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Leland H. Gile

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Late Holocene displacement along the Organ Mountains fault in southern New Mexico—a summary

by *Leland H. Gile*, formerly (now retired) Soil Scientist, Soil Survey Investigations, SCS–USDA, Las Cruces, NM 88001

Introduction

This article summarizes a study of soils and geomorphology along a segment of the Organ Mountains fault. The study indicates that the latest displacement along the fault took place about 1,000 years ago, and that maximum displacement was about 15 ft. The fault, which may be one of the youngest in New Mexico, must have been accompanied by severe and extensive earthquake activity. Although New Mexico contains abundant evidence of faulting, most of it apparently has not taken place in geologically recent time. This aspect needs further study because of the greatly increased significance of potential for earth movement and its effects on urban development and storage of hazardous wastes. Because many faults show evidence of repetitive long-term faulting in the same place, studies are also needed on the chronology and prediction of faulting and the earthquakes that accompany it.

The Organ Mountains fault occurs along the eastern side of the San Andres and Organ Mountains in southern New Mexico (Seager, 1981). Alluvial fans of several ages have been displaced by the fault. This feature is well shown at the Cox Ranch (Fig. 1), about 3.5–4.5 mi south of US–70. Here the fault and the chronology of movement are of particular interest because the White Sands Missile Range Headquarters are only about 1 mi downslope. The studied segment of the fault is designated the Cox segment, after the historic Cox Ranch house located on the upthrown side of the fault.

Soil parent materials are dominantly monzonite sediments; smaller amounts of andesite are also present. Most of the materials contain abundant rock fragments that range in size from pebbles to boulders and were deposited as debris flows. Other materials

