.

Chemical analyses from devitrified, lithophysal and vapor-phase zones of an ash-flows sheet in southern Nevada, newly named the Yucca Mountain Member, indicate limited compositional variation. Nonwelded vitric tuff at the edges of the ash-flows sheet differs appreciably in composition from crystallized tuff because of incipient secondary alteration of metastable glass shards.

241 Lipman, P.W., Christiansen, R.L., and O'Conner, J.T., 1966, A compositionally zoned ash-flows sheet in southern Nevada: U.S. Geological Survey professional paper 524-F, 47 p.

Several ash-flows sheets in southern Nevada display systematic chemical and mineralogical zonations; in each of these zoned sheets, basal crystal-poor rhyolite grades upward into crystal-rich quartz latite. These compositional changes appear to reflect vertical variations in the magmas from which the ash-flows sheets erupted. The Topopah Spring Member of the Paintbrush Tuff is typical of such compositionally zoned units and is discussed in detail. Variations in welding, crystallization, composition, mineralogy, texture, and chemistry are discussed. The variations of the above parameters are interpreted with respect to magmatic differentiation.

242 Lobmeyer, D.H., 1986, Geohydrology of rocks penetrated by test well USW G-4, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey, Water Resources Investigations report 86-4015, 38 p.

Test well USW G-4 was drilled on the eastern flank of Yucca Mountain to a depth of 915 meters. The well is near the site proposed for a exploratory shaft that would aid site characterization. Two pumping tests were run. Transmissivity for the entire saturated section is about 600-meters squared per day. Most of this flow is thought to come from a single zone 10-meters thick below a depth of 892 meters. Tests indicated that the section above 892 meters has a transmissivity of only 7 meters per day.

243 Lobmeyer, D.H., Whitfield, M.S., Lahoud, R.G., and Bruckheimer, L., 1983, Geohydrologic data for test well UE-25b#1, Nevada

Test Site, Nye County, Nevada: U.S. Geological Survey open-file report 83- 855, 48 p.

Data on drilling operations, lithology, core analyses, borehole geophysics, hydrologic monitoring, hydraulic testing, and groundwater chemistry for well UE-25h#1 are presented. This well is located on the east flank of Yucca Mountain.

244 Long, J.W., et al., 1983, Prediction of downhole waveforms: Sandia National Laboratories report SAND82-2478, Albuquerque, NM, 442 p.

A least-squares linear prediction method using an optimum finite impulse response filter was used to predict a downhole-velocity waveform. A filter was determined from surface and downhole-velocity waveforms from several underground nuclear test events at each of several locations. Separate filters were determined for vertical, radial, and tangential components. Filters for each component for several events were averaged. The measured surface velocity waveform for an event was used with the filter to predict the downhole-velocity waveform for that event. The coherence between the measured and predicted velocity waveforms was evaluated using a normalized mean squared error. The simulated downhole waveform was compared with the downhole-velocity waveform measured on that event. The method was applied to velocity waveforms generated by test events of Pahute Mesa and in Yucca Flat. There is insufficient data to date from a recently installed surface/downhole pair in Yucca Mountain to apply the method as it was applied to other pairs. There is a similarity in geology of Yucca Mountain and Rainier Mesa. Therefore, the average filter from Rainier Mesa was applied to the surface-velocity waveforms at Yucca Mountain from one event to predict the downhole waveform. The coherence between the predicted and measured vertical and tangential waveforms was better than between the predicted and measured waveforms at Rainier Mesa. The coherence for the radial component was poorer.

245 Maldonado, F., 1985, Geologic map of the Jackass Flats area, Nye County, Nevada: U.S. Geological Survey Map I-1519.

A geologic map of Jackass Flat, including Yucca Mountain, is presented.

246 Maldonado, F., Koether, S.L., 1983, Stratigraphy, structure, and some petrographic features of Tertiary volcanic rocks at the USW G-2 drillhole, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 83-732, 83 p.

This study examined the stratigraphy, petrology, and fault and fracture frequency in the drillhole. The Paintbrush Tuff, tuffaceous beds of Calico Hills, Crater Flat Tuff, lava and flow breccia, tuff of Lithic Ridge, bedded and ash-flows tuff, lava and flow breccia, bedded tuff conglomerate and ash-flows tuff, and older tuffs of USW G-2 were penetrated in descending order. A fracture analysis was performed along with identification of fault zones.

247 Maldonado, F., Steele, S.G., and Townsend, D.R., 1979, Supplementary lithologic logs of selected vertical drillholes in Area 12, Nevada Test Site: U.S. Geological Survey report USGS-474-261 (Area 12-50), 61 p.

Lithologic data has been collected from drillholes in the Rainier and Aqueduct Mesas since 1970. Data presented in this report include locations and lithologies for one slant and 22 vertical drillholes greater than 152.4 m in depth.

248 Malmberg, G.T., and Eakin, T.E., 1962, Groundwater appraisal of Sarcobatus Flat and Oasis Valley, Nye and Esmeralda Counties, Nevada: State of Nevada Department of Conservation and Natural Resources, Groundwater Resources-Reconnaissance Series report 10, 38 p.

The estimated average annual recharge and discharge from the groundwater reservoir in Sarcobatus Flat is 3,500 acre-feet. Twelve-hundred-acre-feet of the recharge are thought to be derived from basin precipitation and 2,300 acre-feet are attributed to groundwater underflow from Stonewall Flat and Gold Flat. A groundwater budget is calculated for the basin and suggests that up to 3,500 acre-feet could be pumped from the basin without exceeding perennial yield. Groundwater chemistry is high in sodium and bicarbonate. The estimated average annual recharge to and discharge from Oasis Valley is on the order of 2,000 acre-feet. About 250-acre-feet are derived from precipitation within the basin and about 1,800-acre-feet are derived from underflow from Gold Flat. Groundwater development is restricted to springs along the flood plain of the Amargosa River. Six of these springs provide water to Beatty even though the fluoride content is about four times above the recommended limits. A considerable amount of water with low levels of fluoride may exist in the alluvial aquifer adjacent to the Bullfrog Hills. Limited recharge to this system prevents the exclusive use of this aquifer for municipal supply.

249 Mansure, A.J., and Ortiz, T.S., 1984, Preliminary evaluation of the subsurface area available for a potential nuclear waste repository at Yucca Mountain,: Sandia National Laboratories report SAND84-0175, Albuquerque, NM, 26 p.

The first purpose of this study was to determine if adequate area exists to contain the underground facilities of the repository within the devitrified, densely welded, Topopah Spring Member in areas that contain less than 15-20% lithophysae. The second purpose was to identify a preliminary location within the primary area of exploration, where conditions are favorable for the proposed underground facilities. Results indicate that an area significantly larger than the proposed underground facilities of the repository exists. However, because the primary area of exploration has been the central portion of Yucca Mountain, adjacent areas are less well characterized. Portions of the areas identified in this study may not meet all of the above criteria. The study also identified an area with favorable conditions for the proposed repository. This area is a slab that dips 5°6'NE from a strike direction of N11°18'W. The area of the slab is about 1850 acres.

250 McKay, E.J., and Sargent, K.A., 1970, Geologic map of the Lathrop Wells quadrangle, Nye County, Nevada: U.S. Geological Survey Map GQ-883.

A geologic map of southern Yucca Mountain and Lathrop Wells is presented.

251 McGovern T.F., 1983, An evaluation of seismic reflection studies in the Yucca Mountain area, Nevada Test Site: U.S. Geological Survey open-file report 83-912, 57 p.

An evaluation of various seismic studies conducted at Yucca Mountain was undertaken in order to assess its suitability in that environment. A wide variety of techniques were employed ranging from the most simple to elaborate 3-D surveys. In each case, extensive noise studies were conducted, and based upon their results, parameters were chosen for multifold CDP recording. In every case the signal-to-noise ratio was such that no reflections were discernible.

252 Mckeown, F.A., and Dickey, D.D., 1960, Interim report on geologic investigations of the U12e tunnel system, Nevada Test Site, Nevada: U.S Geological Survey report TEI-772, 17 p.

A description of the lithology, structure, and geochemistry of the tunnel beds as they occur in the U12e tunnel system is presented.

253 Mckeown, F.A., and Dickey, D.D., 1960, Some relation between geology and effects of underground nuclear explosions at Nevada Test Site, Nye County, Nevada: U.S. Geological Survey professional paper 400-B, p. B415-B417.

This report examines the extent and intensity of fracturing and concurrent tunnel damage from nuclear tests as it relates to local petrologic and physical properties and pre-existing fracture sets.

254 **McKinley, P.W., and Benson, L.V., 1986, Groundwater chemistry at selected sites in the Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey, open-file report, 84 p.**

Groundwater chemistry of wells and springs is presented for 276 selected sites in the Yucca Mountain area. Where the data are available, information on well depth, yield, water depth, and pumping time is also noted

255 **Medica, P.A., O'Farrell, T.P., and Collins, T.P., 1981, Survey of Yucca Mountain, Fortymile Canyon, and Jackass Flats in Nye County, Nevada for desert tortoise, *Gopherus agassizi*: EG&G report EGG-1183-2438, Goleta, CA, 14 p.**

The objective of this brief survey was to determine if *G. agassizi* is present west of Fortymile Canyon in the Yucca Mountain area or along the major access roads which lead through Jackass Flats to Fortymile Canyon and Yucca Mountain.

256 **Mihevic, T.M., and Tyler, S.W., 1987, Overview of impacts of Rainier Mesa wastewater disposal facilities: Desert Research Institute Letter report, 22 p.**

An initial assessment of the Area 12 tunnel ponds as waste disposal sites is given. A brief discussion of the hydrology of Rainier Mesa and the total discharge from each tunnel is given as is an initial estimate of each tunnels radionuclide inventory contained within one-years discharge.

257 **Miller, C.H., 1976, A method for stress determination in N, E and T tunnels, Nevada Test Site, by hydraulic fracturing, with a comparison of overcoring methods: U.S. Geological Survey report USGS-474-222, 13p.**

Twenty-nine intervals in 10 core holes were hydraulically fractured in N, E, and T tunnels. The maximum and minimum stresses from these holes were favorably compared to stresses determined by nearby overcore methods. If fracture orientation can be measured, then the direction of minimum principal compressive stress can be determined and the orientation of the plane of the maximum and intermediate principal compressive stresses can also be determined.

258 **Miller, C.H., Cunningham, D.R., and Cunningham, M.J., 1972, Permeameter studies in U12g.10 experimental drift, Rainier Mesa, Nevada Test Site: U.S. Geological Survey report (Rainier Mesa-14), 61 p.**

A method is presented that is utilized to determine the depth to which natural, stress-induced and blast-induced fractures extend around tunnel openings driven in volcanic rocks at Rainier Mesa. Sections of three-inch drillholes were packed off and were injected with air. The rate of decay of pressure is correlatable to the degree of fracturing in the geologic medium. Permeabilities within the 1-foot packed off intervals ranged from 1,000 to 0.001 millidarcies.

259 **Miller, C.H., Kibler, J.D., and Ege, J.R., 1975, A new permanent-installation device for monitoring stress changes in NX core holes: U.S. Geological Survey report USGS-474-214, 54 p.**

A solid-inclusion probe was developed to monitor stress changes in rock. The probe can detect stress changes from 0 to 5,000 psi from a few milliseconds to a few years in the time domain. Eight permanent probes were field tested in the G, E, N, and T tunnel complexes. The changes in the stress field with respect to time is discussed. The effects of nuclear tests on the local stress field were also measured.

260 **Miller, C.H., and Miller, D.R., 1977, Orientation of explosion-induced surface fractures estimated from preexplosion fractures and *in situ* stress measurements: Bulletin of the Engineering Geologist, vol. 14, no. 1, p. 27-37.**

An underground nuclear test caused surface cracks that were orientated as estimated from the measurement of preexplosion fractures and *in situ* stress. Theoretical fracture planes are orientated N. 28° E. within the Aqueduct Mesa and the explosion-produced fractures above U12t 02 drift were generally orientated in this direction.

261 **Miller, C.H., Miller, D.R., Ellis, W.L. and Ege, J.R., 1975, Determination of *in situ* stress at U12e.18 working point, Rainier Mesa, Nevada Test Site: U.S. Geological Survey report USGS-474-217, 21p.**

A three-dimensional stress determination was taken in U12e.18 drift. The magnitude and orientation of the maximum, intermediate and minimum principal stresses are 1,006 lbs/in^2 and S. 4° W., 864 lbs/in^2 and S. 28° W., and 404 lbs/in^2 and S. 75° E. Potential planes of fracture are estimated from the orientation of the principal stresses to strike about N. 14° E. and dip about 78° NW.

262 **Mitchell, D.L., 1984, Evaluation of habitat restoration needs at Yucca Mountain, Nevada Test Site: EG&G report EGG-10282-2030, Goleta, CA, 10 p.**

The extent of restoration needed to minimize the impact of a proposed high-level radioactive waste repository is evaluated. Generalized techniques to minimize restoration efforts and the need for demonstration projects are also presented.

263 **Moncure, G.K., Surdam, R.C., and McKague, H.L., 1981, Zeolite diagenesis below Pahute Mesa, Nevada Test Site: Clay and Clay Minerals, vol. 29, no. 5, p. 385-396.**

The Tertiary volcanics in the Silent Canyon Caldera beneath Pahute Mesa have been divided into three vertical mineralogical zones that vary in thickness and transgress stratigraphic boundaries. *Zone* 1, the uppermost zone, includes unaltered of incipiently-altered rhyolitic glass. *Zone* 2 is characterized by a predominance of clinoptilolite and subordinate amounts of smectite, cristobalite, and mordenite. *Zone* 3 is a complex mineral assemblage that includes analcime, quartz, calcite, authigenic K-feldspar and albite, kaolinite, chlorite, and mixed layer of illite/smectite. The genesis of these three mineral zones is also described.

264 **Montazer, P., Weeks, E.P., Thamir, F., Yard, S.N., and Hofrichter, P.E., 1985, Monitoring the vadose zone in fractured tuff, Yucca Mountain, Nevada: U.S. Geological Survey, Denver Colorado, 30 p.**

The U.S. Geological Survey has been conducting hydrologic, geologic, and geophysical studies at Yucca Mountain to provide data for the potential suitability of the site. Hydrologic investigations were started in the unsaturated zone in 1982. A 17.5-inch borehole was drilled to a depth of 1,269 feet. Thermocouple psychrometers and pressure transducers were installed at screened intervals and monitored for two years with satisfactory results.

265 **Montazer, P., and Wilson, W.E., 1984, Conceptual hydrologic model of flow in the unsaturated zone, Yucca Mountain, Nevada: U.S. Geological Survey Water-Resources Investigations report 84-4345, 55 p.**

A conceptual model is proposed that describes the flow of fluids through the unsaturated zone at Yucca Mountain. The geology, structure, porosity, permeability, and fracture density of the various hydrogeologic units are used to construct a hypothetical model for flow through porous layers intercalated with double-porosity layers. In this model, flow through fractures can occur at almost all stages of saturation, but the flux magnitude in fractures is largely a factor of the contrast between the matrix and fracture-hydraulic properties and the magnitude of the perturbation of flux at the flow boundaries. In this model, flow is retarded by capillary barriers that occur at the contacts between nonwelded and welded units. The effectiveness of this capillary barrier depends on the magnitude of the flux and hydraulic-head distribution. Hysteresis during wetting phases and air entrapment may result in greater flux in fractures than would otherwise be predicted. Initiation of lateral flow also results. Both

vapor transport and liquid flow can occur simultaneously within the fractured layers of this model. Net infiltration is estimated at 0.5 to 4.5 mm/yr. Water infiltrates primarily into the Tiva Canyon welded unit, but also into the alluvium, Paintbrush nonwelded unit, and Topopah Spring welded unit. Eastward lateral flow occurs within and above the upper contact of the Paintbrush Tuff nonwelded unit. This lateral flow is intercepted by structural features, which transmit most of the infiltrating water to the water table. Percolation through the matrix occurs principally vertically in the welded units and both laterally and vertically in the nonwelded units. Fracture flow is dominant in the Tiva Canyon welded unit during intense pulses of infiltration and is insignificant in the Topopah Spring welded unit except near the upper contact and near the structural features. Temporary development of perched water is possible near the structural features within and above the nonwelded units. This water drains into the structural flow paths and much of it travels directly to the water table. Possible flux ranges of 98.0 to 1 x 10^{-7} are given for various units that occur within Yucca Mountain.

266 Moore, J.E., 1961, Records of wells, test holes, and springs in the Nevada Test Site and surrounding area: U.S. Geological Survey report TEI-781, 22 p.

This report summarizes all of the available information of the source, occurrence, quality, quantity, temperature, and other information on 49 wells and test holes within the Nevada Test Site. Some of these are located on or near Rainier Mesa or Yucca Mountain.

267 Moore, J.E., 1962, Selected logs and drilling records of wells and test holes drilled at the Nevada Test Site prior to 1960: U.S. Geological Survey report TEI-804, 51 p.

Lithologic logs, drillers logs, drilling records, and hydrologic data for 18 wells and test holes on the Nevada Test Site are presented. All of these wells were drilled prior to 1960 and have not been documented in prior reports.

268 Moore, D.E., Morrow, C.A., and Byerlee, J.D., 1984, Changes in permeability and fluid chemistry of the Topopah Spring Member of the Paintbrush Tuff (Nevada Test Site) when held in a temperature gradient: summary of results: Lawrence Livermore National Laboratory report UCRL-15620, Livermore, CA, 33 p.

Permeability measurements made on samples of the Topopah Spring Member of the Paintbrush Tuff at room-temperature and in a temperature gradient show that the initially high (3-65 μ da) permeabilities are little affected by heating to at least 150°C. The fluids discharged from the samples of tuff during the experiments are dilute, nearly neutral solutions that differ only slightly from the starting groundwater composition.

269 Moore, D.E., Morrow, C.A., and Byerlee, J.D., 1985, Permeability and fluid chemistry studies of the Topopah Spring Member of the Paintbrush Tuff, Nevada Test Site: Part II: Lawrence Livermore National Laboratory report UCRL-15667, Livermore, CA, 41 p.

