CONTRASTS BETWEEN SHORT- AND LONG-TERM RECORDS OF SEISMICITY IN THE RIO GRANDE RIFT—IMPORTANT IMPLICATIONS FOR SEISMIC-HAZARD ASSESSMENTS IN AREAS OF SLOW EXTENSION

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ABSTRACT

The Rio Grande rift has a relatively short and unimpressive record of historical seismicity. However, there is abundant evidence of prehistoric (Quaternary) surface faulting associated with large (M=6) earthquakes. This paradox between historical and prehistoric seismicity (paleoseismicity) has important implications for seismic-hazards analyses based primarily on modern seismicity.

The paleoseismic record of faulting in the rift is poorly documented compared to most seismically active regions, mainly because there have been few detailed studies and partly because many of the faults have long recurrence intervals (e.g., 10,000-100,000 years). Nevertheless, a new compilation of Quaternary fault data for the rift suggests Holocene (<10,000 years) movement on at least 20 faults. Several of these faults have evidence for multiple movements; thus, at least 22 large earthquakes of probable M>6.25 were associated with surface ruptures during the past 10,000 years, or one every 450 years.

Because the level of seismicity of the Rio Grande rift is generally low, the populace (in general) believes that earthquakes do not pose a significant threat to them, whereas the presence of abundant young faults tells a different story. From a geologic perspective, the data do not support the notion that the Rio Grande rift must use only catalogs of modern seismicity, but also integrate data from a comprehensive inventory of Quaternary faults, especially those structures showing evidence of movement in the past 100,000 years (a time interval which encompasses a portion of the last ice age). A myth of surface rupture frequency (i.e., having recurrence intervals of 10,000 years or more) can lead to a compliant attitude that strengthens a perception of low seismic potential for the region. Without proper caution, this attitude can manifest in inappropriate construction styles, building codes, land-use policies, and the siting (or relocation) of important or critical facilities.

INTRODUCTION

Virtually all modern earthquake-hazards assessments are based primarily on historical seismicity coupled with geologic evidence of faulting that is associated with strong ground motion (paleoseismology). The predictive nature of these assessments follows the widely accepted paradigm that "the past is the key to the future." This seismological basis for earthquake-hazards assessments is natural, quantitative, and justified through traditional practices. However, a paradox exists in many recently developed countries with short historical records, such as the United States where the recorded history of seismicity may be only 100-300 years long and the instrumental record may be considerably shorter. The problem lies in the potential disparity between short-term records of strong ground motion reflected by historical seismicity and long-term records of strong ground motion indicated from paleoseismic studies. This paper reflects on these disparities and the reasons they exist.

The U.S. and many other countries have geologically distinct regions that fall into markedly different seismogenic settings. Commonly, these regions are directly associated with tectonic provinces, their seismic activity being controlled by their proximity to tectonic plate margins, regional geologic setting, and their current state of stress. Although there is probably a continuum between these regions, let us consider that there are three general types of seismogenic settings in the United States. This simple characterization allows us to frame the present and Neogene seismotectonic setting of the Rio Grande rift.

In tectonically active regions, especially those bordering convergent or transpressive plate margins, large (M>6) earthquakes are associated with catastrophic movement on faults having slip rates that are typically tens or even hundreds per millennial. Earthquakes on such faults are essentially limited to the time span during which faults have been active (i.e., the slip rate is a product of the time of the last earthquake, which is a few thousand years for most large faults). Thus, the earthquake that occurred a little more than 100 years ago in northern Sonora, Mexico, south of Douglas, Arizona, is considered a recent event; the largest felt or recorded earthquake (M 6.3) occurred in 1931 near Valentine, Texas, and although this event did not form a detectable surface rupture, it may have had as much as 38 centimeters of slip in the subsurface (Doser, 1987). This earthquake, and similar-size ones in the Basin and Range Province (Coppersmith, 1994), suggest that the threshold for surface ruptures is in the lower half of the M 6 range (i.e., M 6.25±0.25) for normal faults that have earthquakes nucleating at depths of 15 kilometers or perhaps to 20 kilometers. Thus, there is an apparent paradox in the Rio Grande rift between the short-term record on faults with significant seismicity, no surface rupture, and the long-term record (abundant evidence of late Quaternary faulting and, hence, paleoseismicity). The manner in which this disparity is dealt with has important implications for seismic-hazards analyses.

