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ORIGIN AND HAZARD IMPLICATIONS OF A MATRIX-FREE BOULDER DEPOSIT ON THE EAST FLANK OF THE ORGAN MOUNTAINS, SOUTH-CENTRAL, NEW MEXICO

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Abstract—A boulder deposit on an alluvial fan on the east flank of the Organ Mountains is of special interest due to the large size of the clasts it contains and the lack of any matrix. The boulders are rounded, nearly equidimensional, as much as 10 ft in maximum diameter and composed of igneous rock types. As various aspects of the setting rule out primary matrix-free origins (talus, rock-glacier, boulder-flow or sieve deposition) and transport of such large clasts is unlikely without mud, secondary removal of the finer fraction seems likely. The deposit is, therefore, concluded to be a debris flow from which the matrix has been completely flushed by repeated washings during the larger flow events in the adjacent channel of Ash Canyon. The feature appears to be young, post-dating a Holocene fault whose scarp localized its formation. Such deposits attest to the flash-flood hazard in the area.

INTRODUCTION

Although the east flank of the Organ Mountains provides a variety of interesting geomorphic features, access is normally restricted to those portions lying outside White Sands Missile Range. However, I was able to investigate a large matrix-free boulder deposit on the base while stationed there (Fig. 1). Discovering the origin of this deposit became especially intriguing as Lovejoy (1972) had just described a new type of primary matrix-free boulder deposit in the Franklin Mountains, only 30 mi to the south. The purposes of this paper are to (1) describe the deposit, (2) suggest its probable origin, and (3) discuss its implications for geologic hazards in the area.

The geology of the area was mapped by Dunham (1935) and Seager (1981). The upper channel and tributaries of Ash Canyon drain Tertiary quartz-monzonite terrain, whereas the lower portion crosses various rocks of the Precambrian basement complex. Ash Canyon cuts through the scarp of the prominent north–south-trending structure named the Organ Mountains fault by Seager (1981). The fault cuts the toes of fans along the west side of the Tularosa Basin for more than 60 mi and is locally buried by younger alluvium (Beehner, 1990)..

The climate of the area is semiarid. Scott (1976) reported that the average annual precipitation at the White Sands Missile Range headquarters for the period 1950–1969 was slightly over 10 in. Most precipitation occurs during a 3-month rainy season (July through September). Class-A pan evaporation is 100 in./yr or 10 times the precipitation.

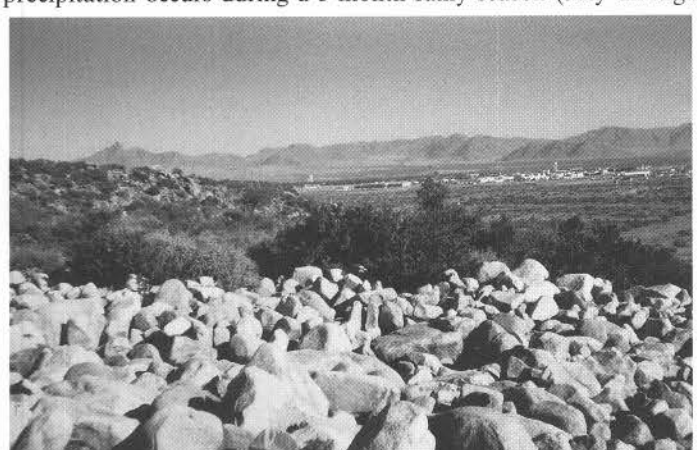

FIGURE 1. General view to the northeast across a portion of the Ash Canyon boulder deposit; note White Sands Missile Range post area in the distance.

Average annual runoff for 1950–1969 was reported to be 0.016 in. or only about 0.2% of rainfall (Scott, 1976). However, rainfall events in the area can be intense and runoff associated with individual storms can be great. For example, a storm in Las Cruces on 29 and 30 August 1935 yielded some impressive intensities: 2.5 in. in 30 min, 4 in. in 2 hrs, 5 in. in 3 hrs, and nearly 6 in. in 4 hrs. The official total rainfall was 6.46 in., but private gages reportedly received 8.0 to 10.0 in. (J. Mueller, personal commun., 1998). According to Houghton (1972), this storm represents the greatest 24-hr local rainfall on record.

