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Caballo fault, Williamsburg section (Class A) No. 2088a

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Compiled in cooperation with the New Mexico Bureau of Geology & Mineral Resources

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Synopsis	**General:** This down-to-the-west normal fault bounds the north-trending, east-tilted Caballo block, south of Truth or Consequences, New Mexico. The fault forms part of the eastern margin of the Palomas Basin, an eastward-tilted, sediment-filled half graben. The fault probably began to uplift the Caballo Mountains in the Miocene, but uplift continued into the Pliocene and Quaternary. The geometry and general movement history of the fault suggest that it has four discrete sections: Holocene fault scarps are present on the Williamsburg (northwestern) and central sections of the Caballo fault. Deposits of the Palomas Formation

	(Pliocene-Pleistocene) and middle Pleistocene to Holocene piedmont-slope deposits are offset along the Williamsburg and central sections of the fault. The northern and southern parts of the fault appear to be of pre-Quaternary age, and thus are not included in the following discussion. About 35 topographic profiles have been measured on the Quaternary age sections to characterize the fault scarp morphology, and two exploratory trenches have been excavated to document the timing of fault movement. **Sections:** This fault has 2 sections. Sections are defined on the basis of geometry, apparent timing of faulting, range-front morphology, and gaps in fault continuity. The Williamsburg (northwestern) and central sections clearly have repeated Pleistocene and Holocene movement, whereas the northern and southern sections do not appear to displace Quaternary deposits, at least as seen in reconnaissance studies. Therefore, only the two Quaternary-age sections [2088a, 2088b] are discussed herein.
Name comments	**General:** The fault is named for the Caballo Mountains. The name appears to have been in common usage by the 1940s and is cited in Kelley and Silver (1952 #1072). However, we have been unable to document the first usage of this fault name. This description includes the Gordon fault, a mountainward fault associated with the Caballo according to Seager and Mack (2005 #1257). **Section:** Herein named the Williamsburg section after the Williamsburg fault (scarp), a 2-km-long scarp on piedmont-slope deposits south and east of the Rio Grande. Williamsburg is a small community on the north side of the Rio Grande, west of Truth or Consequences, New Mexico. Previously called the northern segment of the Caballo fault by Machette (1987 #960) and Foley and others (1988 #991), but this is confusing because there is a main-range bounding (northern) section of the Caballo fault that appears to be inactive (pre-Quaternary). The Williamsburg section of the fault extends from the Rio Grande south and southeast along the western margin of the northern Red Hills (Kelley and Silver, 1952 #1072) where it truncates the southern end of the Hot Springs fault [2100]. To the south, the Williamsburg section joins the central (main) section of the Caballo fault just south of Red Creek. Mapping by Jochems and Koning (2015 #7348) suggests that the Williamsburg section extends northwest across the Rio Grande to join the Mud Springs fault [2101], as originally suggested by Kelley and Silver (1952

	#1072). **Fault ID:** Referred to as fault 9 in Machette (1987 #960) and fault 2 in Machette (1987 #847).
County(s) and State(s)	SIERRA COUNTY, NEW MEXICO
Physiographic province(s)	BASIN AND RANGE
Reliability of location	Good Compiled at 1:24,000 scale. *Comments:* Trace of the fault is from detailed (1:24,000-scale) reconnaissance mapping by Machette (1987 #960) and Foley and others (1988 #991), and from 1:24,000-scale geologic maps of Seager and Mack (2005 #1257), Jochems and Koning (2015 #7348), and Seager (unpub. mapping of Palomas Gap 7.5-minute quadrangle). The geologic map of Kelley and Silver (1952 #1072) does not show this section of the fault, but does project a concealed trace of the Mud Springs fault [2101] south across the Rio Grande to the approximate location of the Williamsburg fault scarp.
Geologic setting	This down-to-the-west normal fault bounds Precambrian, Paleozoic, and Tertiary rocks that are uplifted in the north-trending, east-tilted Caballo block. The fault forms part of the eastern margin of the Palomas Basin, an eastward-tilted sediment-filled half graben. The Caballo fault abuts and truncates the Hot Springs fault [2100] on the north and joins the Red Hills fault [2087] on the south. Quaternary movement on the fault appears to have followed different paths than earlier in the Cenozoic. As a result, the active trace of the Caballo fault is concave to the west, rather than to the east as reflected in the shape of the Caballo Mountains. The Caballo, Hot Springs [2100], Red Hills [2087], and Derry [2086] faults form the western, tectonically active margin of the Caballo uplift (Caballo Mountains, Red Hills, Derry Hills, Round Mountain, and Red House Mountain). Sediment of the Palomas Formation and middle Pleistocene to Holocene piedmont-slope deposits are offset along the northern and central sections of the Caballo fault indicating young movement, whereas the southern section appears to be of pre-Quaternary age.
Length (km)	This section is 8 km of a total fault length of 21 km.

