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Uranium Mill Tailings Remedial Action Project (UMTRAP)

Slick Rock, Colorado

Reports

Preliminary Design for Review

March 1988

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

UMTRA - SLICK ROCK SITES

MEMORANDUM REPORT

AREAS TO BE EXCLUDED FROM REMEDIAL ACTION

(TO BE PROVIDED BY DEPARTMENT OF ENERGY)

SITE SEISMICITY AND DESIGN EARTHQUAKE CRITERIA FOR SLICK ROCK SITE, COLORADO

5057-SRK-K-01-00596-00
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CONTENTS

1. INTRODUCTION

Historically the Colorado Plateau interior is seismically quiescent, the largest event recorded within the area being of magnitude 5.5 to 5.7 (Ref. 1 and 2). Even though the available instrumental earthquake data cover only a short period, the intensity data available cover a much larger period, 1870 to 1985 (Refs. 3 and 4). A review of these data show that most of the earthquake events of engineering significance; i.e., earthquakes of Richter magnitude M equal to or greater than 5.5, or Modified Morcalli Intensity, I equal to or greater than VII, occurred only along the Colorado Plateau boundary; but due to the paucity of information for the Colorado Plateau interior the same data are used for the recurrence interval study of earthquakes of various magnitudes for sites located within that area where site specific studies have not revealed the presence of significant active faults in the vicinity of the site (Ref. 5). Thus for the sites within the Colorado Plateau interior, some degree of conservatism is built into the computed value of the maximum earthquake magnitude where the data and the methodology indicated above are used; the rational justification being the unavailability of a better data base and the long design life of UMTRA tailing piles.

Considering the constraints referred to above, the selection of the Maximum Credible Earthquake (MCE)/Maximum Earthquake (ME) for any UMTRA site within the Colorado Plateau Interior cannot be based entirely on a single source of data and information; it calls for a judgemental decision based on the review of the results of site specific investigation (Ref. 5), and published and unpublished literature available from various sources.

2. HISTORIC SEISMICITY

The Slick Rock site is located in Zone 1 (Minor Damage Potential) on the seismic zone map of the U.S.A. (Ref. 6); maximum modified Mercalli felt intensity during the historic period (1867-1985) in Colorado is VII and the intensity at the Slick Rock site in particular is II to IV (Figure 1, Ref. 3). The Montrose-Ridgeway earthquake (1960) of magnitude M_b = 5.5

was the largest historic earthquake within reasonable distance of the site; however, the isoseismal map (Figure 2, Ref. 3) shows that this earthquake was "not felt" at the Slick Rock site. This is not surprising as the epicenter of the Montrose/Ridgeway earthquake is too far (116 km) from the Slick Rock site. However, it is recognized that because of the long design life of the UMTRA tailings piles, the available historical seismicity data by itself does not provide complete information on the seismic risks associated with the site during its long design life. In the following sections, other alternative data sources are also reviewed.

3. NEAR SITE ACTIVE OR SUSPECTED ACTIVE FAULTS

The suspected active faults nearest to the Slick Rock site, Colorado, are in a group identified as Fault Group 1A (Plate D.3.1, Ref. 5). The U.S. Department of Energy (USDOE) site specific study for the Slick Rock site, involving low sun angle aerial reconnaissance and over the ground investigation, has established this suspected active fault group as associated with inactive salt anticlines. Further investigation has been pursued to verify the findings, observations and conclusions of other investigators who are actively studying the fault and seismic activity in this area, such as the Colorado Geological Survey, USGS, USBR, and Woodward-Clyde consultants. This has involved the review of published and unpublished literature and reports, and telephone conversations with key individuals in various agencies and organizations such as those referred to above. Kirkham and Rogers (1981) identifies the fault group referred to above as Fault #93 (Ref. 7, Plate 1); apparently no detailed field investigation was done by Kirkham and Rogers on this fault group and the questionable activity and age of the faults were inferred from Refs. 8 and 9. This conclusion is drawn based on the review of Refs. 3 and 7 (page 92) and a telephone conversation with William P. Rogers of the Colorado Geological Survey. Ref. 3 presents an updated version of the Kirkham and Rogers (1985) interpretation of Colorado earthquake data.