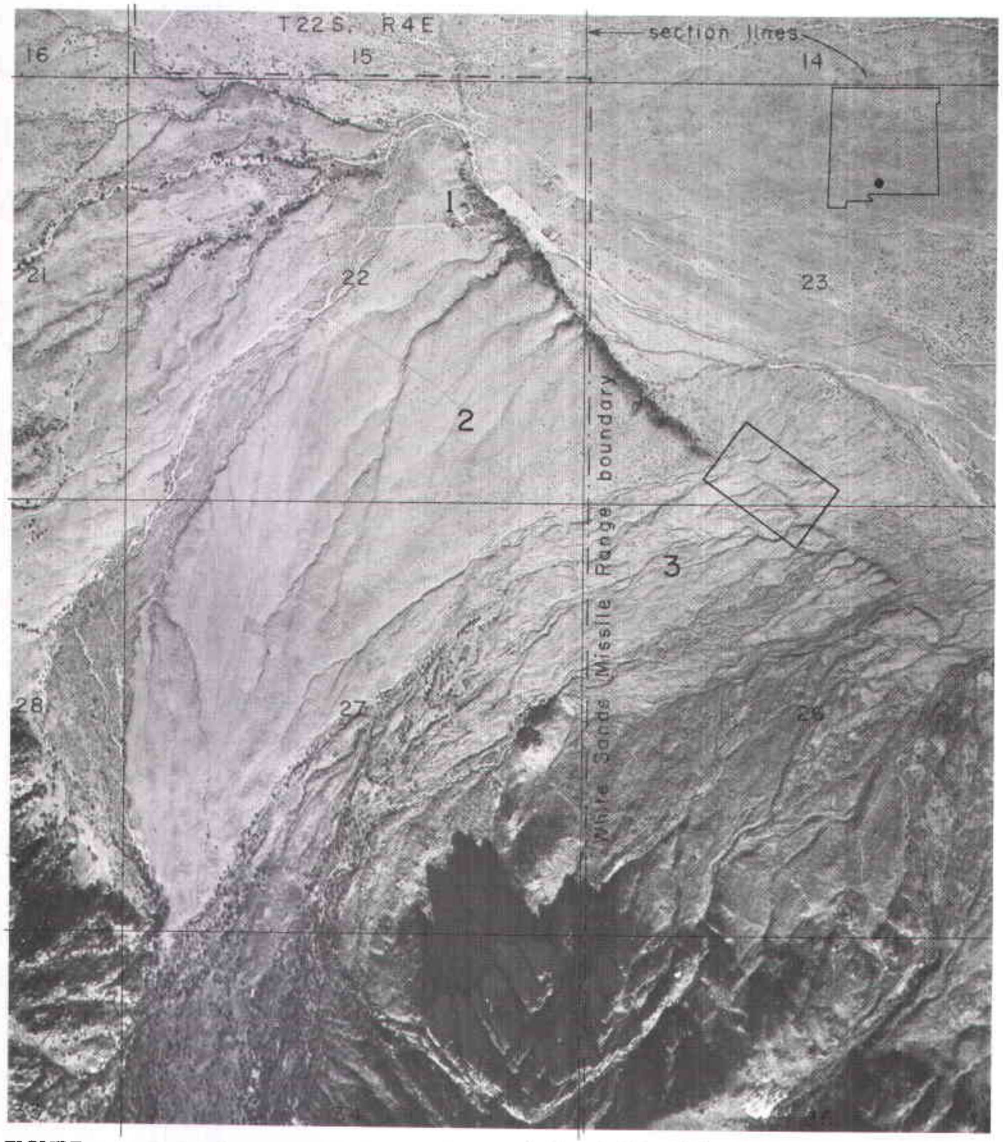

FIGURE 1—1942 aerial photograph showing features in the vicinity of the study area. **1** = Cox Ranch house; **2** = large alluvial fan, dominantly Jornada I (late middle Pleistocene age); **3** = ridges and terraces, dominantly Organ (middle and late Holocene age). The rectangle at right center locates the area of detailed study; it is about 1,390 × 855 ft. The Cox segment of the Organ Mountains fault is the prominent linear feature that extends southeast from just below the Cox Ranch house. The section, township, and range numbers were added to assist with exact location of the study area.

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contain virtually no large rock fragments and are water-laid deposits. The debris flows are useful in studies of soils because, as soil parent materials, they tend to be relatively uniform.

The chronological approach—a model from the Desert Project

The chronological problem of latest displacement is approached by comparing soils and soil–geomorphic relations at the fault with those at the nearby Desert Soil–Geomorphology Project, a study of soil and landscape evolution west and north of the Organ Mountains divide (Hawley, 1975a; Gile and Grossman, 1979; Gile et al., 1981). Piedmont-slope geomorphic surfaces, similar to those at the Desert Project (Ruhe, 1967; Hawley, 1975b; Table 1), are also present on the east side of the mountains.

In many arid regions there is widespread evidence of erosion and deposition caused by past changes in climate, particularly by long severe droughts that followed cooler periods with more effective moisture. Thus, episodes of climatically controlled erosion and deposition provide both discrete deposits and (where the deposits can be dated) a chronology that is independent of faulting and the sedimentation associated with it. Buried charcoal in such deposits has been dated by ^{14}C methods at the Desert Project (Gile et al., 1981).

Soil morphology can be used to distinguish deposits of different ages if the morphological range of soils that have formed in the deposit has been determined. Both the faulting event and the deposits caused by faulting can then be placed in this chronological framework. In making the morphological comparisons, allowance must be made for differences in such factors as parent materials and climate because differences in these factors can have major effects on soil morphology.

^{14}C ages of buried charcoal found in the Desert Project provide good chronological control on sediments and soils of middle and late Holocene age, both on the western piedmont slope of the Organ Mountains and along the Rio Grande valley. The approximate time of latest displacement at the Cox segment is indicated by comparison of the soils and soil–geomorphic relations there with those of the Organ (piedmont slope) and Fillmore (Rio Grande valley) surfaces, the youngest parts of which are of late Holocene age.

Organ sediments occur in a nearly continuous deposit bordering the mountain fronts. The remarkable ubiquity of Organ deposits in areas accessible to Holocene sedimentation is strong evidence for climatic change as the main cause of Organ alluviation. Organ sediments occur downslope of all mountain ranges in the area, even the small ones. Past changes to warmer and drier climates should have decreased vegetative cover, which would tend to cause soil erosion.

