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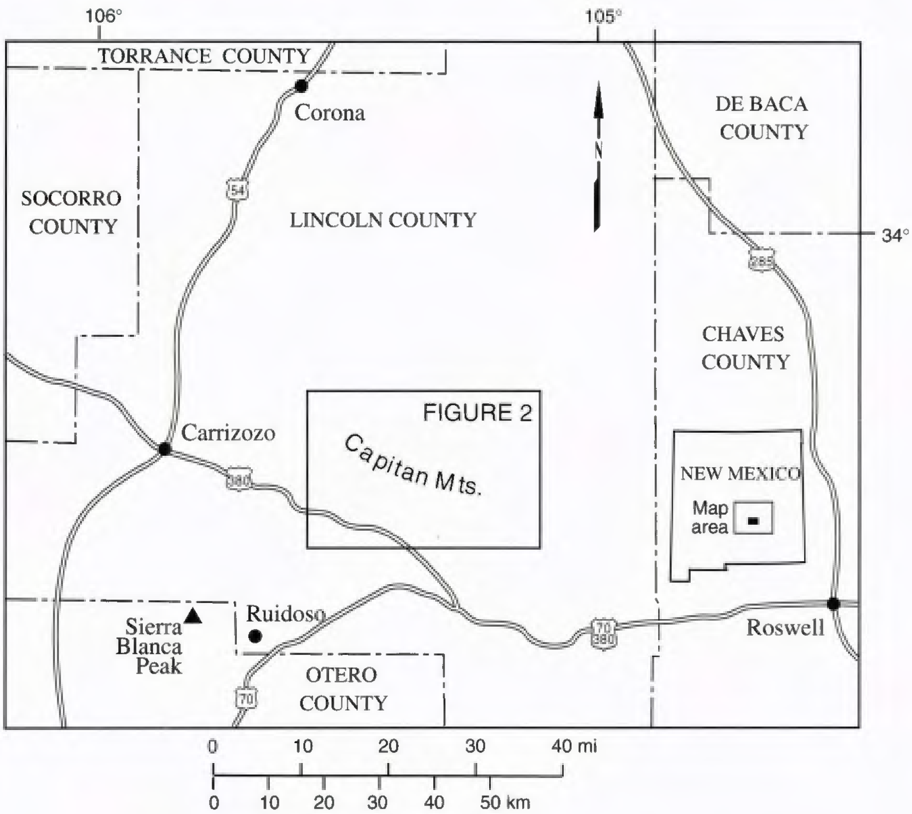


FIGURE 1—Location of Capitan Mountains in south-central New Mexico.


## Abstract

One hundred twenty-four rock glaciers formed during two periglacial episodes of late Wisconsin age below talus and frost rubble at the heads of canyons and ravines at an average altitude of 2,525 m on the north and south sides of the Capitan Mountains. They have steep fronts, and the sides commonly are delineated by lateral ridges that bend to form transverse ridges at the crests of the fronts. The stable debris is formed by blocks and slabs of intrusive igneous rocks with average diameters of about 60 cm.

Two ages are distinguished using the degree of preservation of topographic features and soil development. Older rock glaciers are moderately dissected, bear an eolian mantle approximately 25 cm thick overlain by 7.5 cm of decomposed organic material, and are present in the eastern part of the range below slopes eroded in granite porphyry. Younger rock glaciers are little dissected, have soils formed by decomposed organic material with an average thickness of approximately 7.5 cm, and are present mainly in the western part of the mountains below slopes eroded in aplite and granophyric granite.

The rock glaciers in the eastern part of the range imply two late Wisconsin periglacial episodes characterized by frequently recurring freeze-thaw and a mean annual temperature below 0°C. The distribution and volume of talus and frost rubble indicate that aplite and granophyric granite are more susceptible to freeze-thaw action than granite porphyry. The amount of talus and frost-rubble production is attributed to the chemical composition and intensity of fracturing of the Capitan pluton and suggests that the periglacial climate under which the older rock glaciers were formed was more severe and/or of longer duration than that under which the younger forms were active.


## Introduction

Rock glaciers are deposits of periglacial mass movements and productions of glaciation that have been recognized in many alpine regions throughout the world (Giardino and Vitek, 1988). White (1981) defines a rock glacier as a tongue-shaped or lobate accumulation of unsorted, coarse-to-fine rock debris that moves down valley or away from a valley wall. Two principal types of rock glaciers are distinguished based upon shape and topographic position (Wahrhaftig and Cox, 1959; White, 1981). Tongue-shaped rock glaciers are elongated masses of rock debris that are longer than they are broad and commonly are in cirques or along valley floors. Lobate rock glaciers are masses of unsorted debris that are as broad or broader than they are long. They are present singly or in groups along valley walls as extensions of talus cones or talus aprons. Rock glaciers may move by the creep of a relict glacier inside (ice-cored) or by the recrystallization and creep of interstitial ice within the fine debris (ice-cemented) or by sliding at the base of the frozen debris inside (White, 1981).