USGS open-file report 76-154 on known and suspected active faults in Colorado, compiled by Witkind (1986) (Ref. 8) does not show the fault group identified as No. 1A above (or No. 93 in Ref. 7). The suspected active faults (Nos. 352 through 355) shown on this map as being nearest to the Slick Rock site are still about 50 to 75 km away. The effects at the site from any earthquake (M=6.1 to 6.5) originating on these faults would be less critical than the Floating Earthquake (M = 6.2, epicentral dist. 15 km) selected in the RAP (Ref. 5). Seismic hazard evaluation reports (1980 and 1982) for the Ridgeway Dam and Reservoir (Refs. 1 and 10), located about 100 km west of the Slick Rock site, were also reviewed. Because of the large distance, the effect of any MCE event (M = 6.0 to 6.5) originating on the active Ridgeway fault or its suspected active sister faults will be less critical at the Slick Rock site compared to the effect of the Floating Earthquake (M = 6.2, epicentral distance = 15 km) selected for this site. There is no reference to fault group 1A or its activity in the above report; it is quite possible that because of the very short lengths of these salt anticline faults, the questionable activity, and their large distance from the Ridgeway dam site, they were not considered as significant faults.

4. MICRO-SEISMIC ACTIVITY

Two micro-seismic networks, centered around the Ridgeway Dam and the northeastern end of Paradox Valley, have been in operation for the last 3.5 years for monitoring the seismic activity of the area. According to Bill Spence, USGS (Refs. 11 and 12), who is monitoring the network centered around the Ridgeway Dam for the USBR, the instruments in his network are very sensitive and should be able to pick up micro-seismic activity, if any occurs, as far away as Slick Rock; a review of the data did not indicate any significant micro-seismic activity in the Slick Rock area. The recorded events are of magnitude equal to or less than 2.0 and none are associated with the surface expression of any fault. The Paradox basin network, west of Slick Rock site, is monitored by Woodward Clyde Consultants (WCC) for the USDOE. As far as Slick Rock site seismic activity is concerned, the data from this network confirmed that of the Ridgeway network. Based on the recorded micro-seismic data and their knowledge of the micro-seismic activity of the area, both Bill Spence (USGS) and Ivan Wong (WCC) believe that the choice of Floating Earthquake of magnitude 6.2, originating at 15 km from the Slick Rock site, is adequate and conservative. It can be seen in Figures 3 and 4 that the Paradox Basin network did not record any micro-seismic event further east of the northeastern end of Shay Graben Faults, located about 40 km away from the Slick Rock site (Ref. 13, p. 53). The USGS micro-seismic network data suggest that the maximum regional earthquake that might occur over a period of 100 years is about magnitude 5 (Ref. 12).

5. MAXIMUM CREDIBLE EARTHQUAKE/
MAXIMUM EARTHQUAKE FOR THE SLICK ROCK SITE

a) The Slick Rock site is located in the Colorado Plateau Province, essentially midway between the Intermountain Seismic Belt and the Northern Rio Grande Rift Province. Kirkham & Rogers (Ref. 7, p. 14 to 19) has assigned this province an estimated MCE in the range of 5.5 to 6.5, with seismic activity increasing to the east towards the Southern Rio Grande Rift Province in Colorado (Figures 5 and 6). Therefore, it is logical to conclude that for the Slick Rock site Kirkham & Rogers' estimated MCE should be in the range of 5.5 to 6.0. Hence the choice of the Floating Earthquake of Richter magnitude, M = 6.2, originating at 15 km from the Slick Rock site, appears reasonable but somewhat on the conservative side.

b) On the most recently revised probabilistic acceleration map Algermissen, et al. (1982) (Ref. 14, p. 77) has assigned the Slick Rock area a maximum earthquake magnitude, M_L =6.1; in assigning the maximum magnitudes, M_L, to the source zones, the historic earthquake data as well as the best known seismo-tectonic information were considered. The choice of the floating earthquake magnitude 6.2 for the Slick Rock site in the Draft RAP (Ref. 5) appears reasonable when compared with Algermissen, et al.'s evaluation.

Therefore from (a) and (b) above, as well as from findings discussed in previous sections, the choice of the FE/ME of magnitude 6.2, originating at 15 km from the site, is considered reasonable and adequate and needs no revision.