QUATERNARY FAULTING IN THE RIO GRANDE RIFT

The Rio Grande rift lies within the eastern part of the Basin and Range and the southern part of the Rio Grande Mountains as defined by Fenneman (1931); it forms a nearly continuous, deep, sediment-filled valley of cally <1-2 millimeter, then recurrence intervals for surface rupturing fault are as little as several thousand years (e.g., the Wasatch fault zone) or as long as 10,000 years (e.g., a typical Basin and Range fault) to 100,000 years (e.g., some of the least active Quaternary faults in the Rio Grande rift). Obviously, the 150- to 300-year-long record of felt seismicity only portrays a small fraction of the potentially active faults in these regions.

Finally, in even less tectonically active regions, such as the passive margins of the eastern U.S. and compressional domain of the stable continental interior of the U.S., Canada, and Australia, fault slip rates are probably measured in millimeters per year. In such regions, intervals between surface rupturing events may be extremely long (>100,000 years) or immeasurable. However, these regions also seem prone to clustered earthquake activity; that is, one where seismic structures are recurrently active over relatively short geologic time frames (hundreds to tens of thousands of years), then inactive for long intervals of time (thousands to tens of thousands of years). The New Madrid and Charleston seismic zones (mid-continent and eastern U.S.) appear to be examples of this behavior. For example, the Chavers fault (southeastern Colorado) is an example of faults that have evidence of short-term clustering but no geologic evidence of surface ruptures (Coppersmith, 1994).
earthquake events, the Sangre de Cristo and Organ Mountains have evidence for two separate movements in the Holocene; thus, one should consider that there have been at least 22 large (M 6+0.25) earthquakes associated with surface ruptures in the Rio Grande rift in the past 10,000 years. These data suggest a Holocene composite recurrence interval (CRI) of about 450 years for the above mentioned portion of the rift. Some portions of the rift, especially those settled by Spanish missionaries along the Rio Grande, have been continuously occupied since nearly A.D. 1600, thus the CRI is approaching the time that the region has been occupied by Americans of European origin (i.e., the historical record). The new calculated CRI is considerably less than before (750 years) because I have included faults from a larger area (Texas, Mexico, and southern Colorado) and because there are several newly documented faults in the listing. The most recent movement on the prehistoric faults seems to have been along the Organ Mountains fault about 1,000 years ago (Gile, 1987), whereas the Pitayacahi fault is the only historical surface rupture in the rift (see table 1). Based on past experience, it seems likely that with further paleoseismic studies the number of faults with known Holocene movement will probably increase, and the CRI will decrease somewhat, as it has in many other parts of the Basin and Range. In contrast, the CRI for the rift is roughly equivalent to that of the Wasatch fault zone (5 active segments) in Utah (Machette and others, 1991, table 2), a fault zone which is considerably more active that those typical of the Basin and Range Province.

There are two major urban centers in the relatively sparsely populated Rio Grande rift. The northern center includes Los Alamos, Santa Fe, and Albuquerque, a region where an estimated 50 percent (i.e., 750,000) of New Mexico's population lives (ca. 1.5 million in 1990). This area is close to or includes several Quaternary faults (the Embudo, Parajito, Guaje Mountain, Rendija Canyon, and Hubbell Springs) that have clear evidence for either Holocene or latest Pleistocene events associated with large earthquakes. New studies of the Parajito fault indicate latest Pleistocene (Kelson and others, 1993) or possibly younger movement (James McCalpin, oral communication, 1997), whereas two of its subsidiary faults (the Rendija and Guaje Mountain) are known to be Holocene (Kelson and others, 1993). The Parajito fault has a long history of Quaternary movement—its scarps on 1.1-million-year-old Bandelier Tuff is commonly 120 meters high; more importantly, the fault bounds the west side of the Los Alamos National Laboratory, an important research and defense-related facility. In addition, there are several other critical facilities (Kirkland Air Force Base and Sandia National Laboratory), the State Capital, and Cochiti Reservoir within this region, all of which could be subject to damage from severe ground shaking during large earthquakes on nearby active faults.

