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SEISMICITY AND FAULTS IN NORTHERN NEW MEXICO

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Abstract—The Los Alamos seismograph network has recorded earthquake data from north-central New Mexico for more than 20 years. Re-analysis of data for earthquakes between 1973 and 1988 and new analysis for earthquakes between 1989 and 1994 have provided a set of earthquake locations that are more accurate than previously available. Newly determined epicenters of about 580 events show that earthquakes occur in widely scattered locations through much of the area, although some occur in clusters and some are associated with fault zones. This level of detail has not been seen previously on earlier epicenter maps. Previous studies had concluded that the margins of the Rio Grande rift can not be identified from the seismicity and the new locations confirm that. The areas of greatest seismicity all lie in a roughly horseshoe-shaped zone of activity that surrounds the relatively inactive Valles Caldera and Jemez Mountains. The tectonics of this region would be better understood with additional information from the earthquakes, such as focal mechanisms.

INTRODUCTION

North-central New Mexico is a geologically complex region that includes several tectonic elements. The Rio Grande rift divides the region from north to south, with the Great Plains and the southern Rocky Mountains to the east, and the Colorado Plateau to the west. Los Alamos National Laboratory has operated an earthquake monitoring network, the Los Alamos Seismograph Network (LASN), since late 1973. Between 1973 and 1984 the network comprised 10 or more stations, distributed through an area of about 200 km by 200 km. Since 1984, funding has been adequate only to operate a seven-station network positioned in the immediate vicinity of Los Alamos, covering an area of about 15 by 20 km.

As part of a study of seismic hazards in the Los Alamos area, we re-analyzed well-recorded earthquakes that occurred between 1973 and 1988, and newly analyzed those that occurred between 1989 and 1994. The area studied was 160 by 160 km in size, centered on Los Alamos. The study involved picking P and S arrival times from the original seismograms, and locating the earthquakes with a newly determined velocity structure. With the complex geology of the area, using a single velocity structure throughout is undoubtedly an over-simplification. Yet, the data available are not adequate to determine a more complicated structure. Several studies, such as Olsen et al. (1979), and Spence and Gross (1990), have determined the velocity structure for smaller areas of northern New Mexico. We selected 104 of the best-recorded earthquakes and inverted their arrival times for a layered velocity structure and station corrections (House and Hartse, 1992).

A total of 672 earthquakes were located from the years 1973 to 1994, of which 617 are well located, having computed epicentral errors of 5 km or less. Some earthquakes were located outside the area of study; 581 epicenters are plotted in Figure 1. The largest earthquakes within the area of study are about magnitude 3.

To help judge whether the new velocity structure has improved the accuracy of the locations, we compared the locations of earthquakes in the Albuquerque Volcanoes swarm obtained using data from the network with locations obtained from a detailed study by Jaksha et al. (1981). The original Los Alamos network epicenters for the swarm were about 8 km mislocated, whereas the re-analyzed epicenters are less than 2 km mislocated.

The epicenters of earthquakes between 1973 and 1984 are probably accurate to within a few kilometers. With the small network aperture since 1985, epicenters of earthquakes recorded since then are probably less accurate. Because relatively small errors in the arrival time picks for individual earthquakes can drastically change their epicenters, the following discussion relies on the overall patterns of earthquakes. The distribution of stations, even before 1984, is generally not adequate to reliably determine the depths of earthquakes.

RESULTS

Previous studies, such as those of Cash and Wolff (1984) and Sanford et al. (1991), have shown fairly diffuse seismicity in northern New Mexico. The epicenters shown in Figure 1 show areas with diffuse seismicity, as well as several distinct features. Much seismicity is concentrated in a few areas that collectively define an elongated horseshoe-shaped zone around the Valles Caldera and Jemez Mountains area, which are relatively inactive.

