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A FOSSIL ROCK GLACIER ON SAN MATEO PEAK, SOCORRO COUNTY, NEW MEXICO

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Abstract—A tongue-shaped, fossil rock glacier of Wisconsin age is at the head of a valley at an elevation of about 2,700 m on the northwest slope of San Mateo Peak. It is 285 m long and 75 m wide. Characteristic features include a steep front, a lateral ridge along the northeast flank, and longitudinal and transverse ridges and furrows. The rock glacier is composed of blocks and slabby clasts of rhyolite with lengths of 1–1.2 m. The debris is stable and exposed faces bear a growth of lichen. Surface features indicate that the rock glacier moved by the flow of interstitial ice. The existence of the ice indicates a periglacial climate during the Wisconsin, with a mean annual temperature near freezing and permafrost at about 2,700 m on the northwest slope of the mountain.

INTRODUCTION

Rock glaciers are periglacial mass-movement deposits that occur in mountainous highlands in many parts of the world. Potter (1972: 3027) defines a rock glacier as a tongue-like or lobate mass of angular boulders that resembles a small glacier with ridges, furrows, and lobes on its surface and a steep front at the angle of repose. White (1981) recognized two principal types of rock glaciers distinguished by shape and topographic position. Tongue-shaped rock glaciers are elongated masses of rock debris that are longer than broad. They occur in cirques and on valley floors near their heads. Lobate rock glaciers are as broad as, or broader than, they are long. They are single or multiple lobes that originate at the base of talus cones along valley walls.

Wahrhaftig & Cox (1959), in their studies in the Alaska Range, set a standard for the terminology of the gross features and surface relief of rock glaciers. The front of a rock glacier is the steep face that marks the downvalley end. The sides are abrupt embankments that generally diminish in height upvalley, and the head is the place where the rock glacier merges with the talus that feeds it. Lateral ridges are prominent embankments that border the sides and stand slightly higher than the surface. Surface-relief features include longitudinal and transverse ridges and furrows, conical pits, and meandering furrows. Longitudinal ridges and furrows usually extend the greater part of the length of a rock glacier and parallel the apparent direction of flow. Transverse ridges and furrows perpendicular to the apparent direction of movement are generally convex downslope. They commonly die out against longitudinal ridges or bend sharply to merge with them. Conical pits are steep-sided depressions with walls at the angle of repose. Meandering furrows are incised trenches extending lengthwise down the rock glaciers, commonly near the center.

Active rock glaciers occur either as debris covering a small glacier that moves downslope as a result of the flow of glacial ice (ice-cored rock glacier) or as an ice-cemented mass of debris that moves downslope due to the flow of the interstitial ice (ice-cemented rock glacier) (Péwé 1983a). The debris that comprises rock glaciers may be fed directly onto them by rockfalls, small rock slides, snow avalanches, and glacial processes or may be derived from existing land forms such as talus, avalanche boulder tongues, block fields, protalus ramparts, and moraines that resulted from such processes (Luckman & Crockett 1978: 541). Ice-cored rock glaciers are distinguished by saucer- or spoon-shaped depressions between the base of cirque headwalls and the rock glaciers, longitudinal furrows along both sides, central meandering furrows, and conical or coalescing collapse pits (White 1976: 79–80). Ice-cemented rock glaciers lack depressions at their heads and have continuous talus and avalanche slopes feeding onto the rock glaciers (Luckman & Crockett 1978: 542).

Fossil rock glaciers are useful in reconstructing ancient Quaternary environments because they indicate periglacial climates characterized by frequent freezing and thawing. The formation of a rock glacier requires a climate that promotes the generation of large volumes of talus by intense freeze–thaw action. At the present time, optimum conditions for ice-wedging apparently take place in a humid climate with frequently recurring freeze and thaw. This process also occurs in dry climates, but probably more slowly (Flint 1971: 271).

