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G188: Volcanoes of the Eastern Sierra Nevada

17 June 2004



Yucca Mountain provided by
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Relative Safety at Yucca Mountain

Currently, there is about seventy thousand metric tons of high-level radioactive waste scattered across the United States (Hanks, 1999). This waste is being stored temporarily in large pools of cool water at the location it was created (Krauskopf, 1988). The possibility of radioactive leakage at one of these sites has prompted the United States government to look for a permanent location to store this nuclear waste as it decomposes. Now, with the recent threat of terrorism, the necessity of a secure location in which to deposit high-level waste has become more urgent. Due to both political and scientific reasons, Yucca Mountain was chosen by Congress to be the only site to be studied for the possibility of permanent waste isolation. There is considerable disagreement regarding this site's ability to safely isolate nuclear waste for the minimum ten thousand years mandated by the Environmental Protection Agency (Keller, 1999). Yucca Mountain possesses many geologic qualities which make it a suitable location to store high-level radioactive waste.

One reason that Yucca Mountain is an attractive site for storing nuclear waste is its position within North America. Yucca Mountain is located near the western boundary of the Great Basin province. Water in this geographical region does not drain into any ocean; all of the precipitation is drained internally. Rather than running into an ocean, the water often evaporates, runs into a saline lake to later evaporate, or is stored in

aquifers deep below the earth's surface. The reason that interior drainage is an advantage for a possible high-level waste repository is that the risk of radioactive leakage can be contained within a specific region. If large amounts of radioactive materials were to escape the repository, the impact upon potable water would be localized to the Great Basin at least. The effects of radioactive contamination would be minimized on a global scale. Actually, some scientists think that the aquifer system of which Yucca Mountain is a part is isolated from local major cities. This aquifer connects to Death Valley but is thought to be completely isolated from the aquifer from which Las Vegas draws water (Fenelon, 2002).

The arid climate of Yucca Mountain is another advantage of constructing a high-level waste repository at this location. Annually, Yucca Mountain receives an average of seven and a half inches of rainfall. Of that small amount of rainfall, ninety-five percent of the water evaporates, runs off of the mountain, or is absorbed by vegetation. Only about five percent of Yucca Mountain's meager average rainfall actually penetrates the ground. The most dangerous opponent of permanent nuclear waste storage is water. Radionuclides, or radioactive atoms, are transported efficiently by water. Also, the integrity of the storage canisters is compromised by the presence of water. The containers will eventually corrode and leak radionuclides into the environment, but if the amount of water in the repository can be minimized, the lengths of the canisters' lives would be extended. The aridity of Yucca Mountain reduces the amount of moisture in the repository and in the region's overall water system. If little water enters the mountain, little water will leave the mountain through the aquifer system. Because minimal water moves through Yucca Mountain, radionuclides have a diminished

opportunity to leave the repository and pollute the surrounding environment (Department of Energy, 2003).

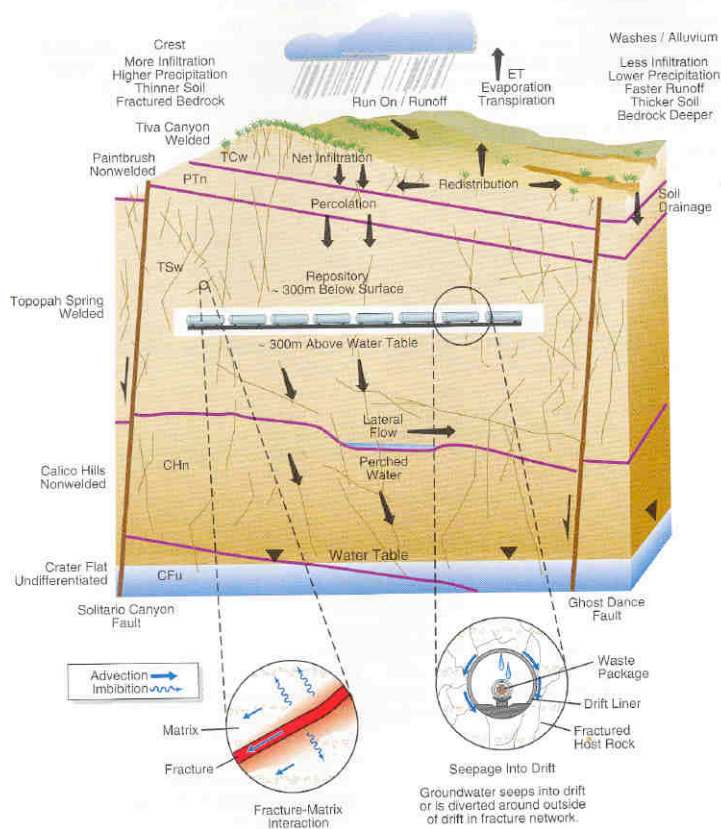


Figure 2.—Block diagram showing stratigraphic and hydrogeologic setting of proposed unsaturated-zone (above water table) repository at Yucca Mountain. From Viability Assessment (v. 3, fig. 3-1).