At the southern margin of the rift, population is mainly concentrated in the El Paso-Juarez metropolitan area (estimated population of more than 1.8 million), with a smaller urban area at Las Cruces (70 kilometers to the northwest). El Paso has nearly 600,000 people living in a relatively small area (El Paso County), whereas

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**Table 1. Faults with known or suspected Holocene movement in the Rio Grande rift.**

(Abbreviations: SM, scarp morphology; ST, stratigraphic relations; S, soils; C14, radiocarbon dating; T, trenching; Mtns., mountains; EQ, earthquake)

<table>
<thead>
<tr>
<th>Name of fault</th>
<th>Number &amp; general location (see figure 2)</th>
<th>Time of most recent event</th>
<th>Evidence for timing &amp; main reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sangre de Cristo (section A)</td>
<td>1. West front of Sangre de Cristo Mtns., NE of Alamosa, Colorado.</td>
<td>Early Holocene</td>
<td>SM, ST, C14, &amp; T; McCalpin, 1982</td>
</tr>
<tr>
<td>Sangre de Cristo (section B)</td>
<td>2. West front of Sangre de Cristo Mtns., NE of San Luis, Colorado.</td>
<td>2-3(?) events in Holocene</td>
<td>ST &amp; T; Kirkham &amp; Rogers, 1981</td>
</tr>
<tr>
<td>Sangre de Cristo (section C)</td>
<td>3. West front of Sangre de Cristo Mtns., near Carlsbad, New Mexico.</td>
<td>Middle to late Holocene</td>
<td>SM &amp; T; Menges, 1990</td>
</tr>
<tr>
<td>Sangre de Cristo (section D)</td>
<td>4. West front of Sangre de Cristo Mtns., near Taos, New Mexico.</td>
<td>Early (?) Holocene</td>
<td>SM &amp; T; Machette &amp; Personius, 1984</td>
</tr>
<tr>
<td>Valle de Vidal</td>
<td>5. East side of Valle Vidal, northern New Mexico.</td>
<td>Late to middle Holocene</td>
<td>SM; Menges &amp; Walker, 1990</td>
</tr>
<tr>
<td>Guaje Mountain</td>
<td>6. West side of Espanita basin, N of Los Alamos, New Mexico.</td>
<td>Middle Holocene</td>
<td>ST, T, &amp; C14; Kelson &amp; others, 1993</td>
</tr>
<tr>
<td>Rendija Canyon</td>
<td>7. West side of Espanita basin, N of Los Alamos, New Mexico.</td>
<td>Early (?) Holocene</td>
<td>SM; Machette &amp; McGimsey, 1983</td>
</tr>
<tr>
<td>La Jencia</td>
<td>9. West side of La Jencia basin, central New Mexico.</td>
<td>1-2(?) events in Holocene</td>
<td>SM, ST, T, &amp; Machette, 1988</td>
</tr>
<tr>
<td>Caballo (Williamsburg scarp)</td>
<td>11. Northern segment of Caballo fault, S of Truth or Consequences, New Mexico.</td>
<td>Early (?) Holocene</td>
<td>SM, ST, C14, &amp; T; Machette, 1987c, Foley &amp; others, 1988</td>
</tr>
<tr>
<td>Caballo</td>
<td>12. Central segment of Caballo fault, S of Truth or Consequences, New Mexico.</td>
<td>Early (?) Holocene</td>
<td>SM &amp; T; Machette, 1987b</td>
</tr>
<tr>
<td>Alamogordo</td>
<td>13. West flank of Sacramento Mtns., Alamogordo, New Mexico.</td>
<td>Early (?) Holocene</td>
<td>SM &amp; ST; Machette, 1987b</td>
</tr>
<tr>
<td>Organ Mountains</td>
<td>14. East flank of Organ Mtns., central New Mexico.</td>
<td>2 events in Holocene</td>
<td>SM, C14, &amp; T; Gile, 1987; Machette, 1987b</td>
</tr>
<tr>
<td>East Franklin Mountains</td>
<td>15. East flank of Franklin Mtns., north of El Paso, New Mexico.</td>
<td>Early (?) Holocene</td>
<td>SM &amp; ST; Machette, 1987b</td>
</tr>
<tr>
<td>Gillespie Mtn.</td>
<td>17. West flank of Animas Mtns., Animas Valley, NW New Mexico.</td>
<td>Holocene</td>
<td>SM; Machette &amp; others, 1986</td>
</tr>
<tr>
<td>Pitayacahi (Somora EQ)</td>
<td>18. East side of San Bernadino Valley, NE Sonora, Mexico</td>
<td>Historic (May 3, 1887)</td>
<td>75 km rupture, scarp height 4 m max., Bull &amp; Paithree, 1988</td>
</tr>
</tbody>
</table>
Citad Juarez just across the Rio Grande has a burgeoning population roughly estimated at 1.2 million in 1990. The largest historical earthquake to affect the El Paso region was a MM VIII (in 1887), which was recorded as a magnitude of 5.5. However, both El Paso and Juarez would be threatened by movement of the East Franklin Mountain fault, which extends through the heart of both urban areas. The East Franklin Mountains fault is the southernmost one-quarter of an 182-kilometer-long fault zone that extends from south of the International Border fence (in the city of Juarez) north through El Paso and Fort Bliss and into New Mexico along the west side of White Sands Missile Range and the Tubacacito Valley. This fault zone is one of the longer active normal faults in the Rio Grande rift, exceeded only by the Sangre de Cristo fault zone in northern New Mexico and southern Colorado. The most recent movement on the East Franklin Mountains fault probably was in the latest Pleistocene or early Holocene (J. Keaton and J. Barnes, written communication, 1995), but the fault has a history of recurrent movement as documented by Quaternary scarps as much as 60 meters high. In earlier studies, Machette (1987b) estimated that this entire fault zone is comprised of five discrete parts (fault segments), each having recurrence intervals of 10,000-20,000 years. If this is true, then a major surface-rupturing earthquake may occur, on average, about once every 2,000-4,000 years (CRI) somewhere on the 182-kilometer-long fault zone. This fault system and many others are invisible (not imaged) on seismicity maps of the Rio Grande rift.