Ice-cemented rock glaciers indicate the presence of permafrost and a periglacial climate of sufficient intensity to allow the ice to occur and deform under pressure (White 1981: 134). They are good indicators of perennially frozen ground in alpine regions and form in areas where the mean annual air temperature is 0°C or lower (Péwé 1983b). They appear to be confined to regions of permafrost, with their fronts lying in the colder parts of the discontinuous permafrost zone (Harris 1981). Fossil, ice-cemented, rock glaciers can be used to delineate ancient zones of permafrost and to determine the decrease in elevation of permafrost during periglacial episodes (Péwé 1983b).

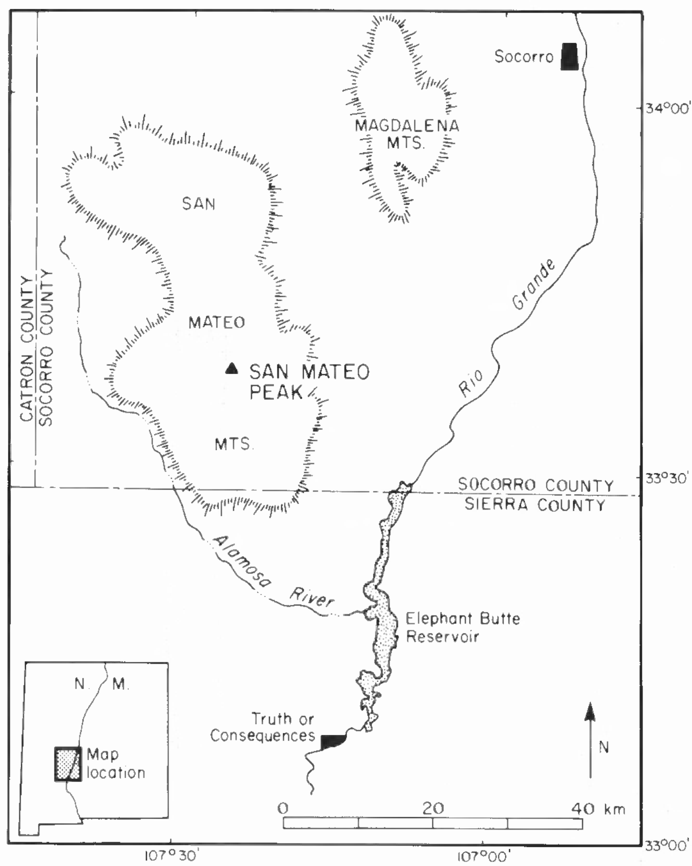

FIGURE 1—Location of San Mateo Peak in the San Mateo Mountains, Socorro County, New Mexico.

GEOGRAPHIC AND GEOLOGIC SETTING

San Mateo Peak is a prominent mountain with a summit elevation of 3,091 m, located near the southern end of the San Mateo Mountains about 55 km northwest of Truth or Consequences in Socorro County, New Mexico (Fig. 1). Access is provided by traveling on U.S. Forest Road 225 a distance of 24 km from the junction of U.S Highway 85 to Springtime Campground. The summit of San Mateo Peak is reached by a pack trail which extends about 8 km northwestward from Springtime Campground. The rock glacier described in this paper is on the northwest flank of the peak and is accessible by foot from the mountain summit (Fig. 2).

The San Mateo Mountains trend in a northwesterly direction for about 55 km and are about 25 km wide. The crest of the range is at about 2,745 m and is approximately 1,220 m above the adjacent valleys of the Rio Grande and Alamosa River. San Mateo Peak along with several other peaks rise above the general summit level and attain elevations of over 3,050 m.

The mountains are formed by an uplifted fault block composed of Tertiary volcanic rocks with a total thickness of 3,050 m (Farkas 1969). A lower series of andesitic tuffs and flows is overlain by a thick mass of rhyolitic ash-flow tuffs which forms most of the higher ridges and peaks of the range. Block faulting of probable late Miocene age uplifted the mountains and downdropped the valleys with displacements of over 2,000 m in some instances.