This paper reports the results of a second set of experiments dealing with the effects of pore pressure, sample orientation, and flow direction on the permeability and pore fluid chemistry of this tuff. The tuff samples used are from outcrop material collected at Fran Ridge near Yucca Mountain.

270 Morales, A.R., 1985, Technical correspondence in support of the final environmental assessment: Sandia National Laboratories report SAND85-2509, Albuquerque, NM, 53 p.

This document contains five separate technical memoranda and letters that were published in order to be cited in the Final Environmental Assessment.

271 Morey, G.W., 1958, The action of heat and of superheated steam on the tuff of the Oak Spring Formation: U.S Geological Survey report TEI-729, 13 p.

Samples of the Oak Spring tuff were heated to 1200°C and subjected to high pressures. The tuff becomes fluid enough to flow at about 1200°C, however, it remains viscous at even higher temperatures. The recrystallization of heulandite to plagioclase feldspar is indicative of the presence of steam at high pressure and temperature during recrystallization.

272 Morrow, C., and Byerlee, J., 1984, Frictional sliding and fracture behavior of some Nevada Test Site tuffs: in Dowding, C.H., and Singh, M.M., [eds] Rock Mechanics in Productivity and Protection: American Institute of Mining, Metallurgical, and Petroleum Engineers, p. 467- 474.

Deformation studies were performed on tuffaceous rocks from Yucca Mountain to determine the strengths and coefficients of friction under confining pressures from 10 - 50 MPa at room temperature. Frictional strengths of 30° sawcut samples increased with pressure and reached values of around 150 MPa at the higher confining pressures. However, the failure strengths of the intact samples were quite unpredictable. The coefficients of friction ranged between 0.7 and 0.9 for all samples. These data can be used in conjunction with *in situ* stress measurements at Yucca Mountain to evaluate the potential for earthquake activity in the region.

273 Morrow, C., Moore, D., Byerlee, J., 1983, Permeability and pore-fluid chemistry of the Bullfrog tuff in a temperature gradient: 24th U.S. Symposium on Rock Mechanics, June 15-18, 1983, p. 819-827.

The purpose of this project is to investigate the changes that take place with time when groundwater comes in contact with heated rock, and to determine the ease with which potential radionuclide-bearing groundwater could be carried into the environment. The permeability of the samples increased by several millidarcies due to thermal cracking. Exposure to hot fluids over time reduced the permeability of the sample by 25-50% of the initial heated samples. Chemical analyses of the discharging fluids indicate that the growth of minerals such as zeolites and smectites are responsible for the observed permeability reductions.

274 Morrow, C.A., Moore, D.E., and Byerlee, J.D., 1984, Permeability and pore-fluid chemistry of the Topopah Spring Member of the Paintbrush Tuff, Nevada Test Site, in a temperature gradient application to nuclear waste storage: Materials Research Society Symposia Proceedings, vol. 26, p. 883-890.

Changes with time of the permeability and fluid chemistry of the Topopah Spring Member have been measured in a temperature gradient. Maximum temperatures of the imposed gradients ranged from 90 to 250°C, minimum temperatures were 36 to 83°C. Confining and pore pressures simulated a depth of about 1.2 km. Heating the tuffs produced little change in the permeability of the tuff. The fluids that discharged from the tuff were of neutral pH and differ little from the original fluid composition.

275 Moss, M., et al., 1982, Effects of composition, porosity, bedding plane orientation, water content and a joint on the thermal conductivity of tuff: Sandia National Laboratories report SAND84-1164, Albuquerque, NM, 28 p.

This study deals with the effects of composition, porosity, bedding-plane orientation, water content and a joint on the thermal conductivity of tuff from the Grouse Canyon Member of the Belted Range Tuff as it occurs within Rainier Mesa.

276 Moss, M., and Haseman, G.M., 1983, Proposed model for the thermal conductivity of dry and water saturated tuff: Sandia National Labora-

tories report SAND83-0535C, Albuquerque, NM, 9 p.

The room-temperature thermal conductivities of two kinds of tuff from the Nevada Test Site have been measured on a linear heat-flow thermal comparator. The results are the basis for an empirical model of the conductivity of these rocks in the dry and water-saturated conditions as a function of porosity. Results indicate that it is justifiable to use a single equation to predict with good accuracy the ratio of saturated to dry-rock conductivity.

277 **Muller, D.C., and Kibler, J.E., 1983, Commercial geophysical well logs from the USW G-1 drillhole, Nevada Test Site, Nevada: U.S. Geological Survey open-file report USGS- OFR-83-321, 22 p.**

Well logs run at USW G-1 drillhole show only limited stratigraphic correlation but correlate reasonably well with the welding of the ash-flows and ash-fall tuffs. Rocks in the upper part of the section have highly variable physical properties, but are more uniform and predictable lower in the section.

278 **Muller, D.C., and Kibler, J.E., 1984, Preliminary analysis of geophysical logs from drillhole UE-25p#1, Yucca Mountain, Nevada: U.S. Geological Survey open-file report 84-649, 14 p.**

Geophysical logs from drillhole UE-25p#1 correlate well with logs through the same geologic units from other drillholes at Yucca Mountain. The following geophysical logs were used in drillhole UE-25p#1: caliper, neutron, density, porosity, velocity, calculated, dielectric, resistivity, spontaneous potential, and gamma ray. The methodology and results of each technique are discussed.

279 **Muller, D.C., and Kibler, J.E., 1986, Preliminary analysis of geophysical logs from the WT series of drillholes, Yucca Mountain, Nevada: U.S. Geological Survey open-file report 86-46, 30 p.**

Geophysical logs from the WT series of drillholes are presented and correlate well with similar logs from other drillholes at Yucca Mountain in the unsaturated zone through the same geologic units.

280 **Naff, R.L., Maxey, G.B., and Kaufmann, R.F., 1974, Interbasin groundwater flow in southern Nevada: Nevada Bureau of Mines and Geology report 20, 28 p.**

A guide to the hydrogeology of the southern Amargosa Desert and adjacent areas in southern Nye County, Nevada and nearby California. Flow systems for Las Vegas and Pahrump Valleys and the Amargosa Desert and Nevada Test Site are described and compared. Focus is on the effects of interbasin flow on quality and quantity of water discharged in the Ash Meadows area.

281 **Neal, J.T., 1986, Preliminary validation of geology at site for repository surface facilities, Yucca Mountain, Nevada: Sandia National Laboratories report SAND85-0815, Albuquerque, NM, 28 p.**

Boreholes and siesmic refraction studies have confirmed that the eastward dipping Tiva Canyon cap rock unit underlies much of the reference conceptual site for repository surface facilities. The style of faulting east of Exile Hill is imbricate normal, as seen elsewhere at the Yucca Mountain site. The alluvial cover ranges in thickness from zero at Exile Hill to 27 m at a point 500 m to the east. *In situ* primary wave velocities average about 1 km/sec in alluvium and 1.4 km/sec in tuff. The range and overlap in velocities virtually precludes using velocity to differentiate between the two types of units.

282 **Nimick, F.B., et al., 1985, Uniaxial and triaxial compression test series on Topopah Spring Tuff from USW G-4, Yucca Mountain, Nevada: Sandia National Laboratories report SAND84-1101, Albuquerque, NM, 105 p.**

Fifty-seven uniaxial and triaxial compression experiments were performed on cylindrical samples taken from the Topopah Spring Member of the Paintbrush Tuff from drillhole USW G-4 at Yucca Mountain.

283 **Nimick, F.B., and Schwartz, B.M., 1987, Bulk, thermal, and mechanical properties of the Topopah Spring Member of the Paintbrush Tuff, Yucca Mountain, Nevada: Sandia National Laboratories report SAND85-0762, Albuquerque, NM**

Experimental data on matrix porosity, grain density, thermal expansion, compressive strength, Young's modulus, Poisson's ratio and axial strain at failure for samples from the Topopah Spring Member of the Paintbrush Tuff are compiled. Heat capacity and emissivity also are discussed.

284 **Nimick, F.B., Van Buskirk, R.G., and McFarland, A.F., 1987, Uniaxial and triaxial compression test series on the Topopah Spring Member from USW G-2, Yucca Mountain, Nevada: Sandia National Laboratories report SAND85- 0703, Albuquerque, NM**

Thirty-six uniaxial and triaxial compression experiments were performed on cylindrical samples taken from the Topopah Spring Member of the Paintbrush Tuff from core hole USW G-2 at Yucca Mountain in southern Nevada.

285 **Nimick, F.B., and Williams, R.L., 1984, A three-dimensional geologic model of Yucca Mountain, Southern Nevada: Sandia National Laboratories report SAND83-2593, Albuquerque, NM, 68 p.**

An initial version of a three dimensional model of Yucca Mountain is presented. The initial implementation of the model is a collection of surface representations— one surface for the base of each stratigraphic zone. The primary method of surface definition is an analytical interpretation technique called Trend Modulation by Multikernel summation. Comparison of predicted and actual elevations in drillholes indicates that the method predicted the elevations at those drillholes to within 71 ft. or less with 95 percent confidence.

286 **Norris, A.E., Wolfsberg, K., and Gifford, S.K., 1985, Chlorine-36 measurements of the unsaturated zone flux at Yucca Mountain: Los Alamos National Laboratory report LA-UR-85-2408, Los Alamos, NM, 10 p.**

A new technique that measures the chlorine-36 content of the tuff from the exploratory shaft at Yucca Mountain will be used to calculate flux through the unsaturated zone over longer periods than possible with carbon-14. Measurements of the chlorine-36 "bomb pulse" in soil samples from Yucca Mountain have been used to confirm that infiltration in not an important recharge mechanism.

287 **Norris, A.E., et al., 1982, Geochemistry studies pertaining to the G-Tunnel radionuclide migration field experiment: Los Alamos National report LA-9332-MS, Los Alamos, NM, 43p.**

This report presents the results of geochemical studies of Tunnel Bed tuff that were performed by Los Alamos National Laboratory as a part of the Nevada Test Site G-Tunnel Radionuclide Migration Field Experiment. A tuff-treated water was prepared and used in laboratory scale measurements of radionuclide sorption onto crushed Tunnel Bed tuff, pulverized fracture-fill material, tuff wafers, and a solid tuff core. Modeling studies were undertaken to determine the effects of matrix diffusion and unsaturated tuff on proposed fracture-flow experiments. Laboratory studies indicate that Tunnel Bed 5 tuff would be of questionable suitability for a fracture-flow nuclide-migration experiment owing to poor reproducibility of the data in comparison to sorption ratio measurements with other tuffs. Modeling efforts showed the difficulty of performing a fracture-flow experiment because of matrix capillary action, which resulted in adsorption of water in the fracture.

288 Norris, A.E., et al., 1986, Fran Ridge horizontal coring summary report hole UE-25h no. 1, Yucca Mountain area, Nye County, Nevada: Los Alamos National Laboratory report LA-10859-MS, Los Alamos, NM, 80 p.

Hole UE-25h#1 was core-drilled during December 1982 and January 1983 within several degrees of due west and 400 ft. horizontally into the southeast slope of Fran ridge at an altitude of 3409 ft. The drilling history and mineralogy of the recovered core and fractures are discussed.

289 Obert, L., 1964, *In situ* stresses in rock, Rainier Mesa, Nevada Test Site: U.S. Bureau of Mines report WT-1869, 95p.

Stress measurements and mechanical properties were taken in Tunnels G, B, E, P, N, and at the Madison and Yuba event sites were taken to determine preshot conditions in the rock surrounding the shot rooms and at the massive concrete plugs.

290 O'Conner, J.T., 1963, Petrographic characteristics of some welded tuffs of the Piapi Canyon Formation, Nevada Test Site, Nevada: U.S. Geological Survey professional paper 475-B, p. 52-55.

This report utilizes sections from the Jackass Flat area for early work in differentiating between Tertiary volcanic units. Two significant petrographic characteristics of four welded-tuff cooling units are the quartz-alkali feldspar-plagioclase feldspar ratios of the phenocrysts and the K_2O-Na_2O ratios of the alkali feldspar phenocrysts. Some welded tuff previously thought to belong to the cooling unit of the Tiva Canyon Member is actually part of the Rainier Mesa Member.

291 O'Farrell, T.P., and Collins, E., 1983, 1982 biotic survey of Yucca Mountain, Nevada Test Site, Nye County, Nevada: EG&G report no EGG 10282-2004, 38 p.

The results of field and literature investigations into the Yucca Mountain biota are presented. The vegetation associations and vertebrate populations are described as is an impact analysis of proposed characterization activities.

292 O'Farrell, T.P., and Collins, E., 1984, 1983 biotic survey of Yucca Mountain, Nevada Test Site, Nye County, Nevada: EG&G report EGG 10282-2031, 38 p.

The results of continued field investigations into the Yucca Mountain biota are presented. Vegetation analysis, small-mammal live-trapping studies, and desert-tortoise surveys were conducted. The impact of proposed site characterization activities were also investigated.

293 O'Farrell, T.P., and Emery, L.A., 1976, Ecology of the Nevada Test Site: A narrative summary and annotated bibliography: Desert Research Institute report NVO-167, Boulder City, NV, 249 p.

A summary of the ecology of the Nevada Test Site is presented. This summary was developed through existing documents which are included in an annotated bibliography. Included are a list of ERDA/NSF Desert Biome Research Memoranda, lists of Nevada Test Site flora and fauna, a list of citations concerning the fate and effects of nuclear and nonnuclear disturbances on the environment, and a compilation of references which were used to develops the document.

294 Ogard, A.E., and Kerrisk, J.F., 1984, Groundwater chemistry along flow paths between a proposed repository site and the accessible environment: Los Alamos National Laboratory report LA-10188-MS, Los Alamos, NM, 48 p.

Groundwater from all of the wells in and around Yucca Mountain have been sampled and analyzed. The results are reported in this document. The speciation and solubility of nuclear waste elements in these groundwater have been calculated using the EQ3/6 computer code. Estimates have also been made of the pH and Eh buffering capacity of the water/rock system of Yucca Mountain.

295 Ogard, A.E., et al., 1984, Retardation of radionuclides by rock units along the path to the accessible environment: In McVay, G.L., [ed], *Scientific Basis for Nuclear Waste Management*, Elsevier Science Publishing Company, Inc., p. 329-336.

The most important retardation process in the tuffs of Yucca Mountain is sorption. Based on information from the mineralogy petrology data there is a total ion exchange capacity of the Calico hills and Prow pass units to sorb 75×10^5 metric tons of waste elements if the entirety of each unit is exposed to the waste elements.

296 Olsson, W.A., 1982, Effects of elevated temperature and pore pressure on the mechanical behavior of Bullfrog Tuff: Sandia National Laboratories report SAND81-1664, Albuquerque, NM, 14 p.

Samples of the Bullfrog Member of the Crater Flat Tuff from drillhole USW-G1 on Yucca Mountain were tested in triaxial compression. The results suggest that the presence of water causes the strength to decrease.

297 Olsson, W.A., and Jones, A.K., 1980, Rock mechanics properties of volcanic tuffs from the Nevada Test Site: Sandia National Laboratories report SAND80-1453, Albuquerque, NM, 39 p.

Uniaxial and triaxial compression tests at constant strain-rate were run on samples of volcanic tuff from hole UE25A#1 at Yucca Mountain and G-Tunnel from Rainier Mesa. The test results show that the degree of welding, reflected in the porosity, is the dominant variable affecting strength and modulus. The presence of water, decreased strain-rate, and elevated temperatures can cause reduced strength under some experimental conditions.

298 Orkild, P.P, 1964, Paintbrush Tuff and Timber Mountain Tuff of Nye County, Nevada: In Cohee, G.V., and West, W.S., Changes in stratigraphic nomenclature by the U.S. Geological Survey, 1964: U.S. Geological Survey Bulletin 1224-A, p. 32-36.

The Piapi Canyon Formation is redefined and raised to the rank of Group. This group includes two new formations known as the Paintbrush Tuff and the Timber Mountain Tuff.

299 Orkild, P.P., Byers, F.M., Hoover, D.L., and Sargent, K.A., 1968, Subsurface geology of Silent Canyon Caldera, Nevada Test Site, Nevada: In Eckel, E.B., 1968, Nevada Test Site: Geological Society of America Memoir 110, p77-86.

Deep drilling in the vicinity of Silent Canyon on eastern Pahute Mesa has revealed a Tertiary volcanic section locally thicker than 14,000 ft. The area drilled covers most of the Silent Canyon Caldera and some of the surrounding area. The caldera is rudely elliptical in plan and measures 10 by 14 miles. The structure, originally inferred from surface mapping and a 20 mgal gravity low, has been confirmed by drilling at 21 sites. Petrographic, chemical and magnetic studies of more than 4000 ft. of drill core have revealed a complex sequence of volcanic rocks.

300 Ortiz, T.S., et al., 1985, Three-dimensional model of reference thermal/mechanical and hydrological stratigraphy at Yucca Mountain, southern Nevada: Sandia National Laboratories report SAND84-1076, Albuquerque, NM, 80 p.

A three-dimensional model of the thermal/mechanical and hydrological reference stratigraphy at Yucca Mountain has been developed for use in performance assessment and repository design studies involving material properties data. The reference stratigraphy defines units with distinct thermal, physical, mechanical, and hydrologic properties. Thickness of the repository unit and depth to groundwater are also discussed.

301 Oversby, V.M., 1983, Performance testing of waste forms in a tuff environment: Lawrence Livermore National Laboratory report UCRL-90045, Livermore, CA, 24 p.

This paper describes experimental work conducted to establish the chemical composition of water which will have reacted with Topopah Spring Member tuff prior to contact with waste packages. This water is then reacted with borosilicate glass, 304L stainless steel, and fuel segments in order to determine the geochemical processes likely to occur within the proposed repository.

302 Oversby, V.M., 1984, Reaction of the Topopah Spring Tuff with J-13 well water at 90°C and 150°C: Lawrence Livermore National Laboratory report UCRL-53552, Livermore, CA, 69 p.

This report describes a series of hydrothermal experiments using crushed tuff from the Topopah Spring Member and natural groundwater from well J-13. The purpose of these experiments is to define the changes in water chemistry that would result from temperature changes caused by emplacement of high-level nuclear waste in a repository in the Topopah Spring Tuff. The main conclusion that can be drawn from this work is that changes in the water chemistry due to heating of the rock-water system can be expected to be very minor.

