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Wisconsin Boulder Flow and Its Geomorphic Implications, Franklin Mountains, El Paso County, Texas

ABSTRACT

A Wisconsin alluvial deposit with surface features similar to those of rubble streams, rock glaciers, or debris flows occurs in Tom Mays Park Canyon in the northern Franklin Mountains between 5,100 and 5,900 ft elev at lat 31°53′ N. This was too low, at this latitude, to permit formation of interstitial ice. The deposits may have resulted from 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. This boulder flow is an aggregate of rhyolite which was uniquely responsive to an ephemeral Wisconsin frosty climate. Maximum erosion in this canyon since middle Wisconsin is about 40 ft in stream alluvium and nil on talus slopes. The term *boulder flow* is proposed for a rock fragment wet flow.

INTRODUCTION

In Tom Mays Park Canyon on the north face of North Franklin Mountain (Fig. 1), there is a deposit 2,000 ft long and 100 to 300 ft wide (Fig. 2) of blocky rhyolite boulders. Surficial transverse and longitudinal ridges (Figs. 3 to 6) form topography similar to that of subarctic rock glaciers (Wahrhaftig and Cox, 1959) or of alpine rubble streams (Richmond, 1962). Similar features are reported 120 mi north at 9,000 ft elev in the San Mateo Mountains of south-central New Mexico (33°32′ N.) by Blagbrough and Farkas (1968), and about 105 mi north at 10,000 ft elev in Sierra Blanca, south-central New Mexico (33°24′ N. approx.), by Richmond (1963). There was no glaciation on North Franklin Mountain, 7,192 ft elev.

SETTING AND CLIMATE

North Franklin Mountain is the highest peak in the Franklin Mountains (*see* Richardson, 1909; Harbour, 1960, 1971; Van Horn sheet, 1969). This tilted fault block range is 2 to 4 mi wide, 25 mi long, 6,000 to 7,000 ft elev. North to north-northwest–striking Precambrian and Paleozoic strata, and Precambrian igneous rocks dip west 25° to 45°, but as much as 90° along the western range front.

Generally, east- or west-flowing streams drain the range. Only three meridional major canyons occur in the range: McKelligon Canyon drains southward; upper Fusselman Canyon and Tom Mays Park Canyon drain mainly north. Westward drainage is to the downcutting Rio Grande. Pediments between the Rio Grande and the Franklin Mountains indicate "late Pleistocene" downcutting of as much as 90 ft (Hawley, 1965; Kottlowski, 1958) which has produced gulleying in the deposit. An early mid-Pleistocene lake which covered the region (Strain, 1965) was emptied by the Rio Grande draining to the southeast. River entrenchment in the lake sediments of the Santa Fe Group is about 400 ft, hence gulleying in Tom Mays Park Canyon has not kept pace with the lowering of the regional base level.

Fault displacement since lake sedimentation is less than 10 ft on the western range flank (Lovejoy, 1971) and perhaps 400 ft along the eastern flank (Sayre and Livingston, 1945). On the west side of the range, therefore, stream gradients increased slightly following range tilting.

Thus, the Franklin Mountains are essentially the same now as in early Pleistocene.

The local climate is hot and arid, with an annual average of 8 in. of rainfall. Except for some shrub oaks, there are no big trees on the range. There is virtually no soil; bedrock is widely exposed. Most rain occurs in late summer, but some occurs in fall during cold-front incursions. Snowfall during winter cold fronts is light and melts soon afterward. On shady

