

**Department of Energy** Washington, DC 20585

AUG 3 1 1992

Mr. Joseph J. Holonich, Director Repository Licensing and Quality Assurance Project Directorate Division of High-Level Waste Management Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission Washington, DC 20555

Reference: Ltr, Roberts to Holonich, dtd 7/22/92

Dear Mr. Holonich:

On July 22, 1992, the U.S. Department of Energy (DOE) sent notification and early information to the U.S. Nuclear Regulatory Commission (NRC) on the June 29, 1992, earthquake near Little Skull Mountain that was collected by the Yucca Mountain Site Characterization Project Office (reference). This Earthquake, of course, is relevant to a determination of whether or not the Yucca Mountain site is suitable for a high-level nuclear waste repository.

At DOE's request, the U.S. Geological Survey has prepared a summary of basic information on the earthquake, including parameters measured by our instrumentation and effects of the earthquake on the immediate area (enclosure). We are certain this assessment would be of interest to the NRC staff.

If you have any questions, please contact Chris Einberg of my staff at (202) 586-8869.

Sincerely,

Sender 9. Sterell



John P. Roberts Acting Associate Director for Systems and Compliance Office of Civilian Radioactive Waste Management

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Enclosure: Information on Little Skull Mountain Earthquake

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cc: w/ enclosures: C. Gertz, YMPO K. Hooks, NRC R. Loux, State of Nevada T. Hickey, Nevada Legislative Commission M. Baughman, Lincoln County, NV J. Bingham, Clark County, NV B. Raper, Nye County, NV P. Niedzielski-Eichner, Nye County, NV G. Derby, Lander County, NV P. Goicoechea, Eureka, NV C. Schank, Churchill County, NV F. Mariani, White Pine County, NV V. Poe, Mineral County, NV E. Wright, Lincoln County, NV J. Pitts, Lincoln County, NV R. Williams, Lander County, NV J. Hayes, Esmeralda County, NV M. Hayes, Esmeralda County, NV B. Mettam, Inyo County, CA

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## United States Department of the Interior

**GEOLOGICAL SURVEY** 



1-330373 (J)

Yucca Mountain Project Branch 101 Convention Center Drive, Suite 860 Las Vegas, NV 89109

> WBS: 1.2.3.1 QA: N/A

August 5, 1992

J. Russell Dyer, Director Regulatory & Site Evaluation Division Yucca Mountain Site Characterization Project Office U.S. Department of Energy P.O. Box 98608 Las Vegas, NV 89193-8608

Subject: Information on the Little Skull Mountain Earthquake

The attached document on the Little Skull Mountain Earthquake of June 29, 1992, by Jim Brune of the University of Nevada, Reno, Seismological aboratory, is being transmitted for your information. If you have any questions please call Jim at (702) 784-4974 (Reno) or myself at (303) 236-0516 (Denver), 791-7141 (Las Vegas).

Sincerely,

Lang K Kan

Larry R. Hayes Technical Project Officer Yucca Mountain Project Branch U.S. Geological Survey

cc: T. Sullivan, YMPO, Las Vegas, NV T. Statton, M&O/WCFS, Las Vegas, NV R. Quittmeyer, M&O/WCFS, Las Vegas, NV C. Goewert, M&O/FLUOR, Las Vegas, NV A.V. Gil, YMPO, Las Vegas, NV J. Stuckless, USGS, Denver, CO LRC File 1.1.01

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### THE LITTLE SKULL MOUNTAIN EARTHQUAKE OF JUNE 29, 1992

#### University of Nevada, Reno, Seismological Laboratory, Reno, Nevada

#### U.S. Geological Survey, Branch of Geological Risk Assessment, Golden, Colorado

#### OVERVIEW

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The Little Skull Mountain Earthquake of June 29, 1992, M = 5.6, is the largest recorded earthquake within the boundaries of the Nevada Test site (several large underground explosions have had larger body wave magnitudes). Although M = 5-6 earthquakes are common in Nevada and could occur almost anywhere, because the earthquake is near the proposed national high level nuclear waste repository at Yucca Mountain (Fig. 1) it is of particular importance and interest. Aftershock recording equipment was installed around the epicenter within a couple of days by the USGS, Branch of Geological Risk Assessment, Golden, and University of Nevada, Reno, Seismological Lab. Thousands of aftershocks have been recorded and are providing a wealth of data for outlining the fault plane of the fault (or faults) which slipped. Also being carried out are studies of source physics (e.g., stress drop and complexity), rock attenuation, and effects of near surface geology on ground motion (e.g., at the Yucca Mountain Field Operations Center, FOC).