Average strike	N18°W (for section) versus N4°W (for whole fault)
Sense of movement	Normal *Comments:* Kelley and Silver (1952 #1072) considered the fault as normal, but suggested that lateral drag of fabric within Precambrian rocks of the Caballo Range may reflect left-lateral movement on the fault. If such movement occurred, it may date from Cenozoic or older deformation.
Dip	65° W. *Comments:* Approximate dip of fault zone as measured in near-surface exposures along an arroyo that is incised into the Williamsburg fault scarp (Foley and others, 1988 #991, fig. 2.7).
Paleoseismology studies	Site 2088-1. Foley and others (1988 #991) excavated the southern wall of a natural stream-cut exposure across the Williamsburg scarp (trench 1 of Foley and others, 1988 #991). This exposure revealed evidence for 3 or 4 surface-faulting events that produced a total of 5.0–5.5 m of offset in the past 150–250 k.y. The two older events yield a net offset of 2.5–3.0 m and are recorded by faulted packages of gravel and loess, each of which is capped by moderately well-developed calcic soil (in loess). Calculations of the amount of secondary carbonate in these soils yields soil-accumulation times of 140–150 k.y. each for a total of nearly 300 k.y., which exceeds the stated probable age of the alluvial surface. The next younger event(s) are evidenced by a package of fault-scarp colluvium that is intercalated with eolian sand. Uncertainties about the origin of these deposits led Foley and others (1988 #991) to suggest one Holocene faulting event of about 2.6 m offset, or two smaller offset events. If there were two events, they were most likely both in the Holocene because there is no discernible soil between the two fault-related deposits. The most recent event is known to be older than 1.6 ka on the basis of unfaulted sediment containing charcoal collected from the exposure.
Geomorphic expression	This section of the fault is marked by a nearly continuous, 2-km-long fault scarp that is formed on an extensive piedmont surface underlain by Tortugas (?) alluvium (Foley and others, 1988 #991), which is graded to a position 25–50 m above the Rio Grande. South of Sec. 9 (T. 13 S., R. 4 W., Williamsburg 7.5-minute quadrangle), the fault forms discontinuous scarps in an irregular

	pattern as they track around the west margin of the northern Red Hills (Jochems and Koning, 2015 #7348; unpublished mapping by Seager). Much of the trace of the fault in this area is obscured by stream erosion. The fault places bedrock against Quaternary sediment and the few remnant scarps are the product of a long history of offset and stream erosion. At Red Canyon, two fault strands cross alluvial terraces and define a minor horst. The easterly strand continues southeast toward the central section [2088b] of the Caballo fault, but the scarps are poorly preserved on high-level piedmont slope deposits. These faults could provide a structural connection between the two active sections [2088a, 2088b]. The scarps appear to face northeast and southwest, and this change in downthrown direction may reflect a component of lateral slip, rather than the predominant normal slip component seen elsewhere. The northern section probably joins the central section approximately 2 km north of Red Canyon (Palomas Gap Creek). The Williamsburg scarps are 4.0–6.4 m high (3.5–6.2 m of surface offset) and there is a thick mantle of eolian sand that buries the lower part of the scarp in many places. This mantle of sand complicates interpretations of scarp morphology. Nevertheless, four scarp profiles measured by Foley and others (1988 #991) showed evidence of compound slopes and multiple faulting events. The youngest element of the scarps are about 2–3 m high and have maximum slope angles of 18°–26°, which suggested a possible age of less than 5 ka.
Age of faulted surficial deposits	This section of the fault displaces sediment of the Camp Rice Formation, and piedmont-slope deposits associated with the Tortugas (150–250 ka) and Picacho (50–150 ka) alluviums according to Foley and others (1988 #991). In addition, Holocene colluvium and eolian sand are offset in a natural exposure across the Williamsburg scarp. Despite strong evidence for middle to late Holocene rupture, Mack and others (2011 #7349) note that four packages of Rio Grande terrace alluvium deposited between 0.2 and 12 ka do not indicated eastward tilting (i.e., toward the Williamsburg fault).
Historic earthquake	
Most recent prehistoric	latest Quaternary (<15 ka)