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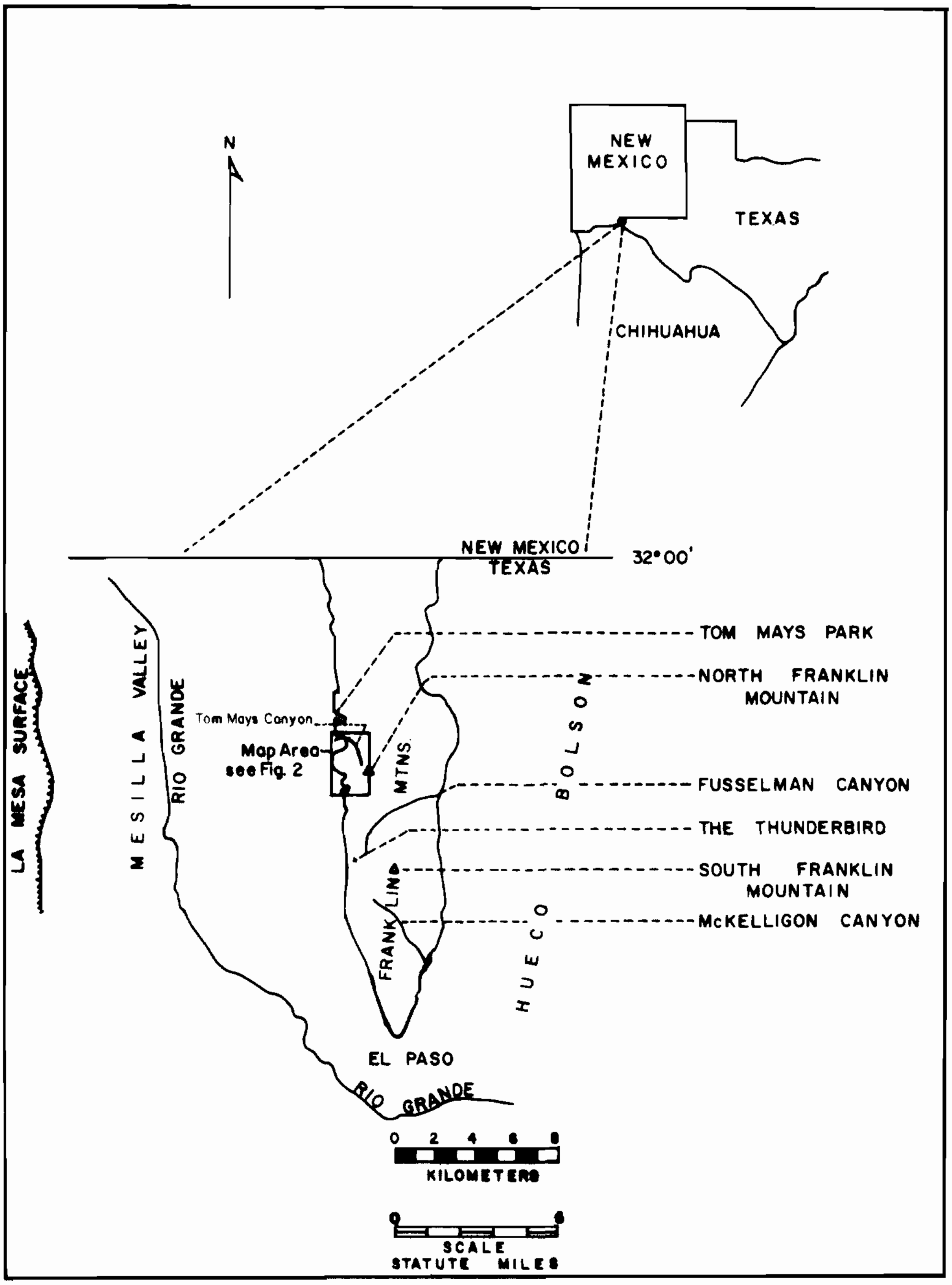


Figure 1. Index map of Franklin Mountains. The detailed map area is enlarged as Figure 2. McKelligon and Fusselman Canyons, and Tom Mays Canyon in the map area are the only three major canyons in the range with significant meridional stretches.

north slopes, a few inches of snow may accumulate. Snow more than 1 ft deep is rare, and only above 6,000 ft elev.

MID-PLEISTOCENE PIEDMONT DEPOSITS FORMED FROM RHYOLITE BOULDERS

The dense, hard Thunderbird rhyolite forms extensive piedmont deposits of blocky alluvium in washes extending westward down to 4,000 ft elev between Fusselman Canyon and Tom Mays Park Canyon. At North Franklin Mountain, these deposits merge with talus.

Deposits of late early Pleistocene alluvium (Lovejoy, 1971) are formed mainly of limestone clasts of the El Paso Group. The rhyolite alluvium contains very little limestone. Erosion has cut older alluvium to depths of 80 ft. The rhyolite alluvium moved along stream gradients steeper than those of streams draining the carbonate rocks. Thus, the rhyolite alluvium extends to higher elevations than does the older carbonate alluvium. Metcalf (1969) referred to these lower level rhyolite deposits on the piedmont as the "Late Phase" of "Canyon Fill" of possible "Woodfordian" age due to "response to increased frost action."

