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FROM: Paul T. Prestholt
Sr. On-Site Licensing Reprsentative

DATE: August 19, 1992

SUBJECT: INFORMATION ON THE LITTLE SKULL MOUNTAIN EARTHQUAKE

Please find enclosed the above-referenced document.

PTP:nan

cc: Joseph Holonich, M/S 4 H 3

Susan / please enter into system. Thanks Bill Belke 8/25/92

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U ted States Department o he Interior

GEOLOGICAL SURVEY

Yucca Mountain Project Branch
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WBS: 1.2.3.1
QA: N/A

August 5, 1992

J. Russell Dyer, Director
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Yucca Mountain Site Characterization
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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 Laboratory, 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), 794-7141 (Las Vegas).

Sincerely,

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

cc: T. Sullivan, YMPO, Las Vegas, NV
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LRH/dz

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

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 = 7.4 Landers 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°43.1'N, 116°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.

6. LACK OF TRIGGERED MICRO-EARTHQUAKE ACTIVITY IN THE IMMEDIATE VICINITY OF THE PROPOSED REPOSITORY SITE AT YUCCA MOUNTAIN.

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.

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

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 Center building damaged by the main event (e.g. Fig 17). Hundreds of records from smaller 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.
Figure 3	Nevada Region Earthquakes, M=5.0 to 5.9.
Figure 4	Nevada Region Earthquakes, M=>6.0.
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 Nevada 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, 12, 13	Boulders Dislodged Along Crest of Little Skull Mountain by June 29th Earthquake.
Figures 14-16	Precarious Rocks on Yucca Mountain Left Standing after Little Skull Mountain Earthquake.
Figure 17	Examples of Digital Recordings of M=4.4 Little Skull Mountain Aftershock.

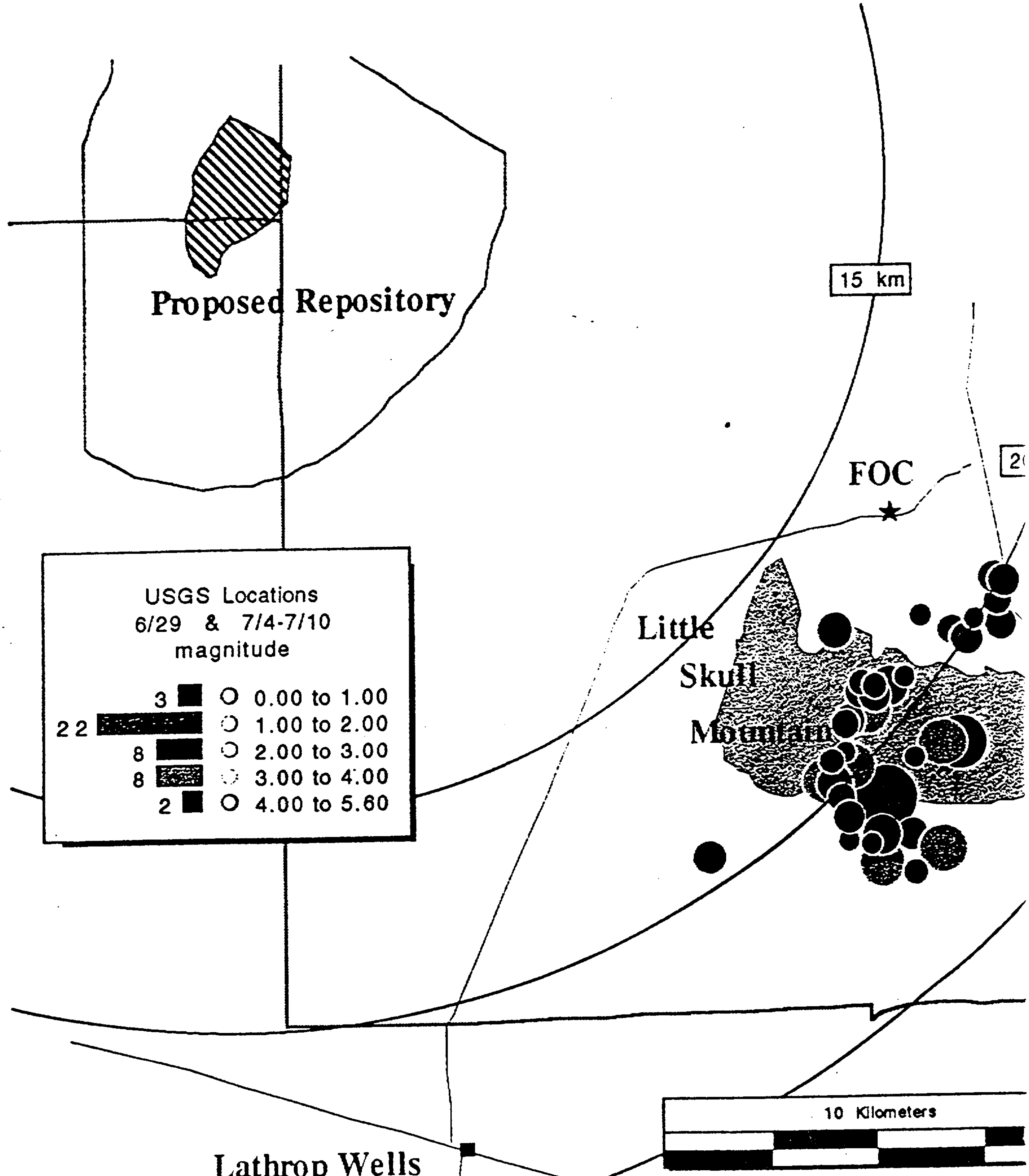

Figure 1: Schematic Map of Little Skull Mountain Aftershock Region Relative to Proposed Nuclear Waste Repository Site.

