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Rio Grande Rift, A Window into the Earth

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INTRODUCTION

Movements of the Earth's crust, which often cause volcanic eruptions and earthquakes, produced a major geologic feature in the Southwest called the Rio Grande rift. Approximately 1000 km long and from 15 to 65 km wide, this rift is a late Cenozoic (less than 30 million years old) physiographic depression that extends from south-central Colorado to northern Mexico and is bordered by the Colorado Plateau and the southern Great Plains (Fig. 1). It is characterized by stretched brittle crust, faulting, volcanism, and high heat flow.

Fig. 1.

Location of the Rio Grande rift (yellow) with respect to the Colorado Plateau (blue) and the Southern Rocky Mountains (green).

Understanding rifts is important because they are targets for geothermal and mineral exploration and because they give us insight into mountain building processes that sculpt the Earth's surface.

RIO GRANDE RIFT STRUCTURE

The Rio Grande rift is a series of north-trending grabens, or valleys, formed during crustal extension,

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Fig. 2.
Location of sedimentary basins in the Rio Grande rift.

when large chunks of crust dropped along normal faults (Fig. 2). As grabens formed over millions of years, they filled with sediments from the surrounding highlands. Because uplift has reversed this basin-filling trend, erosion from the basins now is the dominant process.

Geologists divide the rift into three segments. The southern segment, which belongs to the Basin and Range Province, extends from the Hueco and Los Muertos basins in northern Mexico to Socorro, New Mexico. It is composed of parallel grabens and is the widest part of the rift. Total vertical displacement between the elevated mountain tops and the basin floors exceeds 8 km, and sediment fill in the grabens averages 2.5 km thick. If the

sediments were stripped from this segment, the remaining hole would be as deep as five Grand Canyons.

At Socorro, the rift intersects an ancient crustal flaw called the Morenci lineament; here, the character of the rift changes from parallel basins south of the lineament to an almost linear chain of basins north of the lineament.

The central segment encompasses grabens between Socorro and Taos, New Mexico. Its major basins are the Albuquerque-Belen, the Santo Domingo, and the Espanola, and its greatest vertical displacement, which occurs adjacent to the Sandia Mountains, is 7 km. The Albuquerque-Belen basin contains the thickest deposit of basin sediments, 4 km, in the entire rift, more than twice the depth of the Grand Canyon. South of Taos, the rift intersects the Jemez lineament, which, like the Morenci lineament, is an ancient northeast-trending crustal flaw. Across this intersection, basins tilt in opposite directions. Implications of the intersections between the rift and the Jemez and Morenci lineaments are not fully understood.

The northern segment of the rift extends from the Jemez lineament to Leadville, Colorado, and comprises the San Luis and Arkansas basins. Like those to the south, these basins follow ancient (less than 300 million years old) crustal weaknesses.

Evidence from studies of rift faulting, elevation changes, geophysical data, and high heat flow suggests that all segments of the rift still are geologically active and merit comprehensive study.

DEEP RIFT STRUCTURE

Geoscientists delineate the deep structure of the Rio Grande rift from gravity, heat flow, and seismic data (Fig. 3) that also can be used to approximate the depth of the mantle beneath the Earth's crust. These data show that the mantle is closer to the surface below the rift than west or east of the rift. In particular, the crust is 30 to 35 km thick directly above the rift, whereas it is 45 km thick in the Colorado Plateau and 50 km thick in the southern Great Plains. This image of a thinned crust above a hot mantle helps explain the above average amount of heat that reaches the Earth's surface in the rift.

RIFT VOLCANISM

Volcanism is a common characteristic of continental rifts, and the Rio Grande is no exception. Compared

Fig. 3.

Deep structure of the Rio Grande rift. Numbers refer to seismic compressional wave velocities in km/s.

with other rifts, the Rio Grande erupted a small volume of volcanic rocks. Two types of lava occur here. The first type, andesite and rhyolite, generally is light colored; it is high in silicon, sodium, and potassium and low in calcium, magnesium, and iron. The second, basalt, usually is black; it is high in calcium, magnesium, and iron and low in silicon, sodium, and potassium.

