Proceedings of the 13th Annual British Columbia Mine Reclamation Symposium in Vernon, BC, 1989.
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ABSTRACT

The program for disposal of high-level and transuranic radioactive waste in the United States calls for establishment of a mined repository in geologic formations that will provide for retreivability of the vaste for 50 years. The goal of radioactive waste isolation in mined repositories is to prevent unacceptable concentrations of radionuclides from migrating to the accessible environment. Early concepts of high-level radioactive vaste disposal assumed that containment of the waste by the enclosing rock would be virtually complete. With the application of broader scientific and engineering disciplines, specifically geology and hydrology to the study of prospective environments for vaste disposal, the realization came that total isolation of the vaste in the immediate vicinity of the repository cannot be ensured. Furthermore, it vas realized that the geological and hydrological methods available today are not appropriate for predicting conditions or events that may prevail during the extremely long time required for waste isolation. Earth processes that are of major concern during the waste-isolation storage time include: (1) rates of radionuclide transport in the ground-water flow system which, in turn, reflect chemical reactions of radionuclides with ground water and earth materials; (2) climatic changes; and (3) tectonic and associated erosional events. To compensate for the limitations in our knowledge, the current rationale for waste isolation emphasizes the need for a series of independent barriers to vaste migrations. Multiplicity of these barriers, both engineered and natural, will compensate for uncertainties in predicting natural and man-induced conditions and events that may occur during the time required for waste isolation.

The site selected for intense study for suitability of high level and transuranic radioactive waste isolation is Yucca Mountain in the desert of the southern part of the State of Nevada. The target buiial zone is in welded tuff at a depth below the surface of about 300 meters. The burial zone is in the unsaturated ?^np about inn me fers above the water table. The climate is arid; the average precipitation is about 150 mm/yr. Studies are currently ongoing to determine if the site vill provide long term isolation of radioactive waste.

1. INTRODUCTION

The search for repository sites in the United States is more than tvo decades old and has proven to be considerably more complex, both technically and politically, than was originally conceived. Aside from physical exhumation by erosion, meteorite impact, or volcanic activity, ground-water flow is the only natural mechanism by which radionuclides could be transported to the biosphere from an underground repository. By the end of this century, the United States plans to begin operating the first geologic repository for the permanent disposal of commercial spent nuclear fuel and high-level radioactive waste. Public Law 97-425, the Nuclear Waste Policy Act of 1982 (the Act), specifies the process for selecting a repository site, and constructing, operating, closing, and decommissioning the repository. Congress approved geologic disposal by declaring that one of the key purposes of the Act is "to establish a schedule for the siting, construction, and operation of repositories that will provide reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository" [Section 111(b)(1)].

In February 1983, the U.S. Department of Energy (DOE) carried out the first requirement of the Act by formally identifying potentially acceptable sites in the following locations (the host rock of each is shown in parentheses);

1. Vacherie Dome, Louisiana (salt dome)
2. Cypress Creek Dome, Mississippi (salt dome)
3. Richton Dome, Mississippi (salt dome)
4. Yucca Mountain, Nevada (welded tuff)
5. Deaf Smith County, Texas (bedded salt)
6. Swisher County, Texas (bedded salt)
7. Davis Canyon, Utah (bedded salt)
8. Lavender Canyon, Utah (bedded salt)
9. Hanford Site, Washington (basalt flows)

The locations of these sites are shown in Figure 1.

The Act further requires the DOE to issue general guidelines to be used in determining the suitability of sites. In February 1983, the DOE published draft guidelines for the recommendation of sites for nuclear waste repositories (DOE, 1983). The DOE revised the guidelines after receiving extensive comments from the Nuclear Regulatory Commission (NRC), the states, Indian tribes, other Federal agencies, and the public. The NRC concurred with the revised guidelines in June 1984, and the final guidelines were promulgated in December 1984 (DOE, 1984).

