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DATA RELATED TO LATE QUATERNARY SURFACE FAULTING ON THE SANGRE DE CRISTO FAULT, RITO SECO SITE, COSTILLA COUNTY, COLORADO

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INTRODUCTION

The Sangre de Cristo fault is a major, north-northwest-striking, west-dipping normal fault located about 250 km south of Denver, Colo., (fig.1*A*) that separates the Sangre de Cristo Mountains to the east from the San Luis Valley to the west. It extends from Poncha Pass (PP, fig. 1*B*) southward along the range front, through Great Sand Dunes National Park, and into northern New Mexico as far south as Taos. It is the longest fault in Colorado that has clear evidence of latest Quaternary faulting (Colman, 1985). Slip on the fault has uplifted the rugged peaks of the Sangre de Cristo Mountains to elevations in excess of 4,300 m from the San Luis Valley to the west, where the elevation ranges between about 2,134 and 2,438 m. Historically, the fault has been seismically quiescent even though large fault scarps are present on Holocene and latest Pleistocene deposits along much of its length (Kirkham and Rogers, 1981; McCalpin, 1982, 1986; Colman, 1985).

Based on the presence of Holocene fault scarps, its 205-km-long length (Widmann and others, 2002), and 5–7 km of net Cenozoic throw (Tweto, 1979; Colman, 1985; Wallace, 2004), the Sangre de Cristo fault could be the most hazardous fault in Colorado, but the history of Quaternary movement on the fault is poorly documented. Recent compilations of Quaternary faults have simply divided the Sangre de Cristo fault into a northern part, which is located in Colorado, and a southern part, which is located in New Mexico (U.S. Geological Survey, 2005). Both parts are further subdivided into sections on the basis of geomorphic and geometric evidence. In Colorado, the fault has been divided into four sections; from north to south, the Crestone, Zapata, Blanca, and San Luis sections (Widmann and others, 2002; U.S. Geological Survey, 2005). The geomorphology of the fault and the adjacent range front suggest that at least two parts of the fault in Colorado have markedly different long-term histories of faulting. The northern part, which includes the Crestone, Zapata, and Blanca sections, is marked by a

steep range front, deeply incised valleys, and abundant fault scarps on latest Pleistocene and Holocene deposits (McCalpin, 1982, 1986; Colman and others, 1985); the range crest is typically 3–8 km east of the fault trace (figs. 1*B* and 1*E*). At the southern end of Blanca Peak (fig. 1*C*), the range front steps abruptly eastward and forms the Culebra reentrant (Wallace, 2004; Kirkham and others, 2005). The San Luis section extends from this step southward to the New Mexico border. Along the San Luis section, the range front is more subdued (figs. 1*C* and 1*F*), and the fault trace is complex (Kirkham and Rogers, 1981). In contrast to the range front to the north, a set of foothills separate the range front from the range crest, and the range crest is typically 13 km to more than 20 km east of the fault trace (fig. 1*F*). Fault scarps are discontinuous and are best expressed on middle and early Pleistocene and older deposits (Colman and others, 1985). Thus, the geomorphology suggests significant differences in Cenozoic fault behavior between the San Luis section and sections to the north and south. There is abundant evidence of latest Pleistocene and Holocene movement along almost all of the Sangre de Cristo fault (McCalpin, 1982, 1986; Kirkham and Rogers, 1981; Menges, 1990; Bauer and Kelson, 2004), but few studies have been able to determine the times of individual prehistoric earthquakes. In particular, the San Luis section of the fault has been largely unstudied in comparison to the sections to the north in Colorado (McCalpin, 1982, 1986; Kirkham and Rogers, 1981) and to the south in New Mexico (Menges, 1990; Bauer and Kelson, 2004).

To better understand the fault's late Quaternary history and seismic hazard, we conducted a paleoseismic study at the Rito Seco site in September 2003 (Crone and others, 2004; Crone and Machette, 2005). The site is located about 5.4 km northeast of the town of San Luis in Costilla County, Colorado (fig. 1*D*). Rito Seco is a large, ephemeral drainage that has deposited Quaternary alluvium of various ages across the trace of the fault (figs. 2*A* and *B*) and thus provides a suitable setting for paleoseismic studies. We excavated a 27-m-long, 3-m-deep trench (RSS) across a 2.7-m-high scarp formed on young alluvium that is inset into older Rito Seco alluvium (figs. 2*B* and 4). About 100 m to the north, we excavated a 32-m-long, 5- to 6-m-deep trench (RSN) across a 6.6-m-high scarp formed on older alluvium (figs. 2*B* and 5). We also excavated a 2.5-m-deep soil pit in the older alluvium on the upthrown side for the fault, about 20 m east of the northern trench (fig. 2*B*). In both trenches, we exposed Tertiary sediment of the Santa Fe Group in the footwall of the fault and Quaternary alluvial gravels in both the hanging wall and footwall. Because we exposed correlative Quaternary gravels on both sides of the fault, we can make accurate measurements of the total vertical displacement of these deposits (figs. 4 and 5).