(2)

Aug 1978 through Aug 1990 SGBSN epicenters

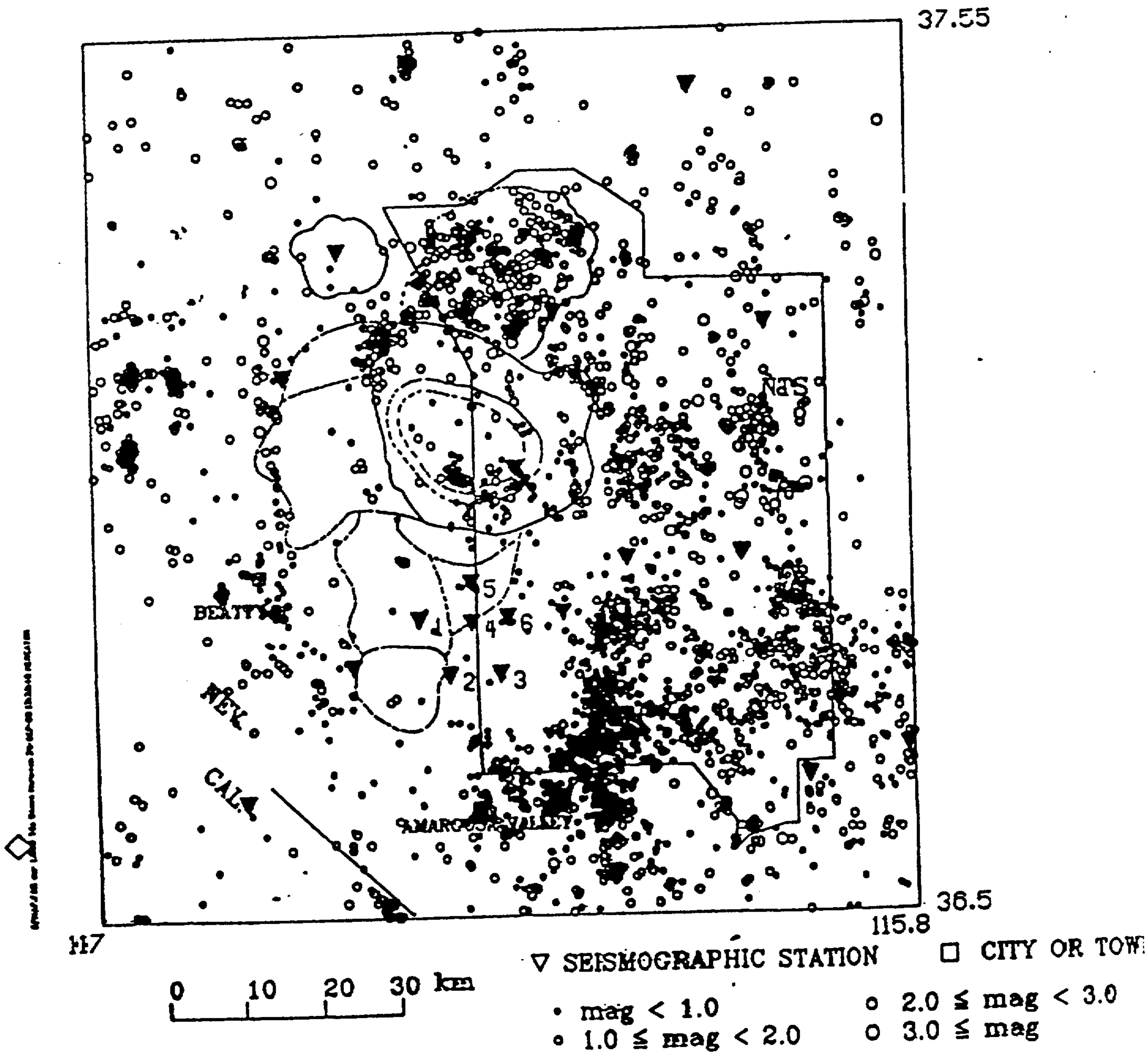

Figure 2: Seismicity Near the Nevada Test Site.