Climate, topographic relief, and the structure and lithology of the bedrock are

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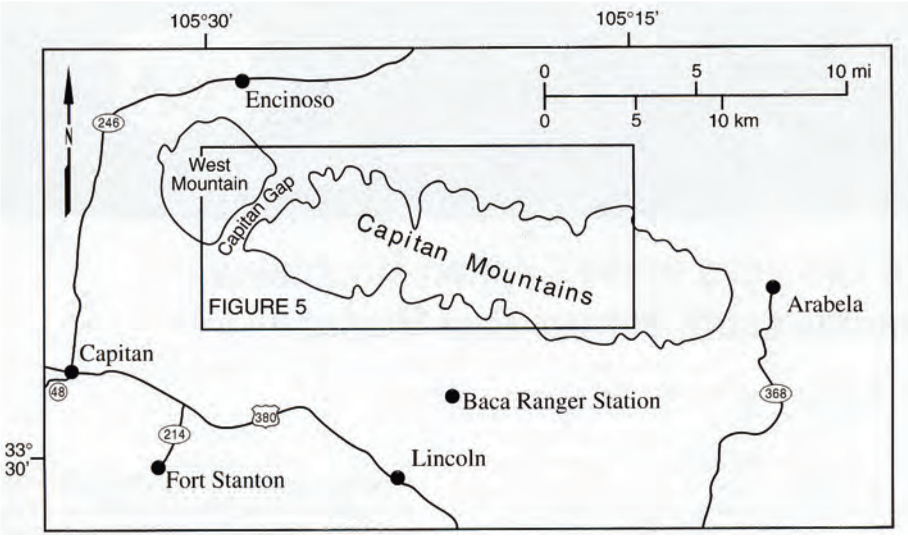


FIGURE 2—Location of the study area in the Capitan Mountains. Base map is the U.S. Geological Survey's topographic map of Roswell quadrangle 1:250,000 scale series.

primary factors in the generation of rock glaciers (Morris, 1981). Frost wedging supplies the debris for the development of rock glaciers and occurs under periglacial climates that are characterized by frequently recurring freeze and thaw (Flint, 1971, pp. 271–274; Washburn, 1980, pp. 73–79). This process is promoted by snow cover of short duration and enough moisture in the ground for cryofraction to occur (Corté, 1987). Climatic elements conducive to the development of interstitial ice in rock glaciers are (1) sufficient precipitation for the formation of the ice and (2) temperatures that are low enough for the maintenance and creep of the ice (Wahrhaftig and Cox, 1959). Interstitial ice (permafrost) can exist in rock glaciers if the mean annual temperature at ground level is 0– -1°C especially if the snow cover is thin and of short duration (Péwé, 1983).

Rock-glacier debris is derived primarily from cliffs undergoing the blocky weathering that occurs in massive igneous, metamorphic, and sedimentary rocks where two or three structural trends of joints are present (Evin, 1987). The process is particularly prevalent if two joint trends are parallel and orthogonal to each other and the other set is oblique. Well-developed bedding planes in sedimentary rocks are also an important control. Frost wedging is effective in dislodging blocks and slabs from cliffs with blocky structure because freeze-thaw action pries apart rock along joints, fractures, and bedding planes.

The purpose of this paper is: (1) to present criteria for distinguishing rock glaciers of two ages in the Capitan Mountains using physiographic preservation and soil development, (2) to note the geographic distribution of the rock glaciers in relationship to the textural and mineralogical zones of the Capitan pluton, (3) to establish the age of the rock glaciers and to present a chronology based upon activity, and (4) to attempt to relate the distribution of the older and younger forms to climatic fluctuation and to the lithology and structure of the pluton.

### Geographic and geologic setting

The Capitan Mountains are located in Lincoln County, New Mexico, approximately 80 km northwest of Roswell and 40 km northeast of Ruidoso in south-central New Mexico (Fig. 1). The range extends in an east-west direction for approximately 32 km and is approximately 7 km wide. West Mountain is a nearly isolated upland with an altitude of 2,272 m and is separated from the main part of the mountains by Capitan Gap (Fig. 2). The summit east of Capitan Gap is 2,600–3,050 m in altitude and rises approximately 900 m above the surrounding alluvial-covered lowlands. The head of Hinchley Canyon and Pierce Canyon Pass are well-defined saddles that break the relatively flat crest (Fig. 3). The saddle at the head of Hinchley Canyon divides the range into western and eastern sections, which have distinctive geologic and physiographic attributes noted below. Summit Peak and Capitan Peak are prominent landmarks above 3,050 m in the eastern part of the range. The north and south flanks of the mountains are cut by numerous steep-walled canyons with maximum depths of approximately 330 m. Many small canyons and ravines are tributaries to the larger canyons.

The Capitan Mountains are formed by an intrusion of mid-Tertiary age composed of alkali feldspar granite with contact zones that are poorly exposed except at the east and west ends (Allen and McLemore, 1991). It is a single but texturally and compositionally zoned pluton that ranges from a roof zone of granophyric granite to an intermediate zone of aplite to a core of porphyritic granite. The intrusion shows a progressive development from west to east of a coarse and porphyritic texture and an increase in mafic minerals. The textural and mineralogical variations appear to be gradational with no evidence for multiple intrusions.

The granophyre zone is fine grained (0.5–2 mm) and has a micrographic texture. It encompasses an area from the west contact zone to just east of Capitan Gap where it grades into an equigranular textured aplite (Fig. 3). The aplite zone extends eastward to the saddle at the head of Hinchley Canyon and also crops out at Capitan Gap where deeper parts of the pluton are exposed. The porphyry zone stretches from the saddle at the head of Hinchley Canyon to the east end of the

