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Geotechnical Branch
Division of Waste Management, NMSS
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Transmittal of Reference Letter Report (Draft)
AO 297

Reference: Preliminary draft; Letter Report on Assessment of Potential for Future Volcanic Hazards at Yucca Mountain

Dear Mr. Blackford:

Attached herewith, please find two copies of the subject draft report prepared by H. Larry McKague.

This preliminary draft letter report is a partial draft manuscript on the potential for volcanism at the Nevada Test Site (NTS) and its immediate vicinity including Yucca Mountain areas. The report contains mostly the background information to put the NTS in the proper perspective. This draft letter report should provide an adequate briefing for the upcoming field trip in February 1987.

Larry McKague will continue his effort in this endeavor; he plans to complete the report sometime in near future. In the meantime, if you and NRC staff have any questions, please let us know.

Sincerely yours,

Dae H. (Danny) Chung
Project Leader

DHC/ic
Encls: as stated (2).

cc: Ms. C. Abrams

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ASSESSMENT OF POTENTIAL FOR FUTURE VOLCANISM HAZARDS AT YUCCA MOUNTAIN, NEVADA

Introduction

The purpose of this report is to assess the volcanic hazard potential at and in the vicinity of Yucca Mountain. Newhall (1984, p. 1) defines volcanic hazards and volcanic risk as "volcanic phenomena (e.g., pyroclastic, flows, ashfall) that can pose a threat to persons or property" and "exposure of individuals to death or injury, and of structure to damage from volcanic hazards", respectively. In this report the potential for future eruptions are discussed and evaluated. Following that the potential role of various volcanic hazards with respect to Yucca Mountain are assessed. No assessment of volcanic risk is made in this report. Crowe (1986, p. 32-35) discusses volcanic risk assessment for the Yucca Mountain.

Since the eruption of Mount St. Helens in 1980 there has been an expanded and intensified effort to develop methods to predict or forecast volcanic eruptions, (Decker, 1986, Tanzieff and Sabroux, 1983, Martin and Davis, 1982, Gudmundsson 1986). The earlier work by Crandell and Mullineaux, 1978, resulted in a notification of potential hazard for Mount St. Helens. At Yucca Mountain concern regarding volcanic hazards is slightly different than in areas where current predictive studies are ongoing. In those areas, recent volcanic activity is well established, i.e. Long Valley, CA, San Miguel, Azores, Mt. Vesuvius, Italy, Japan, Iceland, and Hawaii. In all these areas there are abundant indications of recent volcanism. In many areas there are historical and even on-going records of the volcanism. The concern in these areas is for the immediate safety of the nearby population. Areas where the next significant eruption may be 1000 years in the future are of little concern, especially when they are located in remote areas.

The time frame at Yucca Mountain is for a considerably longer period (10^4-10^5 yrs), for an unmovable population (buried canisters), and for a relatively small area (400 acres). In addition, the volcanic hazards are different. They include the magma itself, volcanic heat, and hypothermal fluids. The repository is located within the earth rather than on its surface, although some surface volcanic hazards could be a problem during the preclosure period.

Background

The proposed Yucca Mountain high level nuclear waste repository would be located in volcanic tuff. The source of the tuff was the Timber Mountain Caldera located several miles to the north. Stewart recognizes four periods of Cenozoic volcanism in Nevada. Cenozoic volcanism started in Nevada approximately 43 M.Y. ago (Stewart, 1980, p. 98). This early activity (43 to 34 M.Y. ago) was centered in northern Nevada. These rocks are primarily andesite to rhyolite and lava flows.

About 34 M.Y. ago there was a significant change in the character of volcanic activity. This second period extends to 17 M.Y. In that interval there were extensive eruptions of quartz latite and rhyolite ash flow tuffs. The volcanos that were the sources of these ash flows were all north of the NTS. Some tuffs associated with this period of volcanic activity are found scattered around the Nevada Test Site (NTS). The 29 M.Y. old ash fall beds, found in the Horse Springs Formation in southern Frenchman Flat, are the oldest volcanic rock known on the NTS. Other older tuffs found on the test site include: the Monotony tuff (26-27 M.Y., Ekren et al., 1971); the White Blotch Spring tuff (24-25 M.Y., Ekren et al., 1971), Fraction tuff (15-18 M.Y., Ekren et al., 1971; and the Tolicha Peak tuff (14-15 M.Y., Ekren et al., 1971).

