# Yucca Mountain:

## Geological History and its future as a Nuclear Waste Repository

Patrick Woodson
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**Abstract**

In 1982 the United States enacted legislation that created the Nuclear Waste Policy Act. This Act was created in order to address the nations growing abundance of spent nuclear fuel and high-level radioactive waste and deposit it in a national geological repository. This paper seeks to show the geological history of the site chosen, Yucca Mountain, Nevada. It also seeks to provide the environmental policy framework in which the site was chosen and the different scientific and political reasoning's behind that choice. The reasoning includes the use of natural barriers such as the welded and un-welded tuff to prevent surface water percolation that could carry radionuclides into the ground water system. Also, the engineered barriers that scientists have worked on developing for two decades that will also help prevent percolation. Particular attention will be paid to examining the ongoing legal struggles that involve the State of Nevada, the Department of Energy, and the proposed geological repository at Yucca Mountain.

**Introduction**

The United States began using Nuclear Power for commercial use in the late 1950's. The use of nuclear energy quickly grew in the following decades due to utility companies seeing the benefits of this new type of energy. According to the Nuclear Engineering department at Missouri-Rolli, by 1991 the United States had twice as many nuclear power plants as any other country in the world. (Nuclear Engineering; University of Missouri-Rolli, 2003) Although this new form of energy was first regarded as environmentally friendly, there were still proposals as early as 1955 to build a nuclear waste repository. (National Research Council, 1957) Currently the United States has 131 surface facilities in 39 states storing our nuclear waste. (DOE: Why Yucca Mountain, 2003) This waste consists of over 4000,000 metric tons of spent nuclear fuel and

400,000 cubic meters of high level radioactive nuclear waste. (Jane C.S. Long et al, 2004) In 1982, Congress enacted the Nuclear Waste Policy Act to ensure that the Department of Energy would "site, design, construct, operate, and close a deep geologic repository." (DOE: Yucca Mountain Project, 2001) After years of studying several sites Congress chose to speed up the process by deciding on Yucca Mountain as the lone destination to be studied and eventually turned into a nuclear waste repository (Figure 1). Since then Congress has spent over 20 years and more than $8 billion dollars on the Yucca Mountain Project. (DOE: Why Yucca Mountain, 2003) Although our government has invested a huge amount of time and money into the project it is still a very controversial and uncertain issue. This is due to the fact that safely and permanently disposing of highly radioactive and hazardous waste is an extremely complex scientific and engineering problem that has many political overtones. (DOE: Yucca Mountain Project, 2001) There are many different aspects that must be examined and predicted before a permanent seal is put on the repository as well as many different groups who support and oppose the project. The reasoning behind choosing Yucca Mountain deals with several different issues such as its geological past and future and continues to be a controversial congressional decision.

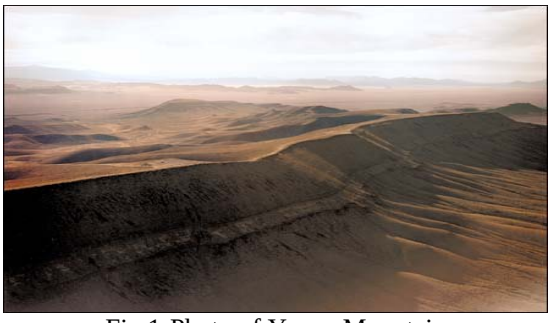


Fig.1-Photo of Yucca Mountain
(USGS website, 2001)

**Observations**

**Geological and Geographic Setting**

Yucca Mountain is a place of particular interest to our national government because it is the proposed site of a nuclear waste repository. This makes the geological history and current setting of the area extremely important. Yucca Mountain is located in Nye County Nevada, which is over 100 miles to the Northwest of Las Vegas in Southwest Nevada. It is located on the government owned Nevada Test Site, which was the area that the United States performed all its nuclear testing from the 1950's until 1992. (Nevada Alliance website, 1999) It is a series of hills that were created by a number of volcanic eruptions that occurred 12 to 14 million years ago. (DOE: Why Yucca Mountain, 2001) The eruptions sent out large clouds of volcanic ash, which is known to geologists as tuff. According to the United States Geological Survey, tuff is a volcanic rock that is composed of magma which has been chilled while being blown into the air and then settles and deposits. When the ash falls to the ground at high temperatures and compresses and consolidates it becomes welded-tuff. (USGS Glossary website, 2007). The eruptions that formed Yucca Mountain ended about 12 million years ago and were responsible for 99% of the material that composes the mountain. Since then there has been very little volcanic activity. The most recent eruption occurred 80,000 years ago and produced the remaining 1% of material in Yucca Mountain (U.S. Department of Energy Fact Sheet website, 2003). These rocks are extremely faulted as a result of all the volcanism. (Jane C.S. Long et al, 2004) Yucca Mountain also has several north-south block-faulted ridges. A few of these faults lie within the proposed repository and are still believed to be seismically active. (Stepp et al, 2001) It is also important to note that the mountain is not on an area of converging continental plates and