Nevada Earthquakes

Magnitudes 5.0 to 5.9

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

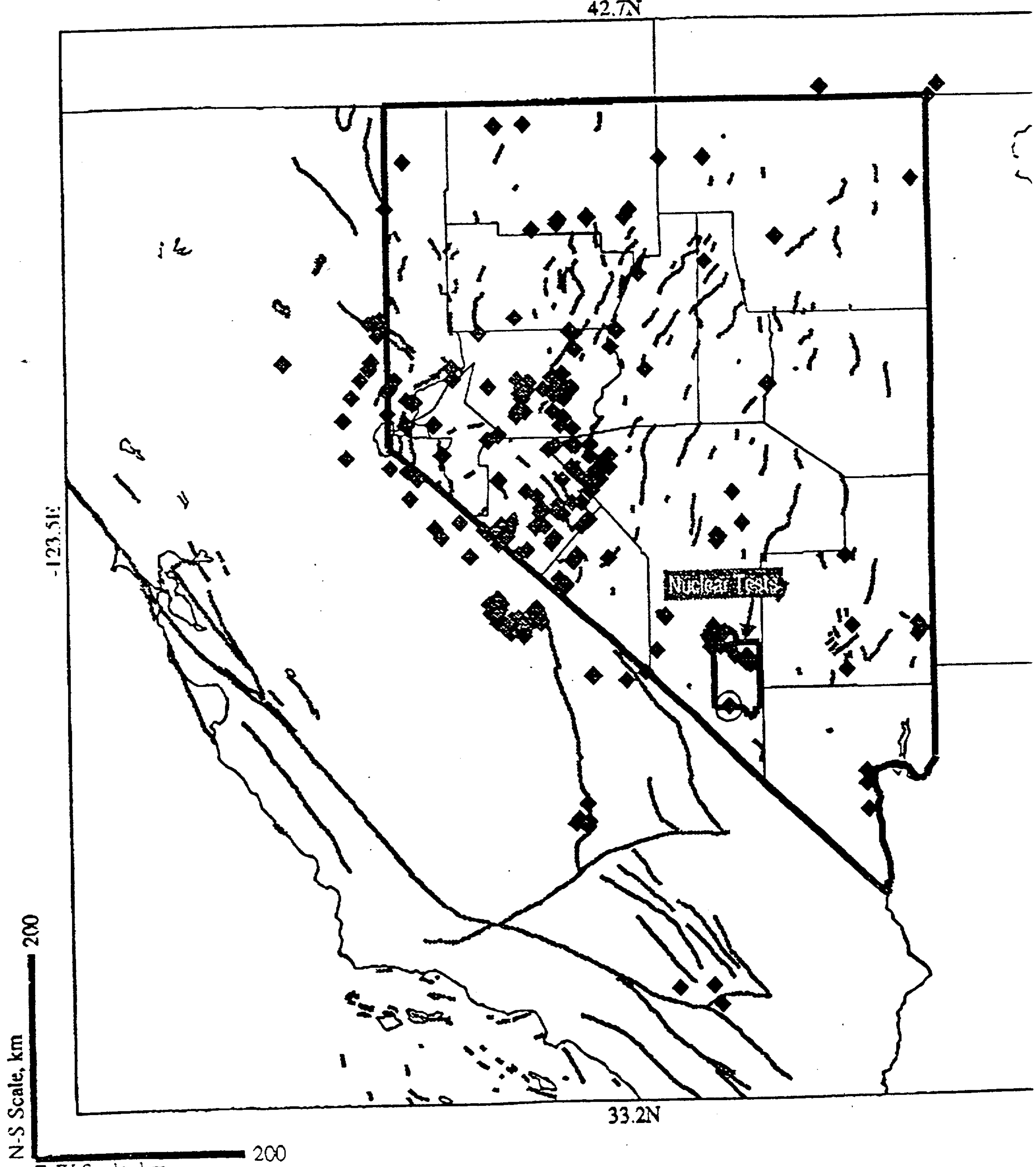

Figure [illegible]. Nevada Region Earthquakes, M=5.0 to 5.9.