TOM MAYS PARK CANYON DEPOSIT

Tom Mays Park Canyon (Fig. 2) is at 6,500 ft elev at its south end and 5,150 ft at the pediment where the granite walls are 150 ft apart. The deposit extends from 5,850 ft to 5,260 ft, is 2,200 ft long and 250 ft wide. The canyon bends 70° W. at 5,450 ft elev. The upper reach trends N. 5° W. and the lower trends N. 75° W. The canyon is mostly shaded during winter. Rock-fall talus (Fairbridge, 1968) fed the deposit from the south wall between canyon floor elevations 5,260 ft and 5,600 ft. Smaller canyons feed rhyolite alluvium to the canyon from the north and east walls between the mouth of the canyon and 5,700 ft elev. Above canyon elevation 5,700 ft, the east and south walls supplied most of the talus. Talus slopes on the inside of the bend merge with the deposit. Talus consists mainly of rhyolite blocks that are 3 ft maximum, with pieces <1 ft average. Talus from the south and east walls above canyon elevation 5,700 ft slopes 30° average; maximum 35° locally. Talus slopes are several hundred feet long in the main canyon up to canyon elevation 5,700 ft.

At canyon elevation 5,900 ft in the main canyon, there is a constriction 10 ft wide at shoulder level for 200 ft, and only a little wider for another 200 ft in which alluvium is only a few feet deep. Above this constriction, the canyon opens into a large fan-shaped collection zone from which talus slopes descend into the canyon.

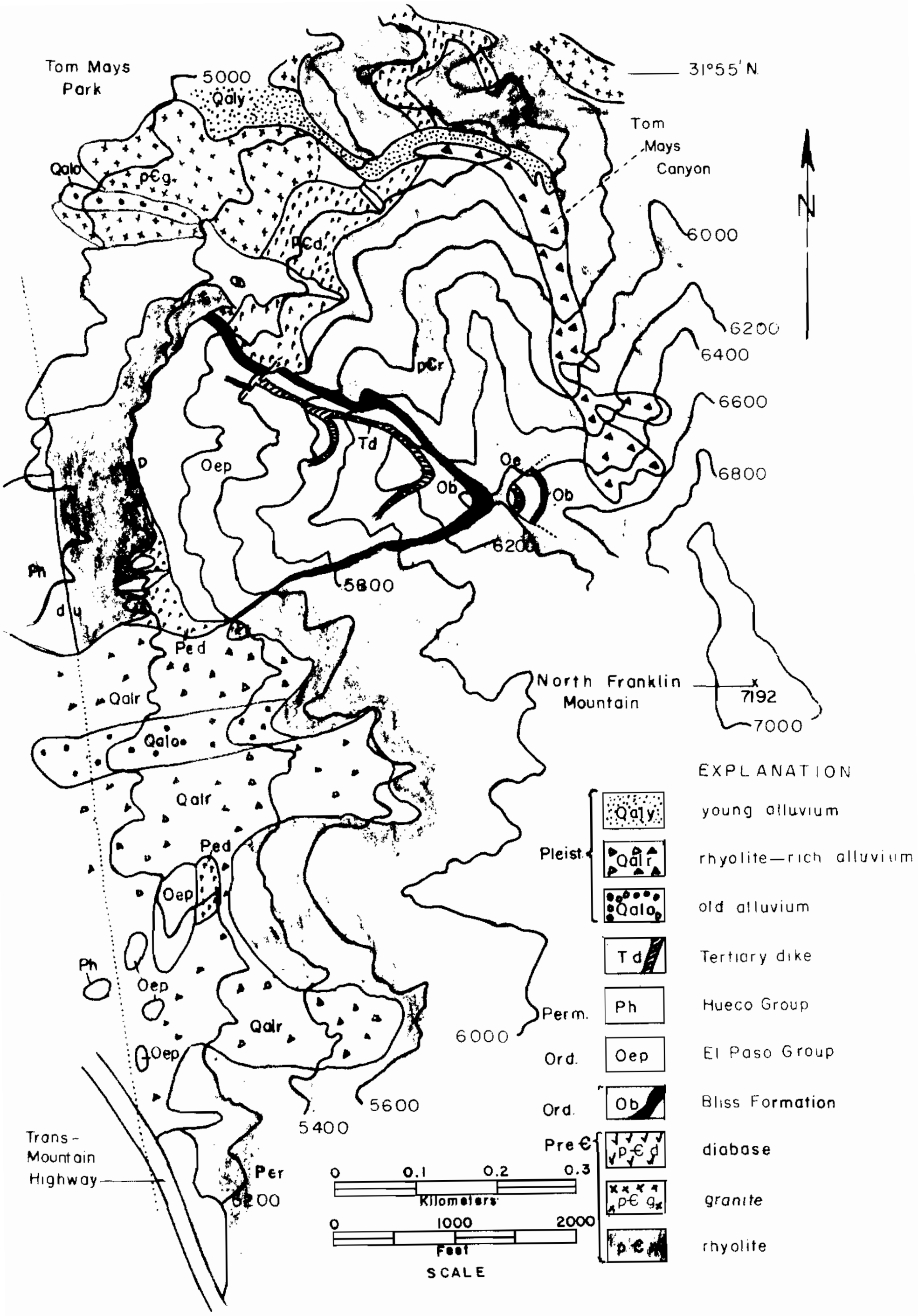
Gullies, which cut the eastern edge of the rhyolite deposit below canyon elevation 5,700 ft, extend from the eastern wall. Along the west edge of the deposit, there is a small gulley 4 ft deep adjacent to either bedrock or more stable talus inside the bend. Deposit relief is about 40 ft with bedrock not exposed. Gulley side slopes (35°) are unstable.