Although some outcrops of these older units are known on the NTS, they have also been identified in deeper drill holes in Yucca Flat. They generally occur as scattered patches buried in valleys or grabens beneath Yucca Flat. Ekren (1968, p. 249) has suggested the Fraction tuff may indicate the beginning of basin and range faulting. Basaltic rocks are rare in this time interval (Steward, 1980, p. 100).

A major change in the character of volcanism in Nevada occurred about 17 M.Y. ago according to Stewart (1980, p. 102). This marked the start of wide spread eruption of mafic lava, mostly basalt and bimodal assemblages of rhyolite and basalt. Most of the basaltic activity took place in northern and western Nevada. Volcanism in southwestern Nevada was part of a belt of largely silicic rocks that extend E-W across Nevada between latitude 37^{o} and 38^{o}N. These rocks are mainly rhyolitic and quartz latitic tuffs. The change in volcanism is much greater in northern Nevada than in southern Nevada. In southern Nevada it appears that the silicic volcanism moved southward with little change in its nature. There does appear to have been more basaltic rocks associated with this period of volcanism (Stewart, 1980, Fig. 48) than with the earlier (34-17 M.Y.) volcanism (Stewart, 1980, Fig. 47) in southwestern Nevada. This period lasted until 6 M.Y. ago.

Except for the older tuffs noted earlier, all silicic tuffs on and adjacent to the NTS were deposited in this interval. The source calderas were either on the NTS or adjacent to it to the west and northwest. The oldest unit erupted from the vicinity of the NTS is the Red Rock tuff (15-16 M.Y., Marvin et al., 1970). With the eruption of this unit there followed an extensive and complex eruptive period that extended to about 6 M.Y. ago. Tuffs from this period and the source caldera are given in Table I.

In the last 6 M.Y. all volcanic activity on or near the NTS has been limited to development of basaltic cinder cones or lavas. The youngest volcanic activity is the Lathrop Wells cone (0.46 M.Y., Sinnock and Easterling, 1983, Table 2, 0.27 M.Y., Vaniman, 1982, Table 1).

Figure 1 is a breakdown of Tertiary/Quaternary volcanic systems in southwestern Nevada and eastern California. It is possible that these systems represent different variations, stages, and/or modifications of a general volcanic process.

In the southwestern Nevada volcanic field rhyolite is the predominant volcanic rock with basalts being subordinate (Christiansen, et al. 1977, p. 946). Differentiated magma series related to both rhyolitic and basaltic parents are also present, but are relatively minor. In addition to the calc-alkalic rocks of the Timber Mountain-Oasis Valley caldera complex, there are peralkalic silicic rocks stemming from trachitic parents associated with Silent Canyon and Black Mountain caldera complexes. Only the small Wahmonie Saylor volcanic center has intermediate composition rocks as a major integral part of the center (Warren and Bloxton, 1986). Warren and Bloxton propose the intermediate composition rocks result from mixing of silicic and basaltic magmas.

In summary it appears that three magma types can account for most of the 16-6 M.Y. old volcanic rocks in the southwestern Nevada volcanic field. They are a basic magma which is the parent magma for the basaltic rocks. Two slightly different magma types are needed to account for silicic rocks. The silicic calc-alkalic ($NaO+K_2>CaO$) magma was the parent magma for the rhyolites from the Timber Mountain-Oasis Valley complex, and a silicic peralkaline magma [$(Al_2O_3/K_2O + Na_2O)<1$] was the parent magma for the rocks from Silent Canyon and Black Mountain caldera complexes.

The occurrence of two different silicic magna types is supported by seismic velocities beneath Timber Mountain and Silent Canyon (Taylor, 1983). Taylor used teleseismic P wave travel times to derive a three dimensional crust and upper mantle structure. Relatively high velocities were observed in both the crust and upper mantle beneath the Silent Canyon caldera. Low velocities were observed in the lower crust beneath Timber Mountain while there was no expression in the upper mantle. Taylor ((1983, p. 2231) suggested differences between the two caldera complexes were related to their volume, recurrence intervals, and mode of enrichment from the mantle-derived source. The peralkaline nature of the Silent Canyon and Thirsty Canyon suggests the trachyte magmas may have ultimately been derived from alkalic basalt magmas parents. In the following discussion the two silicic magma types and associated volcanism are considered together.