The Act requires that, after the guidelines are issued, the DOE must nominate at least five sites as suitable for site characterization. The act specifies that during site characterization, the DOE will construct exploratory shafts for underground testing to determine whether geologic conditions will allow the construction of a repository that will safely isolate radioactive waste. The Act requires the DOE to prepare site-characterization plans for review by the NRC, states, Indian tribes, and the public. After site characterisation and an environmental impact statements are completed, the DOE is to recommend one of the characterized sites for development as the first repository.

In preparation of this report the authors have relied heavily upon the Environmental Assessment of the Yucca Mountain site (DOE, 1986).

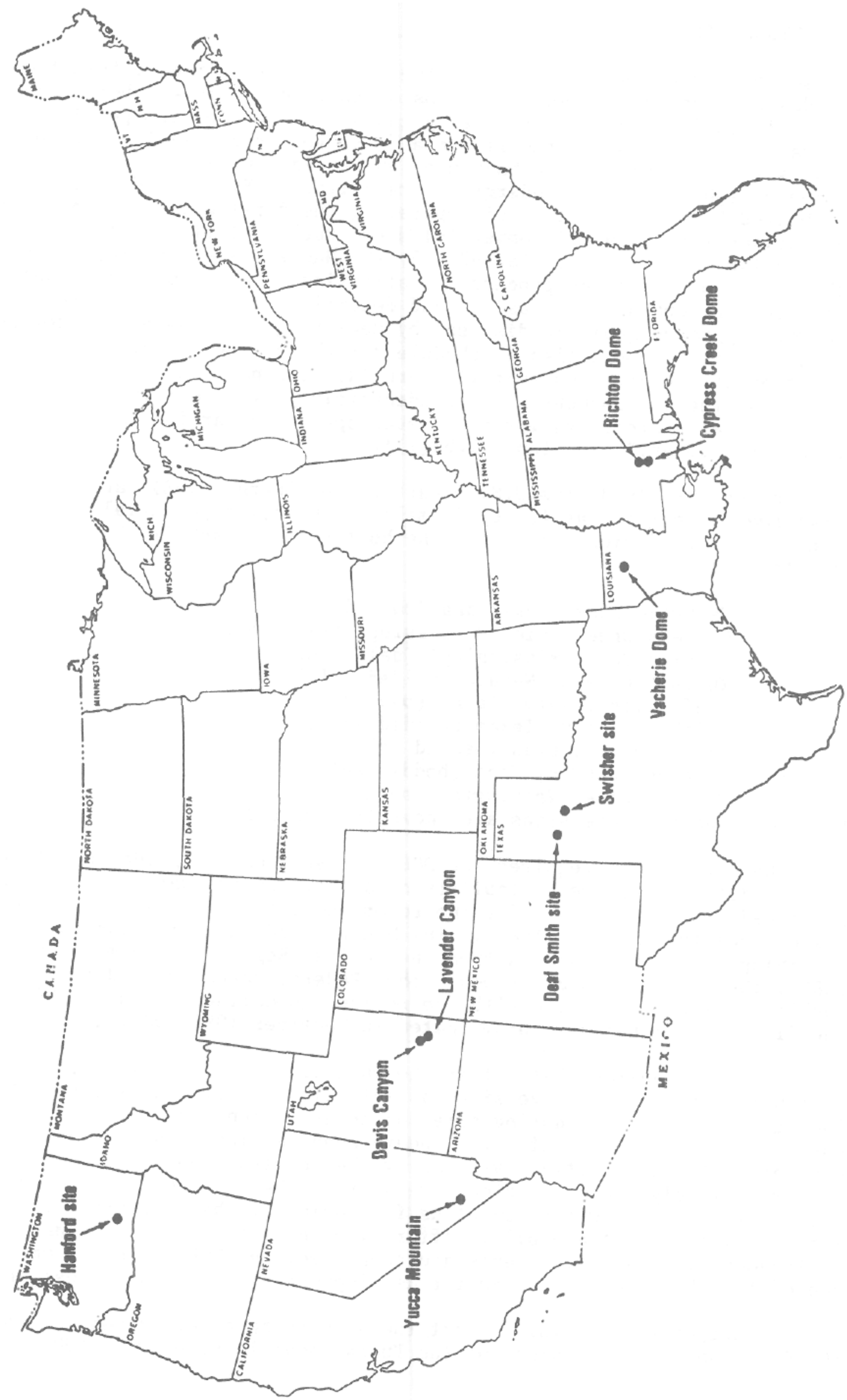

Figure 1.-- Potentially acceptable sites for the first repository. (from DOE, 1986)

2. YUCCA MOUNTAIN SITE

The Yucca Mountain site is in Nye County, Nevada, on and adjacent to the southwest portion of the Nevada Test Site, about 137 kilometers northwest of Las Vegas (Figure 2). The Yucca Mountain site is on three adjacent parcels of Federal land, each under separate control of the DOE, the U.S. Air Force, and the U.S. Bureau of Land Management.

The Yucca Mountain site in Nevada was selected for intense site characterization from among the nine prospective sites for intensive characterization. The Yucca Mountain Site is in the Basin and Range Province, which is characterized by complex structure and stratigraphy. Tertiary and Quaternary tectonic events created the characteristic northward-trending mountain blocks and basins; these events are a continuation of a long geologic history of faulting, volcanism, and plutonism in the Province. Although they share a catastrophic history of earth movement and igneous activity, numerous sections of the Basin and Range Province have distinctly different aspects in age and nature of terrain, rocks, and tectonic events.