San Mateo Peak is formed by rhyolitic welded ash and tuff (Furlow 1965). The northern slope is dissected by several steep-walled valleys 60–150 m deep. The valleys head at about 2,745 m and are tributary to Smith Canyon, one of the major drainages of the San Mateo Mountains. A forest composed mainly of Douglas fir and aspen grows on the peak and indicates a much cooler and more humid climate than that in the adjacent Rio Grande and Alamosa River valleys. Annual precipitation on the peak may be between 65–75 cm, and the mean annual temperature is about 2°C.

Talus forms sheets on many of the steep slopes in the San Mateo Mountains and covers extensive areas of the flanks of the high peaks. Most talus has smooth, concave slopes and is composed of angular fragments of rhyolite ranging in diameter from 0.15–2 m. A few deposits have irregular, hummocky, or wavy surfaces that may have resulted from localized movement of the debris due to frost action or solifluction. Rock glaciers occur at the base of talus at the heads of valleys and gullies on Blue Mountain, San Mateo Peak, San Mateo Mountain, and Vicks Peak (Blagbrough & Farkas 1968). The form described in this paper is the largest and has the best defined surface features.

DESCRIPTION

The rock glacier is below talus at the head of a valley on the northwest side of San Mateo Peak (Fig. 2). It is tongue-shaped and has a length of about 285 m and a width of 75 m (Fig. 3). The toe is at an elevation of about 2,670 m and the head at about 2,800 m. The sides rise as embankments that, for much of their extent, are separated from the valley walls by gullies 1.5–6 m deep. The embankments diminish in height upslope and are absent near the head. The head merges with talus on the valley wall.

The rock glacier is formed by two talus tongues, both of which have steep fronts and ridges and furrows above the fronts. The upper tongue appears to have overridden the head of the lower. The lower tongue has a front 45 m high that slopes 30–40° downvalley. Talus from the valley wall encroaches upon the northeast flank and debris extending