303 Oversby, V.M., 1984, Reaction of the Topopah Spring Tuff with J-13 water at 120°C: Lawrence Livermore National Laboratory report UCRL-53574, Livermore, CA, 29 p.

This report describes a series of hydrothermal experiments using crushed tuff from the Topopah Spring Member and natural groundwater from well J-13. The main conclusion is that changes in the water chemistry due to heating of the rock-water system can be expected to be very minor.

304 Oversby, V.M., 1985, The reaction of Topopah Spring Tuff with J-13 water at 150°C-samples from drill cores USW G-1, USW GU-3, USW G-4 and UE-25h#1: Lawrence Livermore National Laboratory report UCRL-53629, Livermore, CA, 26 p.

Samples of Topopah Spring tuff from drillholes USW G-1, USW GU-3, and G-4 and from the air-drilled horizontal hole at Fran Ridge were reacted with well J-13 water at 150°C. The results were comparable to those obtained in similar experiments.

305 Oversby, V.M., and Knauss, K.G., 1983, Reaction of Bullfrog Tuff with J-13 well water at 90°C and 150°C: Lawrence Livermore National Laboratory report UCRL-53442, Livermore, CA, 51 p.

A series of experiments were conducted to determine the nature and extent of reaction between the Bullfrog Member of the Crater Flat Tuff and natural groundwater from well J-13. Results indicate the following: 1) Increasing the ratio of rock to water increases the rate of approach to steady-state concentrations in solution. 2) Surface outcrop samples contain a minor component of highly soluble material believed to be a residue from the evaporation of surface runoff water in the pores of the rock. 3) Solution analyses for unfiltered samples that have reacted for short periods of time show higher concentrations of Al and Fe than filtered samples. The results from crushed rock samples and wafer samples favorably compare.

306 Palaz, I., 1985, Application of geophysical logs to estimate moisture-content profiles in unsaturated tuff, Yucca Mountain, Nevada: Proceedings from Conference on Characterization and Monitoring of the Vadose Zone, Denver, CO, 15 p.

This paper compares the results of analyses of various geophysical logs that were obtained from two large diameter, air-drilled boreholes at Yucca Mountain with the intent of determining the moisture content of the units. Results indicate that borehole geophysical logs are reliable in determining moisture-content profiles.

307 Pankratz, L.W., 1982, Reconnaissance seismic refraction studies at Calico Hills, Wahmonie, and Yucca Mountain-Southwest Nevada Test Site, Nye County, Nevada: U.S. Geological Survey open-file report 82-478, 27 p.

Reconnaissance refraction surveys consisting of a total of five spreads were conducted in the Calico Hills, Wahmonie, and Yucca Mountain areas. At Yucca Mountain, preliminary interpretations suggest the occurrence of a major, steeply inclined velocity interface 500 m away from the southwest end of of the Yucca C spread. this interface may represent a major fault or erosional feature separating the Topopah Spring and Tiva Canyon members at depth. On the basis of poor-quality data obtained at Yucca Mountain, the subsurface velocity distribution appears to be complex.

308 Peters, R.R., Gauthier, J.H., and Dudley, A.L., 1985, Effect of percolation rate on water-travel time in deep, partially saturated zones: Sandia National Laboratories report SAND85-0854C, Albuquerque, NM, 43 p.

A composite-porosity, continuum model was developed to model flow in a fractured, porous medium. Simulations using data from the Yucca Mountain site and this model in the one-dimensional code TOPSAC indicate that current estimates of the percolation rate result in water movement confined to the matrix and that the water-travel time from the repository to the water table is on the order of hundreds of thousands of years. This result is sensitive to the percolation rate; a ten-fold increase in the rate of percolation may initiate water movement in the fractures, reducing the travel time significantly.

309 Peters, R.R., Klavetter, E.A., George, J.T., and Gauthier, J.H., 1986, Measuring and modeling water imbibition into tuff: Sandia National Laboratories report SAND86-1757C, Albuquerque, NM, 26 p.

To increase a basic understanding of both the hydrologic properties of tuffs and the modeling of flow in partially saturated regimes, the following tasks were performed and the results are reported: (1) Water imbibition experiment into a cylinder of tuff (from a Yucca Mountain drill core) was measured by immersing one end of a dry sample in water and noting its weight at various times. (2) Computer simulation of the experiment using the model TOPSAC with data currently considered for use in site-scale modeling of a repository in Yucca Mountain. The measurements and the results of the modeling are compared.

310 Peters, R.R., Klavetter, E.A., Hall, I.J., Blair, S.C., Heller, G.W., and Gee, G.W., 1984, Fracture and matrix characteristics of tuffaceous materials from Yucca Mountain, Nye County, Nevada: Sandia National Laboratories report SAND 84-1471, Albuquerque NM, 63 p.

Hydraulic tests were performed on tuffaceous samples from 48 different locations on Yucca Mountain. A wide variety of water retention values existed between the different Yucca Mountain lithologies studied. Fracture hydraulic conductivities were higher than matric hydraulic conductivities in all cases.

311 Pippin, L.C., Clerico, R.L., and Reno, R.L., 1982, An archaeological reconnaissance of the NNWSI Yucca Mountain Project Area, southern Nye County, Nevada: Desert Research Institute, Social Sciences Center Publication no. 28, Reno, NV, 111 p.

An archaeological reconnaissance of the 4,368 hectare NNWSI Yucca Mountain Project Area has disclosed 178 prehistoric and · c historic cultural resources sites.

312 Pippin, L.C., and Zerga, D.L., 1983, Cultural resources overview for the Nevada Nuclear Waste Storage Investigations, Nevada Test Site,

Nye County, Nevada: U.S. Dept. of Energy report NVO-266, Las Vegas, NV, 122 p.
Chapters are devoted to: natural setting; history of archaeological research on the Nevada Test Site; cultural setting; and known historic and prehistoric cultural resources within the NNWSI project area.

313 Pippin, L.C., and Zerga, D.L., 1983, Annotated bibliography of cultural resources literature for the Nevada Nuclear Waste Storage Investigations: U.S. Dept. of Energy report NVO-267, Las Vegas, NV
This annotated bibliography contains 193 references compiled in support of the assessment of the cultural resources in the NNWSI project area.

314 Ponce, D.A., Wu, S.S.C., and Spielman, J.B., 1985, Comparison of survey and photogrammetry methods to position gravity data, Yucca Mountain, Nevada: U.S. Geological Survey open-file report 85-36, 11 p.
Locations of gravity stations at Yucca Mountain were determined by a survey using an electronic distance-measuring device and by a photogrammetric method. The data from both methods were compared to determine if horizontal and vertical coordinates developed from photogrammetry are sufficiently accurate to position gravity data at the site. Results show that the two methods have a mean difference of 0.57° 0.70 m in elevation and 0.01 minute horizontally.

315 Poole, F.G., Houser, F.N., and Orkild, P.P., 1961, Eleana Formation of Nevada Test Site and vicinity, Nye County, Nevada: U.S. Geological Survey professional paper 424-D, p. 104-111.
The Eleana Formation as mapped by Johnson and Hibbard (1957) is correlated to various similar clastic units of Late Devonian and early Mississippian age found in and around the Nevada Test Site.

316 Poole, F.G., and McKeown, F.A., 1962, Oak Spring Group of the Nevada Test Site and vicinity, Nevada: U.S. Geological Survey professional paper 450-C, p. 60-62.
The Oak Spring Formation is given group status and is subdivided into two new formations, the Indian Trail and the Piapi Canyon.

317 Poole, F.G., and Roller, J.C., 1959, Summary of physical data five vertical drillholes over the U12b.04 (Evans) explosion chamber, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey report TEI-762, 30 p.
Five core holes were drilled above the U12b.04 drift within Rainier Mesa. The composition, texture, porosity, permeability, density and water content of the tuffs intersected by the drillholes are presented. Acoustic velocity measurements taken within the drillholes and drilling records are also discussed.

318 Price, R.H., 1983, Analysis of rock mechanics properties of volcanic tuff units from Yucca Mountain, Nevada Test Site: Sandia National Laboratories report SAND82-1315, Albuquerque NM, 73 p.
Over 250 mechanical experiments have been run on samples of tuff from Yucca Mountain. Cores from the Topopah Spring, Calico Hills, Bullfrog and Tram Tuff units were deformed to collect data to make an initial evaluation of elastic and strength properties for potential repository horizons. In addition, mechanical test results conducted on Rainier Mesa tuffs are discussed as they overlap and augment Yucca Mountain data.

319 Price, R.H., 1986, Effects of sample size on the mechanical behavior of Topopah Spring Tuff: Sandia National Laboratories report SAND85-0709, Albuquerque, NM, 58 p.
Thirty-four mechanical experiments were performed on intact cylindrical samples of the Topopah Spring Tuff taken from Busted Butte near Yucca Mountain. Results indicated that ultimate strength and axial strain at failure were both inversely related to sample diameter, with simple power law models fitting the data trends very well.

320 Price, R.H., and Bauer, S.J., 1985, Analysis of the elastic and strength properties of Yucca Mountain tuff, Nevada: Sandia National Laboratories report SAND84-2145C, Albuquerque, NM, 9 p.
A large database from more than 100 experiments on drillhole core samples of Yucca Mountain silicic tuff has been assembled. These data have been analyzed and empirical expressions were found which relate elastic properties and strength with porosity plus clay content. These relationships are presented here, in addition to an application of simple elastic composite theory to explain the observed variation of bulk modulus with functional porosity.

321 Price, R.H., Connolly, J.R., and Keil, K., 1987, Petrologic and mechanical properties of outcrop samples of the welded, devitrified Topopah Spring Member of the Paintbrush Tuff: Sandia National Laboratories report SAND86-1131, Albuquerque, NM, 72 p.
More than 50 outcrop samples of the Topopah Spring Member of the Paintbrush Tuff have been analyzed for their petrologic or mechanical properties. In general, the compositions of these samples are very similar to each other and to stratigraphically equivalent samples from drillholes within Yucca Mountain. However, textural features, porosity, elasticity, and strength of the samples exhibited some variability.

322 Price, R.H., and Jones, A.K., 1982, Uniaxial and triaxial compression test series on Calico Hills Tuff: Sandia National Laboratories report SAND82-1314, Albuquerque, NM, 39 p.
Forty-four uniaxial and triaxial compressive experiments were performed on samples of the Tuffaceous Beds of the Calico Hills, obtained from drillhole USW-G1 at Yucca Mountain. Resultant unconfined compressive strengths, axial strains to failure, Young's moduli and Poisson's ratios ranged from 14.2 to 42.0 MPa, .0037 to .0087, 2.52 to 9.72 GPa and .17 to .37, respectively.

323 Price, R.H., Jones, A.K., and Nimick, K.G., 1982, Uniaxial compression test series on Bullfrog Tuff: Sandia National Laboratories report SAND82-0481, Albuquerque, NM, 37 p.
Nineteen uniaxial compressive experiments were performed on samples of the Bullfrog Member of the Crater Flat Tuff, obtained from drillhole USW-G1 at Yucca Mountain on the Nevada Test Site. Resultant unconfined compressive strengths, axial strains to failure, Young's moduli and Poisson's ratios ranged from 4.63 to 153.0 MPa, .0028 to .0058, 2.03 to 28.9 GPa and .08 to .16, respectively.

324 Price, R.H., and Nimick, K.G., 1982, Uniaxial compression test series on Tram tuff: Sandia National Laboratories report SAND82-1055, Albuquerque, NM, 28 p.
Twenty-five uniaxial compression experiments were performed on samples of the Tram Member of the Crater Flat Tuff obtained from drillhole USW-G1 at Yucca Mountain. Resultant unconfined compressive strengths, axial strains to failure, Young's moduli, and Poisson's ratios ranged from 14.5 to 69.2 MPa, .0029 to .0052, 5.17 to 22.5 GPa, and .09 to .38 respectively.

325 Price, R.H., Nimick, F.B., Connolly, J.R., Keil, K., Schwartz, B.M., and Spence, S.J., 1985, Preliminary characterization of the petrologic, bulk, and mechanical properties of a lithophysal zone within the Topopah Spring Mem-

ber of the Paintbrush Tuff: Sandia National Laboratories report SAND84-0860, Albuquerque, NM, 104 p.

Ten large samples of lithophysal tuff were studied as part of the nuclear waste repository project at Yucca Mountain. Macroscopic and microscopic examination led to division of the tuff into three components: (1) very fine-grained, relatively nonporous, feldspar- and cristobalite-rich matrix, (2) coarser more porous, feldspar- and tridymite-rich vapor-phase altered material usually found encircling and, (3) lithophysae, which are cavities often lined with tridymite and occasionally contain carbonate-rich fillings. Results from mechanical tests provided compressive strengths which are lower, and Young's module which are higher, than values predicted from effective porosity.

326 **Price, R.H., Nimick, K.G., and Zirzow, J.A., 1982, Uniaxial and triaxial compression test series on Topopah Spring Tuff: Sandia National Laboratories report SAND82-1723, Albuquerque, NM, 33 p.**

Fifteen uniaxial and triaxial compression experiments were performed on samples of the Topopah Spring Member of the Paintbrush Tuff obtained from drillhole USW-G1 at Yucca Mountain. The water-saturated test specimens were deformed at nominal strain rates of 10^{-2}, 10^{-4}, s^{-1}, confining pressures of 0, 1, 5 and 10 MPa, and room temperature. Resultant unconfined compressive strengths, axial strains to failure, Young's moduli and Poisson's ratios ranged from 44.9 to 176.6 MPa, .0034 to .0057, 22.9 to 40.8 GPa and .15 to .33, respectively.

327 **Price, R.H., Spence, S.J., and Jones, A.K., 1984, Uniaxial compression test series on Topopah Spring Tuff from USW GU-3, Yucca Mountain, southern Nevada: Sandia National Laboratories report SAND83-1646, Albuquerque, NM, 61 p.**

Thirty-five uniaxial compression experiments were performed on cylindrical samples of the Topopah Spring Member of the Paintbrush Tuff obtained from drillhole USW GU-3 at Yucca Mountain.

328 **Prickett, T.A., 1980, Specifications for the development of a fully three-dimensional numerical groundwater model for regional mass transport of radionuclides from a deep waste repository: Camp Dresser and Mckee, Inc., Champaigne, IL, 436 p.**

Specifications are given which are necessary to develop a three-dimensional numerical model capable of simulating regional mass transport of radionuclides from a deep waste repository.

329 **Pruess, K., Tsang, Y.W., and Wang, J.S.Y., 1984, Numerical studies of fluid and heat flow near high-level nuclear waste packages emplaced in partially saturated fractured tuff: Lawrence Berkeley Laboratory report LBL-18552, Berkeley, CA, 46 p.**

The computer code TOUGH was used to model the simultaneous transport of heat, liquid water, vapor, and air in partially saturated, fractured porous rock. Formation parameters were chosen as representative of the potential repository horizon in the Topopah Spring unit of the Paintbrush Tuff.

330 **Purson, J.D., 1983, Evaluation of geochemical properties used in area-to-location screening of a nuclear waste repository at the Nevada Test Site: Los Alamos National Laboratory report LA-9510-MS, Los Alamos, NM, 37 p.**

This report describes three geochemical factors or attributes and their application to an area-to-location screening of the southwestern quadrant of the Nevada Test Site and contiguous areas. Twelve potential host rocks situated in 20 locations are examined. The four units that appear most favorable by geochemical measures are the tuffaceous beds of Calico Hills, granite intrusives, the densely welded Topopah Spring Tuff, and the Crater Flat Tuff at Yucca Mountain.

331 **Quade, J., and Tingley, J.V., 1983, A mineral inventory of the Nevada Test Site, and portions of the Nellis Bombing and Gunnery Range, southern Nye County, Nevada: Nevada Bureau of Mines report DOE/NV/10295-1, Reno, NV, 104 p.**

A comprehensive economic mineral inventory is presented for the Nevada Test Site and surrounding areas.

332 **Ramirez, A.L., and Daily, W.D., 1984, Preliminary evaluation of alterant geophysical tomography in welded tuff: Lawrence Livermore National Laboratory report UCID-20289, Berkeley, CA, 39 p.**

In situ electromagnetic measurements have been performed at 300 MHz to evaluate the applicability of alterant geophysical tomography to delineate flow paths in a welded tuff rock mass. The measurements were made before, during and after a water-based tracer flowed through the rock mass. Alterant geophysical tomographs are compared with independent evidence— borescope logs, neutron logs and dyed-rock samples. Anomalies imaged in the tomograph match fractures mapped with the borescope, and the location of tracer-stained fractures coincides with the location of some image anomalies; other geophysical anomalies exist where tracer-stained fractures were not observed. The field studies were conducted at U12g tunnel at Rainier Mesa in an environment similar to that of the proposed repository horizon at Yucca Mountain.

333 **Ramirez, A.L., and Daily, W.D., 1987, Evaluation of alterant geophysical tomography in welded tuff: Journal of Geophysical Research, vol. 92, no. B8, p 7843-7853.**

Alterant geophysical tomography was operated and evaluated in a welded tuff in order to test its applicability. The field test was conducted in G-Tunnel in Rainier Mesa and was supplemented with a test bed experiment and computer simulation.

334 **Reda, D.C., 1985, Liquid permeability measurements on densely welded tuff over the temperature range 25° to 90°C: Sandia National Laboratories report SAND85-2482, Albuquerque, NM.**

Liquid permeability experiments were conducted on a sample of the Topopah Spring Member of the Paintbrush Tuff. The sample was derived from an outcrop of the formation on Busted Butte. Results indicate liquid permeability using distilled and de-aerated water, to be approximately $3 \times 10^{-19} m^2$ independent of temperature.