Underground storage model. Taken from USGS Circular 1184. Originally from “Viability Assessment of a Repository at Yucca Mountain” by Department of Energy.

Yucca Mountain is also an appealing location for permanent high-level waste storage because of its deep water table. The water table at Yucca Mountain is approximately two thousand feet below the surface (DOE, 2003). This depth has allowed contractors to build the repository above the water table, rather than below, as was originally intended. The possibility of storing high-level waste below the water table was complicated by “high fracture transmissivity coupled with high ground-water temperature” (Hanks, 1999). The United States Geological Survey endorsed the above

water table repository because this site would allow for the retrieval and constant monitoring of the high-level waste. Scientists could detect engineering mistakes early and would then be able to repair those mistakes. Monitoring and retrievability would be impractical for a sub-water table repository due to the extreme depth of the waste. Yucca Mountain's deep water table is also advantageous because water has a large distance to travel before it reaches an aquifer. This distance increases the length of time needed for radionuclides to seep into the water table (Hanks, 1999).

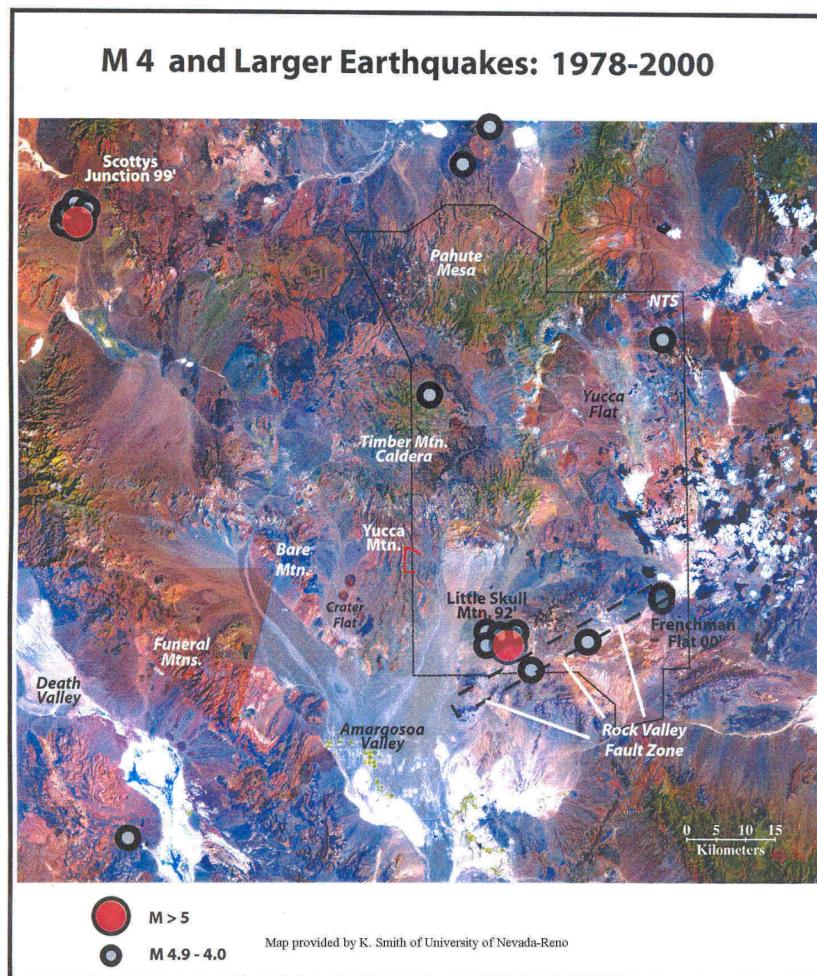
Yucca Mountain is an attractive site for a high-level waste repository because the rock above the water table is unsaturated. The rock which composes Yucca Mountain is riddled with microscopic pores. These pores are partially filled with water, as opposed to saturated rock in which the pores are completely full. The rock's pores provide a resting place for the moving water, and thus slow down its descent to the water table. Thousands of years may pass before water travels from the surface of Yucca Mountain to the repository's tunnels. Thousands of years more may pass before any water that is contaminated by radionuclides would reach the water table. The unsaturated nature of the rock composing Yucca Mountain slows the water flow, which is already limited by the climate, to a near standstill. This slowdown delays the rate at which water reaches the water table and allows radionuclides a longer period of time to decompose before contaminating the region's groundwater (DOE, 2003).