THE DEPOSIT

The boulder deposit occurs on the alluvial fan associated with Ash Canyon, in SE¼ NW¼ sec. 31, T22S, R5E, approximately 1 mi south of the main post complex of White Sands Missile Range (Davies Tank 7.5' topographic quadrangle). More specifically, the deposit rests on the smaller secondary fan formed downslope of the Organ Mountains fault scarp (Fig. 2). Boulders extend not only along and downslope of the fault scarp, but also within Ash Canyon arroyo, upslope of the fault. Although the deposit occupies the highest point on the secondary fan, at an elevation of approximately 4300 ft, it still lies 10 to 20 ft below the major fan surface.

In plan view, the deposit has a lobate or tongue-like shape. The edges of the deposit are somewhat diffuse and indistinct (Fig. 2). It covers approximately 6000 ft^2 and has an average width of 60 ft and an average length of 100 ft. The thickness of the deposit probably does not exceed 15 ft. The feature is currently being dissected by flow from Ash Canyon.

The boulders are composed of various igneous rock types. They are rounded and have more or less equidimensional shapes. Few have maximum diameters less than 1 ft; most are 2–4 ft in maximum dimension. The largest boulder seen measured 3 ft x 5 ft x 10 ft (Fig. 3). The clasts are so loosely packed and matrix free that one can, in places, slip down between them and walk among the boulders at ground level.

The age of such a deposit is difficult to determine; however, its general position and character attest to its geologic youthfulness. It post-dates the faulting that produced the prominent scarp where it is localized. A study of this fault on the Cox Ranch, 3 mi to the north, suggests that displacement took place as recently as 1000 yrs B.P., based on soil, geomorphic, and stratigraphic evidence (Gile, 1987).

FIGURE 2. Aerial view of the Ash Canyon boulder deposit (U.S. Army photo).

POSSIBLE ORIGINS

The hypotheses regarding the origin of the deposit are limited. Either it consisted only of boulders when laid down (primary matrix-free deposit), or it originally consisted of a mixture of boulders and some finer-grained matrix that has subsequently been flushed away (secondary matrix-free deposit). Topography rules out a rock-fall (talus) origin, and elevation rules out an ice-creep (rock-glacier) origin. Primary matrix-free origins possible in this setting are, therefore, limited to boulder flow and sieve deposition. The main secondary matrix-free origin is that of a flushed debris flow.

Boulder flow

Lovejoy (1972) applied the term "boulder flow" to an extensive primary matrix-free boulder deposit in Tom Mays Park Canyon in the northern Franklin Mountains, El Paso County, Texas. He graciously took me to examine the deposit and to learn first-hand his understanding of its origin. The boulders consist almost entirely of rhyolite and have an average diameter of less than 1 ft. Based on associated fossil snails, Metcalf (1969) assigned the deposit a Wisconsin age.

The surface morphology of the boulder flow is of particular interest. The deposit has a hummocky surface, characterized by hemispherical depressions as much as 20 ft in diameter and 6 ft in depth. Tongues of finer gravel extend from the centers of the depressions across their downslope rims. These depressions were described as "elutriation orifices." That is, high-intensity storms produce more water than the canyon can get rid of quickly, owing to the impermeable bedrock beneath the canyon. In places, the flood water saturating the bouldery fill bursts to the surface forming the depressions and the downstream tongues of finer clasts. Presumably, such features form early in a high-intensity flow event; the location of the surface bursts may be controlled by bedrock highs beneath the canyon fill.

Lovejoy considered boulder flow to be a heretofore unrecognized slope process, involving what he termed "rock-fragment wet flow." He concluded that the Tom Mays Park Canyon deposit was caused by "...major flash flood deposition of rock-fall talus-slope accumulations, resulting from intense frost action, in a regimen originally suited to the transport of products of a normally arid, frost-free climate" (Lovejoy, 1972, p. 3501). The absence of matrix was attributed to the lack of mud generation during weathering in the source area.

Sieve deposition

Hooke (1967, p. 438) proposed the term "sieve deposit" for masses of coarse material deposited in response to the complete infiltration of the runoff waters carrying them. Such deposits are lobate and resemble debris-flow deposits, but lack a mud matrix. They are restricted to alluvial fans deficient in fine sediment.

Debris-flow with subsequent flushing

Debris flows are masses of rubble, moving as plastic, tongue-like bodies of boulders, mud, and water, in various proportions. These features result from ephemeral flow events and are thus common on alluvial fans in arid regions.

A matrix-free boulder deposit could be formed by the repeated washing away of the finer fraction of a debris flow until only the coarse clasts remain. Such flushing would be facilitated if the debris flow is situated adjacent to a source of runoff, such as an active drainageway. The edges of flushed debris flows should be somewhat indistinct because some boulders would tumble down and roll as the supporting matrix is removed and others could be moved short distances directly by the flushing waters. Such deposits are not purely conjectural. Beatty (1963) proposed a flushed-debris-flow origin for lobate fields of boulders with little matrix observed on alluvial fans in the White Mountains of California and Nevada.