Three ages of Organ alluvium were dated by eight lenses of buried charcoal at the Gardner Spring radiocarbon site, on the upper piedmont slope in the Desert Project (Gile and Hawley, 1968; Gile, 1975; Table 1). Buried charcoal in the lower part (but not the base) of Organ I alluvium has been dated at about 6,400 years B.P. Thus, the beginning of Organ erosion and sedimentation is thought to coincide approximately with the onset of the warm, dry Altithermal interval, which lasted from about 7,500 to 4,000 years B.P. (Antevs, 1955). Organ II and III alluviums indicate at least two drought-caused deposits since the Altithermal interval ended. In contrast, a climatic shift to a cooler, moister interval, the Little Ice Age, began in the southwestern United States in the 14th century (Fritts, 1976).

TABLE 1—Geomorphic surfaces and soil age of the upper piedmont slope in the Desert Project. The age of the geomorphic surface and its soils is considered to be the same. On a constructional surface, for example, all would date from the approximate time that sedimentation stopped and soil development started. All surfaces except the Doña Ana have been observed in the vicinity of the Cox segment. Years B.P. = years before 1950, following the custom for reporting radiocarbon ages.

Geomorphic surface	Soil age (years B.P. or epoch)
Arroyo channels	Historical (since 1850)
Organ	100–7,000
III	100(?)–1,100
II	1,100–2,100
I	2,200–7,000
Isaacks' Ranch	Earliest Holocene–latest Pleistocene (8,000–15,000)
Jornada II	Late Pleistocene (25,000–75,000)
Jornada I	Late middle Pleistocene (250,000–400,000)
Doña Ana	Early to middle Pleistocene (>400,000)

All soils at Gardner Spring are strongly calcareous throughout because of high-carbonate parent materials (primarily limestone), and they lack the noncalcareous, reddish-brown Bt horizons in many soils of Organ age with low-carbonate parent materials. The latter soils are illustrated at the Isaacks' radiocarbon site south of Gardner Spring, where two buried charcoal lenses were dated at about 4,000 and 4,200 years B.P. (Gile, 1975). At both places the charcoal occurred in C horizons beneath reddish-brown Bt horizons of about 6YR hue that in places laterally grades to 5YR. Because the alluvium above the charcoal must be younger, it could fall within the age range of Organ II alluvium, which is at least 1,100 years old, but not older than about 2,100 years (Table 1). This range in age would also apply to alluvium of much of the younger part of the extensive Fillmore surface, where charcoal beneath it has been dated at about 3,960, 3,750, 2,850, and 2,620 years B.P. Archaeological evidence indicates that large areas of the Fillmore surface were stabilized by about 1,000 years B.P.; therefore, the minimum age for much of the Fillmore is similar to that of Organ II alluvium. These chronological relations suggest regional significance for a period of drought-caused erosion and deposition between about 1,000 and 2,000 years B.P.

Soils and sediments of the Fillmore surface also provide evidence for the time required for the development of reddish-brown Bt horizons. Most soils of the Fillmore surface occur in less stable landscape positions because of erosion associated with downcutting of the Rio Grande valley, and they are more arid than most soils of the Organ surface. Nevertheless, soils that have formed in low-carbonate parent materials at the stablest sites have distinct, though thin, reddish-brown Bt horizons of 5YR hue and are 1,000–2,000 years old.

Soils and sediments in the age range of Organ III, although not identified at the Isaacks' radiocarbon site, have been observed at various places. Soils with thick, dark A horizons, but without reddish-brown Bt horizons, occur in the youngest landscape positions adjacent to arroyos (low, young terraces) on the upper piedmont slope. These soils have formed in the youngest Organ sediments and would fall within the age range of Organ III (about 100–1,100 years B.P.).

Soils, sediments, and chronology at the fault

Above the fault scarp at the Cox segment (Fig. 1), Organ sediments occur in a situation that is very common in the Desert Project:

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they are inset against older, higher sediments of the Jornada I and II surfaces (Table 1). The three Organ alluviums dated at Gardner Spring have also been identified at the Cox segment. Organ I alluvium is an important part of the chronological framework for the middle and late Holocene at the fault, but it is not involved in determining the time of latest displacement, which is established by Organ III and II alluviums and their soils.