Nye County which is largely rural has a population density of 0.5 person per square mile. The three unincorporated towns closest to the proposed site are Amargosa Valley, Beatty, and Pahrump. The total population of Nye County in 1980 was 9,048. The 1980 population of Clark County, which adjoins Nye County on the east, was 463,087, with a density of 58.8 persons per square mile. Approximately 96 percent of this population resides in the Las Vegas valley. Incorporated cities in the Las Vegas valley include Henderson, Las Vegas, and North Las Vegas. Unincorporated towns and communities in the Las Vegas valley are East Las Vegas, Enterprise, Grandview, Lone Mountain, Paradise, Spring Valley, Sunrise Manor, and Winchester.

3. GEOLOGIC CONDITIONS

This section summarizes the stratigraphy, structure, seismicity, and mineral-resource potential of the Yucca Mountain site and nearby areas. Descriptions of stratigraphy and structure of the Nevada Test Site and vicinity are found in Lipman and others (1966), Eckel (1968), Byers and others (1976), Stewart (1980), and Maldonado and Koether (1983).

The regional stratigraphic setting of Yucca Mountain is characterized by the four major rock groups shown in Figure 3. The first and oldest of these groups, the Precambrian crystalline rocks, are not exposed in the vicinity of Yucca Mountain but may occur at great depths beneath portions of the site. The second group, Upper Precambrian and Paleozoic sedimentary rocks, is present at the surface about 15 kilometers east of Yucca Mountain at Calico Hills, where it is composed of Devonian and Mississippian argillite and carbonates. This group is also observed 30 to 40 kilometers southeast of Yucca Mountain in the Specter Range and Skeleton Hills, where predominantly Cambrian and Ordovician carbonates and some quartzite are exposed. Carbonates and quartzite of similar age are also present at Bare Mountain about 14 kilometers west of Yucca Mountain. Silurian carbonates have been encountered at depths of 1,250 meters and 2,5UO meters in two drill holes bordering Yucca Mountain to the east.