Yucca Mountain's rock composition is also conducive to permanent high-level waste isolation. Yucca Mountain is composed mostly of tuff, or consolidated volcanic ash. Tuff has the ability to actually absorb radionuclides, which allows the Yucca Mountain's bedrock to actually filter contaminated water before it reaches the water table

(Krauskopf, 1988). Yucca Mountain has alternating layers of welded and nonwelded tuff. The repository is situated at the center of a large layer of welded tuff (Hanks, 1999). This variety of tuff does not absorb radionuclides as well as nonwelded tuff, but it is sturdier and can accommodate the repository's tunnels (Krauskopf, 1988). A thick layer of nonwelded tuff is conveniently below the welded layer which encapsulates the repository (Hanks, 1999). This layer absorbs radionuclides well, so any contaminated water which percolates through this layer will have its dangerous radicals filtered by the rock (Krauskopf, 1988). In addition, the saturated zone beneath the water table of Yucca Mountain is laden with volcanic rocks, clay, silt, and sand. The latter three materials were transported by water. These materials either absorb or dramatically slow down the flow of radionuclides which are leaked from the repository (DOE, 2003). The geological composition of Yucca Mountain is one of the location's greatest assets for permanent high-level waste storage.

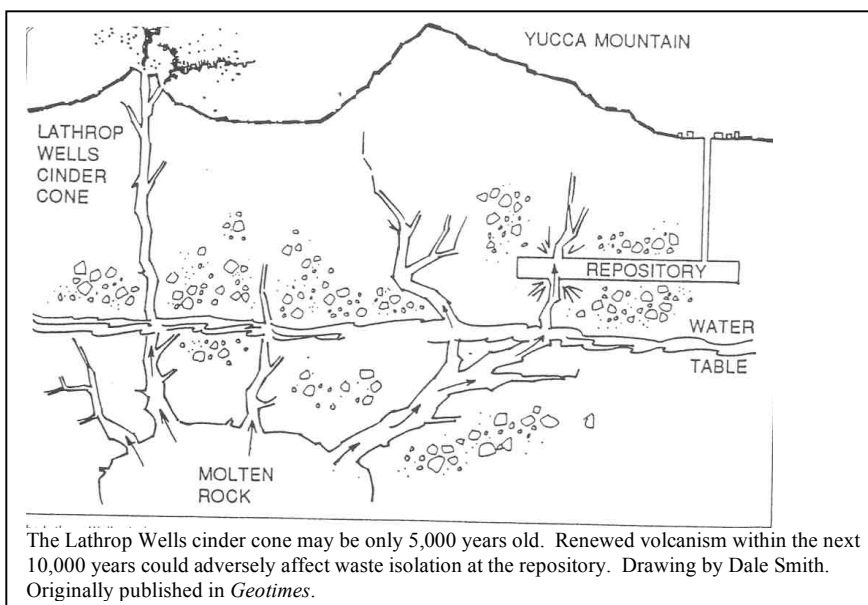
Although the present-day climate at Yucca Mountain limits the amount of moisture that reaches the repository's tunnels, the climate is quite conducive to waste container corrosion. Little moisture penetrates Yucca Mountain, so corrosion due to direct contact between the canisters and liquid water can be minimized. The humidity inside of Yucca Mountain is around ninety-eight to ninety-nine percent, which creates an oxidizing environment. High humidity dramatically accelerates canister corrosion. Several solutions to this problem have been proposed. One solution is to use ceramic canisters to store waste, because they have already been oxidized. Another proposed solution is cathodic protection using an outer layer to electrically shield an inner layer inside the canister. One other less likely solution is to allow the canisters to heat the

repository. The heat which radiates from the canisters may be used to keep the temperature inside the tunnels above the boiling point of water for more than ten thousand years. By raising the temperature inside the tunnel, some scientists propose that problems with corrosion due to water could be offset. Other scientists argue that the increased temperature inside the repository may adversely affect the integrity of the canisters. The Department of Energy is currently studying this option in order to find a way to extend the canister's lifespan (Whipple, 1996).



In terms of geology the Yucca Mountain area has recently been active tectonically. The Yucca Mountain region is part of the Basin and Range province, and for the last fifteen million years this area has undergone immense stretching due to

tensional forces. This region is basically being pulled apart. The stress placed on this province has caused widespread fracturing and created the mountains and valleys in the region. The mountains continue to rise, and the valleys continue to fall. This province is still stretching at a rate of approximately one hundred twenty millimeters per year (Dott, 1994). Seismic activity is not rare in this area, which is a major concern for a location which may in the future house high-level nuclear waste. In 1992, a magnitude five earthquake occurred at Little Skull Mountain, which is less than twenty-five kilometers from Yucca Mountain. Throughout the last thirty years, numerous magnitude four earthquakes have occurred around Little Skull Mountain (K. Smith, 2004). Some people fear that an earthquake may occur which damages the repository at Yucca Mountain in some way. Rocks may fall from the ceiling of the tunnels and damage the containment canisters. Most scientists from the United States Geological Survey assert that this is unlikely, because no existing underground structures have sustained major damage due to seismic activity (Hanks, 1999). The possibility of a major seismic event still exists, though, and preparations should be made to deal with this threat.