Several aspects of the earthquake occurrence are unique. The time of the earthquake was apparently in part determined by the occurrence of the M = 7.4Landers earthquake, which triggered a considerable amount of activity throughout the western U.S. The Little Skull Mountain earthquake caused considerable damage to the Field Operations Center for the Yucca Mountain project, -- the first earthquake known to have caused significant damage on NTS. The earthquake occurred within the relatively dense Southern Great Basin Seismic Network operated by the USGS (now in the process of transfer to the University of Nevada, Reno). A very sensitive 4-station micro-earthquake array was in operation near the proposed repository site and continued to operate through both the Landers and Little Skull Mountain earthquakes (and up to the present). This array provides important information on the microseismicity in the immediately vicinity of the proposed repository, but also gives a continuous record of the activity at Little Skull Mountain before and after the Landers and Little Skull Mountain earthquakes.

Finally, the earthquake provided an important opportunity to study rockfalls caused by earthquakes. The earthquake dislodged numerous large boulders from the crest of Little Skull Mountain, and further study of these boulders, and others possibly dislodged by earlier earthquakes, may provide important data on seismicity in the region, and on the erosional effects of earthquake shaking. Some constraints may be placed on the ground motion expected at Yucca Mountain based on the ground acceleration that would be necessary to topple precarious rocks observed near the proposed repository site.

#### 1. BACKGROUND SEISMICITY AND TECTONIC SETTING.

The region near Little Skull Mountain has been one of low level seismicity since the installation of the Southern Great Basin Seismic Network (Fig. 2). Based on this, a moderate sized earthquake in the region was not unexpected. Earthquakes with magnitudes greater than 5 have occurred in many parts of Nevada (Figs. 3 and 4), and, given a longer record of seismicity, they undoubtedly would be observed in most regions of Nevada. The tectonic region near Little Skull Mountain is part of the Walker Lane Province at the western edge of the Basin and Range, and has a mixture of North tending normal faults, and NW and NE striking strike slip faults.

#### 2. DESCRIPTION OF THE MAIN EVENT.

The origin time of the main event was June 29, 1992, at 10:14:22 GMT. The preliminary location is  $36^{\circ}43.1^{\circ}N$ ,  $116^{\circ}16.35W$ , at a depth of 13 km below sea level (Figs. 5 and 6). The preliminary magnitude is 5.6. These values are subject to small changes once data analysis is complete.

#### 3. PRELIMINARY AFTERSHOCK LOCATIONS AND INTERPRETATION.

A number of portable instruments were installed in the region of Little Skull Mountain beginning about 1 day after the earthquake. These instruments will provide accurate locations for hundreds of aftershocks, and are expected to outline the fault which ruptured. Preliminary results indicate a northeast trending zone dipping to the southeast (Figs. 5 and 6). The aftershocks suggest the rupture began at a depth of about 13 km below sea level and ruptured upward, northwest, in roughly the direction of the Yucca Mountain Field Operations Center (FOC), reaching a depth of about 5 km. This may in part have contributed to the damage at the FOC. If this turns out to be the correct fault plane, it does not appear to be correlated with any mapped surface faults, a situation typical for earthquakes of this magnitude in the Basin and Range.

#### 4. FAULT PLANE SOLUTION FOR THE MAIN EVENT AND SOME AFTERSHOCKS.

The preliminary fault plane solution based on short period data indicates a northeast striking normal fault dipping either to the SE or NW (Fig. 7). The preliminary moment tensor solution based on longer period waves is consistent with this (Fig. 8). The aftershock data suggests the SE dipping plane is the fault plane. Aftershock fault plane solutions indicate both normal faulting, similar to the main event, and strike slip faulting. This suggests a complex stress release pattern.