Soils of Organ III age (100–1,100 years B.P.)

Organ III sediments occur in two ways along and below the fault: as terraces inset against higher Organ II ridges and as sediments along and below the fault scarp that truncates the Organ II ridges. Two levels of terraces are apparent in Organ III alluvium. The higher and older of the two is designated early Organ III; the lower one is designated late Organ III. The terraces differ only slightly in elevation, and their soils are about the same: they have thick, dark A horizons, but no reddish-brown Bt horizons. The Organ III terraces cross the fault zone and are unfaulted.

Soils of the Organ III terraces have thick, dark A horizons with substantial accumulations of organic carbon. Distinctly higher percentages of clay, silt, fine sand, and very fine sand occur above the C horizon than in it, indicating accumulations of these components since soil development began. Position of the accumulations above the C horizon, youth of the soils, and dust trap studies at the Desert Project indicate that parts of these components were derived from dustfall. The debris-flow materials, with abundant large rock fragments throughout, constitute a natural and efficient dust trap because the surficial fragments would help to trap the dustfall and because those deeper in the soil would concentrate the fine earth that is analyzed in the laboratory. Similar percentages of fine sand, very fine sand, and silt in soils of both Organ III and I age suggest that input of these components from dustfall rapidly decreases when their buildup in the soil reaches a critical level. However, clay content increases progressively in the soils of Organ II and I, indicating longer movement of dust-derived clay into the soils.

The transition from the dark A horizon to the lighter-colored C horizon is characterized by significant changes in soil structure, consistence, and texture. As clay, silt, and the finer sand fractions decrease with depth, the massive, soft, loamy sand that dominates the A horizon gradually changes to the single grain, loose sand of the C horizon. These changes illustrate the effect of dustfall additions on soil properties at considerable depth in the soil: enough clay, silt, and the finer sand fractions have accumulated to slightly bind the soil materials together, constituting an important transitional stage in soil development to the older soils of Organ II.

The scarp landscape consists of three contrasting features that also differ in age: the moderately sloping alluvium of Organ II age, along the upper edge of the steep scarp; the scarp itself, of Organ III age, mantled by cobbles and stones; and, below the scarp, moderately sloping sediments of late Organ III age, with a surface largely free of rock fragments (Fig. 2). Sediments beneath the scarp and beneath the area below it also differ. Beneath the scarp, abundant large rock fragments occur throughout; beneath the surface below the scarp, fine earth dominates. The large rock fragments of the scarp constitute scarp colluvium that accumulated immediately after displacement. The fine-earth zone just downslope from the scarp overlaps it in part, is younger, and in places is still accumulating.

Soils of Organ II age (1,100–2,100 years B.P.)

Soils of the Organ II ridges have thin A horizons and thick, reddish-brown Bt horizons dominated by sandy loam texture, thus contrasting with the soils of Organ III, which have thick A horizons dominated by loamy sand texture. Because of increased clay and silt, consistence of the Bt horizon is slightly hard in contrast to soft consistence of the thick A horizon in the soil of Organ III. However, relative youth of the Organ II soils is indicated by the small size of the clay increase from A to Bt horizon (usually about 3–4%). The close relation of such clay curves to soil age has been shown for soils formed in similar materials at the Desert Project, and a similar relation to age would be expected in this area if older soils were fitted into the developmental scheme.

Significant changes in color have taken place in the soils of Organ II. Hues have reddened to 5YR in much of the Bt horizon, showing that reddening from the C horizon hue of 7.5YR to 5YR can occur in only 1,100–2,100 years. The reddening is attributed to slight weathering of biotite and hornblende (in the monzonite and andesite parent materials) in the upper part of the A horizon and subsequent movement of iron, along with the clay, into the Bt horizon. As with the soils of Organ III, a striking change in soil structure, consistence, and texture is evident towards the C horizon. The massive, soft, loamy sand or sandy loam in the lower part of the Bt horizon gradually changes to the single grain, loose sand of the C horizon.

