[AMERICAN JOURNAL OF SCIENCE, VOL. 257, FEBRUARY 1959, P. 81-94]

American Journal of Science

FEBRUARY 1959

PLEISTOCENE GLACIERS ON SOUTHERN CALIFORNIA MOUNTAINS*

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ABSTRACT. The deposits of 7 valley glaciers have been mapped in the San Gorgonio area of the San Bernardino Mountains in southern California. These ice bodies headed at elevations between 10,300 and 11,300 feet, the lowest elevation attained was 8700 feet, and lengths were 0.5 to 1.7 miles. Dry Lake glacier was the largest. It covered 0.84 square miles on the north slope of San Gorgonio Mountain.

The principal products of glaciation are cirques and huge terminal embankments of coarse angular debris up to 700 feet high. Sharp-crested end moraines, typical recessional loops, and a number of other relations indicate that these embankments were formed by glaciers rather than as rock glaciers or debris flows. Two separate episodes of glaciation are recognized; both are considered Wisconsin.

Features previously attributed to glaciers in the San Gabriel Mountains were restudied. It is concluded that this range escaped glaciation in the Wisconsin and probably all earlier Pleistocene stages. San Jacinto Peak may have been glaciated, but definite proof has not yet been found.

INTRODUCTION

Evidence of glaciation on the slopes of San Gorgonio Mountain[3] has previously been reported (Fairbanks and Carey, 1910; Vaughan, 1922, p. 335-336). New maps, air photos, developments in the knowledge of mountain glaciation, and international interest in this occurrence (Klebelsberg, 1949, p. 463, 510; Flint, 1957, p. 310) motivated restudy of this and other possible sites of glaciation on southern California mountains. Glaciers in marginal areas are particularly sensitive indicators of environmental change and afford a possible means of establishing links with other Pleistocene events. Field work amounting to 29 man-days was carried on principally during weekends from May of 1954 to December of 1957.

PHYSICAL SETTING

For this report, southern California is arbitrarily defined as that part of the state south of Latitude 35° N. This eliminates high peaks of the southern Sierra Nevada and Telescope Peak in the Panamint Range. San Gorgonio Mountain (11,502 feet), the highest point in southern California, is in the southeastern part (34° 06′ N., 116° 49′ W.) of the San Bernardino Mountains (fig. 1). To the southeast across San Gorgonio Pass is San Jacinto Peak (10,831 feet), and to the west is the San Gabriel Range, which attains an elevation of 10,080 feet.

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[3] Reprint of a paper on this subject by Ingle and Moran (1958) was received after the present article had been set in type.