#### 5. EVIDENCE FOR TRIGGERING BY THE LANDERS EARTHQUAKE.

As mentioned above the area near Little Skull Mountain was an area of low level seismicity. In February 1992 there was a sequence of small events (largest magnitude 2.4) at Little Skull Mountain, and it would be logical to associate these with premonitory activity, or foreshocks, of the June 29 event.

Nevertheless there is strong evidence that seismic waves from the Landers, California (M = 7.4) earthquake determined the actual time of the Little Skull Mountain Earthquake sequence, along with numerous other sequences in the western U.S. (Big Bear Lake, CA; Geysers, CA; Lassen, CA; Shasta, CA; Mammoth, CA; Fish Lake Valley, NV; Mina, NV; Smith Valley, NV; Death Valley, CA). Foreshocks of the Little Skull Mountain earthquake began appearing on the University of Nevada Seismological Laboratory (UNRSL) microearthquake array at Yucca Mountain within a couple of hours of the Landers earthquake (they may have started sooner but were hidden in the large amplitude waves of aftershocks of the Landers earthquake). The foreshock sequence then increased in frequency and size up until the time of the Little Skull Mountain earthquake about one day later. The evidence does not rule out the possibility that the Little Skull Mountain earthquake would have occurred more or less at the same time even if the Landers earthquake had not occurred, but does constitute strong circumstantial evidence that the Landers earthquake controlled the timing of the Little Skull Mountain Earthquake. THE PROPOSED REPOSITORY SITE AT YUCCA MOUNTAIN.

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The region within about 20 km of the proposed repository boundary is a region of very low seismicity as determined from the Southern Great Basin Seismic Network operated by the USGS for the last 20 years. Furthermore, the microearthquake level (down to magnitudes less than zero), is also very low. The University of Nevada Seismological Laboratory (UNRSL) has operated a sensitive micro-earthquake network near the proposed repository site for over a year (Fig. 10) and found no microearthquake activity in the immediate vicinity of the proposed repository. Neither the Landers earthquake nor the Little Skull Mountain earthquake triggered any apparent microearthquake activity on faults in the immediate vicinity of the repository within the first 6 days (later data has not yet been reviewed). No microearthquakes have yet been observed from nuclear explosions occurring during operation of the microearthquake array, but a more careful study needs to be made. Microearthquake activity might indicate fault instability or high stress level. Lack of triggered microearthquake activity by either the Landers and Little Skull Mountain earthquake, or nuclear explosions, suggests that faults in the neighborhood of the repository (e.g., the Ghost Dance fault and the Solitario Canyon faults) are not as unstable as faults in regions for which activity was triggered.

#### 7. ROCKFALLS AT LITTLE SKULL MOUNTAIN, AND PRECARIOUS ROCKS AT YUCCA MOUNTAIN.

The Little Skull Mountain earthquake dislodged numerous large boulders along the crest of Little Skull Mountain (Figs. 11, 12, 13). This was to be expected as a consequence of the high ground accelerations likely in the immediate vicinity of the earthquake (probably of the order of .4 g--no strong motion instruments were in operation there at the time to confirm this).

Near the proposed repository site in Solitario Canyon a large number of precariously balanced rocks have been documented (Figs. 14-16). A technique is being developed to use such rocks to place upper limits on the ground motion for the last several thousand years. This technique involves quantitative estimates of the acceleration needed to topple the boulders, along with quantitative estimates of the time the rocks have been standing, based on the thickness of rock varnish which has developed. Although the technique requires further quantification, it does suggest that the region of Solitario Canyon near the proposed repository site has not been subjected to large ground accelerations (greater than about 0.2 g) in the last few thousand years. The Little Skull Mountain earthquake may have generated accelerations of the order of .05 g to .15 g at some sites of precarious rocks. Thus it would constitute important data if any of the rocks had been toppled. At present, about 2/3 of the precarious rock sites have been visited, and none have been found to have been toppled. The other sites will be visited in the near future.