Potential for Silicic Volcanism in Southwestern Nevada

As noted above, the last silicic volcanism in southwestern Nevada occurred about 6 M.Y. ago. The potential for renewed volcanism has been briefly addressed by Crow and Sargent (1978). They concluded (p.23) that "...the risk of recurrence of Black Mountain-type volcanism is probably small." Their conclusion was based on: (1) the youngest volcanic rocks are on the order of 7 M.Y. old and the magma should now be completely solidified, unless the heat had been replenished by new magma and (2) the volume of "... volcanic material erupted during successive cycles of activity declined progressively". This is interpreted as indicating a waning of volcanism consistent with the cessation of volcanism.

In 1983 Crowe et al. (p.3) indicated that the restriction of Quaternary age silicic volcanism to margins of the Great Basin as a third reason for considering the probability of renewal of silicic volcanism as finite, but extremely small. Crowe et al. (1986, p. 251) again note these three reasons for considering the recurrence of silicic volcanism to be negligible.

There appear to be two types of silicic volcanism which need to be considered; very large caldera complexes and smaller bimodal (coexisting basalt-rhyolite magmas) centers. The two may have similar origins, but different reflect in size of volume which could in turn reflect the then current tectonic environment.

The calderal complexes are large volcanic structures which explosively erupted large volumes of siliceous pyroclastic material. Basaltic rocks associated with the caldera complexes are volumetrically subordinate and occur around the perifery of the caldera complex.

Bimodal volcanism is a smaller volume volcanic process where the volumes of silicic and basaltic material are more nearly equal. In addition, the two magmas may erupt nearly contemporaneously and show signs of magma mixing. Examples of such systems would include the Greenwater volcano in the Greenwater and Black Ranges east of Death Valley (Crowe, et al. 1986, p. 23), and the Pliocene volcanic rocks of the Coso Range (Bacon, 1982; Novak and Bacon, 1986).

The underlying cause for the two types of silicic volcanism may be very similar, i.e., basaltic magma intrusion at the base of the crust causing partial melting of overlying silicic crustal rocks.

Volume of basaltic material and/or resident time of the basaltic magma may determine the volume of silicic melt formed.