In this report, we present detailed maps of the trenches and a compilation of field and laboratory data used to support our interpretation of the history of four (PE1–PE4) prehistoric surface-faulting earthquakes at this site (figs. 4 and 5). We will present a detailed discussion of our interpretations in a subsequent report.

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Figure 1*A*. Map showing Cenozoic (yellow) and Quaternary (red) faults and historical earthquakes (orange dots) in Colorado. Image is from the Colorado Geological Survey.

Figure 1*B*. Map showing the Sangre de Cristo Range and San Luis Valley in south-central Colorado. White arrows show location of the Sangre de Cristo fault, which bounds the western side of the range. PP, Poncha Pass. Outline shows area of figure 1*C*. Image obtained from NASA Applied Sciences Directorate Earth Science Enterprise Scientific Data Purchase Program map server at https://zulu.ssc.nasa.gov/mrsid.

Figure 1*C*. Map showing the San Luis section of the Sangre de Cristo fault; dashed red line shows trace of the fault. Outline is location of the Rito Seco study area shown in figure 1*D*. Image obtained from NASA Applied Sciences Directorate Earth Science Enterprise Scientific Data Purchase Program map server at https://zulu.ssc.nasa.gov/mrsid.

Figure 1*D*. Aerial photograph of the Rito Seco study site. Solid red lines show generalized traces of the Sangre de Cristo fault; bar and ball on downthrown side. Dashed fine red line shows probable fault along eastern side of mesa. Outline shows approximate area of most of the geologic site map shown in figure 2*A*. The green triangle labeled WP indicates location of waypoint Ritoseco-Rd 19.5 in table 4.

Figure 1*E*. Oblique view to the east of the Crestone section of the Sangre de Cristo range showing the steep range-front morphology and proximity of the range crest. Image available at http://earth.google.com (last accessed December 2006).

Figure 1*F*. Oblique view to the east of the San Luis section of the Sangre de Cristo range showing the relatively subdued range-front morphology and distance to the range crest. Image available at http://earth.google.com (last accessed December 2006).

Figure 2*A*. Geologic map of Quaternary and Tertiary deposits in the vicinity of the Rico Seco study site overlain on aerial photograph. Red lines show generalized traces of the Sangre de Cristo fault. Outline shows area of detailed site map shown in figure 2*B*.

Figure 2*B*. Geologic map of the Rito Seco site showing locations of trenches, fault scarps, scarp profiles, and GPS waypoints. Scarp profiles are shown in figure 3. Maps of trench walls are shown in figures 4 and 5. GPS data are listed in table 4.

Figure 3. Topographic profiles across fault scarps adjacent to and near trenches at the Rito Seco site. See figure 2*B* for locations. Green diamonds are data points. A man-made canal along the base of the scarp has locally modified the slope profiles, but has not substantially affected measurements of scarp heights or surface offsets. Scarp heights and surface offsets are based on definitions of Bucknam and Anderson (1979).

Figure 4. Map of south wall of trench across Sangre de Cristo fault at the Rito Seco South (RSS) site. Full description of units is given in table 1. Data for luminescence and radiocarbon samples are given in table 5.

Figure 5. Map of south wall of trench across Sangre de Cristo fault at the Rito Seco North (RSN) site. Full description of units is given in table 2. Data for luminescence and radiocarbon samples are given in table 5.

Table 1. Unit descriptions for the Rito Seco South (RSS) trench.

Table 2. Unit descriptions for the Rito Seco North (RSN) trench.

Table 3. Soils data from the Rito Seco trench sites.

Table 4. GPS data and surveying control for the Rito Seco trench sites.

Table 5. Luminescence and radiocarbon sample data for the Rito Seco North (RSN) and Rito Seco South (RSS) trenches.

This map was produced on request, directly from digital files, on an electronic plotter

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