Nevada Earthquakes

Magnitudes 6.0 and Greater

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

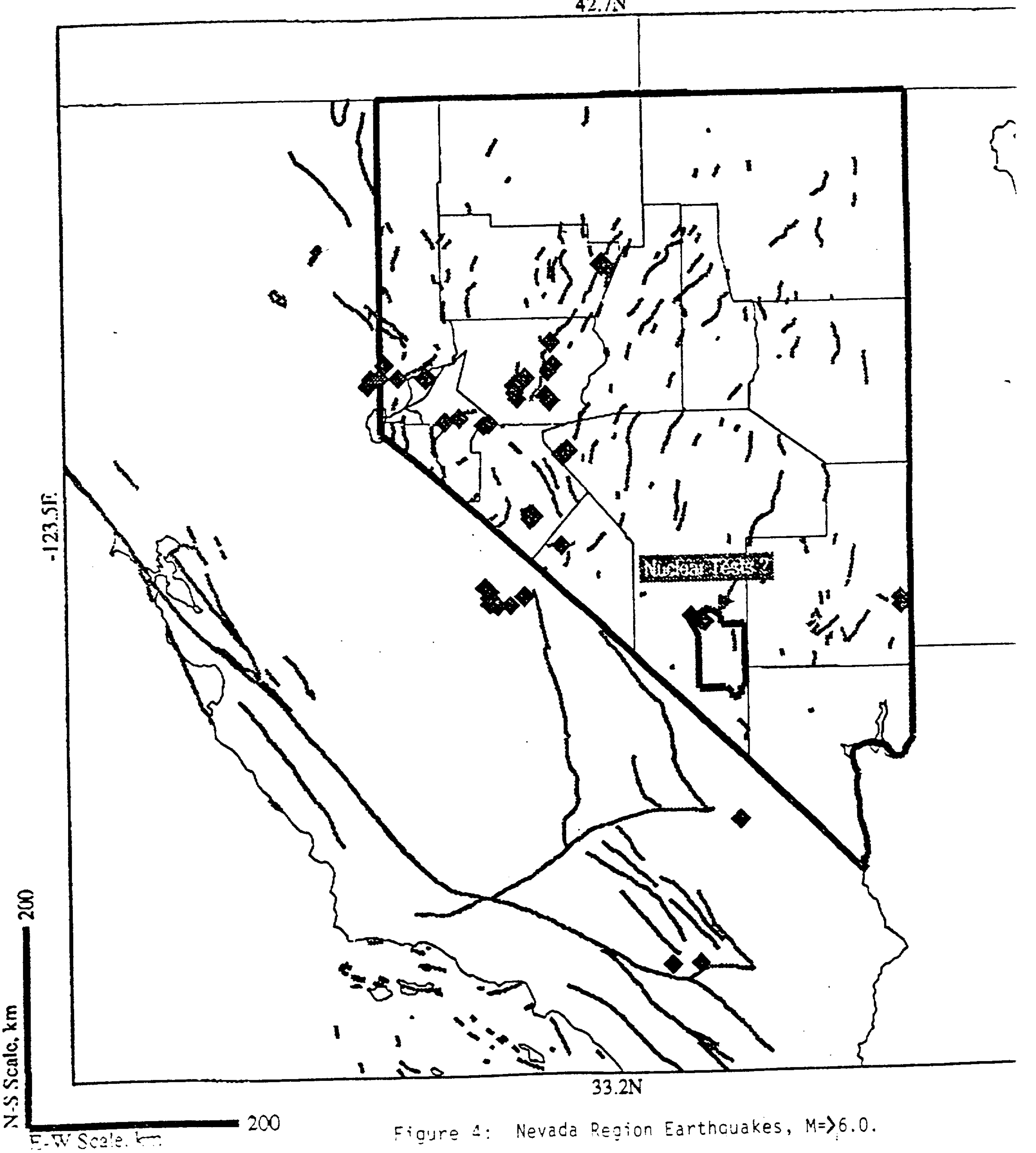

Figure 4: Nevada Region Earthquakes, M=>6.0.

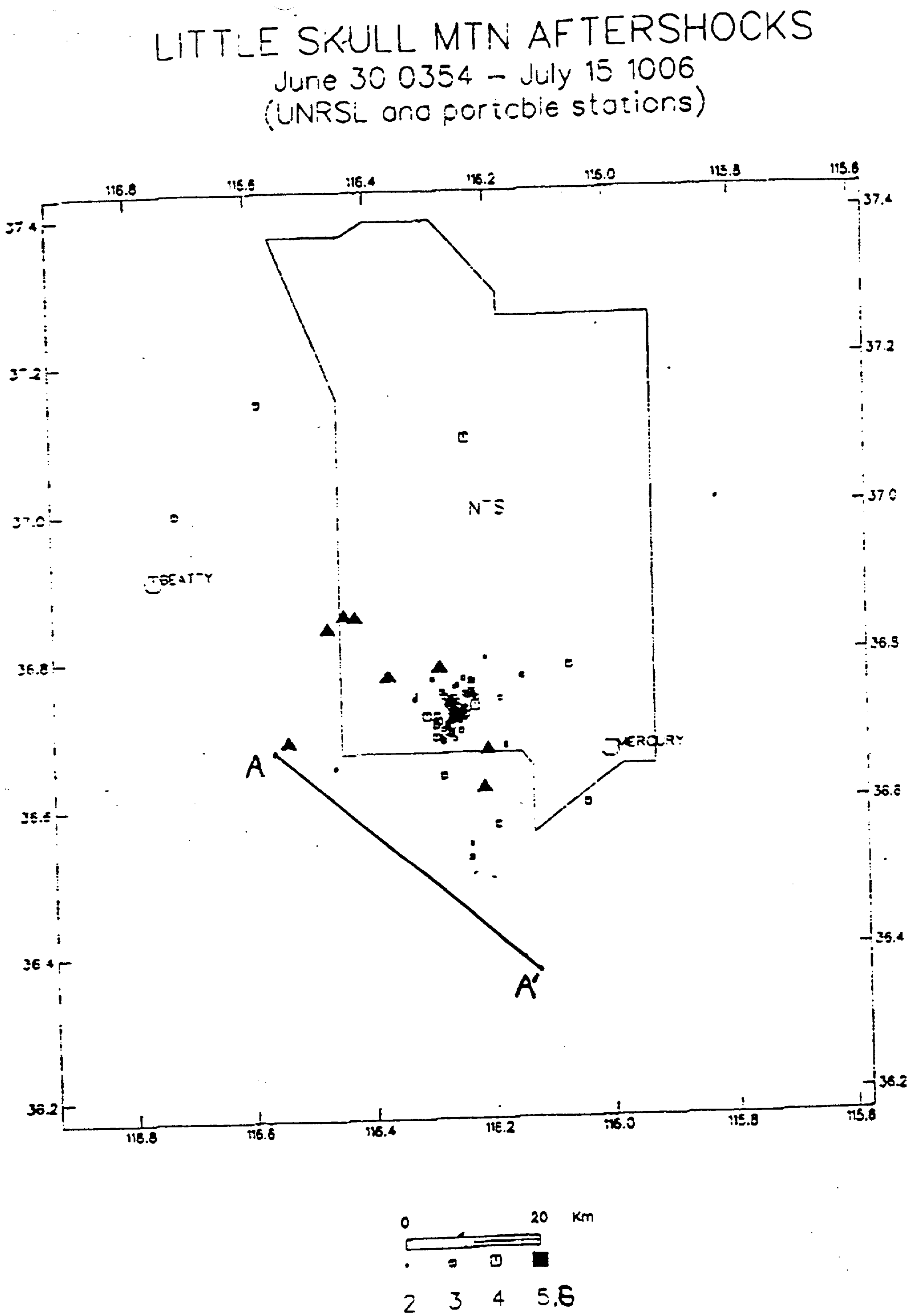

Figure 5. Little Skull Mountain, Main Shock and Aftershocks, Map View.