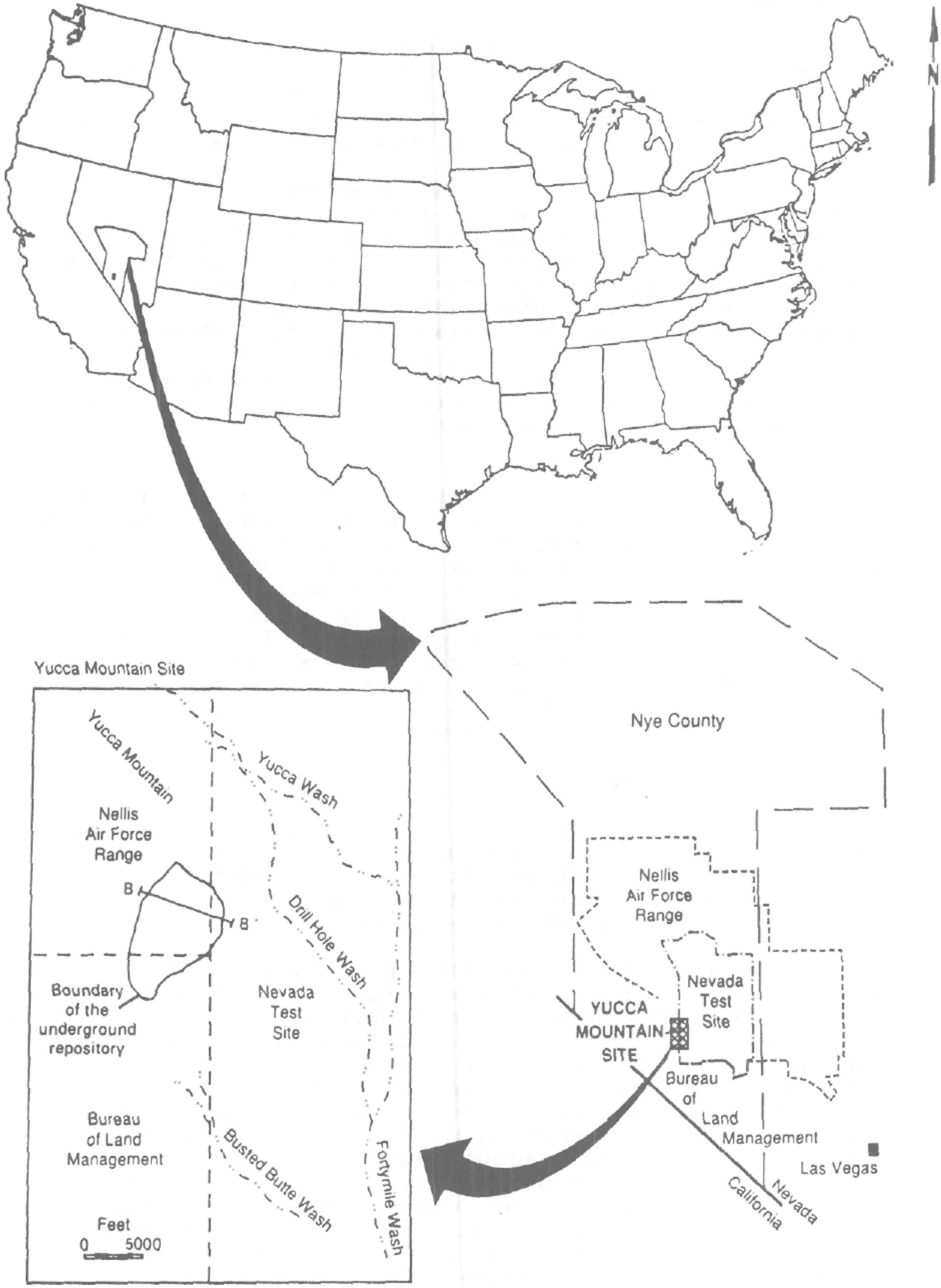

Figure 2.— Location of the Yucca Mountain site in southern Nevada.
(from DOE, 1988)