PROBABLE ORIGIN

The two primary matrix-free origins (boulder flow and sieve deposition) may be ruled out for the Ash Canyon deposit because of the abundance of fines produced by weathering in the Organ Mountains. Fan material exposed in the fault scarp and banks of alluvial-fan distributaries is composed of mud and boulders.

The Ash Canyon deposit, therefore, is concluded to be a flushed debris flow. This interpretation is supported by several observations: (1) its position adjacent to Ash Canyon arroyo suggests a likely source and path for a debris flow; (2) this position also accounts for the source of runoff necessary for subsequent flushing of the fines; (3) the presence of washed, debris-flow levees (channel-margin remnants of previous debris flows) along the arroyo upslope of the deposit attests to the occurrence of such flows on the alluvial fan; (4) runoff from the intense storms observed in the area could easily reach the lower portion of the fan where the deposit lies; (5) transport of a block as large as 3 ft x 5 ft x 10 ft this far down the fan surface would be facilitated by its entrainment in

FIGURE 3. Largest boulder seen in the Ash Canyon deposit: 3 ft high x 5 ft wide x 10 ft long.

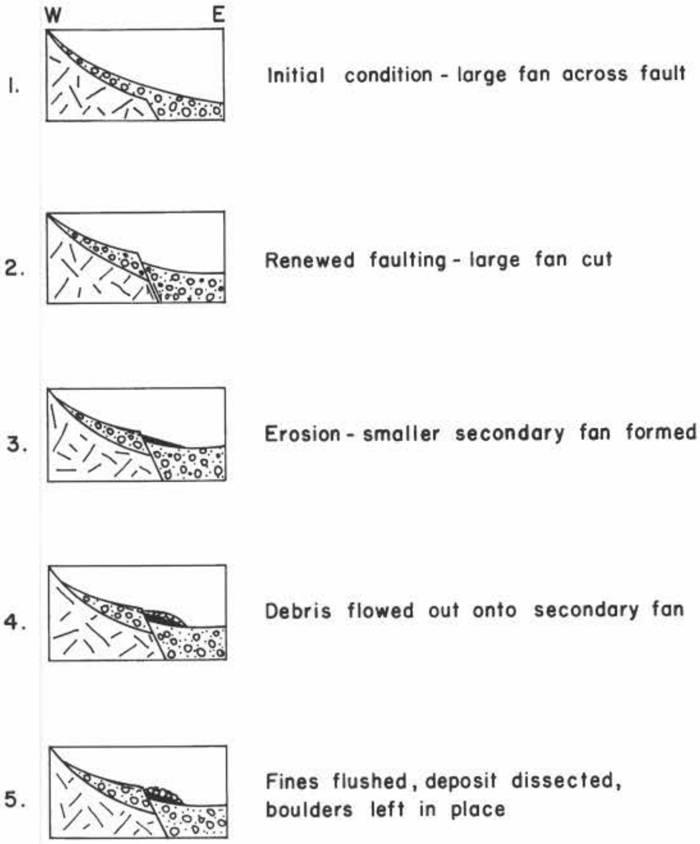

FIGURE 4. Sequence of events believed responsible for the Ash Canyon boulder deposit.

a matrix-laden debris flow. The presumed sequence of events leading to its formation and subsequent flushing are shown in Figure 4.

IMPLICATIONS FOR GEOLOGIC HAZARDS

The boulder deposit is a red flag for public safety in the area. The debris flow from which it was derived resulted from an ephemeral flow event, probably a flash flood. The alluvial fan, as well as the older-looking matrix-free boulder deposits on the secondary fan associated with Ash Canyon, document that such flow events have been common in the geologic past.

Historical precipitation intensities (as cited above) and runoff data suggest that flash floods continue to be a threat in the area. Unfortunately, some of these have been lethal. On 19 August 1978, five people (three adults and two children) were swept to their deaths from the access road to White Sands Missile Range (Anonymous, 1978). One of the adults who perished was an off-duty military policeman who tried to help a family whose vehicle was stalled on the flooded road. Just before they were washed away, he radioed that a 12-ft wall of water was coming toward them. The flash flood occurred in what was considered to be a "normally dry" arroyo, reportedly in response to a 1-in. rainfall in the Organ Mountains. The rainfall was probably much greater, especially on pediments upslope from the White Sands Missile Range (J. Mueller, personal commun., 1998). The U.S. Geological Survey estimated the peak discharge of the flood at 21,300 cfs (P. Borland, personal commun., 1978).