335 **Reda, D.C., 1986, Influence of tranverse microfractures on the imbibition of water into initially dry tuffaceous rock: Sandia National Laboratories report SAND86-0420C, Albuquerque, NM, 40 p.**

The isothermal imbibition of liquid water into initially dry, welded, tuffaceous rock was studied. Results indicate that transverse microfractures were a significant impedence to liquid transport. Comparison of saturation vs time measured up and down gradient of the microfractures indicated the potential occurrence of vapor-driven transport of water vapor from the fracture apertures into the matrix pore volume down gradient. It is postulated that adsorption of this vapor onto pore surfaces resulted in the formation of a thin liquid film, which was eventually overrun by the fracture-delayed wetting front. Combined results of this and previous investigations suggest that the detailed hydrologic characterization of tuffaceous rocks on a submeter scale will be most difficult.

336 **Reheis, M.C., 1986, Preliminary study of Quaternary faulting on the east side of Bare Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 86-576, 14 p.**

Active faults bound the east side of Bare Mountain, 15 km west of the proposed repository at Yucca Mountain. Geo-

morphic features, stratigraphy, and soil development indicate that two 3-km-long segments of the range front fault probably moved in Holocene or late Pleistocene time.

337 **Rice, W.A., 1984, Preliminary two-dimensional regional hydrology model of the Nevada Test Site and vicinity: Sandia National Laboratories report SAND83-7466, Albuquerque, NM, 91 p.**
Pacific National Laboratory documented the data requirements, boundary conditions, and calibration of a two-dimensional, finite difference, hydrologic model of the Nevada Test Site and vicinity.

338 **Robinson, B.P., and Beetem, W.A., 1975, Quality of water in aquifers of the Amargosa Desert and vicinity, Nevada: U.S. Geological Survey report USGS-474-215, 64 p.**
The USGS has interpreted the rate and direction of groundwater movement away from the Nevada Test Site by using hydrologic data including the results of hydraulic tests and geophysical surveys in deep wells. This report is a compilation of the analytical data resulting from an intensive sampling program.

339 **Robinson, G.D., Structure of pre-Cenozoic rocks in the vicinity of Yucca Mountain, Nye County, Nevada— A potential nuclear-waste disposal site: U.S. Geological Survey Bulletin 1647, 22 p.**
This report is a preliminary interpretation of the gross distribution and present structure of the largely buried pre volcanic rocks in the study area of about 2,200 km^2 surrounding the site.

340 **Robison, J.H., 1984, Groundwater level data and preliminary potentiometric surface maps, Yucca Mountain and vicinity, Nye County, Nevada: U.S. Geological Survey Water Resources Investigation 84-4197, 11 p.**
This report contains data on groundwater levels and preliminary maps of the potentiometric surface beneath Yucca Mountain and adjacent areas. The water level surface shown generally represents unconfined conditions

341 **Rogers, A.M., Harmsen, S.C., and Carr, W.J., 1981, Southern Great Basin seismological data report for 1980 and preliminary data analysis: U.S. Geological Survey open-file report 81-1086, 151 p.**
Earthquake data for the calendar year 1980 are reported for earthquakes occurring within and adjacent to the southern Great Basin seismograph network. Locations, magnitudes and selected focal mechanisms for these and prior events are compiled and presented in relation to the geology of the region. The principal results are that (1) earthquakes concentrate in fault zones having a northeast orientation, (2) fault zones having a northwest orientation are quiescent or nearly so, and (3) no earthquakes have been detected closer than 12 km to the proposed Yucca Mountain repository site.

342 **Rogers, A.M., Harmsen S.C., Carr, W.J., and Spence, W., 1983, Southern Great Basin seismological data report for 1981 and preliminary data analysis: U.S. Geological Survey open-file report 83-669, 240 p.**
Earthquake data for the calendar year 1981 are reported for earthquakes occurring within and adjacent to the southern Great Basin seismograph network. Locations, magnitudes and selected focal mechanisms for these and prior events are compiled and presented in relation to the geology of the region. The data is collected to aid in the evaluation of the seismic hazard to Yucca Mountain and the proposed repository site. Yucca Mountain lies within a large area of relatively low level seismicity. One M 1.7 earthquake has been located in the Yucca Mountain block in about one year of intense monitoring. At present, somewhat conflicting geologic, seismologic, and stress evidence hinders accurate conclusions about the seismic hazard at the proposed repository site.

343 **Rogers, A.M., Perkins, D.M., and McKeown, F.A., 1976, A catalog of seismicity within 400 km of the Nevada Test Site: U.S. Geological Survey open-file report 76-832, 44 p.**
This catalog contains two tables. Table 1 contains all the historical earthquakes since 1959 within 400 km of the Retrievable Surface Storage Facility (RSSF) prime site on the Nevada Test Site with Modified Mercalli intensity 4.0 a greater through 1974. Table 2 contains all known earthquakes of magnitude 3.0 or greater within 70 km of the RSSF prime site.

344 **Rosenbaum, J.G., Rivers, W.C., 1984, Paleomagnetic orientation of core from drillhole USW GU-3 Yucca Mountain, Nevada: Tiva Canyon Member of the Paintbrush Tuff: U.S. Geological Survey open-file report 85-48, 116 p.**
This report presents the results of the application of the paleomagnetic technique to the orientation of 83 core segments from drillhole USW GU-3. All the core is from the reversely magnetized Tiva Canyon Member of the Paintbrush Tuff. Orientations for the core segments were determined by comparing the remnant directions from the core segments to a paleomagnetic reference direction.

345 **Rosenbaum, J.G., Snyder, D.B., 1984, Preliminary interpretation of paleomagnetic and magnetic property data from drillholes USW G-1, G-2, GU-3, G-3, and VH-1 and surface localities in the vicinity of Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 85-49, 73 p.**
The purpose of this report is to document magnetic property data for samples collected from these drillholes as well as from surface sampling localities on and around Yucca Mountain. The directional data obtained establishes paleomagnetic polarities for the various members of the Paintbrush and Crater Flat Tuffs, and for the Tuffaceous Beds of Calico Hills.

346 **Ross, B., 1984, A conceptual model of deep unsaturated zones with negligible recharge: Water Resources Research vol. 20, no. 11, p. 1627-1629.**
When net recharge is less than about 0.03 mm/yr, moisture movement in deep unsaturated zones at steady state will be dominated by upward movement of vapor driven by the geothermal gradient. With zero-net recharge, there will be a downward flow of liquid water equal to the upward vapor flux. This will produce a profile of suction potential versus depth qualitatively similar to that expected if recharge is not negligible. Consequently, the existence of a region of uniform potential is not in itself evidence of recharge.

347 **Ross, C.S., and Smith, R.L., 1961, ash-flows tuffs, their origin, geologic relations and identification: U.S. Geological Survey professional paper 366, 77 p.**
This report deals with the history of the conceptual origins for ash-flows tuffs, gives detailed descriptions of their geologic characteristics, mode of occurrence, criteria for their recognition; and considers their distribution and consolidation.

348 **Rundberg, R.S., 1987, Assessment report on the kinetics of radionuclide adsorption on Yucca Mountain tuff: Los Alamos National Laboratory report LA-11026-MS, Los Alamos, NM, 93 p.**
The kinetics of sorption was measured by observing the uptake of radionuclides by tuff wafers and crushed tuff as a function of time. In addition, the broadening of breakthrough curves for cations eluted through crushed-tuff columns was interpreted in terms of adsorption kinetics. The results of these measurements are consistent with a diffusion-limited adsorption mechanism for simple cations, such as strontium, cesium, and barium. The adsorption kinetics for these simple cations is sufficiently fast so that equilibrium

can be assumed for the retardation of these chemical species in the groundwater velocities that would be reasonable for most release scenarios. The actinides, in particular plutonium, exhibited a slow time dependence for adsorption. The lack of reproducibility in sorption measurements makes the interpretation of those results tenuous. The further study of actinide sorption kinetics is therefore, recommended.

349 **Rush, F.E., 1971, Regional groundwater systems in the Nevada Test Site area, Nye, Lincoln, and Clark Counties, Nevada: U.S. Geological Survey Water Reconnaissance Series, report 54, 23 p.**

A mass balance approach is utilized to estimate total groundwater flowing through the Pahute Mesa, Ash Meadows and Sarcobatus Flat groundwater basins. The total groundwater in storage and perennial yields are also estimated.

350 **Rush, F.E., Thordarson, W., and Bruckheimer, L., 1983, Geohydrologic and drillhole data for test well USW H-1, adjacent to Nevada Test Site, Nye County, Nevada: U.S. Geological Survey open-file report 83-141, 43 p.**

This report presents data collected to determine the hydraulic characteristics of rocks penetrated in test well USW H-1. Data on drilling operations, lithology, borehole geophysics, hydrologic monitoring, core analysis, groundwater chemistry and pumping and injection tests for well USW H-1 are presented

351 **Rush, F.E., Thordarson, W., and Bruckheimer, L., 1984, Geohydrology of test well USW H-1, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report Water Resources Investigations 84-4032, 62 p.**

This report contains the results of hydraulic testing, hydrologic monitoring, and geophysical logging of test well USW H-1.

352 **Rush, F.E., Thordarson, W., and Pyles, D.G., 1984, Geohydrology of test well USW H-1, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Water-Resources Investigations report 84-4032, 55 p.**

The drilling procedures, geohydrologic setting, lithology, geophysical logs, radioactive tracer surveys, core analyses, static-water levels, aquifer test, and groundwater chemistry for well USW H-1 at Yucca Mountain are presented. Seeps were noted with a down-hole televideo logger in the unsaturated zone. It was not known if this was detergent or groundwater from a perched zone.

353 **Russell, C.E., 1987, Hydrogeologic investigations of flow in fractured tuffs in Rainier Mesa, Nevada Test Site: University of Nevada, Las Vegas, Masters Thesis, 156 p.**

A hydrogeologic study was conducted within the mesa with emphasis on several parameters: 1) the source of fracture water within the tunnel beds, 2) period of principal recharge, 3) hydraulic residence time, 4) hydraulic response lag time, 5) total amount of recharge per year infiltrating into the U12n tunnel catchment basin, 6) extent of mixing between fracture systems and, 7) the effects of nuclear testing on localized groundwater chemistry and discharge. The success in determining the various parameters was mixed

354 **Russo, A.J., and Reda, D.C., 1988, Drying of an initially saturated fractured volcanic tuff: Sandia National Laboratories report SAND87-0293C, Albuquerque, NM, 6 p.**

The isothermal drying of a Topopah Spring sample was studied. The specimen contained several microfractures transversely orientated to the direction of water or vapor migration. These fractures were found to be regions of rapid dryout and during imbibition studies, the microfractures inhibited liquid transport.

355 **Sargent, K.A., Noble, D.C., and Ekren, E.B., 1964, Belted Range Tuff of Nye and Lincoln Counties, Nevada: in Cohee, G.V., and West, W.S., Changes in stratigraphic nomenclature by the U.S. Geological Survey, 1964: U.S. Geological Survey Bulletin 1224-A, p. 32-36.**

The Indian Trail Formation is restricted to the eastern half of the Nevada Test Site and the Tub Spring and Grouse Canyon Members are placed in a new formation named the Belted Range Tuff.

356 **Sargent, K.A., and Orkild, P.P., 1973, Geologic map of the Wheelbarrow Peak-Rainier Mesa area, Nye County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-754.**

This map contains a geologic map of Rainier Mesa and the area to the north and northeast.

357 **Sass, J.H., and Lachenbruch, A.H., 1982, Preliminary interpretation of thermal data from the Nevada Test Site: U.S. Geological Survey open-file report USGS- OFR-82-973, 30 p.**

Analysis of data from 60 wells in and around the Nevada Test Site, including 16 in the Yucca Mountain area, indicates a thermal regime characterized by large, vertical and lateral gradients in heat flow. Estimates in heat flow indicate considerable variation on both regional and local scales. The variations are attributable primarily to hydrologic processes involving inter-basin flow with a vertical component of velocity of a few mm/yr.

358 **Sass, J.H., Lachenbruch, A.H., and Mase, C.W., 1980, Analysis of thermal data from drillholes UE25a#3 and UE25a#1, Calico Hills and Yucca Mountain, Nevada Test Site: U.S. Geological Survey open-file report 80-826, 25 p.**

Thermal data from two sites about 20 km apart indicate that heat flow both within and below the upper 800 m is affected significantly by hydrothermal convection. The thermal data indicates a net upward flow beneath Calico Hills and a net downward flow beneath Yucca Mountain.

359 **Schoff, S.L., and Moore, J.E., 1964, Chemistry and Movement of groundwater, Nevada Test Site: U.S. Geological Survey Trace Element Investigations TEI-838, 73p.**

Three chemical types of water are distinguished at the Nevada Test Site and vicinity: 1) Na-k water is related to tuff and to alluvium containing detrital tuff, 2) Ca-Mg water is related to limestone and dolomite, or to alluvium containing detritus of these rock types and, 3) a mixed chemical type derived from mixed rock types. Distribution of these water types and the progressive changes in the dissolved solids suggest that the groundwater in the Nevada Test Site moves toward the Amargosa Desert.

360 **Schoff, S.L., and Moore, J.E., 1968, Sodium as a clue to direction of groundwater movement, Nevada Test Site: U.S. Geological Survey professional paper 600-D, p. D30-D33.**

Sodium dissolved in water generally stays in solution. It is the predominant cation in groundwater in volcanic aquifers in the Nevada Test Site, but is nearly lacking in alluvial and carbonate-rock aquifers in southern Indian Springs Valley south of the Nevada Test Site. The low content of sodium in the water of Indian Spring valley shows that the water has not migrated into the valley from the Nevada Test Site.

361 **Schoff, S.L., and Wilmarth, V.R., 1961, Review of hydrology of Areas 3 and 12, Nevada Test Site: U.S. Geological Survey Technical Letter NTS-2, 10 p.**

The geological surveys studies of subsurface water conditions in areas 3 and 12 were documented. Two new drillholes were drilled within Area 12, these were test wells one and two. The elevation of the regional water table was defined within these wells.

362 Schoff, S.L., and Winograd, I.J., 1961, Hydrologic significance of six core holes in carbonate rocks of the Nevada Test Site: U.S. Geological Survey report TEI-787, 97 p.

Six core holes drilled in the northern part of Yucca Valley penetrate paleozoic carbonates to depths of hundreds of feet. None of these drillholes reached the regional water table, however, two entered a perched zone of saturation in marble. Several lines of evidence suggest that the carbonate rocks, if saturated, would yield water to appropriately constructed wells penetrating them. Yields of 6 gpm may be expected.

363 Schoff, S.L., and Winograd, I.J., 1962, Potential aquifers in carbonate rocks, Nevada Test Site, Nevada: U.S. Geological Survey professional paper 450-C, p. C111-C113.

Two drillholes, U12e.M-1 drilled within the U12e tunnel complex of Rainier Mesa and ME-3 in northern Yucca Flat were drilled to the regional aquifer in order to test its permeability. U12e.M-1 was finished in the unsaturated zone and was injection-tested whereas ME-3 intersected the water table.

364 Science Applications International Corporation, 1985, Tectonic stability and ground motion at Yucca Mountain: report of a workshop at SAIC, August 7-8, 1984 and January 25-26, 1985, La Jolla, CA, SAIC report 84/1847.

The historic seismic record at Yucca Mountain is too brief and incomplete to provide an accurate assessment of the frequency/magnitude relationship of the quality required to extrapolate future seismicity. *In situ* stress measurements indicate that failure is possible along favorably orientated faults in the Yucca Mountain region. However, no quantitative statements about earthquake probability and magnitude associated with failure can be determined from *in situ* data alone. The determination of the largest earthquake in the region is highly uncertain because of unknown fault characteristics at depth and because of tenuous links between fault dimensions and EQ cap . y.

365 Scott, R.B., and Bonk, J., 1984, Preliminary geologic map of Yucca Mountain, Nye County, Nevada, with geologic sections: U.S. Geological Survey open-file report 84-494.

A geologic map and cross section of Yucca Mountain and vicinity are presented.

366 Scott, R.B., Castellanos, M., 1984, Stratigraphic and structural relations of volcanic rocks in drillholes USW GU-3 and USW G-3, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 84-491, 121 p.

Stratigraphic and structural studies from these holes in southern Yucca Mountain have been correlated with similar results in central and northern Yucca Mountain and with results of surface mapping to produce a conceptual model of the geology of the rock volume being considered as the potential repository. Lithologic description of the rock units and location and orientation of faults and fractures are also discussed.

367 Scott, R.B., et al., 1983, Geologic character of tuffs in the unsaturated zone at Yucca Mountain, southern Nevada: in Mercer, J.W., Rao, P.S., and Wendell, I., [eds.], *Role Of The Unsaturated Zone in Radioactive and Hazardous Waste Disposal*, Ann Arbor Science, Denver, CO, p. 289-339.

The geologic setting and a conceptual hydrogeologic flow model is presented for the unsaturated zone of Yucca Mountain. Within this model recharge is assumed to occur and vertical flow dominates. Perched groundwater tables may exist above relatively nontransmissive zeolitized nonwelded tuffs. Lateral flow may occur within these saturated zones.

368 Scott, R.B., et al., 1984, Geological and geophysical evidence of structures in northwest-trending washes, Yucca Mountain, southern Nevada, and their possible significance to a nuclear waste repository in the unsaturated zone: U.S. Geological Survey open-file report 84-567, 23 p.

Geological and geophysical evidence suggests that five prominent linear northwest-trending washes in the northeastern part of Yucca Mountain are underlain by zones of right-lateral strike-slip faults. The strikes, sense of motion, geographic position, and age of these Yucca Mountain strike-slip faults are similar to those of the regional Walker Lane-Las Vegas Valley shear zones. These strike-slip zones may affect the proposed repository site at Yucca Mountain in the following ways: 1) the stability of mined openings may be affected where brecciated or highly fractured zones are encountered; 2) the fractured zones may allow recharge to drain rapidly from the repository; 3) at greater depths, the fracture zones may provide hydrologic conduits past the sorptive zeolite units within Yucca Mountain.

369 Senterfit, R.M., Hoover, D.B., Chornack, M., 1982, Resistivity sounding by the Schlumberger method in the Yucca Mountain and Jackass Flats area, Nevada Test Site, Nevada: U.S. Geological Survey open-file report 82-1043, 41 p.