Most andesitic and rhyolitic lava is concentrated in the Jemez Mountains, an enormous volcanic pile that is one of the world's largest dormant volcanoes. Eruption of the widespread Bandelier tuff 1.1 to 1.4 million years ago is among the youngest events of the Jemez Mountains volcanic complex. The volume of ash from the Bandelier tuff eruption exceeds the May 18, 1980 Mount St. Helens eruption by a factor of 600.

Not surprisingly, this huge volcanic complex is located at the intersection of the Rio Grande rift and the ancient Jemez lineament. For at least the last 10 to 13 million years, this intersection has had a major effect in controlling volcanism.

Geologists believe that the Jemez volcanic rocks originated by melting deep within the crust. Molten rock rose into the shallow crust, forming magma chambers near the surface. Periodic venting from these chambers gave rise to the Jemez Mountains and also emplaced large amounts of heat in the uppermost crust. The Los Alamos National Laboratory's Hot Dry Rock Project at Fenton Hill and Union Geothermal's hydrothermal exploration in the Jemez Mountains now extract this heat.

Basaltic lavas occur along the entire rift as small volcanic fields (Fig. 4), most of which are younger than 5 million years and resulted from relatively short-lived

Fig. 4.

Location of basaltic lava fields (blue) in the Rio Grande rift (yellow).

eruptions. Petrologists study the chemical compositions of these lavas to determine the environment where the lavas originated and how they evolved. Such research on subsurface magma processes enables scientists to characterize the Earth's interior, knowledge essential to geothermal energy exploration and development.

The Rio Grande rift's average heat flow of 2.5 heat flow units is significantly greater than the Earth's average of 1.5 heat flow units. Areas along the rift where the subsurface is hotter than average are prime candidates for geothermal exploration.

Hydrothermal resources (hot water greater than 30°C near or at the surface) and hot springs exist throughout the rift. Some of these areas have been designated known geothermal resource areas (KGRA); that is, areas where hydrothermal reservoirs may exist. The most prominent KGRA within the rift is the Valles Caldera in the Jemez Mountains (Fig. 5).

Fig. 5.

View from Apollo 9 of the Jemez Mountains and Valles Caldera on the western edge of the Rio Grande rift.

Subsurface hot water is not necessary to tap this heat. In the Jemez KGRA, the Los Alamos National Laboratory successfully uses the Hot Dry Rock energy extraction system, by which cool surface water is circulated through artificial fractures far below the surface of the hot rocks.

With current technology, the Rio Grande rift has great geothermal potential that includes space heating and agricultural application, but with electric production limited to the Valles Caldera. However, with improved drilling and instrumentation technology, economic geothermal resources within the rift are sure to increase.

EARTHQUAKE ACTIVITY

Earthquakes along the rift have been noted since 1849, with the most intense period of reported earthquakes occurring in Socorro in 1906 and 1907. These

earthquakes toppled chimneys and cracked adobe walls, forcing many residents to live in tents.

In 1962, the Los Alamos National Laboratory established a seismic net in northern New Mexico to evaluate the risk of earthquakes generated by the Hot Dry Rock experiment at Fenton Hill to facilities in the area. The Los Alamos net augments stations operated by the New Mexico Institute of Mining and Technology and the United States Geological Survey.

According to these seismic net data, most recent earthquake activity occurs in the Socorro and Espanola regions, but is perceptible only instrumentally. Activity recorded from the seismic net in New Mexico represents a mere second in the million-year history of earthquake activity. However, geologic evidence suggests more vigorous mountain building over the last few million years than does the short-term seismic evidence. The discrepancy between this geologic evidence and microseismic activity demonstrates the need for an expanded net and a much longer recording interval.

WHAT NEXT?

The origin and evolution of the Rio Grande rift are related to the late Cenozoic history of the Colorado Plateau and the entire Basin and Range Province of the southwestern United States. Geoscientists recognize that these events derive from the recent plate tectonic history of the western United States margin. However, major aspects of this important concept are understood poorly or not at all. To rectify this lack of understanding, investigators from many government and academic institutions are studying the Rio Grande rift. Because this knowledge is important to national energy and weapons technology, the Los Alamos National Laboratory must remain in the forefront of Rio Grande rift research.

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