**SEISMICITY**

Seismicity in the rift is relatively diffuse with few meaningful concentrations or associations with active faults (figure 3). About half of the earthquakes shown in figure 3 are within the rift, and the other half are in the Colorado Plateau Province and, to a lesser extent, the Great Plains Province adjacent to the rift. Much of the felt (but not recorded) seismicity for the period 1849-1961 (Northrup, 1976) was concentrated along the Rio Grande rift, while the historical (through 1977), the Great Plains and Colorado Plateaus - two provinces considered to be tectonically stable—had equivalent or greater seismicity than the Rio Grande rift (Sanford and others, 1991). The most recent moderate size earthquake was an M 5.7 shock that struck Alpine, Texas (east of the rift) in April 1995. Thus, modern seismicity within the rift is remarkable only for its subdued level and lack of association with known Quaternary faults.

Even though the rift seems to be a relatively quiet seismogenic region, past history shows its potential for large and devastating earthquakes. For example, the 1887 Sonoran earthquake (Mw 7.4) of northern Mexico has not been traditionally associated with the Rio Grande rift because the earthquake occurred in Mexico and the rift has been considered to be a largely U.S. feature. However, many of the rift structures in New Mexico and west Texas continue south into Chihuahua and Sonora. The 1887 Sonoran earthquake occurred along the Pichachy fault (Bull and Pearthree, 1988)—a range-bounding, north-south-trending, high-angle normal fault that is a southward continuation of Quaternary faulting in the San Bernardino Valley of southwestern New Mexico (see Machette and others, 1986). As such, this fault should be considered as a modern rift structure. It has the characteristics of a major surface-rupturing rift fault (see for example Pecos Valley and Carlsbad, 1987; Machette, 1988) in that it has an extremely low slip rate and long-recurrence interval (Bull and Pearthree, 1988). Although almost forgotten because it occurred about 110 years ago, movement on the Pichachy fault formed the longest (75 kilometers) historic surface rupture of a normal fault in North America. Tucson, then a dusty frontier town and now a major urban area, was subject to strong ground motion and portions of the intervening country experienced both liquefaction and artesian water spots.