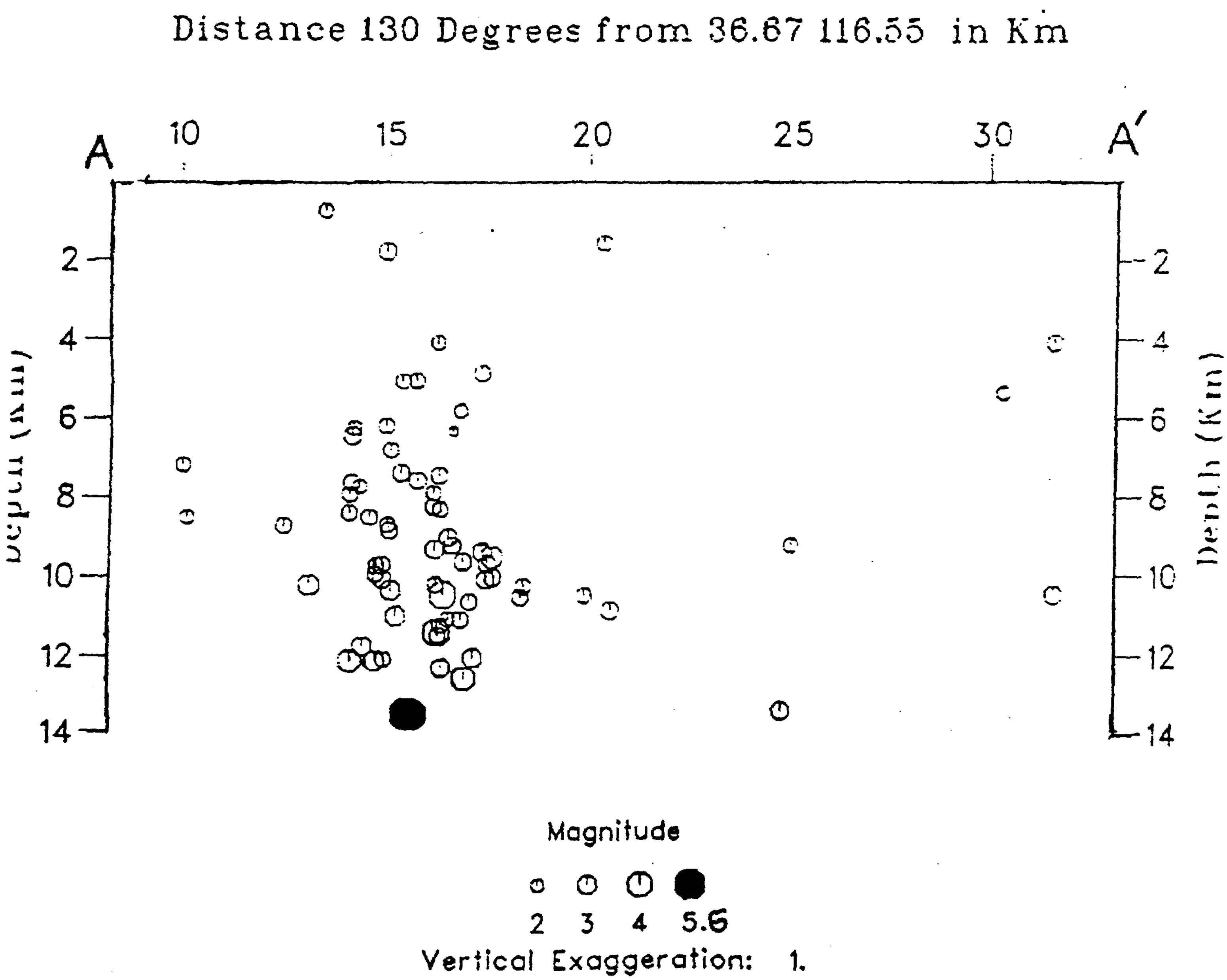

Figure 6: Little Skull Mountain, Main Shock and Aftershocks. Section plot for A-A' of Figure 5.