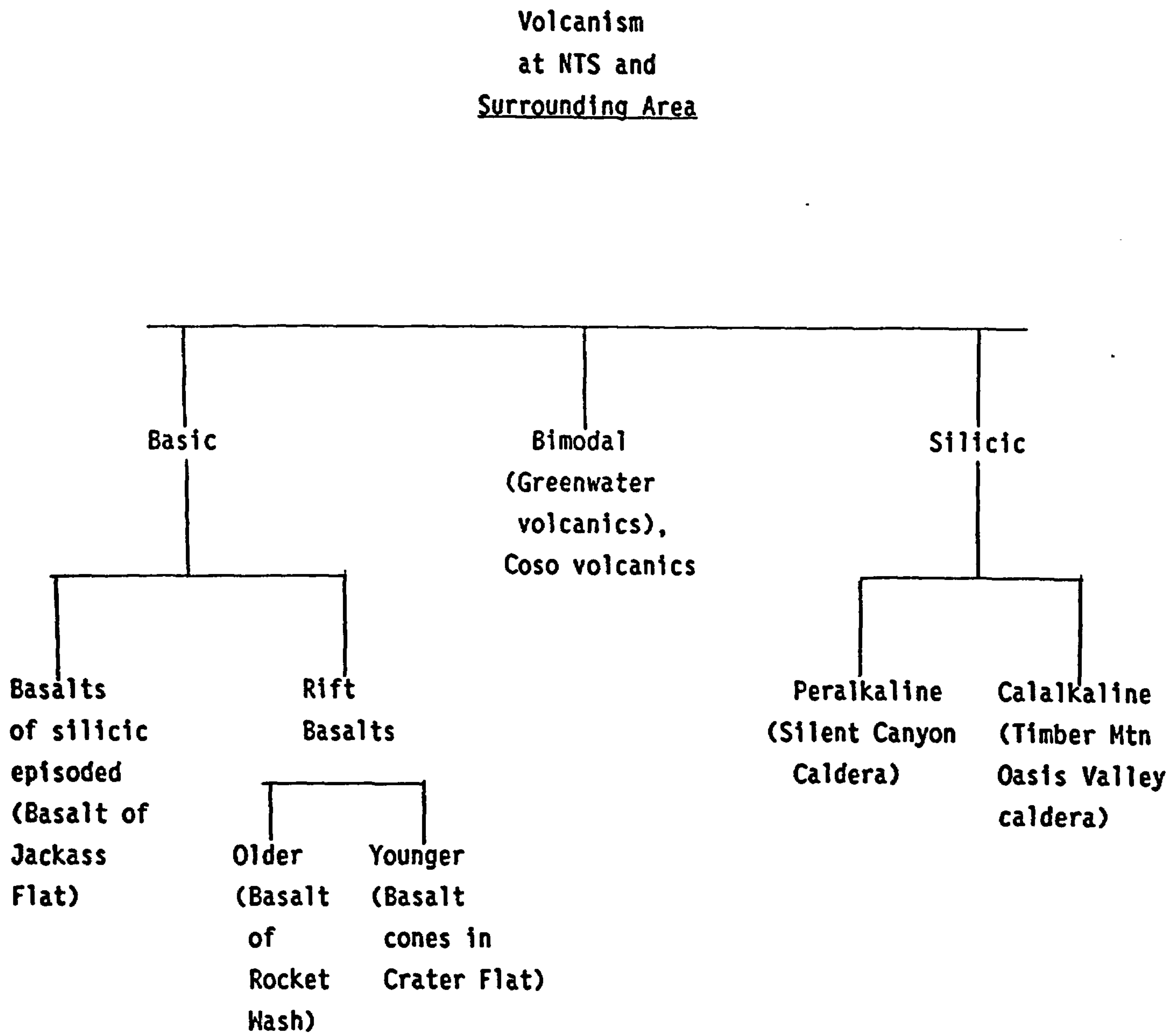

Figure 1. Breakdown of volcanic systems in southwestern Nevada and eastern California, with examples.

Bailey, R. A., 1980, Structural and Petrologic Evolution of the Long Valley, Mono Craters, and Mono Lake Volcanic Complexes, Eastern California, EOS Trans. AGU, v. 61, p 1149.

Christiansen, R. L., Lipman, P.W., Carr, W. J., Byers, Jr. F. M., Orkild, P. P., and Sargent, K. A., 1977, Timber Mountain-Oasis Valley Caldera Complex of Southern Nevada, Bull. Geol. Soc. Am., v. 88, p. 943-956.

Crandell, D. R., and Mullineaux, D. R., 1978, Potential Hazards from Future Eruptions of Mount St. Helens Volcano, Washington, U.S.G.S. Bull. 1383-C, 26 p.

Crowe, B. M. (1986) Volcanic Hazard Assessment for Disposal of High-level Radioactive Waste in Active Tectonics, Geophysical Study Committee, National Research Council, National Academy Press, Washington, D.C., p. 247-260.

Crowe, B. M., Wohletz, K. H., Vaniman, D. T., Gladney, E., Bower, N., 1986, Status of Volcanic Hazard Studies for the Nevada Nuclear Waste Storage Investigations, Heiken, J. H. eds., Los Alamos National Laboratory, v. II, LA-9325-MS, p. 1-101.

Crowe, B. M., Vaniman, D. T., Carr, W. J., 1983, Status of Volcanic Hazard Studies for the Nevada Nuclear Waste Storage Investigations, Los Alamos National Laboratory, LA-9325-MS, p. 1-47.

Crowe, B., Self, S., Vaniman, D., Amos, R., and Perry, F., 1983, Aspects of Potential Magmatic Disruption of a High-Level Radioactive Waste Repository in Southern Nevada, Jour. Geol., v. 91, p. 259-276.