The deposit top is hummocky; transverse ridges which are convex downstream and several feet high form a multilobate pattern (Figs. 3, 4, 5). Longitudinal ridges may be partly the result of headward gullying in the deposit. The top of the deposit has a slope computed to be 17°, but the measured slopes reach 25° for short stretches, especially one between canyon floor elevations of 5,540 and 5,600 ft.

Except along the base of the deposit, no vegetation grows on the deposit surface below canyon elevation 5,500 ft because the surface cracks are not clogged with fine material; hence no soil has formed. Above this elevation, however, recent alluvium debouching onto the east side of the deposit has locally clogged the uppermost interstices at gulley mouths upon which a soil has formed to permit growth of desert biota. Above canyon elevation 5,600 ft, modern alluvium lies on the west side of the deposit where plants also grow (Fig. 6).

The present front of the deposit (32°) is about 20 ft high. Remnants of older deposit material occur on the north wall of the canyon (where no talus exists) at canyon elevation 5,150 ft. The present front, which is not the original front of the deposit, consists of rocks much coarser than those in the adjacent modern talus and modern alluvium, probably due to sifting during mass transport, or settlement or ellutriation of fines.

Two small hemispherical depressions, one 20 ft across and 6 ft deep, and the other a bit smaller, which resemble kettle holes, occur on the surface of the deposit, the larger at 5,800 ft elev, and the smaller at 5,600 ft elev. Belts of fine materials rise from the centers of the depressions, cross the downslope lip, and extend


Tom Mays Park
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Trans-Mountain Highway
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Kilometers
0
1000
2000
Feet
SCALE
EXPLANATION
Pleist.
Qaly young alluvium
Qalr rhyolite—rich alluvium
Qalo old alluvium
Td Tertiary dike
Perm.
Ph Hueco Group
Ord.
Oep El Paso Group
Ord.
Ob Bliss Formation
Pre Є
pЄd diabase
pЄg granite
pЄr rhyolite

down the outer slope. Both holes occur in very coarse material at the toes of the steepest depositional slopes observed on the deposit. The depressions resemble certain Indian artifacts, but there is no evidence of cobbing; the rim does not seem to be handmade. These holes appear to be neither artifacts nor kettle holes.

TEMPERATURE CONTROLS

Blagbrough and Farkas (1968) described seven stabilized rock glaciers, formed from Tertiary rhyolite on northern slopes in the San Mateo Mountains of south-central New Mexico, 8,500 to 9,500 ft elev. Tongue-shaped rock glaciers are 300 to 900 ft long, 150 to 260 ft wide, and an estimated 50 to 150 ft thick. Lobate rock glaciers are 200 ft long, 150 ft wide, and 50 ft thick. Both types have longitudinal and transverse ridges.

Richmond (1963) noted a shallow cirque on Sierra Blanca Peak at 11,400 ft to 11,500 ft and a terminal moraine of Bull Lake glaciation at 9,850 ft and 10,400 ft. This indicates that North Franklin Mountain (7,192 ft) was too low for glaciation at this latitude. No cirque, moraines, or glacial materials occur.

Thus, either this deposit formed when average local microclimate winter temperature at 5,150 to 5,900 ft was low enough to permit freezing in the rock mass, or interstitial ice was not a necessary agent in its development.