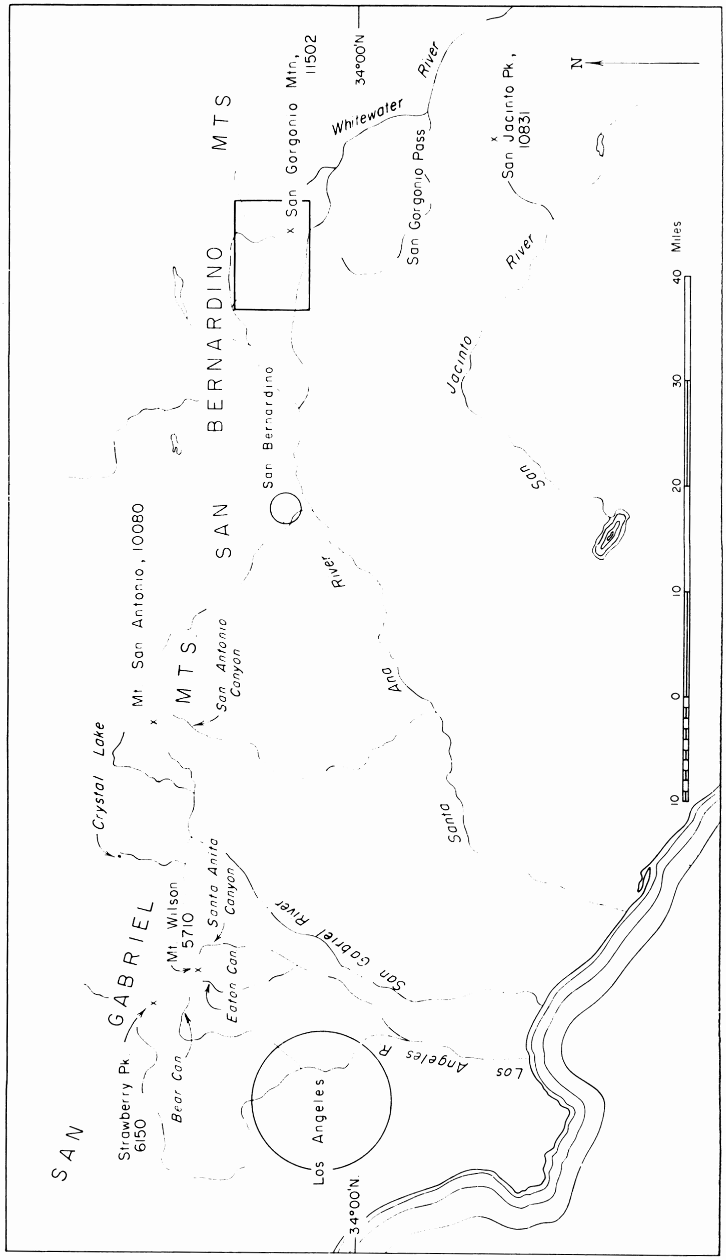


Fig. 1. Map of southern California localities.