6. MAXIMUM EARTHQUAKE ACCELERATION AT THE SITE

In the absence of any significant active line source, the FE is assigned an epicentral distance of 15 km as stipulated in the NRC's SRP (Ref. 15, pp. 2-10). As decided in the Inter-Agency Work Group meetings and stipulated in the SRP (Refs. 15 and 16), $(a_{max})_{84\%\ tile}$ = 0.21g was computed using Campbell's (1981) regression equation (Ref. 17). The $(a_{max})_{84\%\ tile}$ = 0.21g selected in the Draft RAP appears also reasonable when compared with the probabilistic maximum acceleration assigned by Algermissen, et. al. (1982) (Ref. 14) for the Slick Rock site area for different exposure periods. The a_{max} value is 0.09g for a 250-year exposure period and the corresponding value for the 1000-year design life works out to 0.14g (by extrapolation). If on a conservative basis, the maximum acceleration at the site is increased by 20% due to the recent upgrading of the Hebgen Lake earthquake (1959) by Professor Bruce A. Bolt, UCB (Ref. 18), the revised a_{max} will be about 0.17g. Therefore, $(a_{max})_{84\%\ tile}$ = 0.21g, as selected for the Slick Rock site, is adequate and needs no revision.

7. DISCUSSION OF DESIGN EARTHQUAKE MAGNITUDE AND ACCELERATION

The site specific study, and other evidence discussed earlier, indicate that the fault group 1A is not active. Therefore, comparing the maximum acceleration potential for this group with that of the Floating Earthquake (FE)/Design Earthquake (DE) is not necessary. However, for the sake of argument, if we assume that this salt-anticline fault group is active, the potential earthquake magnitude will be about magnitude 5.0$\pm$, using Woodward Clyde Consultants (WCC) equation (Ref. 19). Even though the single spike of site acceleration (0.32g) associated with an earthquake of magnitude 5.0$\pm$ will be higher, its effect at the site will

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Study has shown that a reduction in maximum acceleration by 30% will only reduce the spectrum acceleration by about 5% (Ref. 21, p. 12). However, it must be recognized that the maximum acceleration is only one of the factors determining the severity of an earthquake motion; the frequency content, general acceleration amplitude distribution and significant duration are also important factors that need careful consideration in selecting the design earthquake. Considering all of these factors, even if fault group 1A is proved to be active, though in reality it is not, a magnitude 5.0± earthquake with a peak acceleration associated with this fault group should not be selected as the design earthquake for the simple reasons that in reality the resulting response will be much less severe at the Slick Rock site compared to the FE/DE (M = 6.2, Epicentral Distance = 15 km) selected in the RAP (Ref. 5). In other words, even though the a_{max} of the FE is about 34% smaller than the a_{max} of the magnitude 5.0± earthquake, the spectral acceleration would differ nominally by about 5 to 6%; therefore a magnitude 6.2 earthquake at 15 km from the site, with slightly reduced spectral maximum acceleration, but richer frequency content, greater area under the spectrum, and longer significant duration would be considered a stronger design earthquake motion compared to a magnitude 5.0± earthquake closer to the site.

8. SEISMIC DESIGN PARAMETERS

The recommended design earthquake parameters for the Slick Rock site will be as below:

i) DE Magnitude = FE Magnitude = 6.2

ii) a_{max} for D.E. = 0.21g

These parameters are the same as those presented in the Draft RAP (Ref. 5).

iii) a_{max} for liquefaction analysis, if required, = a_{max} at the pile crest determined by using a_{max} = 0.21g as input ground acceleration for the response analysis. However, liquefaction analysis will not be necessary at the Slick Rock site, so long as the relocated tailings are unsaturated and placed as an engineered- fill above the ground water table, as proposed.

iv) Horizontal Seismic Coefficient K_H (for slope stability analysis) = (a) 0.14 (long term); and (b) 0.11 (during construction).

<u>NOTE</u>:

(a) and (b) are respectively 2/3 and 1/2 of a_{max} = 0.21g (Ref. 16).

9. <u>SUMMARY</u>

1. A review of the results of the site specific study conducted by the USDOE, and of other published and unpublished data and documents, shows that the very short salt anticline faults near the Slick Rock site, identified as Fault Group 1A, are not active.

2. Had the Salt Anticline Fault Group 1A been active, the potential maximum earthquake associated with such a fault would have been about magnitude 5±.

3. A magnitude 5± earthquake at 4 km from the site may have a_{max} = 0.32g at the site but its significant duration will be very short (4 to 5 secs); consequently the response to such an earthquake at the Slick Rock site will be much less severe compared to that caused by a magnitude 6.2 earthquake originating 15 km from the site.