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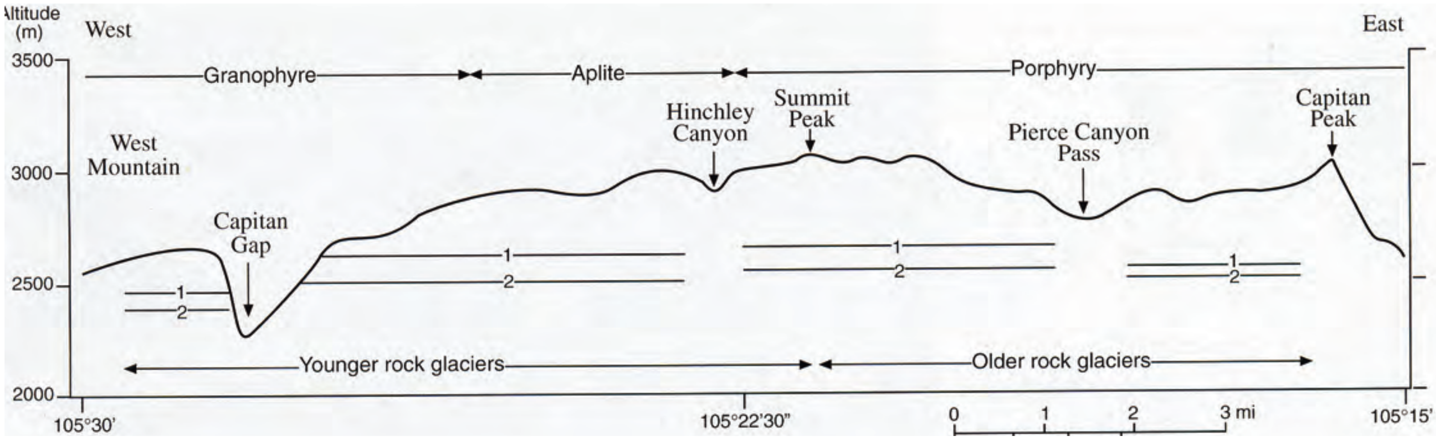


FIGURE 3—East-west cross section along the south side of the Capitan Mountains showing major topographic features, distribution of the textural zones, and the areal extent of older and younger rock glaciers. Location of the textural zones is from Allen and McLemore (1991, p. 118, fig. 7). **1**, average altitude of rock-glacier heads; **2**, average altitude of rock-glacier fronts. Vertical exaggeration approximately x 2.6.

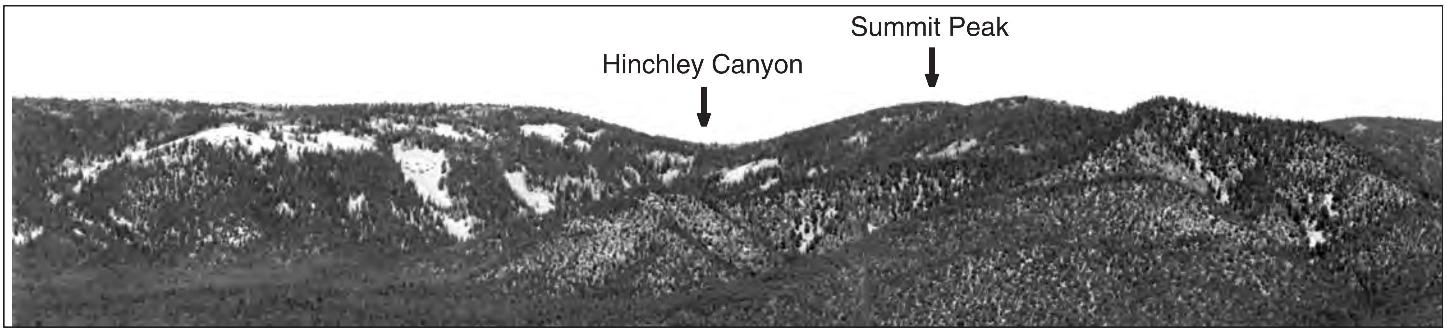


FIGURE 4—South side of the Capitan Mountains showing distribution of talus and frost rubble (light areas) east and west of Hinchley Canyon. The deposits are more extensive on slopes eroded in aplite west of the canyon than on slopes eroded in porphyry to the east. Photograph by Francis G. Varney.

mountains and contains as much as 20% phenocrysts of anorthoclase and, rarely, plagioclase. The distribution of vein and breccia deposits in the range indicates that the granophyre and aplite zones are more intensely fractured than the porphyry zone (McLemore and Allen, 1991).

Rock-fall talus accumulates below cliffs and steep slopes, and frost rubble forms extensive sheets on the upper slopes of the mountains; both obscure the bedrock in many areas (Fig. 4). Some rubble sheets have undulating surfaces formed by many small ridges and furrows. The ridges and furrows are parallel to the contours indicating movement downslope because of solifluction or frost creep. Talus and frost rubble, nearly devoid of soil and vascular plants, cover approximately 30–60% of slopes eroded in granophyre and aplite compared to approximately 20–30% for slopes eroded in porphyry.

No long-term weather records exist for the Capitan Mountains. Stations at Arabela, Baca Ranger Station, and Capitan, however, suggest a mean annual precipitation of 40–50 cm near the base (Gabin and Lesperance, 1977). The slopes may receive 50–75 cm and the crest more than 75 cm of precipitation annually (Tuan et al., 1969). Long-term weather records from Fort Stanton (Kunkel, 1984) and the mean annual lapse rate of 0.72 cm/100 m for south-central New Mexico (Van Devender et al., 1984) suggest the following approximations of current mean annual temperatures for the Capitan Mountains: 5–8°C for the slopes (2,300–2,750 m) and 3°C for the crest (3,000 m).