therefore is much less likely to have any volcanism in the future. According to the U.S. department of Energy, experts believe Yucca Mountain is one of the least likely places in the Western U.S. to experience volcanism. (U.S. Department of Energy Fact Sheet website, 2003) Another key factor dealing with the geography of Yucca Mountain is that it is located in the Mojave Desert, which means it has a very dry and arid climate. It receives less then 7.5 inches of rain fall per year. Of these 7.5 inches of rainfall almost 95% evaporates or runs off. (U.S. Department of Energy website, 2003) This is a very important aspect of the geology because hydrologists have estimated that only 5% percolates through the tuff and eventually reaches the water table that is several hundred meters below the surface. (E. A. Keller, 1999) Also, Yucca Mountain is located in the Basin and Range, which is notorious for seismic and volcanic activity. (Jane C.S. Long et al, 2004) The Basin and Range consists of several linear mountains and valleys that have a distinct north to north west trend and are all closed topographic basins. (G.S. Bodvarsson et al, 2004) Both the hydrology of the area and the seismic and volcanic activity have been studied extensively over the past two decades and have contributed greatly in dealing with the proposed design of the repository.

**Policy Framework**

The following section discussing the political controversy involved with Yucca Mountain has been adapted from The Department of Energy's Yucca Mountain Project: a briefing, 2001. In 1982 Congress and the Department of Energy formed The Office of Radioactive Waste (OCRWM) in order to "develop and manage a federal system for disposing of spent nuclear fuel from commercial nuclear reactors and high-level radioactive waste from national defense activities" (OCRWM website, 2006). This

office that operates under the Department of Energy (DOE) was established under the Nuclear Waste Act of 1982. This law was enacted based on the idea that the generation of people that have benefited from the use of nuclear materials should take on the responsibility of properly disposing of the hazardous waste left behind that could harm future generations. This is why the act required the DOE to "site, design, construct, operate, and close a deep geologic repository." (DOE: Yucca Mountain Project: a briefing, 2001) The law also outlined and established all the legal requirements for choosing the repository site as well as the approval from Congress and the President, and a licensing by the Nuclear Regulatory Commission. Prior to the 1987 amendment to the Nuclear Waste Act there were seven different sites being considered for the repository. President Ronald Reagan narrowed the sites down to three sites located in Washington; Texas; and Yucca Mountain, Nevada. In order to speed up the studying process for the repository and cut the escalating cost of maintaining three study sites Congress amended the act and required the DOE to only study Yucca Mountain. This amendment was intended to speed up the process in order to benefit the American People by getting closer to a solution as fast and efficiently as possible, but it has not been viewed by everyone as a beneficial decision.

Nevada's Opposition

The state of Nevada has adamantly opposed the amendment to the Nuclear Waste Act of 1987 and has taken a strong stance against it, which can be seen when they say:

> Since 1987 when Congress directed that the United States Department of Energy (DOE) characterize only the Yucca Mountain site, Nevada has remained firm in its resolve to halt the project. Now, after nearly twenty years, it is becoming increasingly clear that Yucca Mountain is incapable of isolating deadly high-level nuclear waste and that construction of this monolithic project will seriously

> jeopardize the public health and safety of Nevadans and millions of Americans living along transportation routes. (Nevada State website, 2007)

In order to stop the Yucca Mountain nuclear waste repository from being built they have taken it upon themselves to pursue all legal avenues necessary to halt its progress as well as attempt to expose its flaws. (Nevada State website, 2007) The Nevada Department of Justice has been instrumental in slowing down the process that the OCRWM has to pursue in order to finish the Yucca Mountain Project and complete the repository. As the Nevada Attorney General so eloquently put it, "Nevada has been quietly pulling Jenga-blocks out of the Yucca tower. Soon that tower will come crashing down. It will do so irrespective of politics." (Nevada State website, 2007) They first saw success in July of 2004 when the Court of Appeals ruled in favor of the state. The court stated that the Environmental Protection Agencies (EPA) standard of 10,000 years for radiation containment was arbitrary. By ruling in favor of Nevada they also struck down the Nuclear Regulatory Licensing Standards, therefore voiding the OCRWM's petition for a license. (Yucca Mountain website, 2004) Although Congress and the DOE claim to be pursuing the Yucca Mountain Project for the soul benefit of the American people the State of Nevada feels otherwise, and will continue to battle them in the courts for years to come, which will further prevent the government making progress on the repository.