4. Therefore, it is recommended that the Floating Earthquake (M = 6.2, Epicentral Distance = 15 km) be retained as the Design Earthquake.

5. Even though the a_{max} values of the two earthquakes referred to above may appear widely different, their response acceleration at the site will differ by only 5 to 6%; and the larger magnitude FE (M = 6.2) at 15 km distance, with richer frequency content, larger area under the response spectrum, and longer significant duration, will

be in reality a stronger design earthquake motion compared to that from a magnitude 5+ event near the site (4 km), with a single spike of larger acceleration but short significant duration. The above factors led to the choice of the DE.

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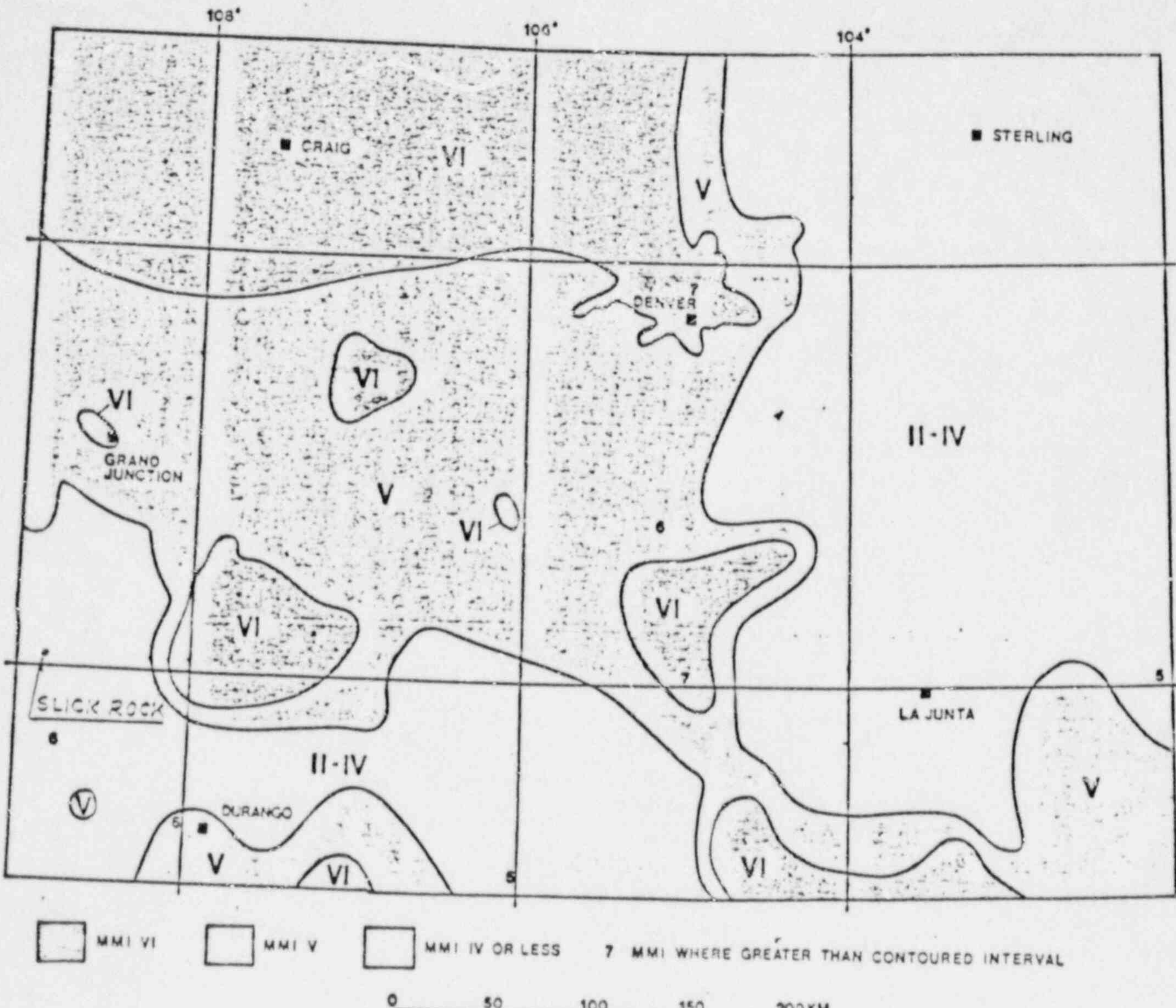