The scarcity of historical surface faulting (figure 2) and the general low level of seismicity of the Rio Grande rift (figure 3) has led the populace in that area to believe that earthquakes do not pose a significant threat to the region. In fact, the most recent series of USGS seismic-hazard maps (Frankel and others, 1996) indicate 1) low levels of ground acceleration (≤0.1 g) with 10 percent probability of exceedance in 50 years and 2) low to moderate (≤0.3 g) levels of ground acceleration much of the with 2 percent probability of exceedance in 50 years (see figure 4a and 4b, respectively). For example, 0.10 g may be an appropriate threshold for damage to older structures (pre-1965 dwellings) or dwellings not made resistant to earthquakes (see Frankel and others, 1996). The seismic-hazard maps shown in figure 4a illustrates the designation of moderate seismicity in areas of slow extension, such as the Rio Grande rift, whereas figure 4b shows the effect of faults on the populated. Thus, the population's perceptions of the hazard are well based on what has happened in New Mexico over the past several centuries. The areas of highest map-
ped ground acceleration are centered over areas where M ≈ 4 earthquakes have occurred historically (compare figure 3 with figures 4a and 4b). Interestingly, one of the areas of large predicted ground acceleration (≤ 0.2 g, figure 4b) is centered over the 1887 Mw 7.4 earthquake partly as a result of continued M 4 earthquakes in the area (which might be aftershocks from 1887 earthquake).

Interestingly, the Pechitian fault, on which this earthquake occurred, has an estimated recurrence interval of 100,000 years or more (see Bull and Peepthre, 1987) for large surface ruptures. Thus, although the Pechitian fault is a highly active fault, large parts of this fault zone will not occur on slip (or slip-rupture) catastrophes. More likely, one might argue that these faults are typically active for long intervals between movements, and that most of the seismicity that is occurring in the rift occurs as minor adjustments on a myriad of non-surface rupturing faults. In a sense, the elephant is snoring. From a geologic perspective, it seems that most major surface-rupturing earthquakes do not occur more frequently than every 500 years. Thus, for a 500-year period, one must use long-term studies of fault activity as a basis for predicting recurrence interval for the Wasatch fault zone in Utah (a world-class normal fault with a Holocene slip rate of 1-2 mm/year) is currently less than 0.1 mm/yr. This finding is consistent with the abrupt change (decrease in this case) in the rate of slip and, by inference, seismic activity along the Socorro Canyon fault zone that occurred during early rift formation (early Miocene time), but by late Miocene time (ca. 9-10 million years ago) the rate was covered by playa deposits of the Popotosa Formation. Subsequent rejuvenation of the mountain range by uplift along the Socorro Canyon fault zone has resulted in about 500 meters of local relief and about 750 meters of vertical offset of the 9-million-year-old playa deposits (C, figure 5). Although these ages and offset amounts are relatively crude estimates, they yield a long-term vertical slip rate of 0.08 mm/yr (750 m in 9 million years).

Two additional datums are present across the fault zone for a general comparison of slip rate: 41-42 million year-old basaltic and a Quaternary (ca. 750,000 years) piedmont surface. These datums have about 200 meters with a Holocene of 0.05 mm/yr (figure 1A and B, figure 4). Using the three datums, the slip rate on the Socorro Canyon fault zone appears to have slowed from 0.4-0.5 mm/yr about 40 million years ago to about 0.05 mm/yr in the Pliocene, and 0.02-0.04 mm/yr in the past 750,000 years of the Quaternary. As with the Wasatch fault zone, there is a 5-10 fold decrease (change in this case) in slip rate and, by inference, seismic activity along the Socorro Canyon fault zone. This slip rate variation (0.02-0.04 mm/yr) and the recurrence interval is probably on the order of 50,000-100,000 years, but the fault is characteristic of many other major faults within the rift. The most recent surface-rupturing event on the Socorro Canyon fault zone appears to have occurred in latest Pleistocene time (Machette and McGinley, 1983), and thus would be considered an active fault in the seismic-hazards sense.