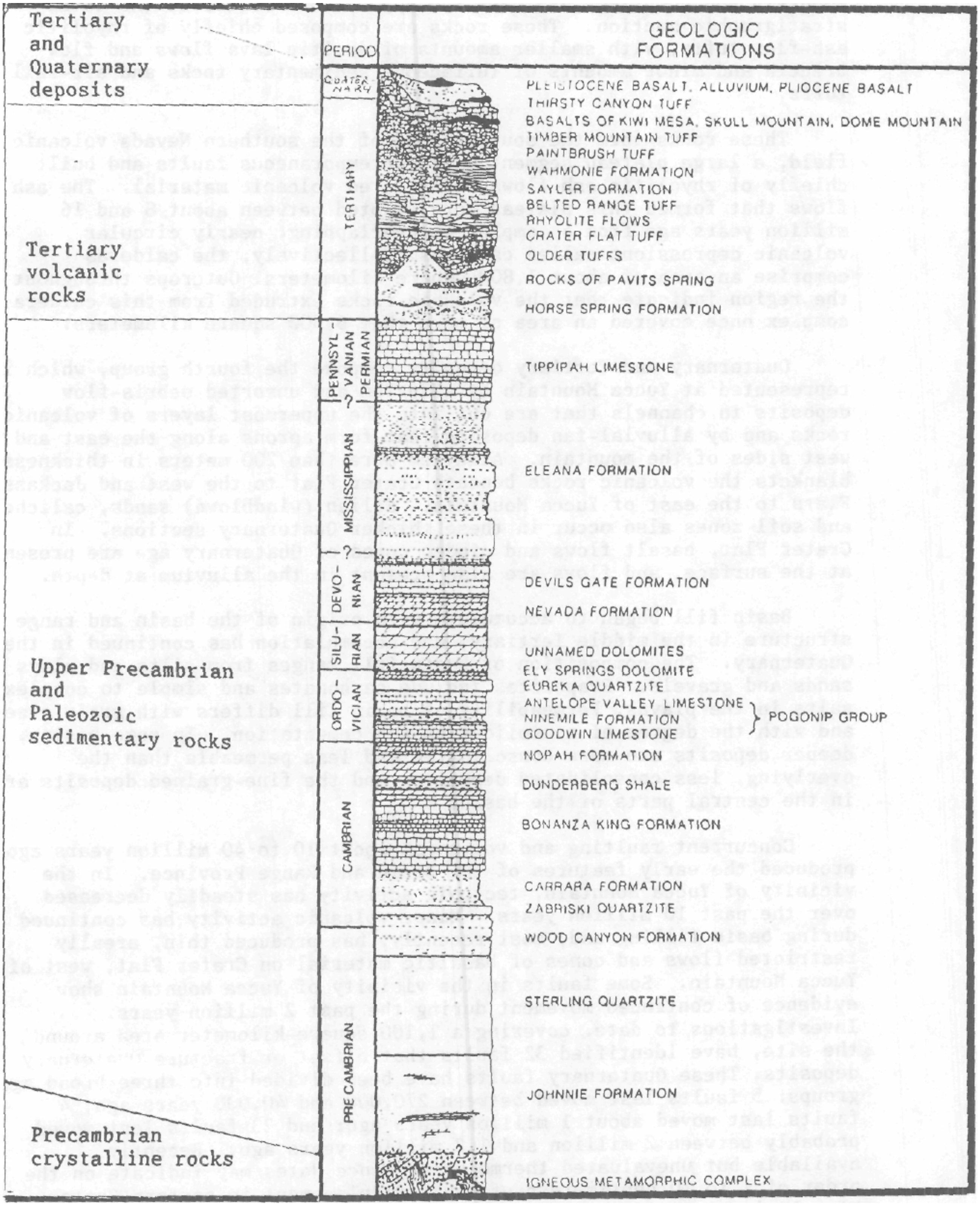

Figure 3.-- Geologic formations in the vicinity of Yucca Mountain, (after DOE, 1986)

The third major group, Tertiary volcanic rocks, occurs at Yucca Mountain and comprises at least the upper 2,000 meters of the total stratigraphie section. These rocks are composed chiefly of rhyolitic ash-flow tuffs, vith smaller amounts of dacitic lava flows and flow breccia and minor amounts of tuffaceous sedimentary rocks and air-fall tuffs.

