Chapter A

Introduction to Geologic and Geophysical Characterization Studies of Yucca Mountain, Nevada, A Potential High-Level Radioactive-Waste Repository

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The safe disposal of high-level radioactive wastes is one of the most pressing environmental issues of modern times. At present, most of these extremely dangerous materials, which have been produced by nuclear power plants at some 100 localities around the Nation and now total tens of thousands of tons, are being stored under temporary conditions at many of the individual plants. In recognition of the critical need for permanent waste storage, Yucca Mountain in southwestern Nevada has been investigated by Federal agencies since the 1970's, as one of the Nation's potential geologic disposal sites. In 1987, Congress selected Yucca Mountain for an expanded and more detailed site characterization effort, and a broad multidisciplinary program of studies was developed by the U.S. Department of Energy (1988) to further evaluate the suitability of the mountain as a safe and permanent underground disposal facility. The scope and objectives of the many kinds of investigations to be pursued were guided in large measure by regulations governing the siting of geologic repositories for high-level radioactive wastes that were issued by the U.S. Nuclear Regulatory Commission (Code of Federal Regulations 10CFR60) and supplemented by further requirements set forth by the U.S. Department of Energy (Code of Federal Regulations 10CFR960).

As an integral part of the planned site-characterization program, the U.S. Geological Survey began a series of detailed geologic, geophysical, and related investigations designed to characterize the tectonic setting, fault behavior, and seismicity of the Yucca Mountain area. A broad goal was to provide essential data for assessing the possible risks posed by future seismic and fault activity in the area that may affect the design and long-term performance, and the safe operation, of the potential surface and subsurface repository facilities.

The results of 13 of the many studies that were undertaken to foster a fuller and more comprehensive understanding of the tectonic environment of Yucca Mountain are presented in this document. Data collection and analyses were performed in accordance with a rigorous (and time-consuming) set of technical procedures and guidelines that were established to comply with quality assurance standards, an essential requirement for activities involved in the siting and licensing of nuclear facilities.

The first four studies described in this document provide information on the tectonic evolution of Bare Mountain and Crater Flat, which are situated immediately west of Yucca Mountain and are integral elements of the Yucca Mountain tectonic setting. In Chapter B, T.D. Hoisch discusses the extent and timing of the unroofing of lower-plate metamorphic rocks at Bare Mountain since the peak of metamorphism in Early Cretaceous time. He uses thermochronologic data to characterize the relatively rapid uplift of the mountain as a result of tectonic denudation by detachment faulting. V.E. Langenheim, in Chapter C, uses gravity data to model three different geometries of the Bare Mountain fault that defines the west edge of Crater Flat. Using magnetic data, she suggests that the most likely geometry is a high-angle, stepped fault. K.D. Smith and others describe the preliminary results of a 100-km-long reversed seismic refraction profile in Chapter D. *P*-wave velocity structure was measured to greater depths than was done in previous refraction studies, and the results suggest that eastern Crater Flat is underlain by a block of high-velocity material, probably cooled Tertiary basaltic magma. G.A. Thompson presents perspectives on Basin and Range structure and basaltic volcanism in the Bare Mountain–Crater Flat area in Chapter E. Applying an observation-based theory of the interactions of stress, earthquakes, and the injection of basaltic dikes, he suggests a model of extension by normal faulting accompanied by injection of basaltic dikes at depth, with intrusions of horizontal dike sheets also being a possibility.

The next group of four papers examines the setting and behavior of several Quaternary faults important to the characterization of seismic hazards at Yucca Mountain. Except for the Death Valley–Furnace Creek fault system, these studies were completed in advance of a detailed program to examine more closely the overall extent and timing of Quaternary fault activity at Yucca Mountain. Using shallow seismic refraction, J.W. Whitney and D.L. Berger, in Chapter F, calculated a long-term slip rate on the Windy Wash fault in Crater Flat along the southeast edge of Yucca Mountain. They measured the offset of a 3.7-Ma basalt to determine a slip rate of 0.027 mm per year (or meters per thousand years) since the late Pliocene. C.D. Harrington and others, in Chapter G, describe the minimum age of exposures of bedrock scarps along the Solitario Canyon and Windy Wash faults using the relatively new technique of cosmogenic radiocarbon dating. In conjunction with field geomorphic relations, they determined that steep bedrock scarps are, for the most part, more than 20,000 years old, and that the present bedrock scarps have been exposed primarily by surface erosion rather than fault displacement. The results of an important new study of offset Holocene fans along the Death Valley and Furnace Creek faults in Death Valley are reported by R.E. Klinger and L.A. Piety in Chapter H. They suggest a vertical slip rate of 1–3 mm per year, with a recurrence interval of 1,000–2,000 years for surface-rupturing earthquakes on the Death Valley fault. A lateral slip rate of 4–9 mm per year was calculated for the Furnace Creek fault, consistent with a relatively short recurrence interval of 700–1,300 years for ground-breaking earthquakes. D.W. O'Leary presents the tectonic significance of the Rock Valley fault zone, located south and southeast of Yucca Mountain, in Chapter I. He describes the left-lateral style of faulting, which may have originated as early as the late Oligocene. As are other large, left-lateral faults in the Walker Lane Belt, the Rock Valley fault has the potential of generating earthquakes of magnitude 7.0 or larger.