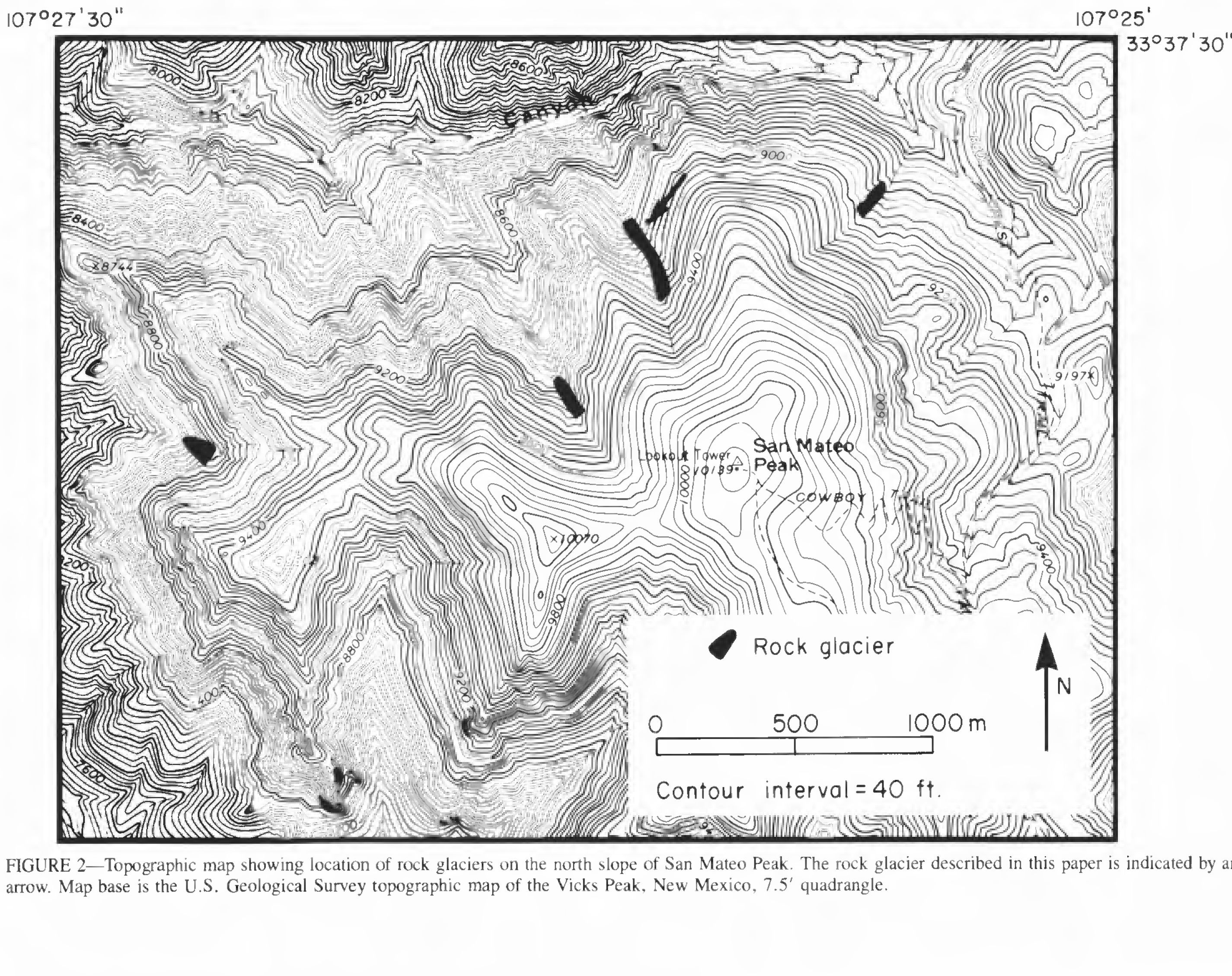

FIGURE 2—Topographic map showing location of rock glaciers on the north slope of San Mateo Peak. The rock glacier described in this paper is indicated by an arrow. Map base is the U.S. Geological Survey topographic map of the Vicks Peak, New Mexico, 7.5′ quadrangle.

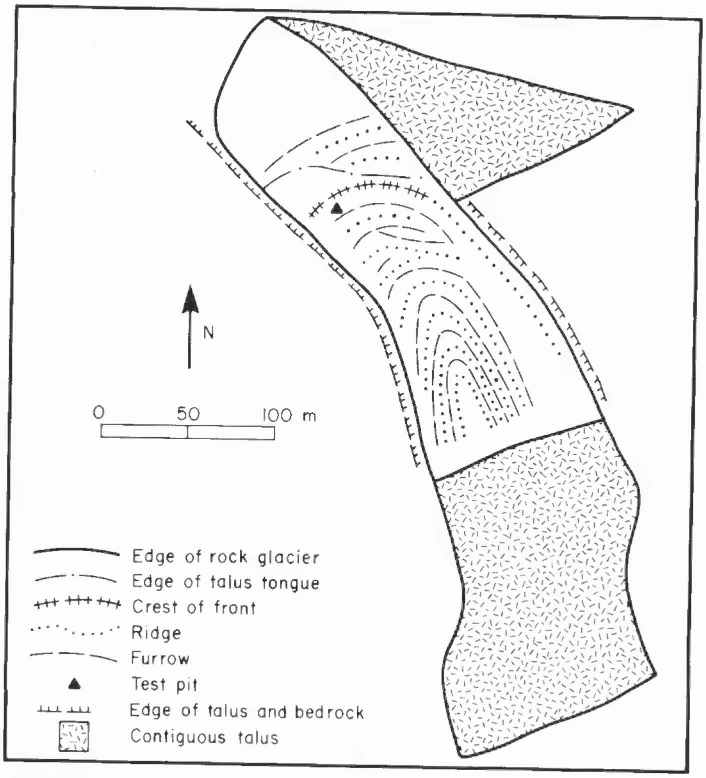

FIGURE 3—Sketch map of the rock glacier taken from U.S. Forest Service aerial photograph CIB 35061 11 146, 1974.

from the front of the upper tongue covers the southwest flank. A transverse ridge is at the crest of the front, and transverse ridges and furrows are between the crest and the base of the upper tongue. Ridge crests are about 1.5 m above the furrows. The surface above the front slopes downvalley at about 10°.