**Geological Setting for the Repository**

The following section has been adapted from the Department of Energy's Fact Sheet on Yucca Mountain, 2001 as well as the Department of Energies Reference Design Description for a Geologic Repository, 2001. Many homes across the United States use electricity that is produced by nuclear power. Eventually the fuel that is used to produce this electricity does not work any longer. When the fuel is no longer useful it is removed

from the reactors and becomes spent-fuel. Also, some of the nuclear materials we use for national defense produce highly radioactive waste. Both of these materials are very harmful to people and the environment. That is why it is essential for the government to protect these materials. Over the past few decades a variety of different options have been considered for removing these nuclear wastes for protection. Some options considered were: sub-seabed disposal, space disposal, ice-sheet disposal, island geological disposal, and leaving it where it is. After countless studies with scientists from all over the world the international scientific consensus is that a deep-hole disposal would be the best option. The scientific term for this is geologic repository.

Natural Barriers

The Department of Energy's basic idea for the geologic repository is to dispose of the radioactive waste and spent fuel in carefully sealed containers deep under Yucca Mountain in tunnels. This would require the transport of all the radioactive materials from the 131 sites around the United States to Yucca Mountain, where they would then be placed in double-layered, corrosion strength packages for burying underground. The repository itself would consist of 60 miles of tunnels. (DOE: Yucca Mountain Project, 2001) These tunnels would be around 660 feet to 1400 feet below the mountain surface. This would place the repository 570 feet to 1200 feet above the water table as seen in figure 2. (DOE: Yucca Mountain Project, 2001)

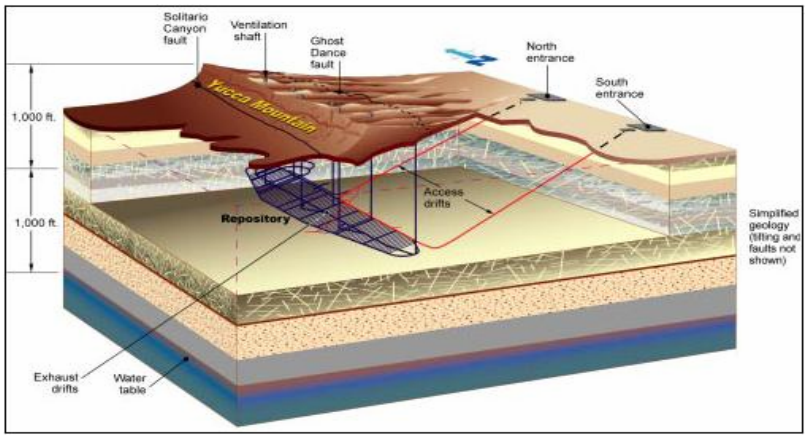



Figure 2-Yucca Mountain stratigraphy and repository layout
(www.ocrwm.doe.gov, 2001)

Although the repository is deep underground and placed in an unsaturated zone, the main concern is the 5% of ground water that does percolate through the surface. (Jane C.S. Long et al, 2004) According the DOE, "water is the primary means by which radioactive elements could be transported from a repository." (DOE: Yucca Mountain Project, 2001) One important aspect of Yucca Mountain is the scientific belief that natural barriers and processes will help prevent water from reaching the nuclear waste inside the repository. All the waste will be stored in "extremely durable corrosive-resistant containers" and will be in solid form. (DOE: Yucca Mountain Project, 2001) By placing these containers deep underground in the repository the radiation emitted from the waste could not possibly harm the environment or people. The only problem is the hazardous radioactive materials have fission products in them that would take hundreds of years of confinement from the environment in order for them to be no longer hazardous. (E.A. Keller, 1999) Also they produce an artificial isotope plutonium-239 that will take a quarter of a million years for it to be considered safe. (E.A. Keller, 1999) This is why hydrologists have been studying the area for so many years to determine the amount of percolation and the future of the hydrology in the area. According to the Department of Energy:

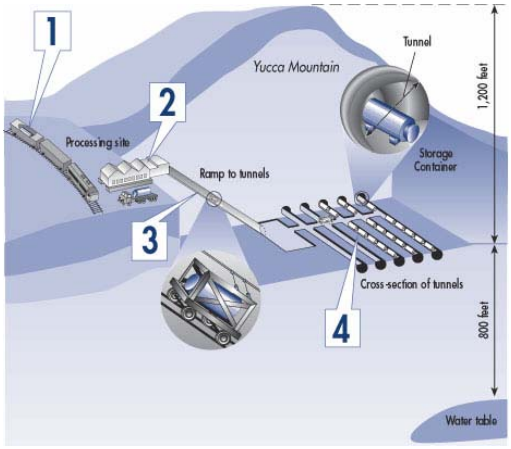
> Over tens of thousands of years, if enough water came in contact with the waste containers, it could eventually corrode through them. If enough water reached the solid waste itself, it could eventually break down into tiny radioactive particles that would be carried into the groundwater. Therefore a repository is designed to keep the radioactive materials dry. (DOE: Yucca Mountain Project, 2001)

Through numerous scientific studie,s it is the DOE's belief that the natural barriers will help prevent water corrosion from happening. They affirm that the dry climate, thick unsaturated rock layers above and below the repository, minerals within the rock that attract and hold radioactive particles, and the deep water table will help prevent any hazardous materials entering the ground water. (DOE: Yucca Mountain Project)

Engineered Barriers

In order to ensure the health and safety of the public the DOE also has plans to place several man made barriers in the repository to work together with the natural barriers. These will consist of drip shields to limit the ability of water to seep through and touch the waste packages, extremely durable and non corrosive waste packages that prevent water from ever touching the waste, solid waste forms that will prevent radionuclides being picked up by water, and inverts that limit the rate of releasing any hazardous materials into the natural barriers. (DOE: Yucca Mountain Project, 2003) One of the main reasons for having so many different types of barriers is to use defense-in-depth. This is to ensure that if one barrier fails for some unforeseen reason there are several others still in effect that will help prevent the leakage of the hazardous materials. An in depth look at the proposed repository and the method for placing the material in the tunnels can be seen in figure 3. Although there have been numerous studies and calculations made to ensure that the repository will be a safeguard to the people and environment, it is very hard to predict what the geological future may hold when

designing a disposal system that is supposed to last longer than recorded human history itself.




1. Canisters of waste sealed in special casks are shipped to site by rail or truck.
2. Waste is removed and placed into multi-layered carrion durable containers
3. An automated system sends the containers down to the tunnels
4. Containers are stored in the tunnels along their sides.

(U.S.NRC website, 2007)

Problems Facing the Potential Repository

When considering building a deep well repository, it is very important to have a clear picture of what the future may hold. Geologists have studied the area for years to look at its geological past so they can uncover the possibilities of its future. According to the Nevada Seismology Laboratory Yucca Mountain experiences about 10 micro-earthquakes per day and about 20 per year that are within 10 miles of Yucca Mountain. These earthquakes are generally of a magnitude less than one and cannot be felt. Historically there have been a few large earthquakes on record. In 1992 there was an earthquake of magnitude 5.6 recorded at Little Skull Mountain not to far away from Yucca. This earthquake did not do any damage to the study facilities at Yucca Mountain. Due to the extensive data that has been collected on the seismic nature of Yucca Mountain the DOE is required to build the repository and all waste canisters with the

ability to withstand any earthquakes of the strongest predictable magnitude. (Nevada Seismological Laboratory website, 2003)

There have been as many as 8 major basaltic volcanic eruptions within 75 miles of Yucca Mountain in the past million years. (Smith et al, 2005) This makes the understanding of future volcanism very important. The DOE has done extensive studies with an expert panel on the future of volcanism around Yucca Mountain. Volcanologists used the abundant amount of data they have and combined it with the geologic setting of Yucca Mountain to create a computer model to predict future volcanism. They found that the likelihood of an eruption occurring in this area in the next 10,000 years would be one in 70 million. (DOE: Why Yucca Mountain, 2001)