These rocks form the southern end of the southern Nevada volcanic field, a large plateau segmented by contemporaneous faults and built chiefly of rhyolitic ash flows and related volcanic material. The ash flows that formed this plateau were erupted between about 8 and 16 million years ago from a complex of overlapping, nearly circular volcanic depressions called calderas. Collectively, the calderas comprise an area of about 1,800 square kilometers. Outcrops throughout the region indicate that the volcanic rocks extruded from this caldera complex once covered an area of more that 6,500 square kilometers.

Quaternary and Tertiary deposits compose the fourth group, which is represented at Yucca Mountain by alluvium and unsorted debris-flow deposits in channels that are cut into the uppermost layers of volcanic rocks and by alluvial-fan deposits that form aprons along the east and west sides of the mountain. Alluvium more than 200 meters in thickness blankets the volcanic rocks beneath Crater Flat to the west and Jackass Flats to the east of Yucca Mountain. Eolian (windblown) sands, caliche, and soil zones also occur in these thicker Quaternary sections. In Crater Flat, basalt flows and cinder cones of Quaternary age are present at the surface, and flows are also present in the alluvium at depth.

Basin fill began to accumulate with origin of the basin and range structure in the middle Tertiary, and accumulation has continued in the Quaternary. The composition of basin fill ranges from silts and clays to sands and gravels. Evaporites include carbonates and simple to complex salts in the playas. Permeability of basin fill differs with grain size and with the degree of consolidation and cementation. In some basins, deeper deposits are more consolidated and less permeable than the overlying, less consolidated deposits, and the fine-grained deposits are in the central parts of the basins.

Concurrent faulting and volcanism about 10 to 40 million years ago produced the early features of the Basin and Range Province. In the vicinity of Yucca Mountain, tectonic activity has steadily decreased over the past 10 million years. Minor volcanic activity has continued during basin filling and, most recently, has produced thin, areally restricted flows and cones of basaltic material on Crater Flat, west of Yucca Mountain. Some faults in the vicinity of Yucca Mountain show evidence of continued movement during the past 2 million years. Investigations to date, covering a 1,100-square-kilometer area around the site, have identified 32 faults that offset or fracture Quaternary deposits. These Quaternary faults have been divided into three broad age groups: 5 faults last moved between 270,000 and 40,000 years ago: 4 faults last moved about 1 million years ago; and 23 faults last moved probably between 2 million and 1.2 million years ago. Recently available but unevaluated thermoluminescence dates may indicate on the order of 1 to 10 centimeters of fault displacement in eastern Crater Flat less than 6,000 years ago. Yucca Mountain and areas to the west and south have had a relatively low level of seismicity throughout the historical record.

There is no evidence that the Yucca Mountain site contains commercially attractive geothermal, uranium, hydrocarbon, oil shale, or coal resources, although low-grade uranium and geothermal resources are found in the general area of the site. Under foreseeable economic conditions and in spite of the many small mining operations in the area, there is no potential at the site for extracting the limited mineral resources.

4. HYDROLOGIC CONDITIONS

Climate in the Basin and Range Province is arid to semiarid; annual precipitation averages about 28 centimeters. Variability in areal distribution is directly related to topographic relief between the ranges and the intervening basins. Precipitation varies from less than 10 centimeters in the basins to as much as 30 to 40 centimeters at higher elevations in many of the ranges. The mean annual free-water-surface evaporation ranges from 90 to 250 centimeters.

The large difference between precipitation and potential rate of water loss by evaporation and transpiration results in little recharge to ground water, little runoff, and few perennial streams and lakes. Average annual runoff from the Basin and Range Province generally is less than 50 millimeters. The few perennial streams that originate within the Basin and Range Province have their sources at higher elevations in the ranges within the Province, or in the bounding highlands and ranges, principally the Sierra Nevada, west of the province, or the Wasatch Mountains, east of the Province. Two perennial streams flowing through the Province, the Colorado River and the Rio Grande, originate outside the Province.