Blagbrough and Farkas (1968) believed that the rock glaciers in the San Mateo Mountains formed about 2,000 ft below the Wisconsin orographic snow line. Citing Wahrhaftig and Cox (1959), Blagbrough and Farkas considered that the San Mateo glaciers moved by interstitial ice flow.

In the San Mateo Mountains, freezing of interstitial water in rock glaciers occurred at and above 8,500 ft. The present latitudinal variation of average annual temperature for this latitude is about 2°F per degree of latitude (Encyclopaedia Britannica, 1966, Vol. 5, p. 920, Fig. 8). The Franklin Mountains are 2.5° south of the San Mateo Mountains, and should be 5°F warmer than the San Mateo Mountains. The standard lapse rate is 3.5°F/1,000 ft. The normal temperature at 8,500 ft would be 12°F less than that at 5,150 ft. Thus, Pleistocene cooling by local factors of about 17°F would have been required to permit freezing of interstitial water in this deposit.

Figure 2. Geologic map of the Tom Mays Park–North Franklin Mountain area, northern Franklin Mountains (*compare* Harbour, 1971). The layered units (rhyolite and Paleozoic beds) dip generally about 35° W., but near the mountain front, these beds steepen and locally become vertical. The Bliss sandstone pinches out west of North Franklin Mountain. The old alluvium contains very little rhyolite; the rhyolite alluvium contains very little El Paso limestone (*see* Lovejoy, 1971, Fig. 2 and p. 434–435). The rhyolite alluvium west and southwest of North Franklin Mountain is being dissected by modern arroyo cutting, but there is no ready differentiation between young alluvium and rhyolite alluvium in this monolithic deposit.

Figure 3. View down the canyon showing coarse bouldery surface.

NOMENCLATURE

Leopold and others (1964) discussed mass movements, using the Highway Research Board Landslide classification. This classification does not give a name to a deposit formed of rock fragments in a very wet flow. For rock fragments in a dry flow, the term "rock fragment flow" is used. For sand or silt in a wet flow the terms "debris flow or sand or silt flow" are used. The term "boulder flow" is suggested here for a rock fragment wet flow.

The surface form of a boulder flow is much like that of rock glaciers (Wahrhaftig and Cox, 1959; Blagbrough and Farkas, 1968) and remarkably similar to that of alpine felsenmeer (Richmond, 1962). It most nearly resembles "frost lag rubble streams" of Richmond (1962) in its surface form but does not form in situ in the same way. Mudflow deposits may be lobate and have a surface relief of 10 to 20 ft, according to Leopold and others (1964), and it may be that either mudflow or debris flow accounts for some of the surface features found in the piedmont alluvial rhyolite deposits west of the Franklin Mountains, but the absence of fine

Figure 4. View up canyon showing surface hummocks, and young alluvial coating of the surface of the deposit at left center at the foot of the steep slope.

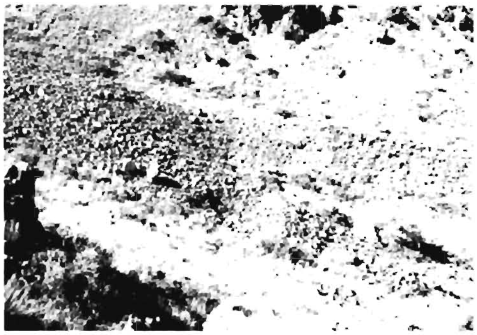

Figure 5. The upper ellutriation orifice, 5,800 ft elev, is at lower center. Note its position at the base of a steep slope on which are located some of the biggest boulders in the deposit. Note steep original slope to left of orifice.

particles in this boulder flow suggests that an origin different in degree, if not in kind, from that of mudflows ought to be considered.

SIGNIFICANCE

The North Franklin Mountain boulder-flow deposit exhibits some features worthy of note, including the two small pseudo-kettle holes or ellutriation orifices, and the very hummocky surface, more reminiscent of rock glaciers than of alluvial deposits. The very presence of the deposit at this latitude and elevation where frost action would not normally be expected is significant.

Also, this deposit is composed of materials identical to those in major west-trending washes on the west flank of North Franklin Mountain which extend all the way to the Rio Grande. The age, development, and geomorphic and tectonic significance of those deposits will be treated elsewhere.

ORIGIN

This boulder flow probably formed in a manner somewhat- like that of debris flows which contain large clasts. The name bouldery debris flow might be reasonable for this type of deposit, but the distinction is that there is much less fine material in a boulder flow than in a debris flow. It is the proportion of fine particles, and not the maximum size of clast, which is the significant difference. For this reason, stream gradients must be steeper to produce movement; surface form is more accentuated; the ellutriation orifices at the bases of the steepest slopes will form to drain interstitial water under pressure.