The upper tongue has a front about 8 m high that slopes 35° downvalley. A well-defined transverse ridge is at the crest of the front and bends to form a lateral ridge that rises as a steep embankment 3–9 m high along the northeast flank (Figs. 4, 5). Longitudinal and transverse ridges and furrows are on the surface above the front. Most longitudinal ridges bend to form transverse ridges that are convex downslope. Ridges commonly have basal widths of 3–6 m. Ridge crests are usually 2–5 m above furrows, which are 2–5 m wide. The surface above the front slopes 10–15° downvalley.

The rock glacier is composed of angular to subangular blocks and slabby clasts of rhyolite derived from the valley walls. The average size is 1–1.2 m with range from 0.15 to 2 m. Debris comprising the ridges has an average length of 1.2–2 m and is larger than that in the furrows and on the frontal faces where dimensions are 15–90 cm.

Debris on the surface of the rock glacier is stable, with 30–60% of exposed faces covered with lichen. Desert varnish is on the exposed faces of some of the debris, and a few fragments have undergone frost shattering while on the rock-glacier surface. Soil is absent and a few trees grow on the front of the lower tongue midway between the base and crest.

No exposure of the interior of the rock glacier is available for study, so the structure and composition below the surface are unknown. A test pit about 1.2 m deep was excavated just above the crest of the front of the upper tongue on 29 April 1966. It showed that ice formed a matrix cementing debris 2.5–15 cm in diameter below surface fragments 1–1.2 m in diameter. The ice apparently formed by the freezing of late-spring melt water and probably did not persist through the summer.

FIGURE 4—Oblique aerial view of the upper tongue of the rock glacier showing longitudinal and transverse ridges and furrows above the front. Prominent lateral ridge (arrow) about 10 m high delineates the northeast flank and bends to form the transverse ridge at the crest of the front. View is to the northwest. Photo W.O. Hatchell 1966.

FIGURE 5—Surface of the upper tongue of the rock glacier above the front. Lateral ridge in the foreground forms a steep embankment on the northeast flank and bends to form a transverse ridge at the crest of the front. The man at the right (arrow) is at the crest of the front; the man on the left (arrow) is on a higher transverse ridge.

AGE

Glacial events on Sierra Blanca Peak in south-central New Mexico about 145 km east of the San Mateo Mountains (Richmond 1963) and in the White Mountains in east-central Arizona about 200 km west of the San Mateo Mountains (Merrill & Péwé 1972, 1977) provide a reference for determining the age of the rock glacier on San Mateo Peak. Two substages of Wisconsin Glaciation are mapped on Sierra Blanca Peak (Tab. 1). A shallow cirque, at an elevation of about 3,500 m, is on the northeast side of the mountain. Terminal moraines are in the cirque and in a canyon extending to the northeast. Terminal moraines of the Bull Lake Glaciation are considerably dissected and are covered by a mature soil about 90 cm thick. Terminal moraines of the Pinedale Glaciation are little dissected and bear an immature soil about 25 cm thick. Talus on the cirque headwall is stable and is covered by soil and vegetation. No glacial nor periglacial deposits of Neoglacial age occur between the youngest Pinedale moraine and the cirque headwall.

Glacial deposits of pre-Wisconsin, Wisconsin, and Neoglacial age are described in the White Mountains. The Purcell Glaciation of pre-Wisconsin age is marked by highly subdued moraines. Weathering has produced deep pits on the boulders and a moderately to well-developed soil. Evidence for the Smith Cienega Glaciation of early Wisconsin age consists of moderately subdued moraines and fluvial and lacustrine deposits. The moraines are covered by a zonal soil less than 40 cm thick and pits are beginning to develop on the boulders. The Baldy Peak Glaciation is marked by sharp-crested moraines that contain boulders without pits and that bear a shallow, azonal soil less than 20 cm thick. A single, well-preserved, bouldery moraine, protalus ramparts, and periglacial talus represent deposits associated with the Mount Ord Glaciation of Neoglacial age. The original surface of the moraine is preserved. Boulders on the surface are fresh and a weak azonal soil about 12 cm thick has developed on the sediment between the boulders.