Water deficiency of the Basin and Range Province, measured by the excess of potential evapotranspiration compared to precipitation, is a significant characteristic with respect to waste isolation. As a consequence of the climate, the ground-water recharge is low and depth to ground water is great in some areas. The unsaturated zone, where rates of vertical movement of water are slow, is a prospective zone for disposal of high-level radioactive waste.

The hydrologic system encompassing Yucca Mountain exhibits low precipitation, deep water tables, and closed topographic and ground-water basins (Winograd and Thordarson, 1975). Ground water is recharged by the slow infiltration and downward percolation of precipitation and surface water through intergranular pores and perhaps through factures in the rocks overlying the water table. At Yucca Mountain, most of the precipitation, averaging 150 millimeters per year, is returned to the atmosphere through evaporation and plant transpiration before it can infiltrate deep enough to become ground-water recharge. Only a small fraction (probably 3 percent or less) of the annual precipitation reaches the depth proposed for the repository. The ground-water flow system encompassing Yucca Mountain has been delineated by Bedinger and others (1989). The flow system includes a large part of the Nevada Test Site and extends southward into California, ultimately discharging into Death Valley. The discharge area nearest Yucca Mountain is in Ash Meadows, Nevada, about 50 kilometers south of Yucca Mountain.

At Yucca Mountain, a repository would be constructed in the unsaturated zone 200 to 400 meters above the water table. The movement of ground water in the unsaturated zone is typified by a very low flux.

of water moving downward, primarily through the intergranular pores of the tuff layers (Montazer and Wilson, 1984). In the saturated zone below, water moves laterally through fractures and pores in the tuffs and in the underlying carbonate-rock aquifers. Flow of ground water in the region has been modeled by Waddell (1982); Czarneckl (1985) employed a digital model of the flow system to examine the effects of changes in climate on the ground-water flow system.

5. GEOLOGIC REPOSITORY

A geologic repository will be developed much like a large mine. Shafts will be constructed to allow for the removal of excavated material and to permit the construction of tunnels and disposal rooms at depths between 330 and 1300 meters below the surface. Other shafts will be constructed to allow for the transfer of waste. Surface facilities will be provided for receiving and preparing the waste for emplacement underground (Figure 4). The surface and underground facilities will occupy about 400 and 2,000 acres of land, respectively. When the repository has been filled to capacity and its performance has been shown to be satisfactory, the surface facilities will be decommissioned and all shafts and boreholes will be backfilled and permanently sealed.

A repository can be viewed as a system of multiple barriers, both natural and engineered, that act together to contain and safely isolate the waste. The engineered barriers will include the waste package, the underground facility, and the shaft and tunnel backfill materials. The waste package will consist of the waste (either spent nuclear fuel or solidified high-level waste) a metal container, and specially designed backfill material to separate the waste container from the host rock. The waste container and backfill material will enhance long-term isolation by delaying eventual contact between the waste and the geologic environment. The underground facility will consist of underground openings and backfill materials not associated with the waste package. These barriers will further limit any ground-water circulation around the waste packages and will impede the subsequent transport of radionuclides into the environment.

The geologic, hydrologie, and geochemical features of the site constitute natural barriers to the long-term movement of radionuclides into the accessible environment. These natural barriers will provide waste isolation by impeding radionuclide transport through the ground-water system into the accessible environment and will possess characteristics that reduce the potential for human interference in the future.

Although the DOE plans to use engineered barriers--as required by both NRC in 10 CFR Part 60 and the U.S. Environmental Protection Agency (EPA) in 40 CFR Part 191--the DOE places primary reliance on the natural barriers for waste isolation. Therefore, in evaluating the suitability of sites, the use of an engineered-barrier system will be considered to the extent necessary to meet the performance requirements specified by the NRC and the EPA but will not be relied on to compensate for deficiencies in the natural barriers.