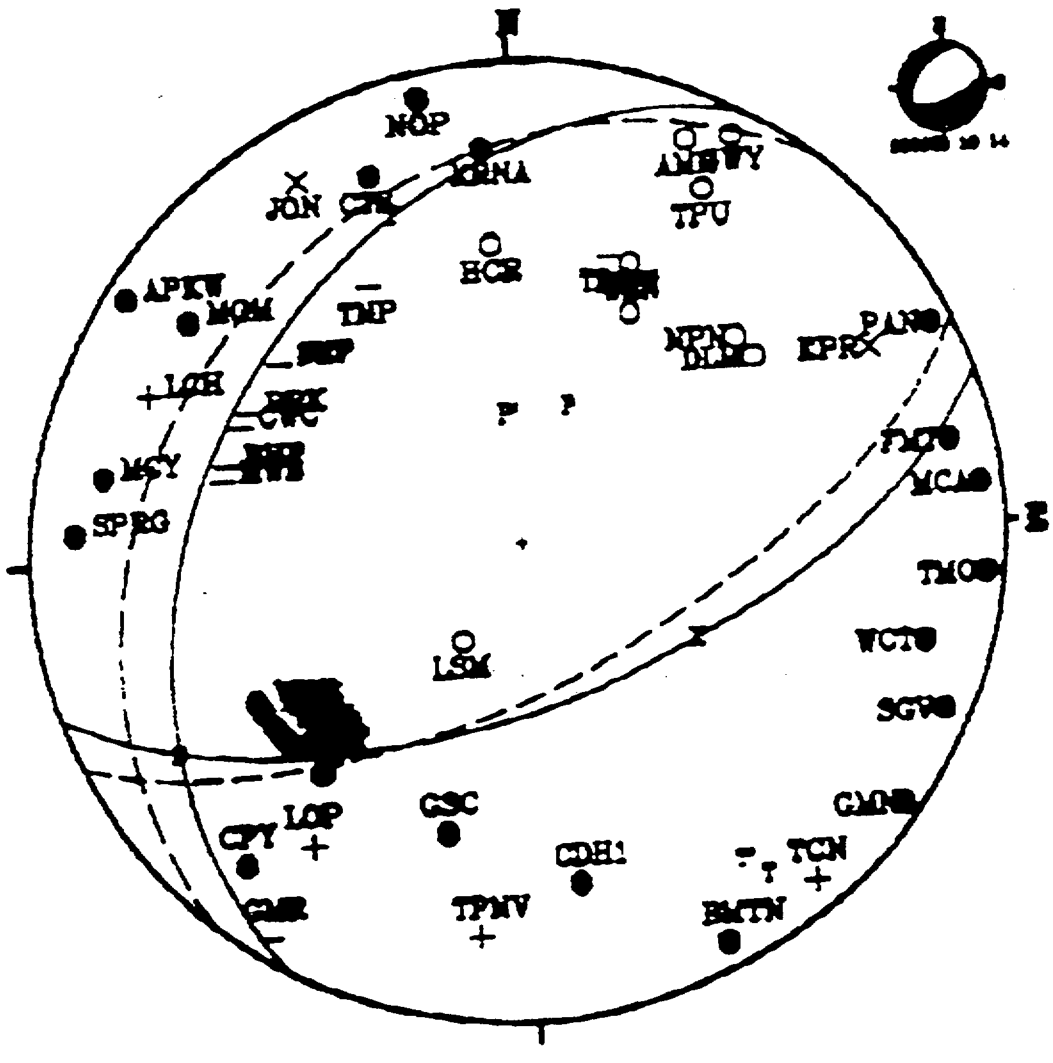

Figure 7: Fault Plane Solution for Little Skull Mountain Main Event from Local, Short Per

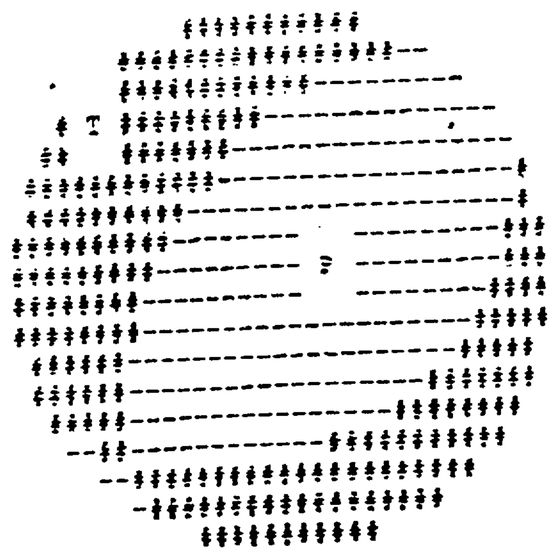

Figure 8: Fault Plane Solution for Little Skull Mountain Main Event, Based on Long Period Teleseismic Waves (Harvard Moment Tensor Solution).