Another major difference between debris flows and boulder flows is that boulder flows form primarily from talus accumulation and not from distinct landslides; they are alluvial deposits which have formed over a longer period of time, although, in any given period of mass movement, a boulder flow probably occurs as rapidly as does a debris flow. Finally, these boulder flows have formed in stream regimes which were originally graded for smaller clasts and which had cross sections for smaller volumes of material. Thus the onset of talus accumulation resulted in stream clogging. The boulder flows formed in the canyon itself, and not on its slopes as do mudflows, resulting from damming of flash-flood waters by the coarse alluvium.

The ellutriation orifices form as the result of pressure increase of flash-flood waters which suddenly inundate coarse-grained sieve deposits (Hooke, 1967) of the proximal fan regime within the confines of bedrock canyon walls. Their occurrence at the bases of the steepest original longitudinal slopes in the boulder flow deposit is explained by this process. Debris flows would probably have too much fine material and the resultant frictional loss would slow the draining waters, but coarser grained boulder-flow materials would permit more rapid interstitial flow. During boulder flow, the water would be moving at essentially the same rate as the boulder mass, but in the waning stage of the flash flood at a certain velocity, rather high for the boulders, the boulder mass would suddenly deposit and stop, whereas the water would retain a considerable momentum.

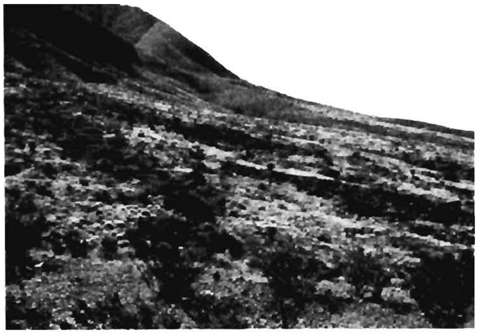

Figure 6. Piedmont deposits of rhyolite boulders at 4,700 ft elev. Note hummocky surface and perched position above present arroyo.

The rapid loss of this momentum would provide the energy needed to form the ellutriation orifice.

Obviously, the onset of talus accumulation represents a change in climate. The original rhyolite boulder flow here probably began in early Pleistocene. Lovejoy (1971) suggested that at the Thunderbird in the Franklin Mountains there has been about 100 ft of downcutting in Paleozoic limestone and Precambrian rhyolite since early Pleistocene in the same period during which the Rio Grande has been entrenched 400 ft in lake deposits of the Santa Fe Group. In the canyon at the Thunderbird, however, talus accumulation in rhyolite bedrock was not a major factor in erosion. At Tom Mays Park Canyon, because of clogging of the canyon, the downcutting may have been inhibited, rather than aided by the rapid accumulation of talus. Because of this protection by clogging, less than 100 ft of downcutting occurred here since early Pleistocene. In fact, the gradients of the major arroyos which carry primarily rhyolite are steeper than those which carry other rock types; therefore these arroyos debouch into the piedmont at higher elevations.

SUMMARY AND CONCLUSIONS

A type of boulder accumulation called boulder flow occurs in one canyon in the Franklin Mountains, lat 32° N., 5,500 ft elev. The boulder flow formed as a result of accumulation of boulders from rhyolite which reacted to cold Pleistocene climates by forming extensive talus slopes. Streams graded for smaller clasts and lesser volumes were clogged by these accumulations. Flash-flood waters dammed by the boulders produced boulder-charged surges which produced topographic forms similar to those of rock glaciers and certain alpine felsenmeers. Rapid drainage of interstitial waters in the waning stages of the flash floods produced circular depressions resembling kettle holes called ellutriation orifices. The boulder-flow deposits, consisting of clasts larger than normal for the stream regime, seem to have protected the drainage from erosion, hence downcutting has apparently been less than normal for this region, and stream gradients, which are steeper as a result of the coarser clasts, carry the streams to higher elevations at the mountain front.

ACKNOWLEDGMENTS

Jerry Mueller and William Cornell reviewed this paper and offered helpful editorial suggestions. Jerry Mueller called my attention to glacial front features similar to the ellutriation orifices described here. The origins of both appear to be similar. Terrie Ingle typed the manuscript and Jim Blackwell prepared part of the drawn illustrations.

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