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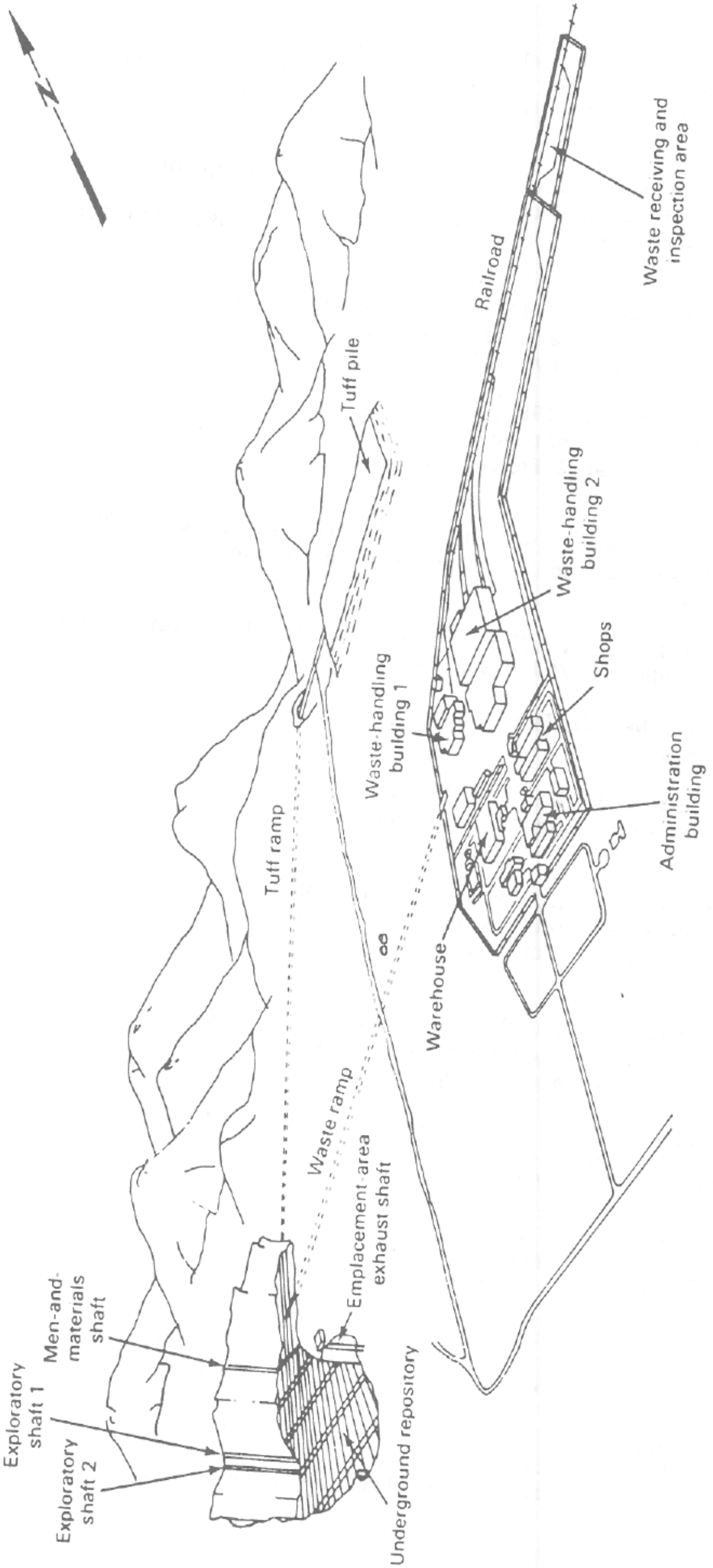

Figure 4.-- Perspective ofd the proposed repository at Yucca Mountain. (from DOE, 1988)

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