A Schlumberger resistivity survey was made in the west-central sector of the Nevada Test Site to determine the geoelectric characteristics of the area and to relate them to the thicknesses and horizontal continuity of the lithologic units in the Yucca Mountain and Jackass Flats areas, and to locate faulting within the survey area. A total of 29 soundings are included.

370 Shepard, A.O., 1961, A heulandite-like mineral associated with clinoptilolite in tuffs of Oak Spring Formation, Nevada Test Site, Nevada: U.S. Geological Survey professional paper 424-C, p. C320-C323.

A heulandite-like mineral, found in the Oak Spring Formation is discussed. The heulandite-like mineral can be distinguished from heulandite by its slower phase change during heating and the higher temperatures required for phase change and destruction. It is also detectable by x-ray diffraction methods after the phase change and prior to mineral destruction

371 Sinnock, S., 1982, Geology of the Nevada Test Site and nearby areas, southern Nevada: Sandia National Laboratories report SAND82- 2207, Albuquerque, NM, 55 p.

This report addresses the geologic setting of the Nevada Test Site in the context of current waste isolation policy. The intent is to provide a synthesis of geological conditions at the Nevada Test Site and nearby areas so that a general background of information is available for assessing the possible role of geology in providing protection for humans from buried radioactive waste.

372 Sinnock, S., Easterling, R.G., 1983, Empirically determined uncertainty in potassium-argon ages for Plio-Pleistocene basalts from Crater Flat, Nye County, Nevada: Sandia National Laboratories report SAND82-2441, Albuquerque, NM, 15 p.

This report investigates the accuracy of K-Ar age determinations for late Cenozoic basalts in Crater Flat. The use of statistics was employed to determine the uncertainty and error involved in the age determinations of these young basalts.

373 Sinnock, S. and Lin, Y.T., 1987, Preliminary bounds on the expected postclosure performance of the Yucca Mountain repository site, southern Nevada: Journal of Geophysical Research, vol. 92, no. B, p 7820-7842.

Based on the current data and understanding of site characteristics at Yucca Mountain, the likely performance range of a mined repository for spent nuclear fuel can be calculated. The calculated travel times and mass transport of radionuclides are compared to EPA and NRC regulations.

374 Sinnock, S., Lin, Y.T., and Tierney, M.S., 1986, Preliminary estimates of groundwater travel

time and radionuclide transport at the Yucca Mountain repository site: Sandia National Laboratories report SAND85-2701, Albuquerque, NM, 156 p.

This report presents the assumptions, methods, and data used in a probabilistic approach to the calculation of groundwater travel times and total radionuclide releases to the water table below Yucca Mountain. Results from the analyses consist of distributions of groundwater travel time from the disturbed zone to the water table and the cumulative curie releases to the water table.

375 **Smith, C., and Ross, H.P., 1982, Interpretation of resistivity and induced polarization profiles with severe topographic effects, Yucca Mountain area, Nevada Test Site, Nevada: U.S. Geological Survey open-file report 82-182.**

A detailed numerical model and geological interpretation has been completed for 9.5 line miles of dipole-dipole resistivity and IP data at Yucca Mountain. Results indicate a major fracture zone which trends N 45°W. along the eastern flank of Yucca Mountain. A large area of uniformly high resistivity and few inferred faults occurs west of the inferred fracture zone, beneath the crest and eastern flank of the mountain. The data suggests that this is the most favorable location for a possible repository site within the study area.

376 **Smith, D.M., Updegraff, C.D., and Bonano, E.J., 1985, Preliminary assessment of radionuclide vapor transport in unsaturated tuff: Sandia National Laboratories report SAND85-0829C, Albuquerque, NM, 14 p.**

The possibility of radionuclide migration in the vapor phase for unsaturated tuff has been investigated. Radionuclide movement could be the result of either aerosol migration or convection/diffusion of volatile species. A diffusion model for supersaturation of air in tuff groundwater indicates that there is no possibility of aerosol formation under repository conditions. As a first order approximation, the maximum ratio of transport in the vapor phase to that in the liquid phase is given by 1000 Kw where Kw is the vapor-liquid coefficient for the particular radionuclide.

377 **Smith, D.M., Updegraff, C.D., Bonano, E.J., and Randall, J.D., 1986, Assessment of radionuclide vapor-phase transport in unsaturated tuff: Sandia National Laboratories report NUREG/CR-4693, Albuquerque, NM, 56 p.**

This report describes bounding calculations performed to investigate the possibility of radionuclide migration in a vapor phase associated with the emplacement of high-level waste canisters in unsaturated-tuff formations. Two potential transport mechanisms were investigated: aerosol migration and convection/diffusion of volatile species. Results indicate that the formation of aerosols in the repository environment is not possible and vapor transport for iodine may play an important role in the overall release scenario depending on the particular repository conditions.

378 **Smith, R.L., 1960, Zones and zonal variations in welded ash-flows: U.S. Geological Survey professional paper 354-F.**

The various zones of welding and crystallization that occur within welded ash-flows tuffs are discussed. The effects of the underground topography and multiple cooling units on field interpretations are also presented.

379 **Smith, G.V., et al., 1981, Preliminary survey of tuff distribution in Esmeralda, Nye, and Lincoln Counties, Nevada: Sandia National Laboratories report SAND79-1539, Albuquerque, NM, 118 p.**

This report inventories the surface distribution of silicic tuffs in Nye, Esmeralda, and Lincoln Counties, Nevada, based on a review of available literature. Tuff distribution is discussed on a regional basis. Tuff thicknesses and alterations, structural complexity, and proximity to recent faulting, recent volcanism, and mineral resources are discussed for each area.

380 **Smyth, J.R., 1982, Zeolite stability constraints on radioactive waste isolation in zeolite-bearing volcanic rocks: Journal of Geology, vol. 90., p. 195-201.**

Zeolites are unstable at elevated temperatures and at low water vapor pressures, and they may break down by reversible dehydration or irreversible mineralogical reactions. All of the breakdown reactions occurring with increased temperatures involve a net volume reduction and evolution of fluids. Thus, they may provide a pathway (shrinkage fractures) and a driving force (fluid pressure) for release of radionuclides to the biosphere. These reactions may be avoided by keeping zeolite-bearing horizons saturated with water and below about 85°C. This may restrict allowable gross-thermal loadings in radioactive waste repositories in zeolite-bearing volcanic rocks.

381 **Smyth, J.R., and Caporuscio, F.A., 1981, Review of the thermal stability and cation exchange properties of the zeolite minerals clinoptilolite, mordenite, and analcime, applications to radioactive waste isolation in silicic tuff: Los Alamos National Laboratory report LA-8841-MS, Los Alamos, NM, 31 p.**

The cation-exchange capacity of the Yucca Mountain zeolites may allow them to pose as a barrier to the cationic species of radionuclides. However, zeolites are unstable at elevated temperatures and at low water vapor pressures. Therefore, these minerals may restrict allowable gross thermal loadings at waste repositories in volcanic rock.

382 **Smyth, J.R., Thompson, J., and Wolfsberg, K., 1980, Microautoradiographic studies of the sorption of U and Am on natural rock samples: Radioactive Waste Management, vol 1, no. 1, p. 13-24.**

Selective sorption of uranium and americium by specific minerals in complex geologic materials (granite, argillite, tuff and alluvium) has been investigated by means of autoradiography on rock thin sections. Results indicate that low-temperature, hydrous (commonly secondary) mineral phases are much better sorbers of uranium than primary, high-temperature, anhydrous phases. This suggests that one percent or less of secondary alteration phases may completely dominate the sorption properties of a rock.

383 **Snyder, R.P., 1977, Geology of the Gold Meadows Stock, Nevada Test Site: U.S. Geological Survey report USGS-474-179, 10 p.**

The Gold Meadows stock outcrops in an elongate pattern about one mile north of Rainier Mesa. The stock ranges from grano-diorite to calc-alkaline granite, and three of five modes indicate that the rock is quartz monzonite. The age of the stock has been calculated as 91.8 ± 2.6 my. Gravity and flow-banding data indicate a source area to the southwest of the present outcrop. Groundwater measurements from one deep drillhole indicate perched water at several places in the stock.

384 **Snyder, D.B., and Carr, W.J., 1982, Preliminary results of gravity investigations at Yucca Mountain and vicinity, southern Nye County, Nevada: U.S. Geological Survey open-file report 82-701, 36 p.**

Additional studies resulted in 423 new gravity stations in the Yucca Mountain area. A linear increase of 0.26g/cm^3/km is indicated within the thick tuff sequences. This steady increase of density within the tuff sequences makes the density contrast across the basal contact of the tuff the only strong source of gravity fluctuations. Isostatic and 2.0-g/cm^3 Bouguer corrections were applied to the observed gravity values to remove deep-crust-related regional gradients and topographic effects, respectively. The resulting residual-gravity plot shows significant gravity anomalies that correlate closely with structures inferred from drillhole and surface geologic studies.

385 Snyder, D.B., and Carr, W.J., 1984, Interpretation of gravity data in a complex volcano-tectonic setting, southwestern Nevada: Journal of Geophysical Research, vol. 89, no. B12, p 10,193-10,206.

A regional gravity study, based on an irregular 2-km data grid, was conducted at Yucca Mountain as a part of the NNWSI research. The results were used to delineate the pre-Tertiary surface.

386 Spaulding, W.G., 1983, Vegetations and climates of the last 45,000 years in the vicinity of the Nevada Test Site, Nevada: U.S. Geological Survey open-file report 83-535, 210 p.

This study characterizes long-term climatic variability inherent in this area. Specifically, paleoenvironmental and paleoclimatic reconstructions spanning the last 45,000 years are offered to facilitate calculations of potential variations in water-table levels and groundwater recharge.

387 Spaulding, W.G., Robinson, S.W., and Paillet, F.L., 1984, Preliminary assessment of climatic change during Late Wisconsin time, southern Great Basin and vicinity, Arizona, California, and Nevada: U.S. Geological Survey Water-Resources Investigations report 84-4328, 40 p.

Concentration and relative abundance of plant microfossils illustrate compositional variations in samples from the Eleana Range-2 packrat midden. Nine macrofossil assemblages spanning 6,500 years record local vegetation changes in the southern Great Basin of Nevada during the last half of the Late Wisconsin glacial age.

388 Spengler, R.W., Byers, F.M. Jr., and Warner J.B., 1981, Stratigraphy and structure of volcanic rocks in drillhole USW-G1, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 81-1349, 54 p.

This report gathers and interprets information on the thickness, lateral extent, correlation, and structural characteristics of the volcanic rocks obtained from this drillhole. X-ray diffraction and chemical analyses were performed to aid in rock identification.

389 Spengler, R.W., Chornack, M.P., Muller, D.C., and Kibler, J.E., 1984, Stratigraphic and structural characteristics of volcanic rocks in core hole USW G-4, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 84-789, 77 p.

Stratigraphic section from core hole USW G-4 is composed entirely of thick sequences of ash-flows tuff that are separated by fine- to coarse-grained ash-fall tuff and tuffaceous sediments. All rocks are of Tertiary age and vary in composition from rhyolitic to quartz latitic. Major stratigraphic units include the Paintbrush Tuff, Tuffaceous Beds of the Calico Hills, and Crater Flat Tuff.

390 Spengler, R.W., Muller, D.C., and Livermore, R.B., 1979, Preliminary report on the geology and geophysics of drillhole UE25a-1, Yucca Mountain, Nevada Test Site: U.S. Geological Survey open-file report 79-1244, 43 p.

Drillhole UE25a-1 penetrates the Tiva canyon and Topopah Spring Members of the Paintbrush Tuff, Tuffaceous Beds of the Calico Hills, and the Prow Pass and Bullfrog Members of the Crater Flat Tuff. This drillhole provides detailed stratigraphic and structural control of tuffs underlying northeastern Yucca Mountain.

391 Spengler, R.W., and Rosenbaum, J.G., 1980, Preliminary interpretations of geologic results obtained from boreholes UE25a-4, -5, -6, and -7, Yucca Mountain, Nevada Test Site: U.S. Geological Survey Open file report 80-929, 33 p.

Four drillholes were drilled in order to identify near-surface structural features that may be present beneath Drillhole Wash, one of four linear northwest-trending washes that transect the northeastern part of Yucca Mountain. The drillholes intersected, in descending order, the Tiva Canyon, Yucca Mountain, Pah Canyon, and Topopah Spring Members of the Paintbrush Tuff. The results are best explained by small scale tectonic rotation that occurred about a near-vertical axis as a result of minor strike-slip or oblique-slip movement within Drillhole Wash.

392 Squires, R.R., Young, R.L., 1984, Flood potential of Fortymile Wash and its principal southwestern tributaries, Nevada Test Site, southern Nevada: U.S. Geological Survey Water Resources Investigations report 83-4001, 33 p.

This study provides information regarding the probable characteristics of the 100-year, 500-year, and regional maximum floods and the resulting areas of probable inundation along Fortymile Wash and its southwestern tributaries. The study identifies the extent of and effect flooding would have on possible waste disposal facilities. Also the peak flow magnitudes, average flow velocities, and depths that might be expected during the 100-year, 500-year, and regional maximum floods are given.

393 Stock, J.M., Healey, J.H., and Hickman, S.H., 1982, report on televiewer log and stress measurements in core hole USW G-2, Nevada Test Site, October-November, 1982. U.S. Geological Survey open-file report 84-172, 31 p.

Hydraulic fracturing stress measurements and a borehole televiewer log were obtained in hole USW G-2 from the east side of Yucca Mountain. Total logging depth was 1200 m.

394 Stock, J.M., et al., 1985, Hydraulic fracturing stress measurements at Yucca Mountain, Nevada, and relationship to the regional stress field: Journal of Geophysical Research, vol. 90, no. B10, p. 8691-8706.

Hydraulic fracturing stress measurements and acoustic borehole televiewer logs are presented for holes USW G-1 and USW G-2 at Yucca Mountain

395 Stock, J.M., et al., 1986, report on televiewer log and stress measurements in holes USW G-3 and UE-25p1 Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 86-369, 91 p.

Hydraulic fracturing stress measurements and televiewer observations were made in drillholes USW G-3 and Ue-25p1 on Yucca Mountain, Nevada. The results from USW G-3 are similar the the results reported previously from USW G-1 and USW G-2 with a low minimum horizontal principal stress in a direction approximately N 65°W.

396 Sutton, V.D., 1984, Data report for the 1983 seismic-refraction experiment at Yucca Mountain, Beatty and vicinity, southwestern Nevada: U.S. Geological Survey open-file report 84-661, 196 p.

In June 1983, a seismic-refraction survey was conducted in the vicinity of Yucca Mountain and Beatty to better define the P-wave velocity structure of the upper crust in this area.

397 Sutton, V.D., 1985, Data report for the 1985 seismic-refraction experiment at Yucca Mountain and vicinity, southwestern Nevada: U.S. Geologic Survey open-file report 85-591, 282 p.

Seismic-refraction data from Yucca Mountain are presented.

398 Swadley, W.C., Hoover, D.L., and Rosholt, 1984, Preliminary report on Late Cenozoic faulting and stratigraphy in the vicinity of Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 84-788, 42 p.

Mapping of surficial deposits and examination of faults in natural and trenched exposures in a 1100 km^2 area around the site of a potential repository for radioactive waste at Yucca Mountain have identified 32 faults that offset or frac-

ture Quaternary deposits. Where the amount of Quaternary offset can be estimated, dip-slip movement is on the order of 3 m or less on faults in and near Yucca Mountain. Maximum Quaternary offset within the study area may be as much as 30 m. No strike-slip movement was demonstrated nor can it be ruled out. The Quaternary faults are divided into three broad groups: five faults moved between about 270,000 and 40,000 years ago; four faults moved about 1 my ago; and 23 faults moved probably between 2 to 1.2 my ago. Offset of Holocene deposits has not been demonstrated.

399 **Swadley, W.C., and Hoover, D.L., 1983, Geology of faults exposed in trenches in Crater Flat, Nye County, Nevada: U.S. Geologic Survey open-file report 83-608, 15 p.**
Study of fault movement along the eastern edge of Crater Flat indicates that the main fault movement occurred about 1.1 my ago. Later fault movement occurred approximately 40,000 to 260,000 years ago with the older date most likely.

400 **Swolfs, H.S., and Savage, W.Z., 1985, Topography, stresses, and stability at Yucca Mountain, Nevada: 26th U.S. Symposium on Rock Mechanics, Rapid City, SD, June 26-28, 1985, p. 1121-1130.**
Plane-strain solutions are used to analyze the influence of topography on the state of stress at Yucca Mountain. The results are in good agreement with the measured stress components obtained in drillholes by the hydro-fracture method, particularly those measured directly beneath the crest of the ridge.

401 **Sykes, M.L., Heiker, G.H., and Smyth, J.R., 1979, Mineralogy and petrology of tuff units from the UE25a#1 drill site, Yucca Mountain, Nevada: Los Alamos National Laboratory LA-8139-MS, Los Alamos, NM, 76 p.**
This paper investigates the mineralogy and petrology of the rock units encountered in the UE25a#1 drillhole. Zeolites mineral assemblages are studied in the tuff units encountered and are compared to the mineralogical, textural and compositional properties of the tuffs encountered at the J-13 drill site.

402 **Szabo, B.J., Carr, W.J., and Gottschall, W.C., 1981, Uranium and thorium dating of Quaternary carbonate accumulations in the Nevada Test Site region, southern Nevada: U.S. Geological Survey open-file report 81-119, 35 p.**
Several types of carbonates were collected from the Nevada Test Site area and were dated by the uranium-series method. Among the significant age obtained were three dates of greater than 400,000 years on calcite-filling fractures above and below the water table in an exploratory drillhole within Yucca Mountain.

403 **Szabo, B.J., and Kyser, T.K., 1985, Uranium, thorium isotopic analyses and uranium-series ages of calcite and opal, and stable isotopic compositions of calcite from drill cores UE25a#1, USW G-2 and USW G-3/GU-3, Yucca Mountain, Nevada: U.S. Geological Survey open-file report 85-224, 25 p.**
Fracture- and cavity-filling calcite and opal in the unsaturated zone of three drill cores at Yucca Mountain were analyzed for uranium and stable isotope contents, and were dated by the uranium-series method. Stable isotope data indicate that the water from which the calcite precipitated was meteoric in origin. The decrease in ^{18}O and increase in ^{13}C with depth are interpreted as being due to the increase in temperature in drillholes corresponding to an estimated maximum geothermal gradient of 43° per km. Of the 18 calcite and opal deposits dated, four of the calcite and all of the opal samples yield dates older than 400,000 years and the rest of the calcite deposits yield dates between 26,000 and 310,000 yrs.