Near the Nacimiento fault zone are two prominent clusters, one just south of 35°48', near a bend in the San Ysidro-Jemez fault zone, and the other just northeast of Cuba. Both clusters were mainshock-aftershock sequences. Farther north, earthquakes are scattered along the Gallina-Archuleta arch. Epicenters to the east of the arch are almost entirely north of the Rio Chama and extend to the southeast about as far as Abiquiu Reservoir (36°12'N and 106°24'W).

To the south and east of Abiquiu Reservoir is a fairly dense cluster of epicenters. Overall, the cluster trends roughly north-south, and the epicenters south of the Rio Chama coincide with several relatively short, north–south-trending faults on Lobato Mesa. These earthquakes have occurred as a series of swarms. A swarm is a series of earthquakes that occur in a distinct time interval and whose magnitudes are similar. In contrast, a mainshock-aftershock sequence contains one earthquake notably larger than the remaining earthquakes. The Lobato Mesa area is at the western edge of a 10–15 km wide zone of subsidence identified by Reilinger et al. (1979) from leveling surveys.

Earthquakes just to the west of Española define a northeast-southwest trend, with a cluster in the northeast that lies near the northern end of the Puye Fault zone, a series of short, generally north–south-trending faults. Extending farther south is a diffuse zone of seismicity that trends north–south, passes east of Los Alamos and extends as far south as the cluster near a bend in Tijeras-Cañoncito Fault zone.

Isolated from these trends is a cluster of epicenters about 20–30 km west–southwest of Taos. It is not associated with the nearby Embudo Fault zone, and contains a set of individual earthquakes that have no temporal relation to each other.

The lack of seismicity along the Embudo, Pajarito, Tijeras-Cañoncito and Pecos–Picuris fault zones is in strong contrast to the abundant seismicity along the trends of the Nacimiento fault zone and the Gallina-Archuleta arch. That lack of seismicity is not a result of inability to detect and locate earthquakes in these areas, because the network included stations near these areas between 1973 and 1984.

DISCUSSION

The margins of the Rio Grande rift cannot easily be discerned from the seismicity plotted in Figure 1. In north-central New Mexico, the Sangre de Cristo uplift forms the eastern edge of the rift (Kelly, 1979). The position of the western edge of the rift is controversial, but it may extend as far west as Abiquiu in the northern portion of the study area (Baldridge et al. 1994). Near Los Alamos, the Pajarito fault zone appears to bound the western edge of the rift (Kelley, 1979; Manley, 1979). Farther south, the rift shifts westward, to the margins of the Albuquerque-Belen basin (Kelley, 1979). Sanford et al. (1991) also found that the boundaries of the Rio Grande rift are not easily identifiable in a plot of seismicity throughout New Mexico.

The differing seismicity of the prominent fault zones may indicate different slip behavior along them. Those fault zones with little seismicity may be inactive, may slip aseismically, or may slip only in episodes separated by long time periods of little or no slip. From the seismicity