Vegetation zonation in the Capitan Mountains ranges from desert grassland near the base to the spruce-fir association on the crest (Martin, 1964). The pinyon-juniper association extends up to an average altitude of approximately 2,200 m on the lower slopes. The transition association is between approximately 2,200 and 2,700 m, and the spruce-fir association is above 2,750 m on the upper slopes and crest. Aerial photographs reveal that the slopes and crest of the mountains are more heavily forested in the eastern part of the range in porphyry terrane as compared to the slopes and crest in the west in granophyre and aplite terrane.

## Description

One hundred twenty-four rock glaciers developed below talus at the heads of ravines and small tributary canyons and on the floors of major canyons on the north and south sides of the Capitan Mountains (Fig. 5). Blagbrough (1976, 1991) observed the distribution of rock glaciers throughout the range but only described the forms in the western part of the range in detail. The average altitude of the heads is approximately 2,574 m, and the average altitude of the fronts is 2,474 m (Table 1). The lengths are between 56 and 1,565 m (Table 1), and the widths average approximately 70 m. The rock glaciers in ravines and tributary canyons are the extensions of talus at the drainage heads. Those on the floors of major canyons are composed of talus that accumulated as sheets along the base of side walls and head walls. Frost rubble encroaches upon the heads and flanks of many rock glaciers on canyon floors and suggests downslope movement of debris after the rock glaciers became inactive (Fig. 6).

The rock glaciers have steep fronts 5–60 m high that slope approximately 30° (Fig. 7). Heads merge with talus on the steep mountain slopes, and the surfaces above the fronts slope downstream at approximately 15°. Flanks are steep embankments 5–10 m high and commonly are separated from the sides of canyons and ravines by gullies. Lateral ridges 1–5 m high delineate the flanks of many rock glaciers and bend to form transverse ridges at the crest of the fronts. On many rock glaciers, depressed areas are 1–5 m below lateral ridges and extend from the crest of the fronts to the heads. Longitudinal and

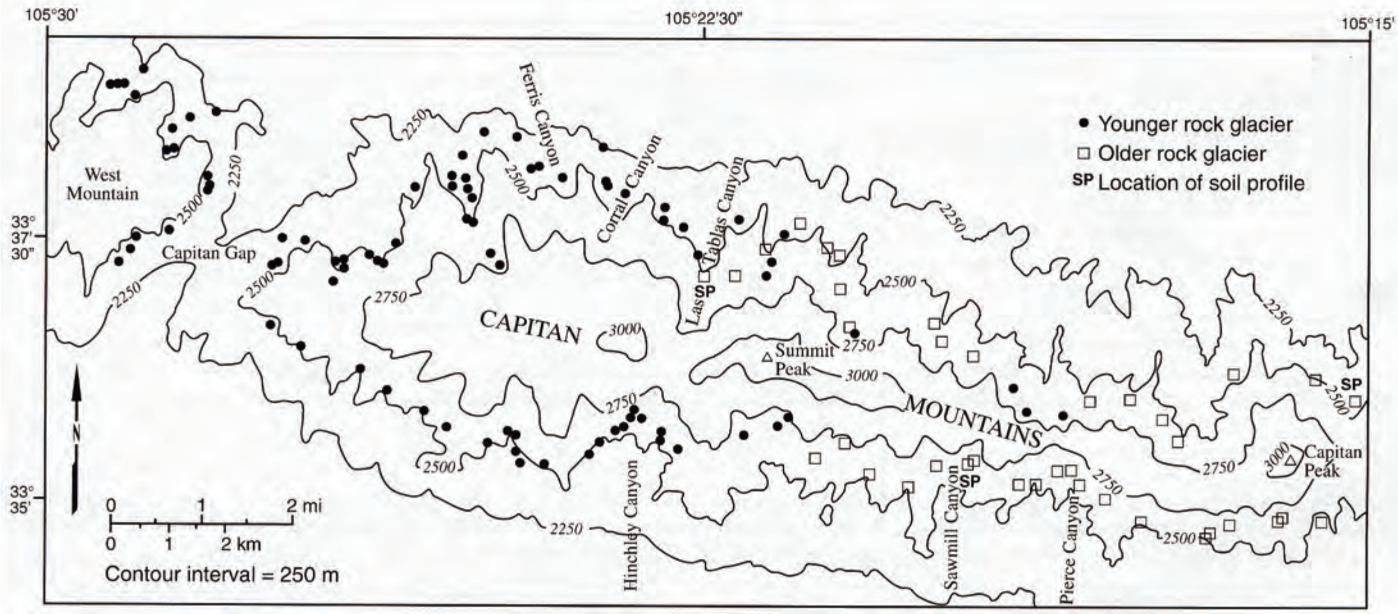


FIGURE 5—Localities of older and younger rock glaciers in the Capitan Mountains. Rock-glacier symbols denote positions of the fronts. Base maps are the U.S. Geological Survey's topographic maps of Capitan Pass, Capitan Peak, Encinoso, and Kyle Harrison Canyon 7½-min quadrangles.

transverse ridges and furrows are common surface features that result in a hummocky topography with a relief of approximately 3 m on some surfaces. Conical pits, with a mean depth of approximately 3 m, and oblique ridges and furrows that trend at approximately 45° to the apparent direction of movement are less commonly developed.

Rock glaciers of two ages are distinguished based upon the preservation of the topographic expression and soil development. Thirty-eight older rock glaciers are present in the eastern part of the mountains below slopes eroded in porphyry (Table 2). They are moderately dissected and show good preservation of the tongue-shaped form. The gross features, such as steep fronts, flanks, lateral ridges, and depressed areas, are somewhat subdued. Longitudinal and transverse ridges and furrows are either poorly defined or unrecognizable on aerial photographs. The debris of the rock glaciers is formed from blocks and clasts of porphyry with average diameters of 30–90 cm.