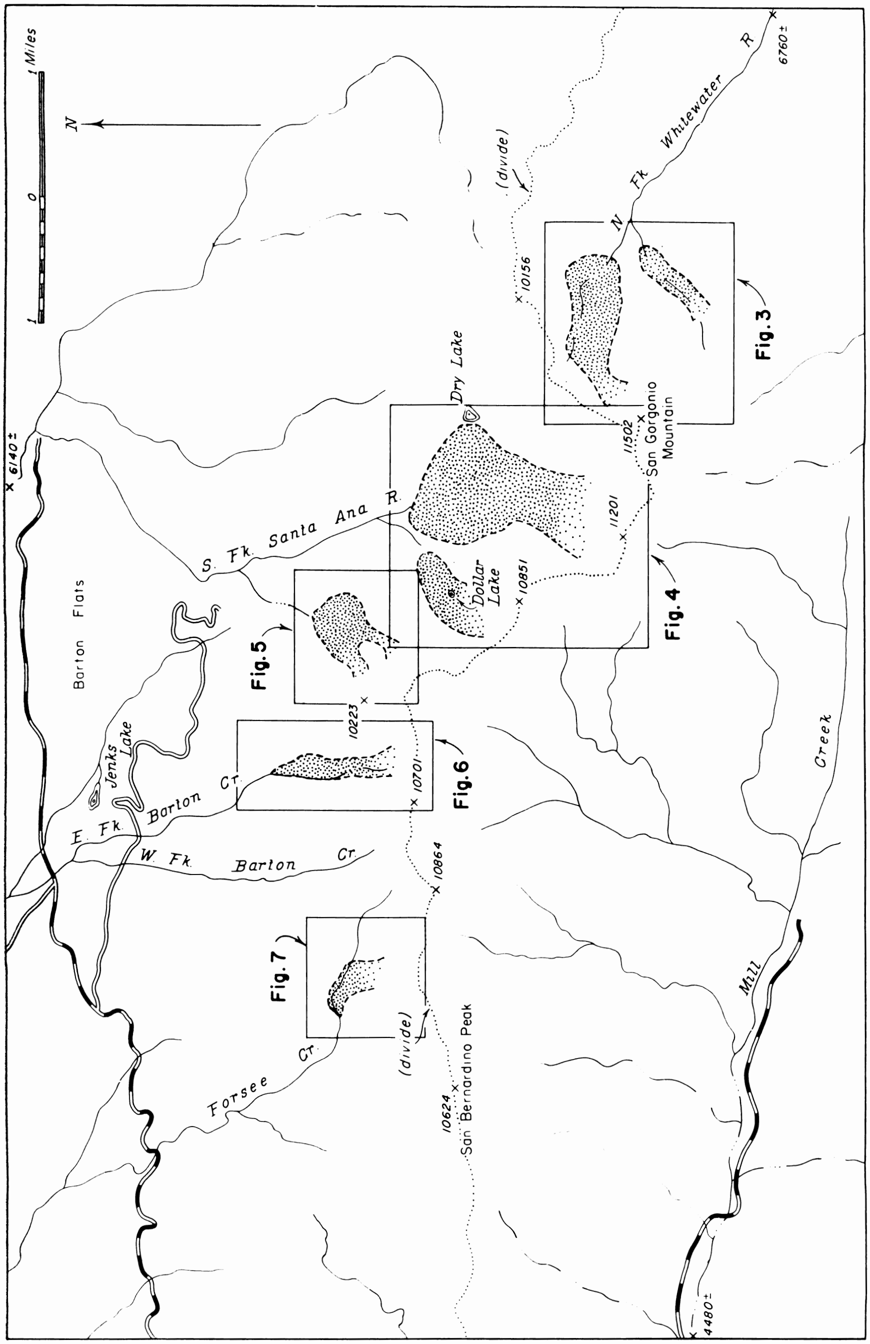


Fig. 2. Glaciated sites in the San Bernardino Mountains.

GLACIATION OF THE SAN GORGONIO MOUNTAIN AREA

Introduction

Localities of principal interest are on San Gorgonio Mountain and along a high ridge extending 6 miles west to San Bernardino Peak, shown on the new San Gorgonio Mountain quadrangle (1/62,500, 1955). Most elevations along this ridge are between 10,400 and 11,200 feet. The average annual precipitation above 8500 feet on San Gorgonio Mountain probably approaches 50 inches (Troxell, 1954, plate 6A), much of which is snow. Under present conditions snow banks linger well into July in protected places high on north-facing slopes.

The Glaciers

At least 7 cirque and valley glaciers formed in the San Gorgonio Mountain area (fig. 2). They headed at elevations between 10,300 and 11,300 feet, and none descended below 8700 feet (table 1). Lengths were 0.5 to 1.7 miles and areas 0.1 to 0.84 square miles. The Dry Lake glacier on the north side of San Gorgonio Mountain was the largest. Steep gradients, as much as 800 to 1000 feet per mile, prevented the ice from attaining a thickness in excess of a few hundred feet.

Consideration has been given to the possibility that the deposits and as-

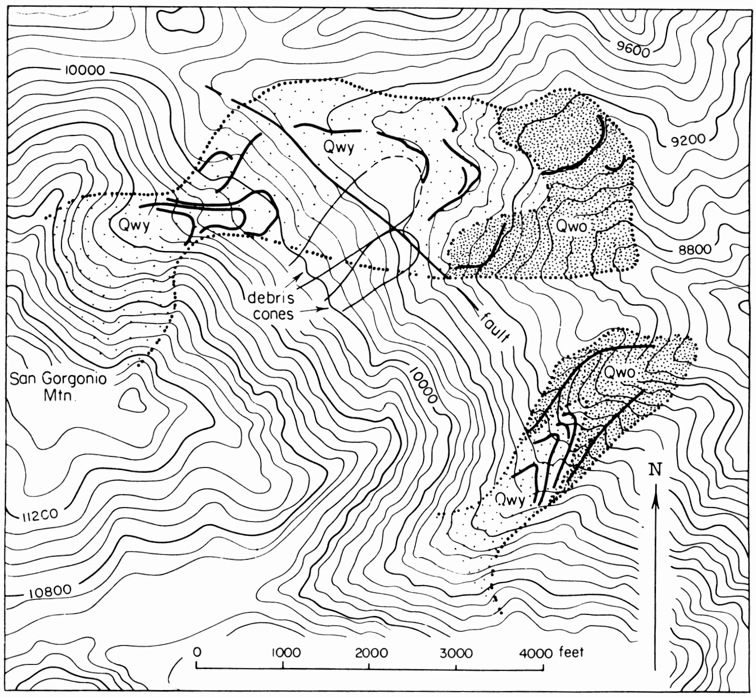


Fig. 3. Glacial deposits in the North Fork of Whitewater River area. South Prong at lower right. Qwo = old episode and Qwy = young episode of glaciation. Heavy lines represent individual moraines. Same designations apply for figures 3 to 7 inclusive.