Changes due to weathering of large rock fragments also have taken place. In the soils of Organ II, some of the component crystals, ☞

FIGURE 2—View of the fault scarp and one of the study trenches. Note the contrast between the scarp zone, with its numerous rock fragments and dense vegetation, and the area below the scarp, which has fewer rock fragments and less vegetation. Soils in Organ II alluvium occur at the tape in the upper end of the trench. About 1.5 ft this side of the tape, the distinct reddish-brown Bt horizon of the soils in Organ II alluvium abruptly disappears. Disappearance of the Bt horizon and the increase in slope along the scarp zone mark the boundary between Organ II alluvium and the scarp colluvium of early Organ III age. Soils in the scarp colluvium have thick, dark A horizons and no Bt horizons. Soils below the scarp (right foreground) are in late Organ III alluvium. They have A horizons with less organic carbon than soils in the scarp colluvium and no Bt horizons. The tape is about 5 ft long. The Organ Mountains are in the background.

or groups of crystals, of individual rock fragments (commonly pebbles or cobbles) are so loose that they would have separated in transport before being deposited. Thus, the weathering must have occurred after the materials were deposited and must have been caused by soil moisture because the soils are moistened to substantial depths. Rock fragments weathered in this way are in the minority, however; most fragments are so hard that they are broken with a hammer only with difficulty, indicating that only a few of the fragments were strongly weathered before they were transported. The weathering appears to be physical rather than chemical because interiors of the rocks appear fresh and there is little or no visible clay. Presence of these weathered rocks in soils of Organ II age, but not Organ III age, indicates that such weathering can occur in a minimum time ranging from about 1,100 to 2,100 years.

Time and amount of latest displacement

Because Organ II sediments have been displaced along the fault, the latest displacement must be younger than some time within the age range of Organ II, namely 1,100–2,100 years B.P. Just above the scarp, Organ II sediments have a distinct reddish-brown Bt horizon that abruptly disappears below the crest of the scarp and that does not occur in the scarp colluvium below. Weathered rock fragments, a distinct feature in the soils of Organ II alluvium, are also conspicuously absent from the scarp colluvium. Soils of the scarp colluvium are similar to soils of the Organ III terraces. This combination of soil and geomorphic evidence indicates that the displacement took place at somewhat less than the minimum time in the age range of Organ II, or less than about 1,100 years B.P. and within the age range of Organ III.

Organ III sediments have a chronological range of 100–1,100 years. Extension of the highest Organ III terraces across the fault zone indicates that the displacement must have taken place in earliest Organ III time, and, for this reason, the time of the latest displacement is estimated to be about 1,000 years B.P. The amount of displacement was estimated by slope extrapolation from a downdropped Organ II remnant below the fault. Maximum displacement is estimated to be about 15 ft.

ACKNOWLEDGMENTS—I am indebted to Bill Seager for informing me about the chronological problem of latest displacement along the Organ Mountains fault. The study was greatly aided by the interest and assistance of Rob Cox, who graciously expedited access to the fault and provided precipitation data. Initial investigations began in 1978, but due to the pressure of other work it was impossible for me to return to the fault until the fall of 1983. I thank LeRoy Daugherty and Carol Taschek for arranging the initial excavations and John Hawley for making arrangements for me to resume investigations in 1983. John Hyndman, of White Sands Missile Range, provided valuable assistance in arranging security clearance and in obtaining aerial photographs of the fault. I thank the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) for financial support of the study and Director Frank Kottlowski for his interest and support. I am grateful to John Hawley and Bill Seager for reviewing the manuscript and to Deborah Shaw for helpful editorial comments. Finally, many thanks go to my wife, Dora, for typing the manuscript. The manuscript from which this summary was drawn is currently being processed and will be published by NMBMMR as Bulletin 116.

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Geographic names

U.S. Board on Geographic Names

Bluff Tank—tank, along a tributary of the stream flowing through Leggett Canyon, 1.6 km (1 mi) west–northwest of Pine Lawn; Catron County, NM; sec. 34, T7S, R20W, NMPM; 33°39′31″ N, 108°53′33″ W; *not*: Pine Lawn Tank.