404 **Szabo, B.J., and O'Malley, P.A., 1985, Uranium-series dating of secondary carbonate and silica precipitates relating to fault movements in the Nevada Test Site region and of caliche and travertine samples from the Amargosa Desert: U.S. Geological Survey open-file report 85-47, 12 p.**
Analyses of secondary carbonate samples from Yucca Mountain and from Crater and Yucca Flats yielded minimum ages for the last significant displacement of faults between 27,000 and 219,000 years. Dating results of an opaline carbonate rock sample from a fault on the east side of Yucca Mountain indicate the age of the deposit is greater than 360,000 years.

405 **Tarr, A.C., and Rogers, A.M., Analysis of earthquake data recorded by digital field seismic systems, Jackass Flats, Nevada: U.S. Geological Survey open-file report 86-420, 70 p.**
Analysis of 59 time series from ten small-magnitude earthquakes in the southern Nevada Test Site yielded several significant results.

406 **Terry, S.S, 1974, Geology of the UE12t#3 vertical drillhole, Area 12, Nevada Test Site: U.S. Geological Survey report 474-213, 20 p.**
The UE12t#3 vertical drillhole is located in the north end of Rainier Mesa and was drilled to a total depth of 663 m. It is collared in the Rainier Mesa Member of the Timber Mountain Tuff above the U12t.03 drift. The stratigraphy, structure, engineering geology, and physical properties and their relation to tunneling are discussed.

407 **Terry, S.S., and Cunninghan M.J., 1975, Geology of the U12n.07 UG-3 drillhole, Area 12, Nevada Test Site: U.S. Geological Survey report USGS-474-207, 28p.**
The U12n.07 UG-3 horizontal drillhole was collared at Nevada State coordinates of N. 892,242, E. 634,966 at an elevation of 1849 m within the tunnel beds of Rainier Mesa. This report contains stratigraphic, structural, geophysical, mechanical property and geological engineering data.

408 **Teufel, W.L., 1981, Frictional properties of jointed welded tuff: Sandia National Laboratories report SAND-81-0212, Albuquerque, NM, 37 p.**
Simulated joint experiments were conducted on the Grouse Canyon Member of the Belted Range Tuff with an emphasis on joint friction.

409 **Thomas, K.W., 1987, Summary of sorption measurements performed with Yucca Mountain, Nevada, tuff samples and water from well J-13: Los Alamos National Laboratory report LA-10960-MS, Los Alamos, NM, 99 p.**
The sorption studies undertaken from 1977 to 1985 by LANL are summarized and the data tabulated in the appendix. Sorption has been investigated as a function of mineralogy, temperature, particle size, waste-element concentration, water composition, sorption time, and other variables. The major elements studied were americium, cesium, neptunium, plutonium, thorium, uranium, strontium, technetium, tin, barium, radium, cerium, europium, and selenium.

410 **Thordarson, W., 1965, Perched groundwater in zeolitized-bedded tuff, Rainier Mesa and vicinity, Nevada Test Site, Nevada: U.S. Geological Survey report TEI-862, 89 p.**
Zeolitic-bedded tuff at the base of the tuff sequence within Rainier Mesa controls the recharge rate of groundwater to the underlying and more permeable Paleozoic aquifers. The zeolitic tuff is a fractured aquitard with high interstitial porosity and low interstitial permeability and fracture-transmissivity. The tuff is generally fully-saturated interstitially hundreds of feet above the regional water table, yet no appreciable volume of water moves through the interstices because of the very low permeability. The only freely-moving water observed in miles of underground workings occurred in fractures, usually fault zones. The top of fracture

saturation lies within a few hundred feet of 6,000 ft. Head gradients indicate a downward-flux-fracture water and the interstitial has 25- to 35-times greater specific conductance than does the fracture water.

411 Thordarson, W., 1983, Geohydrologic data and test results from well J-13, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey Water-Resources Investigations report 83-4171, 57 p.

The geology, lithology, geophysical logs, physical properties, static water level, aquifer test, and water quality are presented for well J-13 in Jackass Flats.

412 Thordarson, W., and Robinson, B.P., 1971, Wells and springs in California and Nevada within 100 miles of the point 37° 15' N., 116° 25' W., on Nevada Test Site: U.S. Geological Survey report USGS-474-85, 25 p.

A study of all wells and springs within 100 miles of the Nevada Test Site was conducted. The results are that 6,032 wells and 754 springs are known to exist in this area and those wells located in the valley fill seem to be the best producers. The types of groundwater utilization in urban and rural areas are discussed.

413 Thordarson, W., Rush, F.E., Spengler, R.W., and Waddell, S.J., 1984, Geohydrologic and drillhole data for test well USW H-3, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 84-149, 31 p.

This report presents data collected to determine the hydraulic characteristics of rocks penetrated in test well USW H-3. Data on drilling operations, lithology, borehole geophysics, hydrologic monitoring, pumping, swabbing, and injection tests for the well are presented.

414 Thordarson, W., Rush, F.E., and Waddell, S.J., 1985, Geohydrology of test well USW H-3, Yucca Mountain: U.S. Geological Survey Water-Resources Investigations report 84-4272, 38 p.

The well construction, geology, bore-hole flow survey, geophysical log interpretations, and hydraulic testing are presented for well USW H-3. This well is located on the main ridge of Yucca Mountain.

415 Thordarson, W., Young, R.A., and Winograd I.J., 1967, Records of wells and test holes in the Nevada Test Site and Vicinity: U.S. Geological Survey report TEI-872.

An inventory of all hydrologic wells and test holes located on the Nevada Test Site as of 1966 is presented. The inventory includes the well name, driller, year completed, depth, casing type, formations tested, static water level, yield, drawdown, and various remarks.

416 Throckmorton, C.K., 1987, Photogeologic study of small-scale linear features near a potential nuclear waste repository site at Yucca Mountain, southern Nye County, Nevada: U.S. Geological Survey, open-file report 87-409, 54 p.

Linear features were mapped from 1:2400-scale aerial photographs by means of a Kern PG 2 stereoplotter. Bearings of traces measured in the field were different than those recorded from aerial photographs. The 1:2400 photographic scale even though large was not large enough to identify the majority of fracture traces. Yucca Mountain is poorly suited for this type of study.

417 Tillerson, J.R., and Nimick, F.B., 1984, Geoengineering properties of potential repository units at Yucca Mountain, Southern Nevada: Sandia National Laboratories report SAND84-0221, Albuquerque, NM, 110 p.

This report documents the database of geoengineering properties used in the analyses that aided the selection of the waste emplacement horizon and in analyses synopsized in the Environmental Assessment report prepared for the Yucca Mountain site. Average thermal and mechanical properties (and their anticipated variations) are presented. Based on these data, analyses completed to date, and previous excavation experience in tuff, it is anticipated that existing mining technology can be used to develop stable underground openings and that repository operations can be carried out safely. Data from Rainier Mesa G-Tunnel are included.

418 Travis, B.J., et al., 1983, Numerical simulation of flow and transport in partially saturated, fractured tuff: Los Alamos National Laboratory report LA-UR-83-3341, Los Alamos, NM, 17 p.

A modeling study of flow and transport for Yucca Mountain is presented. Numerical models of mass and heat flow in conjunction with analytical solutions are being used for sensitivity and pathway analysis and to aid in design and interpretation of laboratory and field flow and transport tests in tuff.

419 Travis, B.J., et al., 1984, Preliminary estimates of water flow and radionuclide transport in Yucca Mountain: Los Alamos National Laboratory report LA-UR-84-40, Los Alamos, NM, 75 p.

A preliminary estimate of water flow and radionuclide transport is presented for Yucca Mountain. Several conclusions can be made. Significant fracture flow can occur above the water table, but only in high-saturation, low permeability tuff. Diffusion into the matrix and adsorption have a profound effect on transport. Migration times just to the water table for all but one of the important radionuclides are considerably longer than 10,000 years, and none of the radionuclides considered reaches the accessible environment in less than 10,000 years. Heat load in partially saturated tuff can result in a dry, steam-filled region extending several meters above and below a repository with recharge during cool-down phase.

420 Tyler, L.D., and Vollendorf, W.C., 1975, Physical observations and mapping of cracks resulting from hydraulic fracturing *in situ* stress measurements: Sandia National Laboratories (Prepared for 50th Annual Fall Meeting of the Society of Petroleum Engineers of AIME in Dallas, Texas Sept. 28-Oct. 1, 1975) 16 p.

The purpose of the study was to better understand the hydraulic-fracture technique in experiments conducted in a tuff formation in Rainier Mesa. The experiments are to determine the stresses in the mesa and to examine the fracture behavior produced by the hydraulic fracture technique. The maximum horizontal, vertical and minimum horizontal principle stresses for 1365 ft. of overburden were 1788 psi, 1183 psi, and 1015 psi, respectively. The tests were conducted in existing tunnel complexes and the fractures that were produced during the tests were mapped by mining from the tunnel complex and physically examining the fractured formation. The fractures were not affected by existing cracks or hard rock inclusions. The fractures were approximately vertical except for those where the mesa slope is 60 degrees.

421 URS/John A. Blume and Associates, 1986, Ground motion evaluations at Yucca Mountain, Nevada, with applications to repository conceptual design and siting: Sandia National Laboratories report SAND85-7104, Albuquerque, NM, 126 p.

Probabilistic seismic hazard models were developed for both earthquakes and underground nuclear tests. Analyses yielded horizontal peak ground accelerations of 0.25 g and 0.40 g for the 500-year and the 200-year earthquake ground motions, respectively. Similar analyses for underground nuclear explosions yielded horizontal peak ground accelerations of 0.125 g and 0.15 g for the two levels.

422 U.S. Department of Energy, 1986, Environmental assessment Yucca Mountain site, Nevada Research and Development Area, Nevada:

U.S. Department of Energy report DOE/RW-0073, vol. 1-3.

A detailed examination of the process for selecting Yucca Mountain as a geologic repository and the known physical characteristics that make Yucca Mountain a suitable repository are presented.

423 **U.S. Geological Survey, 1974, U.S. Geological Survey investigations in connection with the Mighty Epic event, U12n.10 tunnel, Nevada Test Site, with a section on geological investigations by G.M. Fairier and D.R. Townsend, a section on geophysical logging and seismic investigations by R.D. Carroll, M.J., Cunningham and D.C. Muller, a section on gravity surveys— Rainier Mesa and U12n.10 tunnel by D.L. Healey and a section on *in situ* stress investigations by W.L. Ellis: U.S. Geological Survey report USGS-474- 228, 191p.**

The geology of U12n.10 tunnel, Rainier Mesa, as it relates to the detonation and support operations of the Mighty Epic event is documented in detail.

424 **U.S. Geological Survey, 1978, U.S. Geological Survey investigations in connection with the Dining Car event, U12e.18 tunnel, Rainier Mesa, Nevada Test Site, with a section on geological investigations by S.G. Steele and G.M. Fairier and a section on geophysical investigations by R.D. Carroll and M.J. Cunningham: U.S. Geological Survey report USGS-474-246, 67 p.**

The Dining Car event was a Defense Nuclear Agency (DNA) nuclear weapons test located in the U12e.18 drift of the E-tunnel complex in Rainier Mesa. This report contains data on the stratigraphy, structure, engineering geology, physical properties, geophysics and stress within the U12e.18 drift.

425 **U.S. Geological Survey, 1982, Geologic, geophysical, and *in situ* stress investigations in the vicinity of the Dining Car chimney, Dining Car/Hybla Gold drifts, Nevada Test Site: U.S. Geological Survey open-file report 82-137, 119 p.**

Studies of the structure, stratigraphy, engineering geology, *in situ* stress, and various geophysical logs were conducted within U12e.20 drift within tunnel beds 4K and 4J. The investigations included a study of the effects of the Dining Car event conducted within U12e.18 drift only 3 m away from the closest point within the U12e.20 drift. The mining conducted within the U12e.20 drift enabled the most extensive examination of postshot effects near a collapse cavity since the Rainier event in 1957.

426 **U.S. Geological Survey, 1984, Aeromagnetic map of the Yucca Mountain area, Nevada: U.S. Geological Survey open-file report 84-206, 8 p.**

This is a map showing magnetic contours of the Yucca Mountain region.

427 **U.S. Geological Survey, 1984, A summary of geologic studies through January 1, 1983, of a potential high-level radioactive waste repository site at Yucca Mountain, southern Nye County, Nevada: U.S. Geological Survey open-file report 84-792, 103 p.**

A narrative summary of the geology of Yucca Mountain is presented. The geomorphology, stratigraphy, tectonic and volcanic framework, structure, seismology, and geologic stability of the potential repository site and vicinity are discussed in detail.

428 **U.S. Geological Survey, 1985, Vegetation and climates of the last 45,000 years in the vicinity of the Nevada Test Site, south-central Nevada: U.S. Geological Survey professional paper 1329, 87 p.**

Plant macrofossils from ancient packrat middens provide the data to infer climatic conditions of the past. The nature and magnitude of previous fluctuations indicate the nature of future climatic change that may impact the repository. The packrat middens can be older than 50,000 years and are common in the region. Each contains abundant mummified plant fossils, representing the plant species growing within about 30 m of the site. Radiocarbon-dated midden samples provide detailed records of climate induced vegetation change. Increased CO_2 within the next 500 years probably will result in a 2 to 3°C increase in annual temperature and intensified rainfall in the Nevada Test Site region. Analogs with previous glacial interglacial cycles indicate that this superinterglacial cycle may be no more than a relatively brief reversal in the protracted trend toward the next ice age. Current models indicate that within the next 10,000 years, climatic conditions may be similar to those of the last glacial age.

429 **Vaniman, D., and Crowe, B., 1981, Geology and petrology of the basalts of Crater Flat, applications to volcanic risk assessment for the Nevada Nuclear Waste Storage Investigations: Los Alamos National Laboratory report LA-8845- MS, Los Alamos, NM, 68 p.**

This report presents the results of field and petrologic studies of the basalts of Crater Flat. These basalts are divided into three distinct volcanic cycles. Preliminary data suggests that successive basalt cycles at Crater Flat may be of decreasing volume by recurring more frequently. This information provides a basis for estimating the probability of volcanic recurrence and the possible effect it may have on a repository at Yucca Mountain.

430 **Vaniman, D.T., Crowe, B.M., and Gladney, E.S., 1982, Petrology and geochemistry of Hawaiite lavas from Crater Flat, Nevada: Contributions to Mineralogy and Petrology, vol. 80, p. 341-357.**

Hawaiite-type lavas were erupted in three cycles (3.7, 1.2, and 0.3 my) at Crater Flat, Nevada. The compositions of all three cycles form a "straddling" alkalic series in which the less-evolved basalts plot near the normative olivine-diopside divide and the more evolved basalts project into the hypersthene or nepheline fields.

431 **Vaniman, D., et al., 1984, Variations in authigenic mineralogy and sorptive zeolite abundance at Yucca Mountain, Nevada, based on studies of drill cores USW GU-3 and G-3: Los Alamos National Laboratory report LA-9707- MS, Los Alamos, NM, 71 p.**

Studies of the mineralogy and petrology of the core recovered from these two drillholes concentrate on the products of low-temperature diagenetic alteration. They indicate less alteration and of lower grade than the cores studied from farther north at Yucca Mountain. The tuff of Calico Hills can not be relied upon as a zeolitized sorptive barrier throughout Yucca Mountain.

432 **Vaniman, D.T., Bish, D.L., and Chipera, S., 1988, A preliminary comparison of mineral deposits in faults near Yucca Mountain, Nevada, with possible analogs: Los Alamos National Laboratory report LA-11289-MS, Los Alamos, NM, 54 p.**

Several faults near Yucca Mountain, Nevada, contain abundant calcite and opal-ct, with lesser amounts of opal-A and sepiolite or smectite. These secondary minerals are being studied to determine the directions, amounts, and timing of transport involved in their formation. Possible analog deposits from known hydrothermal veins, warm springs, cold springs or seeps, soils, and aeolian sands were studied for comparison with the minerals deposited in these faults; there are major mineralogical differences in all of the environments except in the aeolian sands and in some cold seeps. Preliminary conclusions are that the deposits in the faults and in the sand ramps are closely related, and that the process of deposition did not require upward transport from depth.

433 **Vieth, D.L., 1984, Site description and selection process: In McVay, G.L., (ed), *Scientific Ba-***

sis for Nuclear Waste Management: Elsevier Science Publishing Company Inc., p. 279-282.

A cursory overview of the Yucca Mountain site is given and the rationale for its selection is explained.

434 Vine, E.N., et al., 1980, Radionuclide transport and retardation in tuff: Los Alamos National Laboratory report LA-UR- 80-2949, Los Alamos, NM, 9 p.

Batch-sorption measurements were conducted in order to determine which experimental variables are important. Results indicate that particle size (and surface area) are unimportant; whereas groundwater and rock composition are very important. A general correlation has been identified for mineralogy and the degree of sorption for Sr, Cs, and Ba.

435 Vine, E.N., Aguilar, R.D., and Bayhurst, B.P., 1980, Sorption-desorption studies on tuff II - continuation of studies with samples from Jackass Flats, Nevada, and initial studies with samples from Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-8110-MS, Los Alamos NM, 75 p.

Distribution coefficients were determined by the batch technique for sorption-desorption of radionuclides on tuffs from drillhole UE25a#1 and water from well J-13. Under atmospheric conditions, zeolitic tuffs had sorption ratios of approximately 10^3 to 10^4 ml/g with Sr, Cs, Ba, Ce, Eu, Am, and Pu. For non zeolitized tuffs, the sorption ratios were approximately 10^2 to 10^3 ml/g.

436 Vortman, L.J., 1979, Prediction of ground motion from nuclear weapons tests at Nevada Test Site: Sandia National Laboratories report SAND79-1002, Albuquerque, NM, 46 p.