deformation	*Comments:* The most recent event is considered to be younger than 5 ka on the basis of scarp-morphology studies (Machette, 1987 #960); furthermore, the most recent event is known to be older than 1.6 ka on the basis of radiocarbon dating of charcoal collected from unfaulted deposits (Foley and others, 1988 #991).
Recurrence interval	*Comments:* The following is based on data presented by Machette (1987 #960) and Foley and others (1988 #991). Their recurrence interval was based on calculated duration of soil formation, which reflects tectonic stability between the faulting events. The soils have estimated accumulation times of 140–150 k.y. each for a total of nearly 300 k.y., which exceeds the stated probable age of the Tortugas alluvial surface (150–250 ka). If the surface of the Tortugas alluvium stabilized as recently as 150 ka (as Foley suggested), then the average recurrence interval is 75 k.y.; conversely, if the Tortugas alluvium is 250±50 ka (upper age limit), then the average recurrence interval is nearly twice as long. However, there also is evidence for two surface-faulting events that possibly occurred in the Holocene, resulting in shorter recurrence than reflected by the long-term average.
Slip-rate category	Less than 0.2 mm/yr *Comments:* Foley and others (1988 #991) calculated vertical displacement rates of 0.02–0.03 mm/yr for the post-250 ka surfaces along the northern and central sections of the fault. Data from the natural exposure further north (5.0–5.5 m of net offset in the past 150–300 k.y.) suggest similar slip rates.
Date and Compiler(s)	2016 Michael N. Machette, U.S. Geological Survey, Retired Andrew P. Jochems, New Mexico Bureau of Geology & Mineral Resources
References	#991 Foley, L.L., LaForge, R.C., and Piety, L.A., 1988, Seismotectonic study for Elephant Butte and Caballo Dams, Rio Grande Project, New Mexico: U.S. Bureau of Reclamation Seismotectonic Report 88-9, 60 p., 1 pl., scale 1:24,000. #7348 Jochems, A.P., and Koning, D.J., 2015, Geologic map of the Williamsburg 7.5-minute quadrangle, Sierra County, New Mexico: New Mexico Bureau of Geology and Mineral Resources Open-File Geologic Map 250, scale 1:24,000.

#1072 Kelley, V.C., and Silver, C., 1952, Geology of the Caballo Mountains: University of New Mexico Publications in Geology 4, 286 p., 9 pls.

#847 Machette, M.N., 1987, Preliminary assessment of paleoseismicity at White Sands Missile Range, southern New Mexico—Evidence for recency of faulting, fault segmentation, and repeat intervals for major earthquakes in the region: U.S. Geological Survey Open-File Report 87-444, 46 p.

#960 Machette, M.N., 1987, Preliminary assessment of Quaternary faulting near Truth or Consequences, New Mexico: U.S. Geological Survey Open-File Report 87-652, 40 p.

#7349 Mack, G.H., Leeder, M., Perez-Arlucea, M., and Durr, M., 2011, Tectonic and climatic controls on Holocene channel migration, incision and terrace formation by the Rio Grande in the Palomas half graben, southern Rio Grande Rift, USA: Sedimentology, v. 58, p. 1065–1086.

#1257 Seager, W.R., and Mack, G.H., 2005, Geology of Caballo and Apache Gap quadrangles, Sierra County, New Mexico: New Mexico Bureau of Geology and Mineral Resources Geologic Map 74, 1 sheet, scale 1:24,000.