Carrizo Canyon—canyon, 45 km (28 mi) long, heads at 36°34′23″ N, 107°17′06″ W, at the junction of Ciruelas Canyon and Arroyo Compañero, trends west–northwest to Cañon Largo 26 km (16 mi) southeast of Bloomfield; Rio Arriba and San Juan Counties, NM; sec. 17, T28N, R8W, NMPM; 36°39′43″ N, 107°42′30″ W; 1965 decision revised; *not*: Canon Cereza, Canyon Cereza, Carrizo Creek, Cereza Canyon (BGN 1965).

Encinada Mesa—mesa, 30.5 km (19 mi) long and 12.9 km (8 mi) wide, bound on the west by Cañon Largo, on the south by Tapicito Creek, on the east by Albert Canyon, and on the north by Carrizo Canyon, 27 km (17 mi) North of Counselor; encinada is Spanish for "group of oaks"; Rio Arriba and San Juan Counties, NM; 36°37′23″ N, 107°39′38″ W (northwest end), 36°28′54″ N, 107°24′45″ W (southwest end); *not*: Ensenada Mesa.

Little Round Mountain—summit, elevation 1,686 m (5,532 ft), 6.1 km (3.8 mi) southwest of Spurgeon Mesa and 51 m (32 mi) northeast of Clifton, Arizona; Catron County, NM; T10S, R21W, NMPM; 33°26′22″ N, 108°58′48″ W; *not*: Round Mountain.

Little Round Mountain Tank—tank, west of Little Round Mountain and 51 km (32 mi) northeast of Clifton, Arizona; Catron County, NM; T10S, R21W, NMPM; 33°26′15″ N, 108°59′00″ W; *not*: Round Mountain Tank.

Lower Gut Ache Tank—tank on the southeast side of Gut Ache Mesa, 56 km (35 mi) northeast of Clifton, Arizona; Catron County, NM; sec. 20, T9S, R20W, NMPM; 33°30′33″ N, 108°55′30″ W; *not*: Gut Ache Mesa Tank.

Peralta Ridge—ridge, 12.9 km (8 mi) long, extends south from the peak Las Conchas to Tres Cerros 20.9 km (13 mi) southeast of Los Alamos; Sandoval County, NM; Tps. 17N and 18N, R4E, NMPM; 35°48′34″ N, 106°31′10″ W (north end), 35°42′16″ N, 106°32′15″ W (south end).

Pyramid Mountain—peak, elevation 1,521 m (4,990 ft), 1.1 km (0.7 mi) north of the east end of Circle S Mesa and 26 km (16 mi) southwest of Tucumcari, NM; descriptive name applied by geologist Jules Marcou during the Whipple Pacific Railroad Expedition along the 35th parallel in 1853; Quay County, NM; sec. 19, T9N, R29E, NMPM; 34°59′08″ N, 103°54′21″ W; *not*: Crazy Peak, Crazy Woman Butte, Lovers Peak.

Round Mountain—summit, elevation 1,730 m (5,676 ft), 6.7 km (4.2 mi) southwest of Spurgeon Mesa and 50 km (31 mi) northeast of Clifton, Arizona; Catron County, NM; T10S, R21W, NMPM; 33°25′37″ N, 108°58′33″ W.

Twin Sister Tank Number One—tank, on Cradle Mesa, 51 km (32 mi) northeast of Clifton, Arizona; Catron County, NM; T10S, R21W, NMPM; 33°26′58″ N, 108°59′20″ W; *not*: Cradle Mesa Tank Number One.

Twin Sister Tank Number Two—tank, on Cradle Mesa, 51 km (32 mi) northeast of Clifton, Arizona; Catron County, NM; T10S, R21W, NMPM; 33°26′56″ N, 108°59′04″ W; *not*: Cradle Mesa Tank Number Two.

Upper Gut Ache Tank—tank, on the north end of Gut Ache Mesa, 56 km (35 mi) northeast of Clifton, Arizona; Catron County, NM; sec. 17, T9S, R20W, NMPM; 33°31′32″ N, 108°55′03″ W; *not*: Kelly Tank Number One.

—David W. Love
NMBMMR correspondent