Figure 1 : Maximum historical earthquake intensities in Colorado. (Ref. 3)

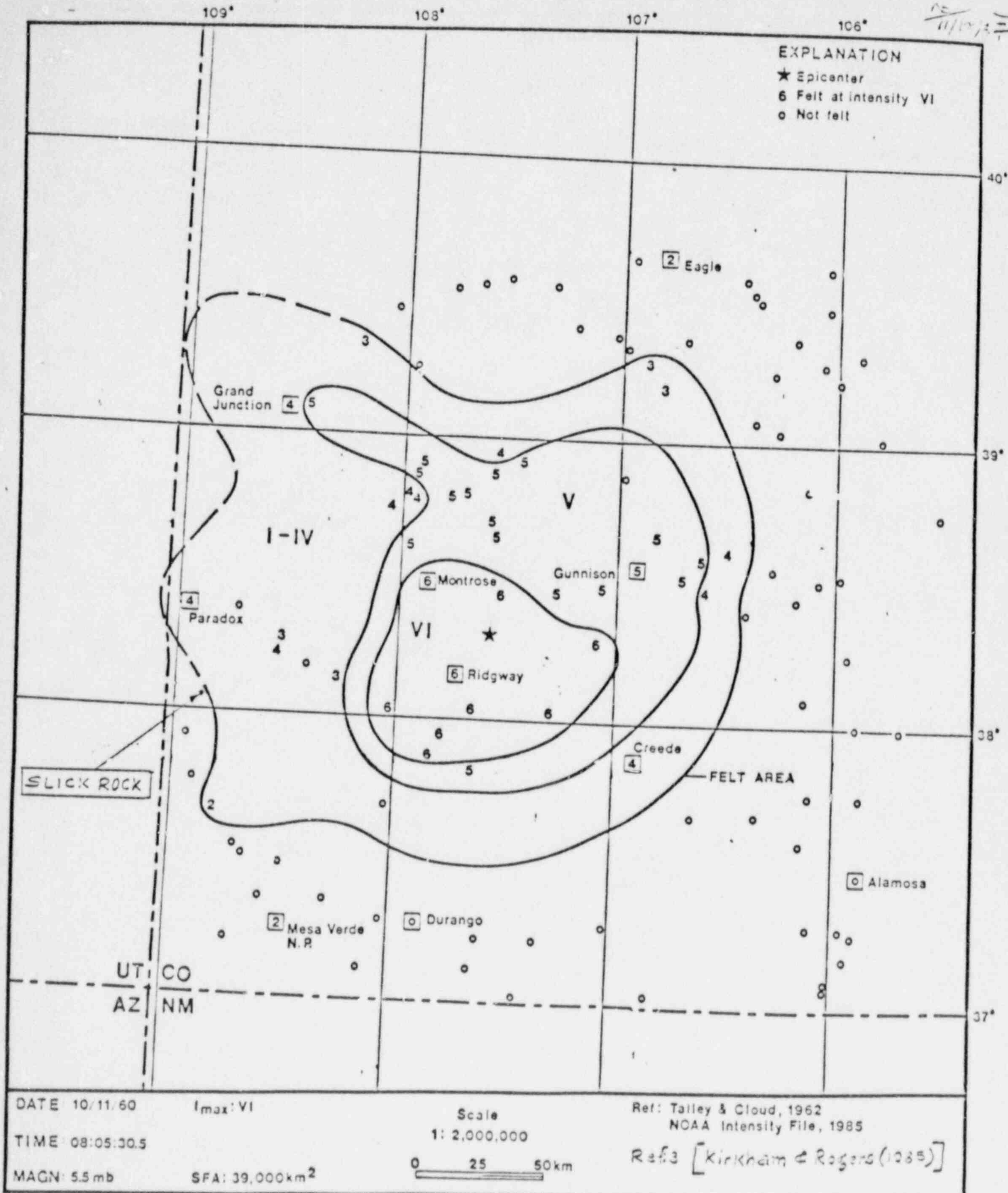

Figure 2: Isoseismal map for the October 11, 1960 earthquake [Montrose [Ridgway]