If one or more of the rocks with very thick rock varnish had been toppled, it might suggest that accelerations of the intensity produced by the Little Skull Mountain earthquake are rare at the proposed repository site. On the other hand if none of the rocks has been toppled, ground accelerations of the level produced by the Little Skull Mountain earthquake may have occurred at the proposed repository site a number of times in the past, and a quantitative study of the stability of the precarious rocks will be required to establish the likely upper bound for ground accelerations experience by the site over the last few thousand years. Based on numerous studies of rockfalls in other earthquakes, it is not likely that the upper limit on acceleration will be more than a few tenths of g. No precarious rocks of the type found in Solitario Canyon have been observed in any of the regions of strong shaking around historical earthquakes in Nevada and California.

#### DATA GENERATED FOR ENGINEERING STUDIES BASED ON GROUND MOTION.

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One of the major efforts outlined in the Site Characterization Plan for the proposed nuclear waste repository is study of the effects of local site geology on ground motion from earthquakes. Aftershocks of the Little Skull Mountain earthquake are providing a wealth of data to advance these studies. For example, over ten 3 component digital records have been obtained from the M = 4.4 aftershock of July 4, including an important record from the Field Operations Centr building damaged by the main event (e.g. Fig 17). Hundreds of records from Lnaller events are being recorded at a variety of sites, (e.g., hard rock, underground tunnels, deep alluvial fill, ridge crests, canyons, and the site of the proposed surface facilities). Once these data are analyzed, we will be able to much better determine ground motions expected at surface facilities and underground.

Figure Captions

- Figure 1 Schematic. Map of Little Skull Mountain Aftershock Region Relative to Proposed Nuclear Waste Repository Site.
- Figure 2 Seismicity Near the Nevada Test Site.

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Figure 3 Nevada Region Earthquakes, M=5.0 to 5.9.

Figure 4 Nevada Region Earthquakes, M=>6.0.

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- Figure 5 Little Skull Mountain, Main Shock and Aftershocks, Map View.
- Figure 6 Little Skull Mountain, Main Shock and Aftershocks. Section plot for A-A' of Fig. 5.
- Figure 7 Fault Plane Solution for Little Skull Mountain Main Event from Local, Short Period Instruments.
- Figure 8 Fault Plane Solution for Little Skull Mountain Main Event, Based on Long Period Teleseismic Waves (Harvard Moment Tensor Solution).
- Figure 9 Events in Nevaza Triggered by Landers, Calif., Earthquake of June 28, 1992, M=7.4.
- Figure 10 Map of University of Nevada, Reno, Yucca Mountain Microearthquake Array.
- Figures 11, Boulders Dislodged Along Crest of Little Skull Mountain by June 29th 12, 13 Earthquake.
- Figures 14- Precarious Rocks on Yucca Mountain Left Standing after Little Skull 16 Mountain Earthquake.
- Figure 17 Examples of Digital Recordings of M=4.4 Little Skull Mountain Aftershock.





#### Aug 1978 through Aug 1990 SGBSN epicenters

Figure 2: Seismicity Near the Nevada Test Site.

## Magnitudes 5.0 to 5.4

255 epicenters determined by The University of Nevada Seismological Laboratory, Reno, and the U.S. Geological Survey, Golden, Colorado. Includes regional and historical events.



E-W Scale, km N-S Exaggeration 0.990177 times.

Figure 3: Nevada Region Earthquakes, M=5.0 to 5.9.

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48 epicenters determined by The University of Nevada Seismological Laboratory, Reno, and the U.S. Geological Survey, Golden, Colorado. Includes regional and historical events.





Figure 5: Little Skull Mountain, Main Shock and Aftershocks, Map View.

Distance 130 Degrees from 36.67 116.55 in Km



Figure 6: Little Skull Mountain, Main Shock and Aftershocks. Section plot for A-A' of Figure 5.

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Figure 7: Fault Plane Solution for Little Skull Mountain Main Event from Local, Short Period Instruments.

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Figure 8: Fault Plane Solution for Little Skull Mountain Main Event, Based on Long Period Teleseismic Waves (Harvard Moment Tensor Solution).





Figure 10: Map of University of Nevada, Reno, Yucca Mountain Microearthquake Array.









Figure 14: Precarious Rocks on Yucca Mountain Left Standing after Little Skull Mountain Earthquake.



Figure 15: Precarious Rocks on Yucca Mountain Left Standing after Little Skull Mountain Earthquake.



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