Decker, R. W., 1986, Forecasting Volcanic Eruptions, G. W. Wetherill, ed., Annual Review of Earth and Planetary Sciences, v. 14, p. 267-291.

Eichelberger, J. C., Gooley, R., 1977, Evolution of Silicic Magma Chambers and Their Relationship to Basaltic Volcanism, J. G. Heacock, ed., Amer. Geophys. Union, Geophysical Monograph 20, The Earth's Crust: Its Nature and Physical Properties, p. 57-77.

Ekren, E. B., Rogers, C. L., Anderson, R., Ernst?and Orkild, P.P., 1968, Age of Basin and Range Normal Faults in Nevada Test Site and Nellis Air Force Range, Nevada, in Eckel, E. B., Nevada Test Site, Geol. Soc. Am. Mem.110, p. 247-250.

Ekren, E. B., Anderson, R. E., Rogers, C. L., and Noble, D. C., 1971, Geology of Northern Nellis Air Force Base Bombing and Gunnery Range, Nye County Nevada, U.S.G.S. Prof. Paper 651, p. 91.

Gudmundsson, A., 1986, Possible Effects of Aspect Ratios of Magma Chambers on Eruption Frequency, Geology, v. 14, p. 991-994.

Lachenbruch, A. H., and Sass, J. H., 1977, Heat Flow in the United States and the Thermal Regime of the Crust, J. G. Heacock ed., Amer. Geophys. Union Geophysical Monograph 20, The Earth's Crust: Its Nature and Physical Properties, p. 626-675.

Lachenbruch, A. H., Sass, J. H., 1978, Models of an Extending Lithosphere and Heat Flow in the Basin and Range Province, R. B. Smith and G. P. Eaton eds., The Geological Society of America, Inc., Cenozoic Tectonics and Regional Geophysical of the Western Cordillera, Mem. 152, p. 209-250.

Martin, R. C. and Davis, J. F., 1982, Status of Volcanic Prediction and Emergency Response Capabilities in Volcanic Hazard Zones of California, Calif. Dept. Conservation, Div. Mines and Geol., Spec. Pub. 63, p. 1-275.

Novak, S. W., and Bacon, C. R., 1986, Oliocene Volcanic Rocks of the Coso Range, Inyo County, California., U.S. Geol. Surv. Prof. Paper 1383, p. 44.

Sanford, A. R., Mott, R. P. Jr., Shuleski, P. J. Rinehart, E. J., Cavavella, F. J., Ward, R. M., and Wallace, T. C., 1977, Geophysical Evidence for Magma Body in the Crust in the Vicinity of Socorro, New Mexico, J. G. Heacock, ed., American Geophysical Union, Geophysical Monograph 20, The Earth's Crust: Its Nature and Physical Properties, p. 385-403.

Sinnock. S., and Easterling, R. G., 1983, Empirically Determined Uncertainty in Potassium-Argon Ages for Plio-Pleistocene Basalts from Crater Flat, Nye County, Nevada: Sand 82-2441, p. 1-17.

Tanzieff, Harown, Sabroux, Jean-Christophe (1983), Forecasting Volcanic Events, Developments in Volcanology 1, p. 1-635.

Vaniman, D. T., and Crowe, B. M., 1981, Geology and Petrology of the Basalts of Crater Flat: Applications to Volcanic Risk Assessment for Nevada Nuclear Waste Storage Investigations, Los Alamos Scientific Laboratory, LA-8845-MS, p. 1-67.

Vaniman, D. T., Crowe, B. M., and Gladney, E. S., 1982, Petrology and Geochemistry of Hawaiite Lavas from Crater Flat, Nevada, Cont. Min. and Petro. v. 80, p. 341-357.

Voogd, B. de, Serpa, L., Brown, L., Hauser, E., Kaufman, S., Oliver, J., Troxel, B., W., Willemin, J., Wright, L. A., 1986, Death Valley bright spot: A Midcrustal Magma body in the Southern Great Basin, Geology, v. 14, p. 64-67.

Warren, R. G., and Broxton, D. E., 1986, Mixing of Silicic and Basaltic Magmas in the Wahmonie Formation, Southwestern Nevada Volcanic Field, EOS, v. 67, no. 44, p. 1261.