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1/13/87

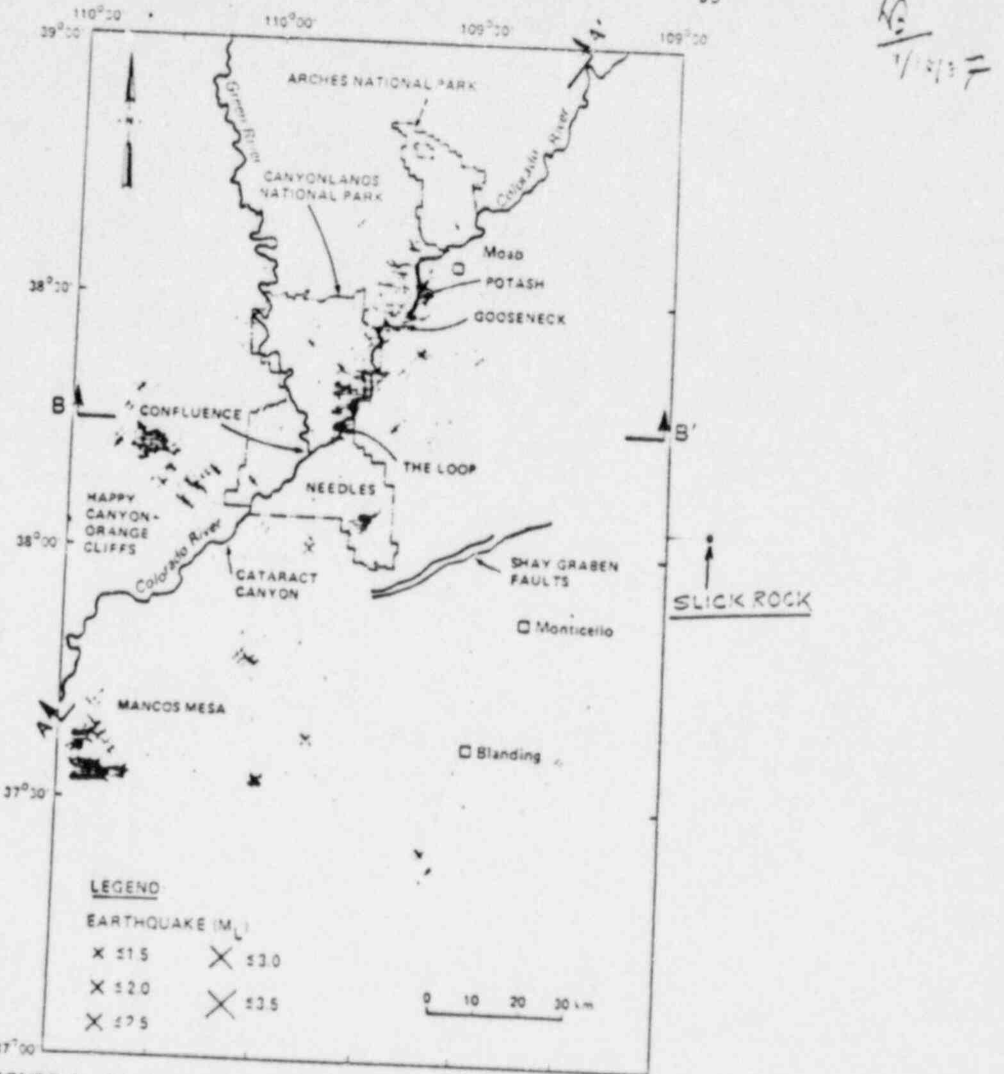

FIGURE 3—Seismicity of the Paradox basin based upon the Paradox Basin network July 1979 through 1985. Cross section BB' is shown in Figure 4. (Ref.13).

FIGURE 4 -Cross section BB': [Location of cross section shown on Figure 3] (Ref.13)