TABLE 1—Comparative altitudinal and morphological data for rock glaciers in the Capitan Mountains.

| | All rock glaciers | Rock glaciers north side | Rock glaciers south side |
|---|---|---|---|
| Number | 124 | 72 | 52 |
| Mean altitude of fronts (m) | 2,474 | 2,443 | 2,517 |
| Range in altitude of fronts (m) | 2,244–2,689 | 2,244–2,659 | 2,378–2,689 |
| Mean altitude of heads (m) | 2,574 | 2,542 | 2,605 |
| Range in altitude of heads (m) | 2,305–2,841 | 2,305–2,841 | 2,427–2,829 |
| Mean length (m) | 305 | 306 | 288 |
| Range in length (m) | 56–1,565 | 56–1,565 | 62–1,105 |

TABLE 2—Numbers of older and younger rock glaciers in the eastern and western parts of the Capitan Mountains.

| | Eastern section porphyry terrane | Western section aplite and granophyre terrane |
|---|---|---|
| Older rock glaciers | 38 | 0 |
| Younger rock glaciers | 14 | 72 |

Soil and vascular plants cover 50–85% of the surfaces on the older rock glaciers. The soil is composed of a dark-gray eolian mantle overlain by a dark-brown horizon formed by decomposed or partially decomposed organic material (Fig. 8). The eolian mantle is 20–30 cm thick and composed primarily of fine sand and silt with larger fragments that range to pebble size. The clasts are angular grains of quartz and feldspar, and no well-rounded, frosted quartz grains were observed. The grains are not coated with either organic stain or calcium carbonate and appear extremely fresh. The eolian mantle contains large amounts of organic material possibly with some calcium carbonate. The upper horizon is approximately 7.5 cm thick and composed of large wood fragments and decomposed organic debris. It also contains sand and silt grains similar to those in the eolian mantle.

The head of an older rock glacier is overridden by the front of a younger form in Las Tablas Canyon on the north side of the range (Fig. 9). The older rock glacier is composed of two talus tongues, both of which have well-defined fronts and flanks. The surface is covered by an eolian mantle with a maximum thickness of approximately 30 cm overlain by approximately 7.5 cm of decomposed to partly decomposed organic debris. The front of the younger rock glacier rises abruptly above the older surface, and debris from the base extends into the depressed area of the upper tongue of the older form (Fig. 10).

Seventy-two younger rock glaciers are present on West Mountain and in the main upland of the Capitan Mountains between Capitan Gap and the saddle at the head of Hinchley Canyon below slopes eroded in granophyre and aplite. Fourteen younger

FIGURE 6—Low-angle aerial photograph showing two younger rock glaciers and extensive frost-rubble sheets in the east and west branches of Corral Canyon on the north side of the Capitan Mountains. The frost rubble was derived from the aplite zone of the Capitan pluton and encroaches upon the heads and flanks of the rock glaciers. The view is to the south and shows the steep fronts and flanks and well-defined longitudinal and transverse ridges and furrows. The rock-glacier surfaces are nearly devoid of soil and vascular plants, suggesting movement near the close of the late Wisconsin.

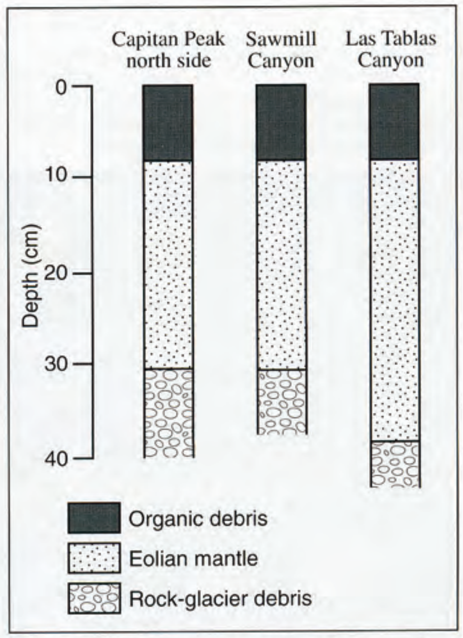


FIGURE 8—Generalized profile of soils on three older rock glaciers in the eastern part of the Capitan Mountains. Localities of profiles are shown in Fig. 5.

FIGURE 7—Low-angle aerial photograph of the large rock glacier in the east branch of Ferris Canyon on the north side of the Capitan Mountains. The view is to the southeast. The rock glacier has a steep front with lateral ridges along the flanks that bend to form a transverse ridge at the crest of the front. A depressed area is between the crest of the front and the head. Two smaller rock glaciers extend from the west wall of the canyon onto the floor.

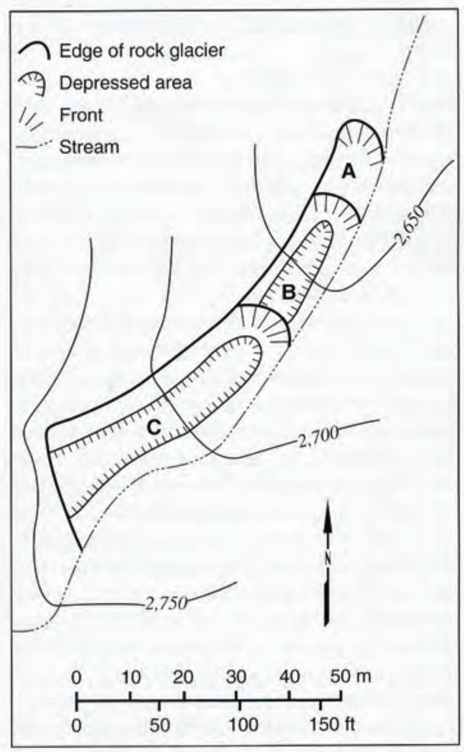


FIGURE 9—Sketch map of rock glaciers in Las Tablas Canyon on the north side of the Capitan Mountains. The older rock glacier is composed of two talus tongues and is overridden by the head of a younger form. Base map is U.S. Forest Service's topographic map of the Capitan Mountains wilderness, 1:24,000 scale. **A**, lower talus tongue of older rock glacier; **B**, upper talus tongue of older rock glacier; **C**, younger rock glacier.