There is debate among scientists regarding the possibility of a future volcanic event at Yucca Mountain. The rock which composes Yucca Mountain is mainly tuff, which is a volcanic rock (Whipple, 1996). This composition points to past volcanic activity in the area and demonstrates that volcanism played a large part in forming this region. In addition, Timber Mountain Caldera is directly north of Yucca Mountain, less than fifteen kilometers away. This caldera was formed by a past, explosive, volcanic eruption (K. Smith, 2004). There are twelve volcanoes which have been active in the last one million years that are within twenty kilometers of the repository (Perry, 2000). Scientists estimate that the youngest volcano in the region, Lathrop Wells, may be anywhere from five thousand to one hundred fifty thousand years old (D. Smith; Turrin, 1991). There is debate within the scientific community about the actual age of the volcano. This argument must be resolved before waste is deposited in Yucca Mountain, because if Lathrop Wells is less than ten thousand years old, it is still considered an active volcano. If magma were to intrude into the repository, the tunnels may be destroyed, exposing the high-level waste to the environment. In a worst case scenario, Yucca Mountain itself could erupt explosively and send the high-level waste into the atmosphere. The USGS claims that the probability of any volcanic event during the repository's ten thousand year isolation period is negligible, but the possibility remains present (Hanks, 1999).

The water table under Yucca Mountain may rise to the level of the proposed repository. Scientists from the USGS observe that the water table in the region surrounding Yucca Mountain was once much higher. Calcite veins are present in the region and can be used to determine the minimum high water level, because calcite veins

are hydrogenic features. Estimates of this previous water table level range from tens to hundreds of meters above its present-day location. This dramatic drop in the water table's depth raises questions about the security of high-level waste which may be buried in the Yucca Mountain repository. If the water table were to rise due to an increase in precipitation, the repository could actually become engulfed by groundwater. This scenario would have detrimental effects upon canister lifespan and the ability of the mountain's bedrock to retard the movement of radionuclides; both the natural and anthropogenic barriers keeping the waste isolated would be breached. The USGS concluded that this scenario is not plausible, because the dramatic climate change that would be needed to move the water table up to the repository would be unprecedented (Winograd, 1988). Despite the fact that this worst-case scenario is unlikely to occur, a significant climate change making the mountain wetter would have an impact on the repository's ability to keep waste isolated from the environment. Even if the water table rose ten meters, the time needed for radionuclides to reach the groundwater could be reduced by hundreds of years. Also, a rise in water table means that moisture is flowing through the mountain at an accelerated rate, which would speed canister corrosion and thus radionuclide leakage. Although the repository is not likely to become submersed by groundwater, climate change is still an unpredictable variable which could lead to early release of radionuclides.

Numerous fractures in the bedrock of Yucca Mountain make the speed at which water percolates to the water table unpredictable. Water travels more easily through fractures than through the rock itself. If the mountain becomes more fractured due to tectonics or volcanism, water will move more easily from the surface to the repository

and from the repository to the water table. Several large faults currently exist which have altered the design of the repository. Scientists are currently studying Ghost Dance Fault in order to determine whether it helps or hinders the movement of water through Yucca Mountain. Alternate excavation may be needed if this fault is found to accelerate the rate at which water flows through the mountain. Throughout the construction of the repository, workers have discovered numerous previously unknown faults, which have complicated the repository's design. As an added disadvantage, when contaminated water travels through fractures, the rock's ability to absorb radionuclides is greatly diminished. If most of Yucca Mountain's water travels through the fracture system, rather than percolating toward the water table, the repository's natural barriers controlling waste isolation will be breached (Whipple, 1996).

Yucca Mountain is an appealing candidate for a high-level nuclear waste repository, but the site is not ideal. The tectonic setting, the possibility of volcanism, and uncertainty about present and future water flow rates raise questions about the mountain's ability to isolate waste for one million years, the time needed for plutonium to decompose to a safe level, or even ten thousand years, as was mandated by the EPA. Despite continuing studies into the mountain's ability to permanently store waste, there is not enough data available to guarantee absolute safety far into the future. The timeline for these predictions is longer than recorded history, which forces scientists to forecast the long-term state of Yucca Mountain using very short-term data. Unfortunately, the decision regarding the future of high-level waste in America will be based on the relative safety of several different alternatives, rather than one absolutely safe solution (Hanks, 1999).

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