PLATE 1
Moraines

Limbs of two end-moraine loops of the younger episode on east side of South Prong of North Fork of Whitewater River.

sociated topographic features might have formed as rock glaciers or debris flows. They are judged to be glacial for the following reasons: (1) The younger end moraines are distinct sharp-crested ridges and not rounded wrinkles or the ends of a series of bulbous concentric lobes such as characterize rock glaciers and debris-flow tongues. (2) Many of the end moraines are colinear with and clearly related to lateral moraines; this is generally not true of the swells or wrinkles on rock glaciers or debris-flow tongues. (3) The deposits inside the lateral ridges of a debris flow in general have a transverse profile convex upward. The deposits described herein have concave upward profiles. (4) Successive debris flows piled one on top of the other form embanked ridges along the centers of which the latest flows have run. There are no such features here. (5) The relatively narrow range in the upper and lower elevation limits for these features and their localization on northward-facing slopes make landslides an unlikely explanation. (6) The deposits are too blocky and lacking in fines to be typical debris-flow products.

The relations at all the glaciated sites suggest two separate glacial episodes of significantly different age. From east to west the glaciers occupied cirques or canyon heads as follows (fig. 2):

South Prong of North Fork of Whitewater River.—At the mouth of this canyon (fig. 3) are two prominent ridges which morphologically and constitutionally have the characteristics of lateral moraines. Plastered on the inside of the eastern lateral ridge is a distinctly younger, sharp-crested ridge, and nestled inside and near the head of these ridges are at least 4 and possibly 6 end moraines (plate 1) of the younger glacial episode (fig. 3). Much of the nourishment for this glacier probably gathered in a cirque on the north face of a peak nearly 11,000 feet high on the ridge south of this canyon (plate 2A). Some snow was also supplied from the steep south face of San Gorgonio Mountain.

North Fork of Whitewater River.—This glacier accumulated in a large cirque (plate 2A) on the northeast face of San Gorgonio Mountain (fig. 3). Its terminal position is marked by a bulky embankment completely choking the canyon and rising fully 700 feet above its east base, where several springs emerge. On the tread above this riser is an irregular complex of knobs, short ridges and closed depressions, cut transversely by a recent fault scarplet (fig. 3). A large lateral moraine projecting from the northeast ridge of the cirque encloses a number of loop moraines of the younger episode. The cirque is choked with coarse talus, but near its mouth are two distinct recessional moraines.

Dry Lake.—The glacial deposits of this locality have the greatest bulk, area, and complexity (fig. 4). The bulbous glacier which formed them was fed by two ice streams draining from large cirques on the north face of San Gogonio Mountain (plate 2B), or more specifically Jepson Peak (fig. 4). The huge embankment of coarse debris left by this ice closes the basin of Dry Lake on its west side and rises steeply 650 feet above South Fork Meadows. Many springs emerge from the base of this porous material. The topography of the tread at the top of this embankment is typically glacial, featuring knobs, depressions, and long curved morainal ridges with a relief of 25 to 100 feet. Flattish areas of outwash are scattered between the prominences. Well-shaped lateral moraines define the west margin, and high in the cirques are some recessional loops. Topographic complexity may be due partly to the fact that the two ice streams which formed the Dry Lake glacier bulb maintained a degree of independent behavior and produced a complex system of narrow loops which are much generalized by the scale of figure 4.