FIGURE 10—Older rock glacier overridden by the front of a younger form in Las Tablas Canyon on the north side of the Capitan Mountains. The man in the center of the photograph is at the contact of the older and younger debris. The surface of the older rock glacier is obscured by soil and vegetation, whereas the front of the younger form is nearly devoid of soil and vegetation. Photograph by John C. Varney.

forms in the eastern part of the range are below slopes eroded in porphyry. The younger rock glaciers have a well-preserved tongue-shaped form and are less dissected than the older rock glaciers. The fronts, flanks, lateral ridges, and depressed areas are well defined and show little modification by erosion (Fig. 7). The longitudinal and transverse ridges and furrows are sharp and easily recognizable on aerial photographs.

The younger rock glaciers in the western part of the range are composed of debris derived from granophyre and aplite. The angular blocks and slabby clasts range in diameter from 15 cm to 2 m and average approximately 60 cm. Many smaller fragments are less than 30 cm in diameter and may have been transported by water. The debris on the lateral ridges commonly is larger than that on the frontal faces and in the depressed areas. Most fragments are oxidized, and some have undergone frost shattering while on the surfaces of rock glaciers. The debris is stable, and lichens cover 20–30% of exposed faces.

Eighteen rock glaciers on canyon floors west of Summit Peak have arcuate ridges and furrows along the flanks, which suggest that they developed from lobate rock glaciers that coalesced on the canyon floor. Seven younger rock glaciers east of Summit Peak are composed of two talus tongues, both of which have steep fronts, lateral ridges, and depressed areas. The upper tongue appears to have overridden the head of the lower. Both tongues have about the same degree of preserved surface features and about the same amount of area covered by soil and vegetation, which implies that they formed during a single periglacial episode.

Soil and vascular plants usually cover approximately 1–15% of the surfaces of younger rock glaciers. The soil is similar to the upper horizon on the older rock glaciers and has an average thickness of approximately 7.5 cm in the western part of the range. It is dark brown in color and is formed by decomposed and partially decomposed organic material mixed with sand and silt. It fills voids between the blocks and slabby clasts. Trees and shrubs grow in the soil and project through the debris on some surfaces.

## Age

No direct dating methods exist for the rock glaciers in the Capitan Mountains at the present time. Age inferences, however, can be made using paleoclimatic data from the Estancia Basin in central New Mexico (Hawley, 1993) and the glacial and periglacial deposits on Sierra Blanca Peak in south-central New Mexico (Richmond, 1986). Allen (1991) and Allen and Anderson (1993) have established a late Wisconsin chronology for pluvial Lake Estancia in the Estancia Basin using radiocarbon dating of organic remains and detailed studies of basin-fill stratigraphy and sedimentology (Table 3). Bachhuber (1989) dates the initial fresh-water phase of Lake Estancia at 24.3 ka, which marks the onset of cold/moist conditions. He also presents evidence for a long preceding cold/dry sub-pluvial interval, which he correlates with the early and middle Wisconsin periods.

Allen (1991) recognized two major high stands for the lake. The older occurred between 20 and 15 ka during late Wisconsin maximum glacial conditions. It was followed by a low stand between 15 and 14 ka when warmer and drier conditions prevailed. The younger high stand began about 13.7 ka and was followed by significant desiccation of the lake between 12 and 11 ka. A minor rise in the lake level at about 10.5 ka is recorded before the final desiccation phase, which was apparently underway by about 10 ka.

Glacial moraines were reported in an alpine valley and small cirque on the northeast side of Sierra Blanca Peak (Richmond, 1963, 1986). Richmond (1963) mapped two older moraines of probable Bull Lake age and three younger moraines thought to be Pinedale (late Wisconsin) in age. The Bull Lake moraines are characterized by broad crests, smooth slopes, and broadly scattered surface boulders. They bear mature soils approximately 90 cm thick with a well-developed B horizon. Pinedale moraines have irregular form, abundant surface boulders, and immature soils approximately 25 cm thick. Because of differences in surface form and boulder frequency, Shroba (1977) suggested that part of the inner Bull Lake moraine of

Richmond is Pinedale in age.

Shroba (1977, 1991) describes two rock-glacier deposits on Sierra Blanca Peak. The older is thought to be late Pinedale in age (about 14 ka) and was previously mapped as Pinedale till by Richmond (1963). According to these interpretations two Bull Lake moraines and two Pinedale moraines are present. The older rock glacier is covered by a loessal matrix 60–110 cm thick and is probably latest Pinedale in age. The deposit extends approximately 800 m through the Pinedale moraines and part way through the Bull Lake moraines and may have formed during the recessional episode of the Pinedale glaciation. The younger rock glacier may be Temple Lake in age (about 12 ka). It is a small deposit approximately 125 m in length near the cirque headwall and is mantled by approximately 40 cm of Holocene loess.