The rock glaciers in the San Mateo Mountains are assigned a Wisconsin age by Blagbrough & Farkas (1968) mainly because the absence of glacial and periglacial deposits of Neoglacial age on Sierra Blanca Peak suggests that the climate in south-central New Mexico during the Holocene has not been favorable for the formation and movement of rock glaciers. Recent studies in the Sacramento Mountains in south-central New Mexico (Van Devender et al. 1984), and in the San Agustin Plains in western New Mexico (Markgraf et al. 1984) suggest very little cooling during the Holocene. However, the glacial and periglacial deposits of Neoglacial age in the White Mountains do indicate a climate somewhat cooler than at present. The rock glacier on San Mateo Peak probably formed during the Wisconsin because climatic changes of sufficient intensity and duration are needed to generate talus and to mobilize the talus into a rock glacier (D.W. Love written comm. 1986). Sharply defined ridges and furrows, restricted growth of vegetation, and absence of soil on the rock glacier suggest that some movement may have taken place in Neoglacial time when the Mount Ord deposits were forming in the White Mountains.

DISCUSSION AND CONCLUSIONS

The rock glacier on San Mateo Peak is thought to be an ice-cemented form because it has contiguous talus extending onto its head and because it lacks the characteristic features of ice-cored forms. It developed from talus that accumulated at the base of steep mountain slopes and became cemented with interstitial ice. The vegetation on its front and the lichen-covered debris demonstrate that it is a fossil form that has been inactive for a considerable time.

The rock glacier indicates a periglacial climate during the Wisconsin with a mean annual air temperature of about 0°C and permafrost at a lower limit of about 2,670 m on the north side of San Mateo Peak. At the present time, alpine permafrost in the White Mountains of east-central Arizona is computed by temperature extrapolation to be at 3,475 m (Péwé 1983a: tabs. 9–5). These figures indicate that permafrost was

TABLE 1—Correlation of late Quaternary glacial and periglacial events in south-central New Mexico and east-central Arizona.

		Sierra Blanca, New Mexico (Richmond, 1963)		White Mountains, Arizona (Merrill and Péwé, 1972, 1977)		San Mateo Peak, New Mexico (This Report)
Holocene	Neoglaciation			Mount Ord		Rock glacier movement
Pleistocene	Wisconsin	Pinedale	Late Middle Early	Baldy Peak	Late Early	Rock glacier formation
		Bull Lake	Late Early	Smith Cienega		
	Pre-Wisconsin			Purcell		

depressed about 800 m on San Mateo Peak during the Wisconsin. This amount of depression is 200 m less than the 1,000 m maximum lowering for Wisconsin permafrost in the Cordillera of North America computed by Péwé (1983b: 172).

Brakenridge (1978) believes that the Wisconsin (full-glacial) climate in the southwestern United States was cold and dry. Wisconsin snow lines and cryogenic deposits are explained by a 7–8°C annual cooling with annual precipitation close to that of the present. The interstitial ice observed in the rock glacier on San Mateo Peak indicates that precipitation in the area is presently sufficient for ice formation and suggests that lower temperatures alone may be the critical factor for rock-glacier movement.

The rock glacier on San Mateo Peak formed under periglacial conditions in the Wisconsin under a climate distinguished by intense diurnal freezing and thawing. Temperatures were low enough for the interstitial ice to develop and for movement to take place under pressure. Mean annual temperature was probably near freezing and annual precipitation may have been close to that of the present. The rock glacier probably became inactive at the end of the Wisconsin when warmer temperatures caused the interstitial ice to melt. Slightly lower temperatures during Neoglacial time regenerated interstitial ice, resulting in some movement.

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