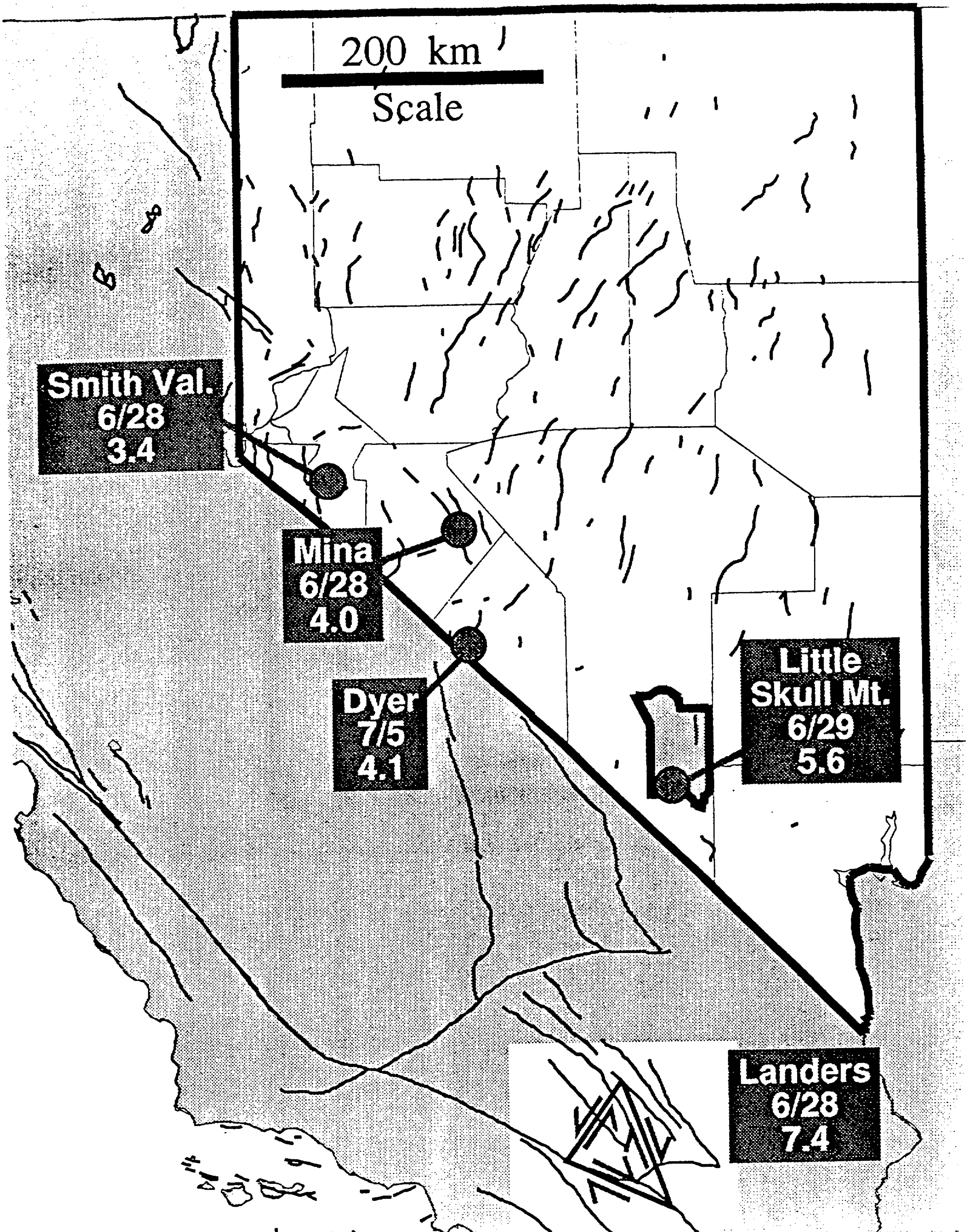

Figure 9: Events in Nevada Triggered by Landers, California Earthquake of June 28, 1992,