As such slope processes constitute a geologic hazard, sound land-use planning is required for alluvial-fan surfaces. The success of such planning depends on the availability of geologic-hazard maps. Ideally, these would not only include the position, displacement and age of faults, but they also would include the location and size of flash-flood deposits. Of special significance are debris-flow and mud-free boulder deposits. Developers, officials overseeing subdivisions and the general public should all be made aware of the hazards implied by such features.

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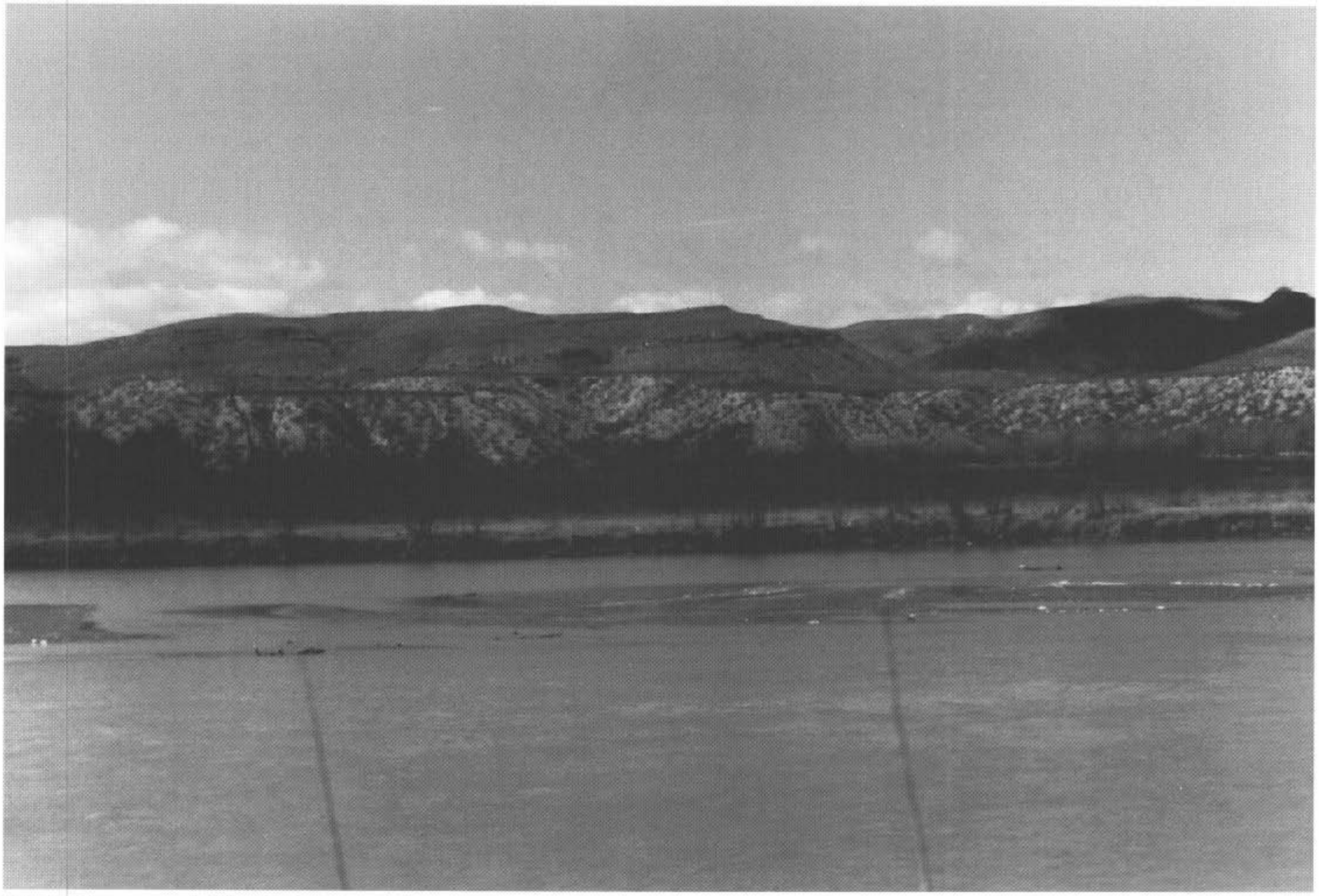

View looking eastward of the Rio Grande and the Robledo Mountains. High cliffs are the Permian Huerco Formation and bluffs are incised late Pleistocene alluvial-fan detritus. Photograph by Greg Mack.