Ground motion data from underground nuclear detonations during FY78 were added to data from earlier detonations; the data were used to formulate a tentative equation for predicting ground motion at the Nevada Test Site. Additional measurements to explore an unexplained seismic anomaly in Jackass Flats are described. Methods used in automatic processing of ground motion data are explained.

437 Vortman, L.J., 1980, Prediction of ground motion from underground nuclear weapons tests as it relates to siting of a nuclear waste storage facility at Nevada Test Site and compatibility with the weapons test program: Sandia National Laboratories report SAND80-1020, Albuquerque, NM, 41 p.

Prediction equations and their standard deviations have been determined from measurements on a number of nuclear weapons tests. The effect of various independent parameters on standard deviation is discussed. Additional data has little effect on the standard deviation since the data sample is large. An example, based on certain licensing assumptions, shows that it should be possible to have a nuclear waste storage facility in the vicinity of Timber Mountain which would be compatible with a 700 kt weapons test in the Buckboard Area if the facility were designed to withstand a peak vector acceleration of 0.75 g.

438 Vortman, L.J., 1982, Ground motion from earthquakes and underground nuclear weapons test— a comparison as it relates to siting a nuclear waste storage facility at Nevada Test Site: Sandia National Laboratories report SAND- 81-2214, Albuquerque, NM, 37 p.

Ground motion generated by a magnitude 4.3 earthquake at the Nevada Test Site was measured at the control point and compared with ground motion generated at about the same distance by four underground nuclear weapons tests. Frequency responses were different for the two sources. If relationship between ground motion from the two sources can be confirmed of other earthquakes, weapons test ground motion could be used to estimate earthquake ground motion for magnitudes for which probability of recurrence is very small.

439 Vortman, L.J., 1983, Stresses and strains at Yucca Mountain from underground nuclear explosions: Sandia National Laboratories report SAND83- 1553, 53p.

The stress and strain imposed on Yucca Mountain by an underground nuclear explosion (UNE) of 700 kt at a distance of 22.8 km is estimated. Peak values of surface ground motion were reduced for repository depth according to experience from a recent measurement at Yucca Mountain. The P-wave produced a strain of 1.25×10^{-5} while the Rayleigh wave produced a horizontal strain of 9.5×10^{-6} and a vertical strain of 5×10^{-6}. Although the strains are small, they are much greater than those caused by earth tides or the east-west extension of the tectonic province in which Yucca Mountain is located.

440 Vortman, L.J., 1986, Ground motion produced at Yucca Mountain from Pahute Mesa underground nuclear explosions: Sandia National Laboratories report SAND85-1605, Albuquerque, NM

Prediction equations were developed for peak vector acceleration, velocity, and displacement from underground nuclear explosions at Pahute Mesa. Separate equations were developed using data from stations on rock, alluvium, and a combination of the two. Results indicate anomalously low accelerations at Test Stand 1 in Jackass Flats. The predictions were 4.7 to 10-times smaller than those observed. Measurements made at Yucca Mountain suggest predictions to be 4.19-times smaller than the observed accelerations.

441 Vortman, L.J., and Long, J.W., 1982, Effects of Repository depth in ground motion- The Pahute Mesa data: Sandia National Laboratories report SAND82-0174, 294 p.

Measurements of ground motion from 10 Pahute Mesa weapons tests were made at seven locations on the Nevada Test Site. Measurements of vertical, radial and tangential acceleration were made at each location and depth, and the three components of acceleration were used to determine peak vector magnitudes of acceleration, velocity, and displacement. Top to bottom ratios of the peak vectors were plotted against depth and an exponential least-squares fit made to the curve. Fits for multiple peaks were better than for single peaks and those for Pseudo Relative Response Velocity were better than the multiple peaks. Scatter is produced by differences in geology and fits to the data can be used as prediction equations.

442 Waddell, R.K., 1982, Two-dimensional, steady-state model of groundwater flow, Nevada Test Site and vicinity, Nevada-California: U.S. Geological Survey Water Resources Investigations report 82-4085, 72 p.

A two-dimensional, steady-state, finite-element model of the groundwater flow system of the Nevada Test Site and vicinity in Nye and Clark Counties, Nevada, and Inyo County, California, was developed using parameter-estimation techniques. The model simulates flow in an area underlain by clastic and carbonate rocks of pre-Cambrian and Paleozoic age, and volcanic rocks and alluvial deposits of Tertiary and Quaternary age.

443 Waddell, R.K., Jr., 1985, Hydrologic and drillhole data for test wells UE-29a#1 and UE-29a#2, Fortymile Canyon, Nevada Test Site: U.S. Geological open-file report 84-142, 25 p.

The aquifer test data from two wells, UE-29a#1 and UE-29a#2 are presented. These wells are located in Fortymile Canyon approximately 7 to 8 miles from Yucca Mountain.

444 Waddell, R.K., Robison, J.H., and Blankennagel, R.K., 1984, Hydrology of Yucca Mountain and vicinity, Nevada-California— Investigative results through mid-1983: U.S. Geological Survey Water-Resources Investigations report 84-4267, 40 p.

The regional and local geology and hydrology surrounding Yucca Mountain are discussed. Both surface and subsur-

face hydrology, the various hydrogeologic units, potentiometric levels, recharge and discharge areas, and hydrochemistry are also presented. The hydrogeology of Yucca Mountain is discussed in detail.

445 **Wahl, R.R., 1969, An analysis of gravity data in Area 12, U.S. Geological Survey Technical Letter, 24 p.**

Available gravity data were augmented by new observations along three profiles through two new drillholes in Area 12: UE12t #1 and UE12p #1. The data were interpreted to allow evaluation of the geologic structure prior to the planning and excavation of two proposed tunnel complexes, U12t and U12p.

446 **Walker, G.E., and Eakin, T.E., 1963, Geology and groundwater of Amargosa Desert, Nevada-California: State of Nevada Department of Conservation and Natural Resources, Groundwater Resources Reconnaissance Series report 14, 45 p.**

Precipitation in the Amargosa Desert averages less than 5 inches annually. Erosion of surrounding mountains have filled the basin with several hundred feet of alluvium. The estimated yearly yield of water from springs and wells combined is 24,000 acre-feet. Groundwater pumpage during the summer of 1962 is estimated to have been 3,000 acre-feet, most of which was used for irrigation. Analysis of 28 samples of water indicate medium-salinity waters which may require leaching of the soil. Water quality generally decreases into the southern portion of the basin. Boron concentrations may represent a problem for irrigation of some crops. For public supply, the water is generally acceptable with the exception of locally high concentrations of fluoride. About 1.4 million acre-feet of groundwater is estimated to be stored in the upper 100 feet of the alluvial aquifer covering a four township area. It is estimated that pumpage of 60,000 acre-feet a year would draw water levels down 100 feet in 25 years and intercept most of the natural discharge from the valley.

447 **Walter, G.R., 1982, Theoretical and experimental determination of matrix diffusion and related solute transport properties of fractured tuffs from the Nevada Test Site: Los Alamos National Laboratory report LA-9471-MS, Los Alamos, NM, 132 p.**

Theoretical and experimental studies of the chemical and physical factors which affect molecular diffusion of dissolved substances from fractures into a tuffaceous rock matrix have been made on rocks from G-Tunnel and Yucca Mountain. A variety of groundwater tracers, which may be useful in a field tracer test at the Nevada Test Site, have also been developed and tested.

448 **Wang, J.S.Y., and Narasimhan, T.N., 1984, Hydrologic mechanisms governing fluid flow in partially saturated, fractured, porous tuff at Yucca Mountain: Lawrence Berkeley Laboratory report LBL-18473, Berkeley, CA, 58 p.**

In contrast to the saturated zone where fluid moves rapidly along fractures, the fractures (with relatively large apertures) will de-saturate first during drainage processes and the bulk of fluid flow would be through the interconnected pores in the matrix. Within a partially drained fracture, the presence of a relatively continuous air phase will produce practically an infinite resistance to liquid flow in the direction parallel to the fracture. The residual liquid will be held by capillary force in regions around fracture contact areas where the apertures are small. Normal to the fracture surfaces, the drained portion of the fractures will reduce the effective area for liquid flow from one matrix block to another matrix block. This report deals with the numerical simulation of the drainage of a fractured, unsaturated tuff column.

449 **Wang, J.S.Y. and Narasimhan, T.N., 1986, Hydrologic mechanisms governing partially saturated fluid flow in fractured welded units and porous non-welded units at Yucca Mountain: Sandia National Laboratories report SAND85-7114, Albuquerque, NM, 83 p.**

A discrete-fracture, porous-matrix model and a composite-medium model were used to study hydrological responses to cycles of pulse infiltration at Yucca Mountain. The pulses were applied to fractures at the top of a vertical column composed of alternating layers of welded and non-welded tuffs. The hydrologic response of the units from 0.1 to 0.5 mm/yr recharge pulses applied at 5,000-year intervals is discussed.

450 **Warren, R.G., 1983, Geochemical similarities between volcanic units at Yucca Mountain and Pahute Mesa: evidence for a common magmatic origin for volcanic sequences that flank the Timber Mountain Caldera: Los Alamos National Laboratory report LA-UR-83-2229, Los Alamos, NM, 32 p.**

Chemical compositions have been determined for certain minerals from a comprehensive set of samples of Crater Flat Tuffs and Tuffs of Calico Hills. Most of these samples were taken from drillholes at Yucca Mountain. Samples of the tuffs and lavas of Area 20, obtained from lavas at Pahute Mesa, were similarly analyzed. The results indicate that the units probably erupted contemporaneously from the same parental magma.

451 **Warren, R.G., Byers, F.M. Jr., and Caporuscio, F.A., 1984, Petrography and mineral chemistry of units of the Topopah Spring, Calico Hills and Crater Flat Tuffs, and older volcanic units, with emphasis on samples from drillhole USW G-1, Yucca Mountain, Nevada Test Site: Los Alamos National Laboratory LA-10003-MS, Los Alamos, NM, 78 p.**

This report contains petrographic and mineral chemical data for phenocrysts in volcanic units of Yucca Mountain drillhole USW G-1 and provides a basis for petrographic comparison of units within Yucca Mountain and the Nevada Test Site.

452 **Warren, W.E., and Smith, C.W., 1985, *In situ* stress estimates from hydraulic fracturing and direct observation of crack orientation: Journal of Geophysical Research, vol. 90, no. B8, p. 6829-6839.**

Estimates of *in situ* stress in G-Tunnel, Rainier Mesa, have been obtained with hydraulic-fracturing techniques. A significant feature of this work is the mineback operations in which the borehole is mined out to reveal the actual fracture. Direct observation of the fracture orientation away from the borehole establishes the direction of the minimum compressive *in situ* stress and the plane of the other two principal stresses. Advantages, limitations and problem areas associated with extracting *in situ* stress fields from hydraulic-fracture-pressure records are discussed in detail.

453 **Waters, A.C., et al., Preliminary stratigraphic and petrologic characterization of core samples from USW-G1, Yucca Mountain, Nevada: Los Alamos National Laboratory LA-8840-MS, Los Alamos, NM, 66 p.**

The purpose of this report is to characterize the stratigraphy and petrology of selected core samples through laboratory investigations. X-ray diffraction and microprobe studies of de-vitrification products of volcanic glass were given particular attention.

454 **Waymire, D.R., and Duimstra, C.O., 1982, *In situ* tuff water migration/heater experiment-instrumentation design and fielding: Sandia National Laboratories report SAND-81-1058, Albuquerque, NM, 30 p.**

The heater and experimental equipment were operated for seven months. The instrumentation measured water depth, alkalinity, temperature, cavity pressure, relative humidity, *in situ* stress changes, and rock-mass displacement.

455 **Weeks, E.P., and Wilson, W.E., 1984, Preliminary evaluation of hydrologic properties of**

cores of unsaturated tuff, test well USW H-1, Yucca Mountain, Nevada: U.S. Geological Survey Water-Resources Investigations report 84-4193, 30 p.

Analyses were made on 15 core samples of unsaturated tuff from test well USW H-1. Moisture-characteristic curves relating saturation and moisture tension were developed from results of mercury-injection tests. Moisture tension and effective permeabilities were calculated for the samples from this drillhole.

456 Welch, E.P., et al., 1987, Version II of the users manual for the tuff database interface: Sandia National Laboratories report SAND84-1643, Albuquerque, NM

A computerized database of physical properties from laboratory tests and field tests of Yucca Mountain tuffs has been compiled. The tuff database interface is presented. This database allows NNWSI participants to retrieve these data.

457 White, A.F., 1979, Geochemistry of groundwater associated with tuffaceous rocks, Oasis Valley, Nevada: U.S. Geological Survey professional paper 712-E, 25 p.

Regional similarities and trends in the aqueous chemistry of the tuffaceous aquifers indicates that most of the recharge entering Oasis Valley is the result of groundwater inflow from Pahute Mesa, Gold Flat and other areas to the north and east. One-half of this water discharges as evapotranspiration and the rest flows through the alluvium southward to the Amargosa Desert. Solute concentrations of sodium and silica suggest that hydrolysis and incongruent dissolution of volcanic glass are the principal reactions in the tuffaceous aquifer. Chloride is leached preferentially to fluoride and stability calculations show that montmorillonite is a stable weathering product within the saturated zone. The water is saturated with respect to silica gel but undersaturated in terms of the zeolite analcime. The lack of saturation suggests that zeolitization occurs in localized geochemical environments, which are not generally reflected in the average groundwater composition. Colinear increases of solutes during evapotranspiration of water in the alluvial aquifer indicate that water contained in this and the tuffaceous aquifer is of the same generic origin. This linearity also indicates that sodium and chloride are neither selectively added or removed from the system and that bicarbonate is only locally affected by dissolution and precipitation of calcite. Calcium concentrations are controlled by the dissolution of calcium sulfate minerals present in lacustrine deposits and by the precipitation of calcite. Fluoride concentration is controlled by fluorite saturation and potassium concentrations are probably controlled by adsorption and fixation by degraded clays common to arid-soil zones and also by uptake by the vegetative cover.

458 White, A.F., and Chuma, N.J., 1987, Carbon and isotopic mass balance models of Oasis Valley-Fortymile Canyon Groundwater Basin, southern Nevada: Water Resources Research, vol. 23, no. 4, p. 571-582.

Environmental isotopes and carbon chemistry provide means of differentiating various recharge areas, flow paths, and ages of groundwater in portions of the Nevada Test Site and vicinity. Regional deuterium and oxygen-18 trends are offset from the present day meteoric line by a deuterium depletion of 5 per mil, suggesting paleoclimatic changes. Partial pressures of CO_2 and ^{18}O and ^{13}C data indicate solubility and isotopic equilibrium between the gas and water in the soil zone with progressive exchange with underlying groundwater in the shallow alluvium of Oasis Valley. Application of a closed system CO_2 model successfully reproduces chemical compositions observed in the alluvium in the Amargosa Desert and in the deep tuff aquifer beneath Pahute Mesa and Yucca Mountain.

459 White, A.F., and Claassen, H.C., 1978, Dissolution kinetics of silicate rocks, application to solute modeling: In Jenne, E.A., [ed], Chemical modeling— speciation, sorption, solubility and kinetics in aqueous systems: American Chemical Society, p449-473.

Experimentally determined dissolution kinetics are applicable to natural weathering processes of silicate rocks. Mass transfer from the mineral to the aqueous phase was determined to be incongruent under a range of experimental conditions. Transfer rates of individual species (Q) at times (t) can usually be described by one or two rate expressions:

$$> Q = Q_p + k_p t^{1/2}$$

$$Q = Q_o + k_l t$$

where K_l is a linear rate constant, K_p is a parabolic rate constant, and Q_o and Q_p is the linear and parabolic mass transferred during an initial surface exchange with hydrogen ions. Detailed investigation of dissolution of a vitric tuff indicates that the rate of mass transfer of a species is described by the parabolic expression and is inversely dependent on the concentration of that species in aqueous solution. A numerical solution to the one-dimensional diffusion equation is presented using a Freundlich isotherm to relate the aqueous ion concentration and the ion density on the surfaces of the vitric tuff.

460 White, A.F. and Claassen, H.C., 1979, Kinetic model for the dissolution of a rhyolitic glass.

Rhyolitic glass reactions consist initially of rapid, surface-ion exchange followed by slower parabolic solid-state diffusion. These mechanisms are consistent with previously reported results for both artificial glasses and silicate minerals. The effect of pH on the composition of fluids derived from glass dissolution was investigated as were the kinetics of the reaction. Experimental data can be modeled successfully by a numerical solution to Fick's second law of diffusion, using a Freundlich adsorption isotherm to describe Na at the glass surface.

461 White, A.F., Claassen, H.C., and Benson, L.V., 1980, The effect of dissolution of volcanic glass on the water chemistry in a tuffaceous aquifer, Rainier Mesa, Nevada: U.S. Geological Survey Water-Supply Paper 1535-Q, 34 p.

Experimental results indicate that geochemistry of groundwater within Rainier Mesa is the result of glass dissolution principally in the Paintbrush Tuff and Miocene tunnel beds. Glass dissolution is incongruent, with the preferential release of sodium, calcium, magnesium, and the retention of potassium. The dominance of glass dissolution is probably related to the porous nature of the vitric tuff, which results in large surface areas and retention time. The cation composition of Rainier Mesa groundwater is progressively modified as a function of depth in the mesa, with a depletion of Ca and Mg relative to Na. The depth at which this occurs coincides with alteration zones containing clinoptilolite and montmorillonite in the tunnel beds. Ongoing precipitation of these minerals is an effective sink for removal of bivalent cations. The range in cation compositions in interstitial and fracture waters are very similar, and compositions for anions are different, with interstitial waters much higher in chloride and sulfate relative to bicarbonate.

462 Whitfield, M.S., Thordarson, W., and Eshom, E.P., 1984, Geohydrologic and drillhole data for test well USW H-4, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey open-file report 84-449, 39 p.

This report presents data on drilling operations, lithology, geophysical well logs, sidewall-core samples, water level monitoring, aquifer tests, injection tests, radioactive tracer borehole flow survey, and water chemistry data for test well USW H-4. This well is located on the eastern flank of Yucca Mountain.