The younger Pinedale moraine on Sierra Blanca Peak may be correlative with the glacial maximum high stand of Lake Estancia. The older rock-glacier deposit on Sierra Blanca Peak probably was active near the beginning of the younger high stand of Lake Estancia, and the younger rock glacier may have been formed at the close of the younger high stand as suggested by the dates cited for the two areas. Much of the loessal matrix on the rock-glacier deposits may have accumulated during the desiccation phase (12–11 ka) of Lake Estancia when warmer and drier conditions prevailed.

Blagbrough (1991) noted that the soils on the younger rock glaciers in the Capitan Mountains are similar to those on the Temple Lake moraines (12 ka) of Richmond (1963) in the Sangre de Cristo Mountains of northern New Mexico. Nonetheless, these forms may be late Wisconsin in age (about 14 ka) because of the time involved in the accumulation of fines on the surface. In addition, the periglacial record in the cirque on Sierra Blanca Peak indicates only minimal cooling during Temple Lake time (12 ka), which would seem to preclude the preservation of interstitial ice in the Capitan Mountains. The sharp constructional relief and restrictive development of soil and vascular plants on the younger forms implies movement near the close of the late Wisconsin (about 14 ka).

The climatic history of the region suggests that the younger rock glaciers in the Capitan Mountains may be correlative with the older rock glacier on Sierra Blanca Peak and the beginning of the younger high stand of Lake Estancia (13.7 ka; Table 3). The thick cover of loessal matrix (60–110 cm) on the older rock glacier deposit on Sierra Blanca Peak as compared to a soil cover of about 7.5 cm on the younger rock glacier in the Capitan Mountains can be explained by the 1,000 m difference in altitude between the two areas. Periglacial conditions probably were much more severe and of longer duration at the higher altitudes on Sierra Blanca Peak resulting in barren mountain slopes above timber line exposed to wind erosion for long periods of time.

Blagbrough (1991) suggested that the older rock glaciers in the Capitan Mountains were of Bull Lake age using the glacial chronology on Sierra Blanca Peak. They are now hypothesized to be of late Wisconsin age (20–15 ka) because of the good preservation of the gross features and weak soil development. Thus, they may be contemporaneous with the younger Pinedale moraine on Sierra Blanca Peak and the glacial maximum high stand of Lake Estancia. The eolian mantle on the older forms may have been deposited during the warm/dry episode that followed the maximum high stand of Lake Estancia.

TABLE 3—Tentative correlation of late Wisconsin pluvial, glacial, and periglacial events in south-central New Mexico.

| Ka | Estancia Basin (Allen, 1991) | Sierra Blanca Peak (Richmond, 1986) (Shroba, 1991) | Capitan Mountains (This report) |
|---|---|---|---|
| 10 | | | |
| | Minor high stand (ca 10.5–10 ka) | | |
| 11 | | | |
| | Desiccation (ca 12–11 ka) | | |
| 12 | | Younger rock glacier (ca 12 ka) | |
| 13 | Younger high stand (ca 13.7–12 ka) | | |
| 14 | | Older rock glacier (ca 14 ka) | Younger rock glaciers |
| | Low stand (ca 15–14 ka) | | |
| 15 | | | Loess |
| 16 | | | |
| 17 | Glacial maximum high stand (ca 20–15 ka) | Younger Pinedale moraine | Older rock glaciers |
| 18 | | | |
| 19 | | | |
| 20 | | | |

## Discussion

The distribution of talus and frost rubble in the Capitan Mountains indicates that the granophyre and aplite zones are more susceptible to freeze-thaw action than the porphyry zone. Production of debris appears to be controlled by the chemical composition and intensity of fracturing of the pluton when favorable climatic conditions exist. The heavy forest growth in the eastern part of the range may be related to the mafic minerals in the pluton at that locality. More intense chemical weathering of the bedrock apparently results in thicker soil, which promotes forest growth. The thicker soil helps protect the bedrock from freeze-thaw action and restricts the formation of talus and frost rubble east of the saddle at the head of Hinchley Canyon. The scarcity of soil, as well as the well-developed fracture system, in the granophyre and aplite zones enables blocks and slabs to be dislodged easily by frost action, resulting in the generation of large volumes of debris.

The characteristics of rock glaciers in the eastern part of the Capitan Mountains indicate two late Wisconsin periglacial episodes separated by a period of warmer and drier conditions. The climate under which the older rock glaciers were generated was of sufficient intensity and duration to produce large volumes of talus and to mobilize the talus into rock glaciers below slopes eroded in porphyry. The snow cover probably was thin and of short duration, which favored intense freeze-thaw action. The mean annual temperature was below freezing, which resulted in the formation and preservation of interstitial ice.

The earlier periglacial episode was followed by warmer and drier conditions, which terminated rock-glacier activity and initiated a period of eolian deposition on the older surfaces. The composition and texture of the sand and silt grains in the eolian mantle suggest that it was locally derived from the erosion of the pluton and/or from alluvial deposits around the base of the mountains.

A later periglacial episode resulted in the generation of 14 younger rock glaciers, possibly at localities where the porphyry is more intensely fractured. The presence in Las Tablas Canyon of an older rock glacier down canyon from the front of a younger form suggests that the later periglacial episode was less severe and/or of shorter duration than the earlier episode. This hypothesis is supported by the stratigraphic record in the Estancia Basin, which demonstrates that the climatic changes during the full glacial high stand were more profound and of longer duration than those of the younger high stand (Allen, 1991; Allen and Anderson, 1993).