Hazards versus Recurrence Time

In regions of high seismicity such as the West Coast, many Holocene faults have a record of movement that suggests relatively high rates of slip (> 5 mm/year), short recurrence interval (e.g., 125,000 years; post high stand of Lake Bonneville; 15,000 years ago). These slip rates are typically 1-2 mm/yr, but some data from the interwell (prior to the M 4 earthquake in 1887) are often associated with ongoing seismicity. Thus, these faults pose an obvious hazard and are recognized as such. However, a closer look at these faults reveals that they are much more often characterized by faults with low slip rates and long recurrence intervals; they are most often associated with}

## Variations in Slip Rate Through Time

When geologic data are used in probabilistic hazard assessments, one of the most important parameters is the slip rate (and the associated recurrence interval) of a fault. In many cases, one must use long-term studies of fault activity as a basis for predicting recurrence interval for the Wasatch fault zone in Utah (a world-class normal fault with a Holocene slip rate of 1-2 mm/year) is currently less than 0.1 mm/yr. This finding is consistent with the abrupt change (decrease in this case) in the rate of slip and, by inference, seismic activity along the Socorro Canyon fault zone that occurred during early rift formation (early Miocene time), but by late Miocene time (ca. 9-10 million years ago) the rate was covered by playa deposits of the Popotosa Formation. Subsequent rejuvenation of the mountain range by uplift along the Socorro Canyon fault zone has resulted in about 500 meters of local relief and about 750 meters of vertical offset of the 9-million-year-old playa deposits (C, figure 5). Although these ages and offset amounts are relatively crude estimates, they yield a long-term vertical slip rate of 0.08 mm/yr (750 m in 9 million years).

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## Preservation of Paleoseismic Evidence

Another problem that must be considered in regional analysis of faults activity is the preservation of the geologic record. Detailed analysis of subsurface well-logs, geologic mapping, and geophysical data from Albuque- que, Nevada, has revealed a complex pat- tern of late Cenozoic deformation (figure 6), far more complex than previously determined from reconnaissance mapping of the basin. Although most of the faults in the subsurface strike north-south, there are a large number of sub-dip faults that strike various southwest-northeast trends. Previ- ous mapping did not reveal surficial evidence for these cross-basin faults, perhaps because the prevailing para- digm was one of Quaternary south faulting related to east-west extension. However, recent surficial geologic mapping and the excellent subsurface work by Hayw (1966) is starting to reveal relations between the fault pat- terns shown in figure 6 and the location and lateral extent of young volcanic centers, deep basins, and the Quater- nary geology of the basin.

The preservation of surficial evidence of this complex structural pattern is another complication in seismic-haz- ards analysis for this particular area, and likely for other basins of the rift. For example, large parts of the land- scape in the Rio Grande rift are formed by either high- level surfaces related to the early Pleistocene filling of the basin (prior to Rio Grande eastward) or are formed by latest Pleistocene (10,000-30,000 year old) sediment in alluvial-fan complexes or in entrenched stream valleys (figure 7). If faults in such basins have average recurrence interval of 50,000-100,000 years, then virtually all faults would be recorded on the high-level surfaces whereas only some of the faults would be expected to have dis- turbed accumulations of late Pleistocene or Holocene age. Thus, in regions where faults are characterized by long recurrence intervals (10,000-100,000 years), one must look at a geologic record that at least one recurrence interval long (or longer) in order to capture spatial and temporal pat- terns of faulting. Additional research using subsurface methods (e.g., seismic reflection, geophysical surveys, analysis of water-well data, etc.) are needed to detect potentially active faults in areas of young land- scapes. One such study noted that older buildings in the business districts of Albuquerque and El Paso are located close to the Rio Grande on young, low, flood-plain surfaces.
Figure 6. Late Cenozoic (Pliocene and Quaternary) faulting in the Albuquerque basin, middle Rio Grande rift. Fault pattern (simplified here) was determined by Hawley (1996) on the basis of detailed analysis of subsurface wells, geophysical data, and geologic mapping. Note the bimodal distribution of faults: predominantly north-south with northeast-trending faults that accommodate disparate basin geometries and/or transfer slip. The bimodal distribution of faults is shown as QT (undifferentiated Quaternary and upper Cenozoic sediment, light stippled pattern); Pliocene and Pleistocene basalt as QTb (o pattern), and Tertiary and older bedrock (dark stippled pattern).