463 Whitfield, M.S., Jr., Eshom, E.P., Thordarson, W., and Schaefer, D.H., 1985, Geohydrology of rocks penetrated by test well USW H-4, Yucca Mountain, Nye County, Nevada: U.S. Geo-

logical Survey Water-Resources Paper 85-4030, 33 p.

The results of hydraulic testing of rocks penetrated by USW H-4, one of several test wells drilled in the vicinity of Yucca Mountain, are presented. The data derived from this hole are drilling procedures and construction, lithology, geophysical logs, water levels, pump test, borehole flow survey, and groundwater chemistry data.

464 Wilmarth, V.R., Botinelly, T., and Wilcox, R.E., 1960, Alteration of tuff by Rainier Mesa underground nuclear explosion, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey professional paper 400-B, p149-151.

The 1.7 kt Rainier nuclear test altered the surrounding tuffs of the now abandoned Oak Spring Formation by the creation of a breccia zone in the vicinity of the test cavity and fusing some of the tuff within this zone to radioactive glass. The cation exchange capacity of the tuffs within 40 ft. of the breccia zone decreased. This is probably related to alteration of zeolites by heat of the explosion.

465 Wilmarth, V.R., and Mckeown, F.A, 1960, Structural effects of Rainier, Logan, and Blanca underground nuclear explosions, Nevada Test Site, Nye County, Nevada: U.S. Geological professional paper 400-B, p418-423.

This report documents the surficial and underground structural effects of three nuclear tests conducted within Rainier Mesa.

466 Winograd, I.J., 1962, Interbasin movement of groundwater at the Nevada Test Site, Nevada: U.S. Geological Survey professional paper 450-C, p. C108-C111.

Hydraulic evidence for interbasin circulation of groundwater through carbonate rocks of Paleozoic age is presented. The study was conducted on Frenchman, Yucca and Jackass Flats'.

467 Winograd, I.J., 1963, A summary of the groundwater hydrology of the area between the Las Vegas Valley and the Amargosa Desert, Nevada, with special reference to the effects of possible new withdrawals of groundwater: U.S. Geological Survey report TEI-840, 79 p.

The hydrology of the central Amargosa Desert, southern Indian Springs Valley, and the Pahrump Valley was studied to determine the effects of additional pumping associated with a new townsite. The townsite was considered for the support of the Nuclear Rocket Development Station located in Jackass Flats on the Nevada Test Site.

468 Winograd, I.J., 1971, Hydrogeology of ash-flows tuff: A preliminary statement: Water Resources Research, vol. 7, no. 4, p. 994-1006.

A preliminary description of the hydrogeology of ash-flows tuffs is presented. Details are given on the interstitial porosity and permeability, fracture transmissivity, spring occurrence, location and discharge that can be found in this type of geologic unit.

469 Winograd, I.J., and Doty, G.C., 1980, Paleohydrology of the southern Great Basin, with special reference to water table fluctuations beneath the Nevada Test Site during the Late Pleistocene: U.S. Geological Survey open File report 80-569, 91 p.

The distribution of calcitic veins in alluvium and lakebeds, and of tufa deposits, between the Ash Meadows discharge area and the Nevada Test Site suggest that discharge from the regional Paleozoic carbonate aquifer during the Late Pleistocene occurred at distances as much as 14 km northeast of Ash Meadows and at altitudes up to 50 m higher than at present. Water-level rises beneath Frenchman Flat during future pluvials are unlikely to exceed 30 m, and future levels might even be 10 m lower than the modern one.

470 Winograd, I.J., and Pearson, F.J., 1976, Major carbon-14 anomaly in a regional carbonate aquifer: possible evidence for megascale channeling, south central Great Basin: Water Resources Research vol. 12, no. 6, p. 1125-1143.

The ^{14}C content of groundwater at the center of a 16-km-long fault-controlled spring line at Ash Meadows in south-central Nevada is 5-times greater than that in water from other major springs along the same lineament. The most plausible hypothesis requires the presence of a major longitudinal heterogeneity in the distal portion of the groundwater basin to explain th anomaly.

471 Winograd, I.J., and Thordarson, W., 1975, Hydrogeologic and hydrochemical framework, south-central Great Basin, Nevada-California, with special reference to the Nevada Test Site: U.S. Geological Survey professional paper 712-C, 126 p.

The geologic strata of the Nevada Test Site have been divided into 10 hydrogeologic units; three of which control the regional movement of groundwater. Synthesis of hydrogeologic, hydrochemical, and isotopic data suggests that an area of at least 4,500 mi^2 is hydraulically integrated into one groundwater basin, the Ash Meadows Basin. Discharge occurs along a fault controlled spring line located at Ash Meadows within the east-central Amargosa Desert. Within the Nevada Test Site, groundwater moves southward and southwestward toward Ash Meadows.

472 Winograd, I.J., Thordarson, W., and Young, R.A., 1971, Hydrology of the Nevada Test Site and vicinity, southeastern Nevada: U.S. Geological Survey open-file report, 429 p.

The geologic strata of the Nevada Test Site has been divided into 10 hydrogeologic units; three of which control the regional movement of groundwater. Synthesis of hydrogeologic, hydrochemical, and isotopic data suggests that an area of at least 4,500 mi^2 is hydraulically integrated into one groundwater basin, the Ash Meadows Basin.

473 Wolfsberg, K., et al., 1979, Sorption-desorption studies on tuff; initial studies with samples from the J-13 drill site, Jackass Flats, Nevada: Los Alamos Laboratory report LA-7480 -MS, Los Alamos, NM, 56 p.

Distribution coefficients were determined for sorption-desorption of radionuclides between each of three different types of tuff from drillhole J-13 and the water from that well. Sorption ratios vary according to the lithologic variation of the tuff. A tuff high in zeolite or glass composition exhibits high sorption ratios for different radionuclides while a de-vitrified tuff exhibits low to intermediate values.

474 Wolfsberg, K., Aquilar, R.D., and Bayhurst, B.P., Sorption and desorption studies on tuff III. A continuation of studies with samples from Jackass Flats and Yucca Mountain, Nevada: Los Alamos National Laboratory report LA-8747-MS, Los Alamos, NM, 71 p.

This report is the third in a series of sorptions studies. Lithologies previously not studied are presented and continuing experiments with U, Pu, and Am are described.

475 Wollenberg, H.A., Yang, J.S.Y., and Korbin, G., 1983, An appraisal of nuclear waste isolation in the vadose zone in arid and semi-arid regions: Lawrence Berkeley Laboratory report LBL-15010, Berkeley, CA, 126 p.

An appraisal is presented of the concept of isolating high-level radioactive waste in the vadose zone of alluvial-filled valleys and tuffaceous rocks of the Basin and Range geomorphic province. A description of the geologic and hydrologic setting of Yucca Mountain is included as a type locality for a tuffaceous rock repository.

476 Worman, F.C., 1969, Archaeological investigations at the U.S. Atomic Energy Commission's Nevada Test Site and Nuclear Rocket Devel-

opment Station: Los Alamos National Laboratory report LA-4125, Los Alamos, NM, 201 p.
Archaeological sites within the Nevada Test site are described and the history and artifacts from each site are presented. A total of 24 designated sites are described as well as isolated surface finds.

477 Wu, S.S.C, 1985, Topographic maps of Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey open-file report 85-620, 55 p.
This report consists of six topographic maps of the Yucca Mountain area. These maps are preliminary and have not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

478 Yang, I.C., et al., 1985, Analysis of gaseous-phase stable and radioactive isotopes in the unsaturated zone, Yucca Mountain, Nevada: From Conference on Characterization and Monitoring of the Vadose Zone, Denver, CO, November 19, 1985, 18 p.
Gas samples were collected at intervals to a depth of 1200 ft. from the unsaturated zone at Yucca Mountain. Samples were analyzed for carbon-14 activity and carbon-13; water vapor in the samples were analyzed for deuterium and oxygen-18. These data could provide insight into the nature of unsaturated zone transport processes.

479 Young, R.A., 1965, Records of wells and test holes drilled at the Nevada Test Site and vicinity since 1960: U.S. Geological Survey Technical Letter NTS-117, 21 p.
The drill logs, lithology, and chemistry of wells drilled on the the Nevada Test Site before 1960 are described.

480 Young, R.A., 1972, Water supply for the Nuclear Rocket Development Station at the U.S. Atomic Energy Commission's Nevada Test Site: U.S. Geological Survey Water-Supply Paper 1938, 19 p.
The Topopah Spring Member of the Paintbrush Tuff is evaluated as a water-supply source for the now defunct Nuclear Rocket Development Station. It is estimated that 37 to 187 billion gallons of water are available for utilization.

481 Yow, J.L., Jr., 1985, Field investigations of keyblock stability: Lawrence Livermore National Laboratory report UCRL-53632, Livermore, CA, 228 p.
Discontinuities in a rock mass can intersect an excavation surface to form discrete blocks (keyblocks) which can be unstable. This engineering problem is divided into two parts: block identification and evaluation of block stability. Keyblocks can be identified from discontinuity and excavation geometry using a whole stereographic projection. Once a block is identified, the forces affecting it can be calculated to assess its stability. The normal and shear stresses on each block face before displacement are calculated using elastic theory and are modified in a non-linear way by discontinuity deformations as the keyblock displaces. The stresses are summed into resultant forces to evaluate block stability. One stable keyblock and 13 fallen keyblocks were observed in the Climax Mine and U12g tunnel at Rainier Mesa.

482 Zielinski, R.A., et al., 1986, Rock-water interaction in ash-flows tuffs (Yucca Mountain, Nevada, U.S.A.)-The record from uranium studies: Uranium, vol. 2., no. 4, p. 361-383.
Forty-eight core samples of variably welded, devitrified, fractured and altered ash-flows tuffs from Yucca Mountain were selected for comparative analysis by uranium-based methods to estimate past interaction with oxidizing water. Tests for such interaction include: (1)chemical fractionation of U from Th; (2) extent of association of U with secondary alteration products; and (3) isotopic fractionation of U from its long-lived daughters. Samples are from the Bullfrog Member, Crater Flat Tuff, and the Topopah Spring Member.

483 Zimmerman, R.M., 1982, Preliminary design and definition of field experiments for welded tuff rock mechanics program: Sandia National Laboratories report SAND-81-1972, Albuquerque, NM, 38 p.
The preliminary design contains objectives, typical experiment layouts, definitions of equipment and instrumentation, test matrices, preliminary design predictive modeling results for five experiments and a definition of the G-Tunnel underground facility.

484 Zimmerman, R.M., 1983, First phase of small diameter heater experiments in tuff: 24th U.S. Symposium of Rock Mechanics, College Station, TX, June 1983, p. 271-282.
Small diameter heaters were installed in U12g tunnel within Rainier Mesa in order to assess the thermal and hydrothermal effects of heat, similar to the type produced by decaying nuclear waste, on welded and nonwelded tuffs. Computed results indicate that the same heat transfer model (includes conduction and radiation only) can describe the behavior of both welded and nonwelded tuffs using empirical techniques to describe pore-water vaporization. Hydrothermal measurements revealed heat-induced water migration. Results indicate that small amounts of liquid water migrated into the welded-tuff borehole early in the heating period. Once the rock-wall temperatures exceeded 94°C, there was mass transport of water vapor to cooler regions.

485 Zimmerman, R.M., Bellman, R.A. Jr., and Mann, K.L., 1987, Analysis of drift convergence phenomena from G-Tunnel welded tuff mining evaluations: Sandia National Laboratories report SAND86-2389C, Albuquerque, NM, 18 p.
This paper discusses the results of vertical and horizontal drift convergence measurements taken during the mining of a repository-sized drift in welded tuff in G-Tunnel. Results are quantified in terms of drift convergence magnitudes and rates that relate to drift stability.

486 Zimmerman, R.M., and Blanford, M.L., 1986, Expected thermal and hydrothermal environments for waste emplacement holes based on G-Tunnel heater experiments: Sandia National Laboratories report SAND85-0123C, Albuquerque, NM, 9 p.
The focus of this paper is to present the results and evaluations of the experiments as they apply to improving predictive capabilities. The thermal aspects are emphasized by comparing the measured temperatures with calculations of predicted temperatures using numerical models, so that the effects of significant parameters can be evaluated and integrated into future predictive models.

487 Zimmerman, R.M., and Board, M.P., 1984, Ambient temperature testing of the G-Tunnel heated block: Sandia National Laboratories report SAND83-2287C, Albuquerque, NM, 15 p.
The purpose of the ambient temperature testing phase is to evaluate rock-mass mechanical properties of a tuff block under biaxial stress changes up to 7.5 MPa above an initialization *in situ* value of 3.1 MPa. Results indicate that the modulus of deformation ranges from 9.7 to 17.0 GPa and Poisson's ratio ranges from 0.21 to 0.33. Other measurements indicated that cross-hole compression-wave velocities and single-fracture permeability values were relatively insensitive to stress changes above the *in situ* value.

488 Zimmerman, R.M., and Finley, R.E., 1987, Summary of geomechanical measurements taken in and around the G-Tunnel Underground Facility, Nevada Test Site: Sandia National Laboratories report SAND86-1015, Albuquerque, NM
A summary of field and supporting laboratory data collected in and around the G-Tunnel Underground Facility (GTUF) is presented. The GTUF investigations included geome-mechanical measurements covering: *in situ* stresses, intact rock and joint-slip strengths, rock-mass deformational behavior, rock-mass thermal and thermomechanical properties, and rock-mass behavior associated with rock dewatering and fracture flows.

489 **Zimmerman, R.M., Nimick, F.B., and Board, M.P., 1984, Geoengineering characterization of welded tuffs from laboratory and field investigations: Sandia National Laboratories report SAND84-1147C, Albuquerque, NM, 12 p.**

Because access into Yucca Mountain has been limited to borehole explorations, early geoengineering materials characterization has been derived from laboratory tests on cores from Yucca Mountain and from laboratory and field tests on welded tuffs located in G-Tunnel at Rainier Mesa. G-Tunnel contains welded tuffs that have similar properties and stress states to those at Yucca Mountain and has been the location of *in situ* rock mechanics testing. The purpose of this paper is to summarize the geoengineering material property data obtained to this date and to compare appropriate laboratory and field data from G-Tunnel to findings from Yucca Mountain. Geomechanical and thermal data are provided and are augmented by limited hydrologic and geologic data. A comparison of laboratory data indicates good agreement between the bulk densities, saturations, moduli of elasticity, Poisson's ratios, and P-wave velocities. The G-Tunnel tuff has slightly lower thermal conductivity, tensile strength, compressive strength and slightly higher matrix permeability than does the Topopah Spring member of the Paintbrush Tuff at Yucca Mountain. From a laboratory to-field scaling perspective, the modulus of deformation shows the most sensitivity to field conditions because of the presence of the joints found in the field.

490 **Zimmerman, R.M., et al., 1985, Thermal-cycle testing of the G-Tunnel heated block: 26th U.S. Symposium on Rock Mechanics, Rapid City, SD, June 26-28, 1985, p. 749-759.**

A rock mechanics field investigation was undertaken in U12g tunnel where tuffs similar to those in Yucca Mountain are found. The objective of the heated block experiment is to evaluate rock mass thermal, mechanical, thermomechanical, and hydrothermal responses on a relatively large scale under controlled stress and temperature conditions. The results indicate the thermal expansion coefficient for constant stress temperature increases had a range of 5.0 to 8.0 times 10^{-6}/°C and compares well to laboratory data. Single fracture permeabilities were relatively insensitive to stress and slightly insensitive to temperature increases under representative *in situ* conditions. The measurements range from 49 to 956 times 10^{-8} cm^2. Moisture contents varied from 55-75% saturation before heating to 15% after heating. A pronounced temperature dependence was noted above 90°C.

491 **Zimmerman, R.M., et al., 1986a, Final report— G-Tunnel heated block experiment: Sandia National Laboratories report SAND84-2620, Albuquerque, NM**

A heated block experiment was conducted in G-Tunnel on the Nevada Test Site to provide input for evaluating the ability of similar jointed welded tuffs to contain radioactive wastes. The heated block experiments included tests to evaluate the behavior of tuff under higher than ambient stresses and temperatures. Field data were collected on thermal, mechanical, thermomechanical, and hydrologic properties of tuff. The experiment, together with laboratory tests on tuff, provides information that increases the levels of confidence and accuracy when extrapolations are made to a full-scale repository at Yucca Mountain.

492 **Zimmerman, R.M., et al., 1986b, Nevada nuclear waste storage investigations project; G-Tunnel small-diameter heater experiments; final report: Sandia National Laboratories report SAND84-2621, Albuquerque, NM, 235 p.**

Designers and analysts of radioactive waste repositories must be able to predict thermal and hydrothermal behavior of tuffs. Therefore, three heater experiments were conducted in both welded and nonwelded tuffs, using a small diameter (10.2 cm) heater. For two experiments, the heater was orientated vertically in fractured welded tuff and in unfractured non-welded tuff; horizontal heater orientation was used in fractured welded tuff. The major focus of the experiments was on evaluation of numerical model applications, emphasizing thermal properties; the secondary focus was on hydrothermal measurements and evaluations.

493 **Zimmerman, R.M., and Vollendorf, W.C., 1982, Geotechnical field measurements— G-Tunnel, Nevada Test Site: Sandia National Laboratories report SAND-81-1971, Albuquerque, NM, 29 p.**

The FY81 geotechnical measurements focused on borehole measurements in the Grouse Canyon welded tuff in G-Tunnel on the Nevada Test Site. These geotechnical measurements were taken to establish baseline reference field data, and gain field testing experience in welded tuff.

ADDENDUM

494 **U.S. Energy Research And Development Administration, 1977, Nevada Test Site final Environmental Impact Statement: Energy Research and Development Administration report 1551, NTIS, Springfield, VA.**

Environmental and Historical use for the entire Nevada Test Site is summarized in accordance with CFR 10, part 711.

495 **Beatley, J.C., 1976, Vascular plants of the Nevada Test Site and central-southern Nevada: Technical Information Center, Springfield, VA, 308 p.**

Plant communities, their distribution and occurrence, are discussed for central-southern Nevada.