The third group of papers characterizes recent seismic activity in the Yucca Mountain region. This information serves as critical input for seismic hazard analyses, seismic design values, and tectonic models for the potential high-level radioactive waste repository. D.H. Von Seggern and J.N. Brune, in Chapter J, present a seismic catalog of the southern Great Basin, which lists seismic events dating back to 1868 for the region within about 200 kilometers of Yucca Mountain. Seismic activity in this region appears to be irregular in space and time. Focal mechanisms are a mixture of normal and strike-slip mechanisms characteristic of Great Basin faulting. K.D. Smith and others, in Chapter K, characterize the 1992 Little Skull Mountain earthquake sequence, which occurred 20 km east of Yucca Mountain. The main shock involved down-to-the-southeast dip-slip on a steeply dipping fault plane, and the nearest strong motion equipment recorded a peak acceleration of 0.206 g (g is the force of gravity, 9.8 m/s^2). That recorded earthquake sequence produced a large amount of data for ground motion modeling at the potential repository. A year later, a sequence of unusually shallow earthquakes occurred on the nearby Rock Valley fault, as discussed by K.D. Smith and others in Chapter L. More than 640 events were recorded, the largest being magnitude 3.7 with left-lateral motion. A unique study by J.N. Brune and J.W. Whitney, described in Chapter M, demonstrates the potential for using precariously balanced rocks on hillslopes near active faults as primitive strong-motion seismoscopes. Numerous precarious rocks are found on the western slopes of Yucca Mountain above the Solitario Canyon fault. This study estimates that ground motions at Yucca Mountain have not exceeded 0.3 g during the past several tens of thousands of years.

The last paper in this collection, Chapter N by Bob Janssen and Geoffrey King, develops mechanical and kinematic models of the Yucca Mountain area. The models use simple normal fault geometries with shear perpendicular to the subparallel faults, as well as isostatic effects, to explain uplift and tilting of structural blocks. In order to simulate the observed topography with these parameters, a fault with a throw of about 3 kilometers, which has no present visible surface expression, is interpreted to underlie Crater Flat.

Data and interpretations from these and other Yucca Mountain studies, as well as information from outside the DOE (Department of Energy) characterization project, will be used to probabilistically assess the fault displacement and vibratory ground motion hazards at the potential radioactive-waste repository (U.S. Department of Energy, 1994). Teams of tectonics experts, who will identify seismic sources and evaluate earthquake recurrence and maximum magnitudes, potential fault displacement, and appropriate tectonic models for Yucca Mountain, will conduct the assessment of fault behavior. A team of ground motion experts will evaluate source and path effects on ground motion, and appropriate ground motion attenuation effects for the potential site. Results of these hazard analyses will then be used in the preclosure seismic design of both surface and subsurface facilities (U.S. Department of Energy, 1996) and in the evaluation of coupled processes that may lead to the future release of radioactive material to the accessible environment. A few examples of tectonically coupled processes are: co-seismic changes in the water table; changes in infiltration rates due to changes in fracture characteristics; and potential rockfalls induced from ground motion.

References Cited

U.S. Department of Energy, 1988, Site characterization plan, Yucca Mountain site, Nevada Research and Development Area: Washington, D.C., U.S. Department of Energy, Office of Civilian Radioactive Waste Management, DOE/RW-0199.

———1994, Methodology to assess fault displacement and vibratory ground motion hazards at Yucca Mountain: U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Topical Report YMP/TR-002-NP.

———1996, Preclosure seismic design methodology for a geologic repository at Yucca Mountain, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Topical Report YMP/TR-003-NP, Revision 1.