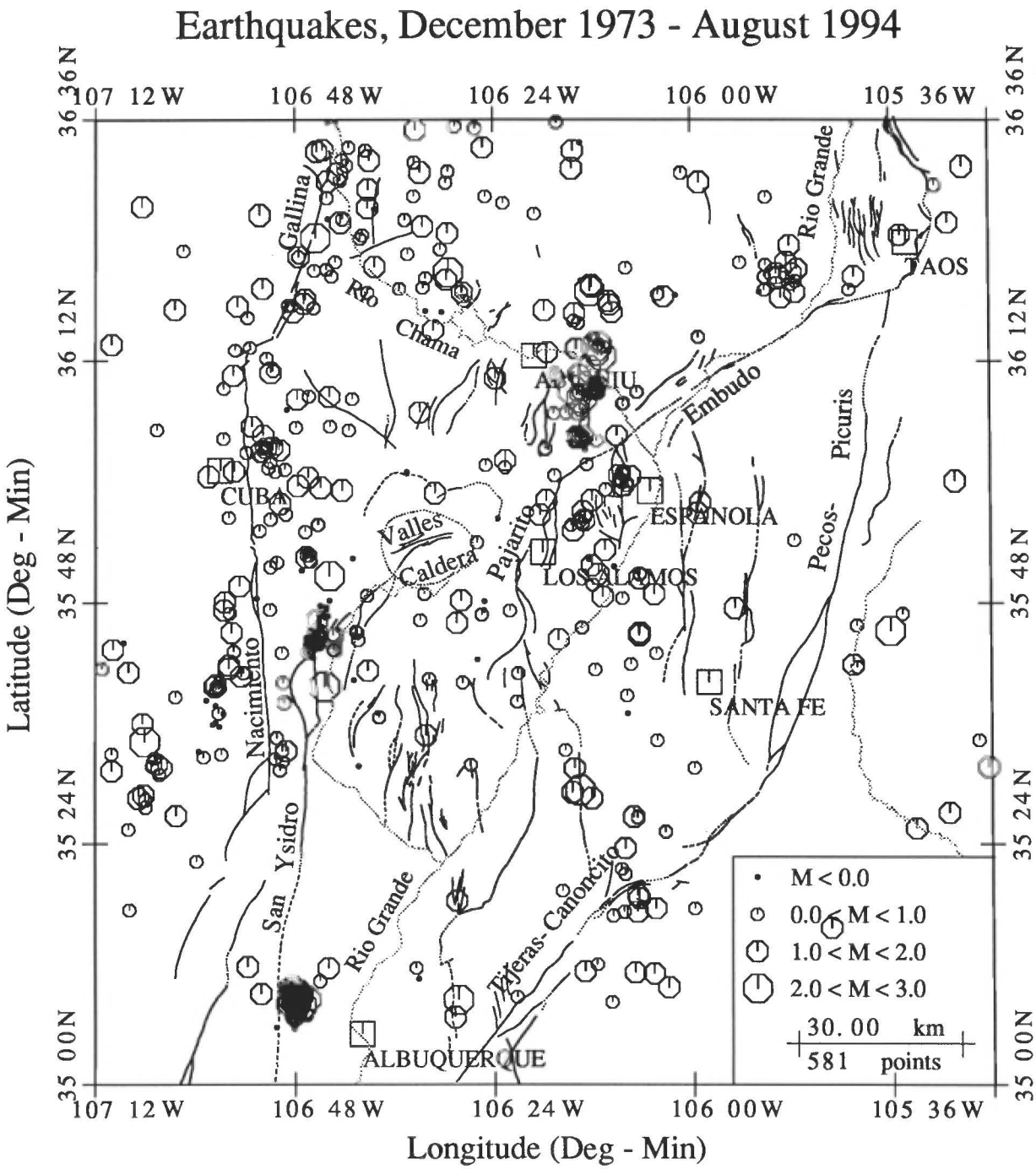

FIGURE 1. Well-located earthquakes in north-central New Mexico between 1973 and 1994. The symbol size is proportional to earthquake magnitude. Faults shown are from the compilation of Wong et al., (unpubl. report for Los Alamos National Laboratory, 1995). Rivers are plotted in gray.

data alone, it is difficult to distinguish between these possible behaviors, but they have very different implications for earthquake occurrence and seismic hazards. Except for the Valles Caldera area, where high heat flow may suppress brittle slip (Cash and Wolff, 1984), it is unlikely for fault slip to occur aseismically. Thus, it seems more likely that the lack of earthquakes along the major fault zones results from episodic activity. Other data from the earthquakes, such as focal mechanisms, would provide additional insight into the fault behavior.

CONCLUSIONS

The re-analysis and new analysis of earthquakes recorded in north-central New Mexico for more than 20 years has provided a set of earthquake locations that are more accurate than previously available. These locations provide more detailed insight into the general character of seismicity and differences in the seismicity of faults. Many earthquakes occur along the Nacimiento fault zone and the Gallina-Archuleta arch, but almost none are present along the Pajarito, Embudo, Tijeras-Cañoncito, or Pecos–Picuris fault zones. The margins of the Rio Grande rift are not discernible from the seismicity.

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