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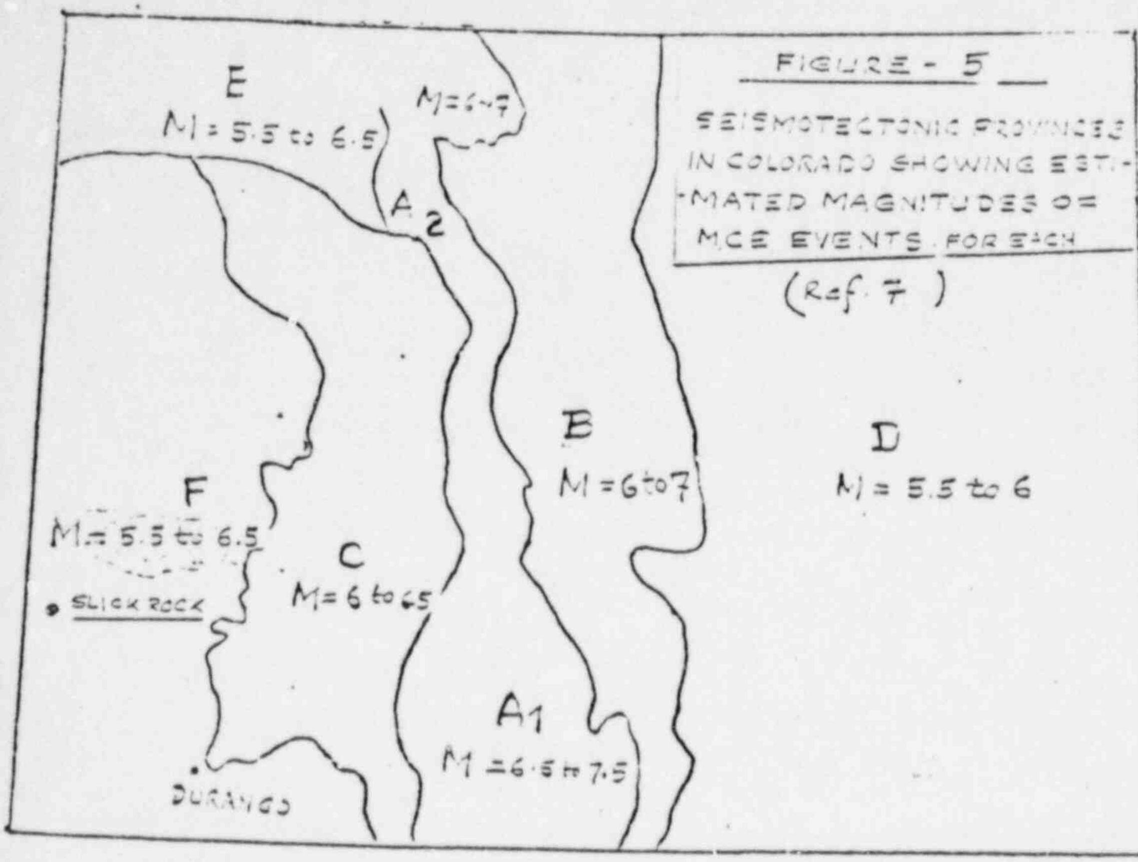


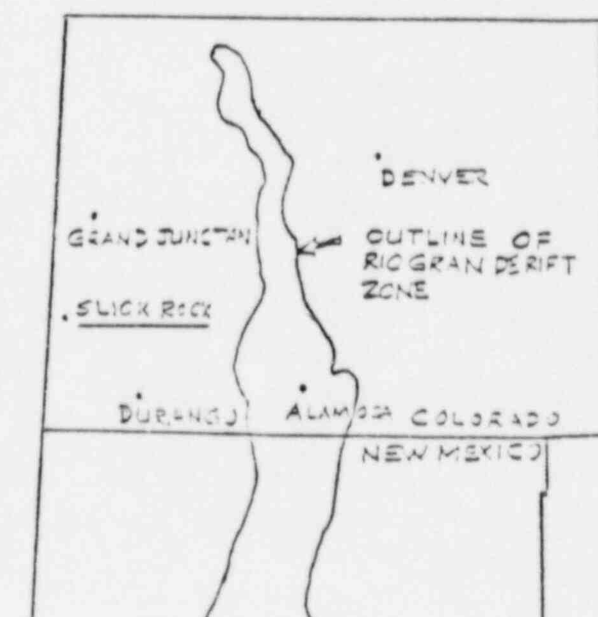
FIGURE - 5

SEISMOTECTONIC PROVINCES IN COLORADO SHOWING ESTIMATED MAGNITUDES OF MCE EVENTS FOR EACH

(Ref. 7)

LEGEND:

A1 SOUTHERN RIO GRANDE RIFT PROVINCE
A2 NORTHERN RIOGRANDE RIFT PROVINCE
B EASTERN PROVINCE
C WESTERN MOUNTAIN PROVINCE
D PLAINS PROVINCE
E UINTA-ELKHEAD PROVINCE
F COLARADO PLATEAU PROVINCE



Source: After Kirkham & Rogers (1981)
(Ref. 7, p14, 17, & 19)

Figure 6. General outline of the Rio Grande rift provi