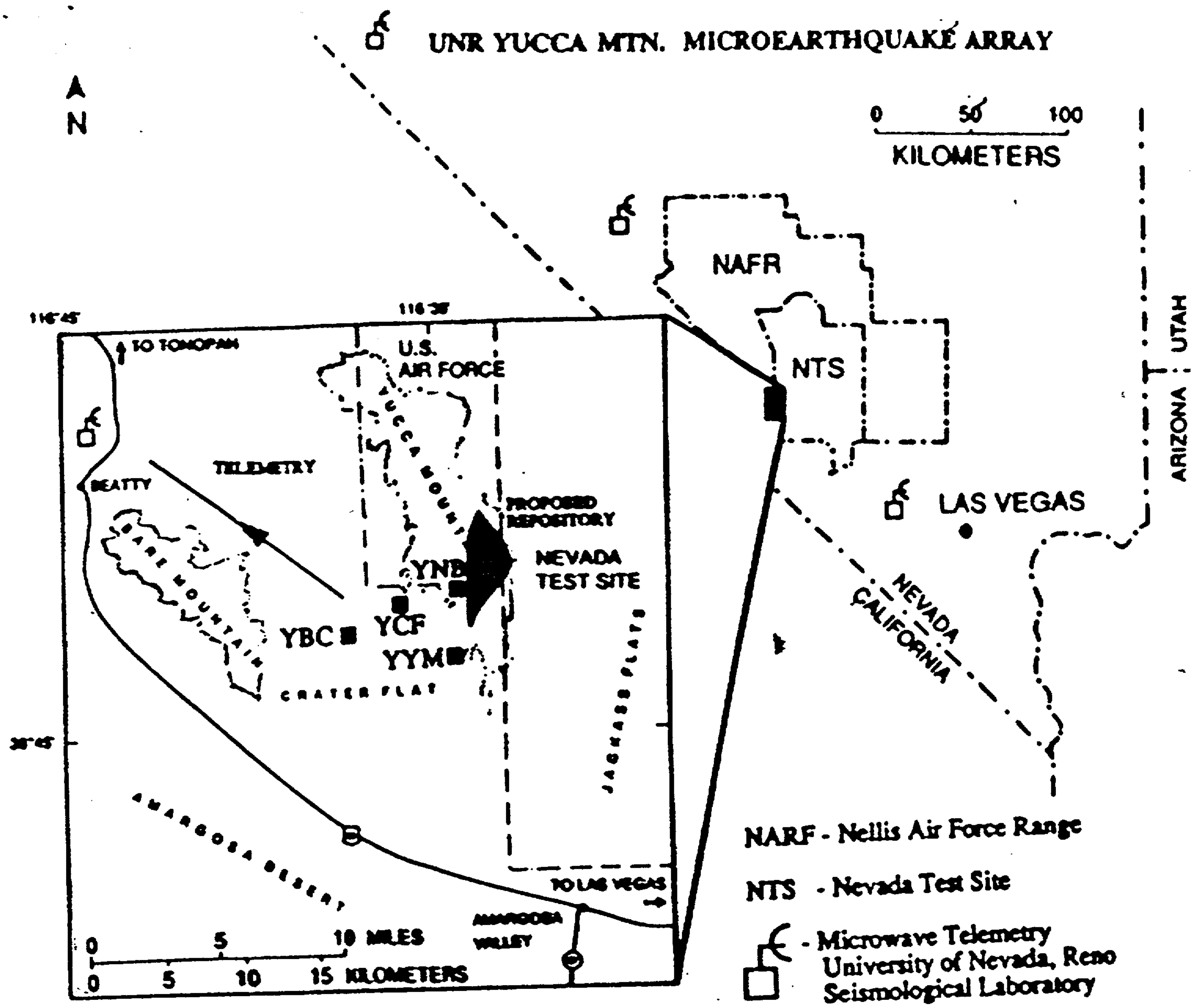

Figure 10: Map of University of Nevada, Reno, Yucca Mountain Microearthquake Array.

Figure 11: Boulders Dislodged Along Crest of Little Skull Mountain by June 29th Earthquak

Figure 12: Boulders Dislodged Along Crest of Little Skull Mountain by June 29th Earthqua

Figure 13: Boulders Dislodged Along Crest of Little Skull Mountain by June 29th Earthquake

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

Figure 16: Precarious Rocks on Yucca Mountain Left Standing after Little Skull Mountain

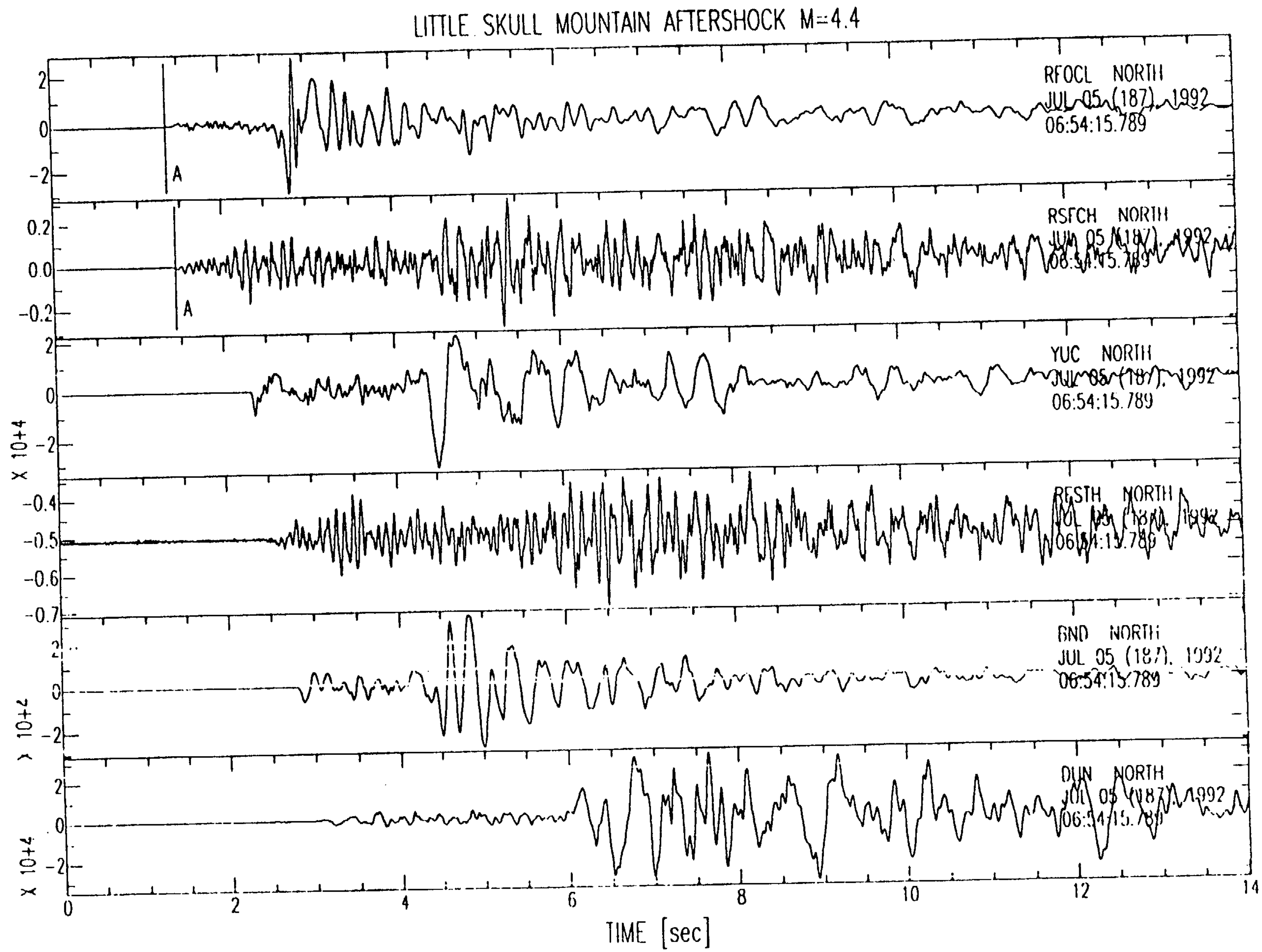

Figure 17: Examples of Digital Recordings of M=4.4 Little Skull Mountain Aftershock.