Figure 7. Quaternary faults and generalized geology of the Albuquerque basin, middle Rio Grande rift. Faults with surficial evidence of Quaternary movement are shown in black; those without such evidence are shown in gray (data from unpublished compilation; see Machette and others, 1996). Symbols: QTb, Quaternary and late Cenozoic basalts; QT, undivided basin deposits; eP, early Pliocene sediment; mP, middle Pleistocene sediment; lP, late Pleistocene sediment; and H, Holocene sediment. Bedrock is shown by the darkest stippled pattern.
A GEOLOGICAL PERSPECTIVE

From a geological viewpoint, it seems obvious that modern seismic-hazard assessments for regions like the Rio Grande rift must use not only catalogs of modern seismicity, but also must integrate data from a comprehensive inventory of Quaternary faults, especially those structures showing evidence of movement in the past 100,000 years. By doing so, the geologic data will portray the true potential for surface-rupturing earthquakes on a time frame equivalent to that of 10,000 to 100,000-year recurrence intervals. Once accomplished, the probability of occurrence of large earthquakes on individual structures may prove to be extremely low, but the location of these potential, strongly-ground-motion-generating structures will be known in relation to urban areas and critical facilities. In addition, the hazard posed by numerous low-slip-rate faults within a given radius (e.g., 50-100 kilometers) of a town, city, or critical facility results in a composite recurrence interval (CRI) that can be as long as 1,000 years (e.g., 1,0700) of each individual fault. A myopic approach of not appreciating the potential for earthquake hazards posed by individual structures (i.e., recurrence intervals of 10,000 years or more) can lead to a complacent attitude that strengthens a perception of low seismic potential. Without proper caution, this attitude can be manifested in inappropriate construction styles, building codes, land-use policies, and the siting (or re-location) of important or critical facilities.

Various mitigation strategies require different portraits of earthquake hazards. Emergency planning and disaster response plans, for example, generally require information regarding the potential effects of a large earthquake that are possible, but perhaps unlikely to occur. Their intention is to base such plans on a worst-case or near-worst-case earthquake scenario. If response plans are in place and can operate effectively for such an earthquake, response to smaller-magnitude earthquakes can easily be accomplished. Probabilistic ground-motion hazard maps for the engineering design of buildings of standard construction have customarily used a 1/500 annual probability of exceedance (approximately 10 percent in 50 years) as a standard (see figure 4a). In recent years, in some circumstances, a lower probability (2 percent in 50 years, figure 4b) might be used for facilities of critical interest. These ground-motion hazard maps generally will not reflect the influence of the large rare earthquakes in the rift that have recurrence times of thousands of years since the probability of that earthquake occurring in any 50-year period is low. On the other hand, design of important or critical facilities such as nuclear and defense facilities, reservoirs, hospitals, and any structures that should remain in service following a large earthquake are generally engineered to stricter standards and may make use of ground-motion estimates at very low probability levels (i.e., 1/100,000 annual or 5 percent in 500 years). In this case, the occurrence of rare, but large earthquakes on long-recurrence faults is of considerable importance. Thus, as paleoseismic information for the western United States becomes more widely known to user communities and to the public, there likely will be an increase in awareness about over what is considered acceptable levels of risk. Clearly, recognizing such seismic-safety issues will require the cooperation and participation of a wide range of users of earthquake-hazard information and the research community.

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