One of the most crucial problems with the proposed repository is shipping all of the hazardous waste to the site from all over the country. The following information has been adapted from DOE: Transporting Spent Nuclear Fuel and High-Level Radioactive Waste to a National Repository, 2002. The DOE has an extensive set of guidelines for the proposed procedures. The hazardous waste would be shipped from all the 131 sites in the 39 different states by rail and truck. All waste would be shipped in large metal casks that have been certified by the NRC and would be completely safe for public health. There would be approximately 175 truck and train shipments over a 24 year period to reach the maximum occupancy of nuclear waste allowed at Yucca Mountain which is 10,000 metric tons. One of the most frequently asked question when dealing with the shipment of hazardous materials is how the DOE will account for the possibility of terrorist attacks. They have a very strict set of guidelines that have been designed to ensure the safety of the public and protect them from any possible attack. Some of the

security measures include: monitoring through a communication center with 24-hour staffing, safeguarded schedule information, escorts for all shipments, and coordinated logistics with local law enforcement agencies. The DOE has taken great consideration and countless scientific studies with the design of the repository, now it is a matter of obtaining the license from the NRC before they move forward with the project.

## Interpretation

Yucca Mountain has been studied for the past 20 years and the Department of Energy has provided conclusive evidence that it is the appropriate spot for a geological nuclear waste repository. The site is in compliance with the guidelines originally provided by the NRC, yet it has not received its license from them due to political turmoil and endless litigation. In 2002 George Bush wrote:

> Proceeding with the repository program is necessary to protect public safety, health, and the Nation's security because successful completion of this project would isolate in a geologic repository at a remote location highly radioactive materials now scattered throughout the Nation. In addition, the geologic repository would support our national security through disposal of nuclear waste from our defense facilities. (Bush, 2002)

The government is looking out for the publics best interest in designing the repository, but the problem lies within the consensus of geologists, engineers, and the social world. It has been nearly impossible to come to one common consensus among these three realms. Geologists have done numerous studies and collected plenty of data in compliance with the original 10,000 year temporal boundary that was originally set, yet they believe this is far too short a time period to make any conclusive decisions. (Jane C.S. Long et al, 2004) On the other hand, this temporal boundary is far too long for reliable engineering. (Jane C.S. Long et al, 2004) Then there is the litigation that continues between the state of Nevada and the government. There stance has been

against Yucca since day one and this can be seen when they say, “Nevada’s official position is that Yucca Mountain is a singularly bad site to house the nation’s high-level nuclear waste and spent nuclear fuel. Not only is the geology of Yucca Mountain unsuited for its mission, the prospect of transporting nuclear waste to such an inappropriate destination represents government folly at its worst.” (Nevada State website, 2007) They do make a strong argument when discussing all the unresolved scientific issues dealing with Yucca Mountain. They cite the need for a better understanding of the hydrology, volcanism, and seismic activity of the region as well as the mountains aquifer draining into one of the largest agricultural regions in Nevada. (Nevada State website, 2007)

Yucca Mountain does have many natural benefits that scientifically lead one to believe it is a good repository site. The arid climate and low precipitation are great benefits for a repository to prevent water from percolating through the surface to the hazardous waste and then transferring hazardous material into the ground water. Geologists and engineers will continue to work together to find the best possible solution to permanently dispose of the high-level radioactive waste and spent nuclear fuel. As for now the Department of Energy has preliminary plans to submit its license application in June of 2008. (OCRWM website, 2007) If all goes to plan they will begin construction and initiate repository operations in 2017.

**Conclusion**

Since the 1987 amendment to the Nuclear Waste Policy Act Yucca Mountain has been at the heart of controversy. Numerous scientific tests have been done and countless data has been collected, yet we are still years away from having a geological disposal

repository. Geological repository does seem to be the best solution for dealing with our nuclear waste, but at the same time I think it is important that we stop producing nuclear waste. There has already been $7 billion dollars invested in this project and there is no clear answer in sight. Much of that money could have been invested in alternative energy sources over the past twenty years. Also it seems completely ridiculous to continue waste production when we have yet to come up with a clear answer as to what we will do with it. On the other hand, the Department of Energy has made fairly convincing scientific and engineering arguments for the repository. Yucca Mountain does provide a wonderful underground spot where nature and scientific engineering will work together to produce the best results. The only problem is predicting the future which can be very erratic in geological terms, especially when you are dealing with millions of years. The Basin and Range is an extremely active geological area and even the most scientific predictions could be useless in 10,000 years. It is essential that politicians, Nevada's public, geologists, and engineers all continue to work together to find the best answers to our nuclear waste problem because it will not be going away anytime soon.

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