Near the close of the late Wisconsin (about 12 ka) the climate again moderated and resulted in the cessation of processes that formed rock glaciers. The organic debris on the older and younger rock glaciers probably formed during the Holocene (11 ka to present) when warmer conditions prevailed. The presence of partially decomposed organic debris indicates that the process continues at the present time.

The absence of observable rock glaciers with the characteristics of older forms in the western part of the Capitan Mountains implies one of three possibilities: (1) the older rock glaciers never formed; (2) they formed but were completely overridden by younger rock glaciers during the later periglacial episode; or (3) they were generated during the earlier periglacial episode, became inactive when less severe conditions prevailed, and were reactivated during the later episode. Because aplite and granophyre are more susceptible to freeze-thaw action than porphyry, it is probable that rock glaciers developed in the western part of the range when older forms were being generated in the east. No younger rock glaciers either situated up valley from or overriding the heads of older forms were observed either in the field or on aerial photographs in the western part of the range. If older rock glaciers exist in the west, they are completely covered by younger forms, which seems unlikely if the earlier periglacial episode was more severe and/or of longer duration than the later episode.

## Conclusions

Physiographic criteria and soil development may be used to distinguish rock glaciers of two ages in the Capitan Mountains. Physiographic expression and soil development suggest a late Wisconsin age and indicate two periglacial episodes separated by a period of warmer and drier conditions. The distribution of older and younger forms appears to be controlled by structure and lithology of the bedrock, although the younger forms in the eastern part of the mountains are not clearly understood. The absence of observable rock glaciers showing the characteristics of older forms in the western part of the range also is subject to interpretation but may be due to the reactivation of older forms during the later periglacial episode. The older rock glaciers in the eastern part of the range were not reactivated during the less severe climate of the later periglacial episode because granite prophyry is less susceptible to freeze-thaw action than the aplite and granophyric granite to the west, which resulted in a scarcity of blocky debris necessary for rock-glacier movement. The rock glaciers suggest a late Wisconsin climatic history for the Capitan Mountains comparable to that indicated by glacial and periglacial deposits on Sierra Blanca Peak and the sedimentary record in the Estancia Basin. Detailed mapping of and an extensive soil sampling program on the forms in the eastern part of the range may indicate a more complex late Wisconsin history than that presented in this paper.

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## Geographic Names

### U. S. Board on Geographic Names

**South Sandia Spring**—spring, in Cibola National Forest/Sandia Mountain Wilderness, 2.4 km (1.5 mi) south of South Sandia Peak, 1.1 km (0.7 mi) east of Three Gun Spring, 4 km (2.5 mi) northwest of Tijeras; Sandovol County, NM; sec. 8 T10N R5E, NMPM; 35°05′56″N, 106°25′32″W; USGS map, Tijeras 1:24,000.

**Steins Peak**—summit, elevation 1,786 m (5,861 ft), on the south side of Doubtful Canyon, 12.5 km (7.8 mi) north–northwest of Steins, 0.8 km (0.5 mi) east of the Arizona State boundary; named for Major Enoch Steen (1800–1880); Hidalgo County, NM; sec. 6 T23S R21W, NMPM; 32°20′01″N, 109°02′ 35″W; USGS map, Doubtful Canyon 1:24,000; *not* Steens Peak.

**Bald Knoll Tank**—reservoir, 38 m (125 ft) by 30 m (100 ft), in Gila National Forest, along the west slope of the Big Burro Mountains, 1.9 km (1.2 mi) northeast of Joe Harris Spring, 4 km (2.5 mi) northwest of Bullard Peak; Grant County, NM; sec. 23 T18S R17W, Gila and Salt River Meridian; 32°43′29″N, 108°34′ 25″W; USGS map, Bullard Peak 1:24,000; *not* Bold Tank.

**Burnt Mill Canyon**—valley, 3.2 km (2 mi) long, in Cibola National Forest, heads at 35°11′26″N, 108°25′13″W, trends southwest to a point 6.3 km (3.9 mi) northeast of the community of Ramah, 6.4 km (4 mi) north of Wild Sheep Mesa; Cibola County, NM; secs. 20, 17, 16, 9 & 10 T11N R15W, NMPM; 35°10′17″N, 108°26′ 35″W; USGS map, Ramah 1:24,000; *not* Oak Hollow.

**Kelly Tank**—reservoir, 61 m (200 ft) by 53 m (175 ft), in Gila National Forest, between Park Canyon and Burro Spring Canyon, 8 km (5 mi) south–southwest of Bullard Peak; Grant County, NM; sec. 23 T19S R17W, Gila and Salt River Meridian; 32°38′20″N, 108°34′16″W; USGS map, Bullard Peak 1:24,000; *not* Burro Spring Tank.

**Oak Hollow**—valley, 4 km (2.5 mi) long, in Cibola National Forest, heads at 35°11′44″N, 108°23′04″W, trends southwest to a point 8 km (5 mi) northeast of the community of Ramah; Cibola County, NM; secs. 14, 15 & 22 T11N R15W, NMPM; 35°10′05″N, 108°24′ 55″W; USGS map, Ramah 1:24,000.

**Richardson Tank**—reservoir, 53 m (175 ft) by 30 m (100 ft), in Gila National Forest, along Burro Spring Canyon, 8.9 km (5.5 mi) south–southwest of Bullard Peak; Grant County, NM; sec. 23 T19S R17W, Gila and Salt River Meridian; 32°38′ 04″N, 108°34′14″W; USGS map, Bullard Peak 1:24,000; *not* Richard Tank.

—David McCraw
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