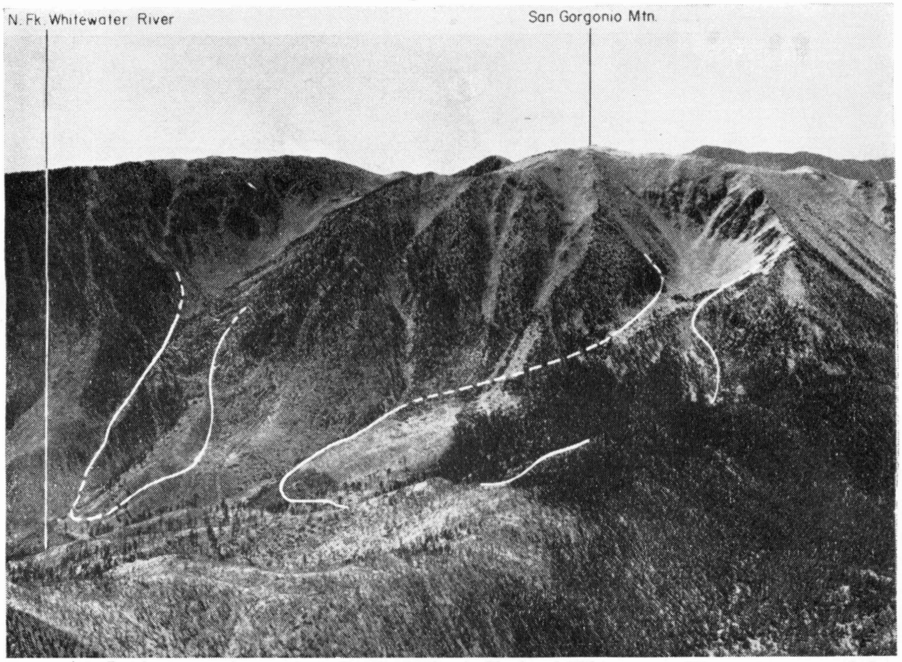
Dollar Lake.—The canyon of Dollar Lake is choked by a large embankment of coarse debris, and the lake is enclosed by a strong end moraine continuous with a lateral moraine extending 0.5 mile to the west on the north side of the canyon (fig. 4). Closure in the lake basin approaches 100 feet. The contact between deposits of the older and younger glaciations is marked by a small step part way down the face of the morainal embankment. Morainal loops and lateral ridges are easily recognized in the older deposits, but the loops are breached by stream erosion. Much of the nourishment for this glacier came from the north face of Charlton Peak.

West Prong of South Fork of Santa Ana River.—This valley held two small cirque glaciers of steep gradient which merged to build a single large embankment of debris during the older glaciation (fig. 5).

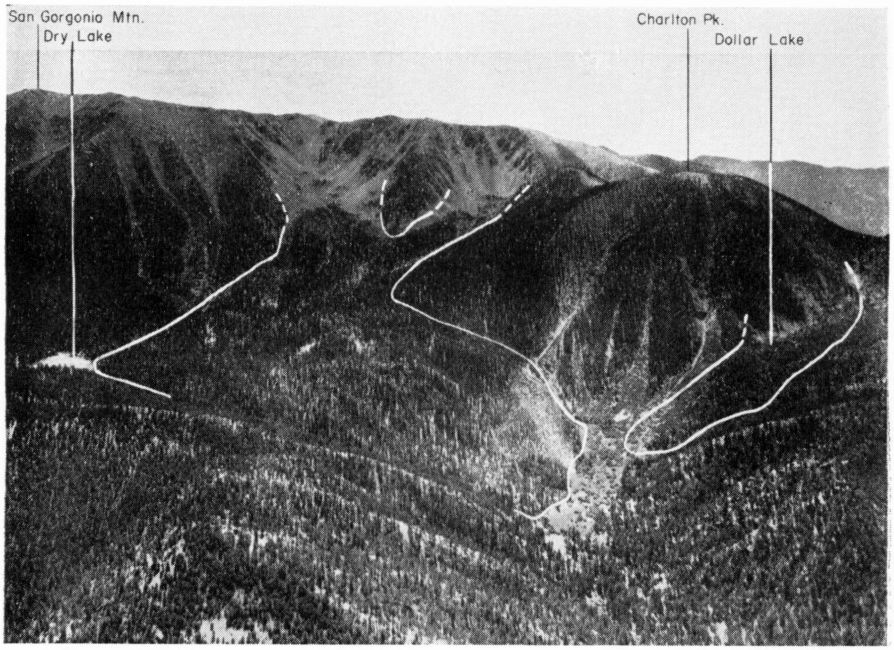
East Fork of Barton Creek.—The glacial deposits in this canyon are among the most instructive of the area. They feature a 700-foot high bouldery embankment choking the canyon from wall to wall (fig. 6). The north face of this embankment, consisting of material laid down during the older episode,

PLATE 2

Air Photos of San Gorgonio Mountain Glaciated Sites



A. Looking southwest into head of North Fork of Whitewater River. Cirque at left fed glacier in South Prong and cirque at right fed glacier in North Fork of Whitewater River. Lateral moraines of older stage visible at mouth of South Prong. Irregular topography of burned area in left foreground underlain partly by deposits of North Fork glacier.



B. Looking southwest into Dry and Dollar lakes area. Two central cirques on north face of San Gorgonio Mountain fed Dry Lake glacier. Note complex mass of morainal debris west of Dry Lake. Dollar Lake glacier fed from steep north face of Charlton Peak at right.

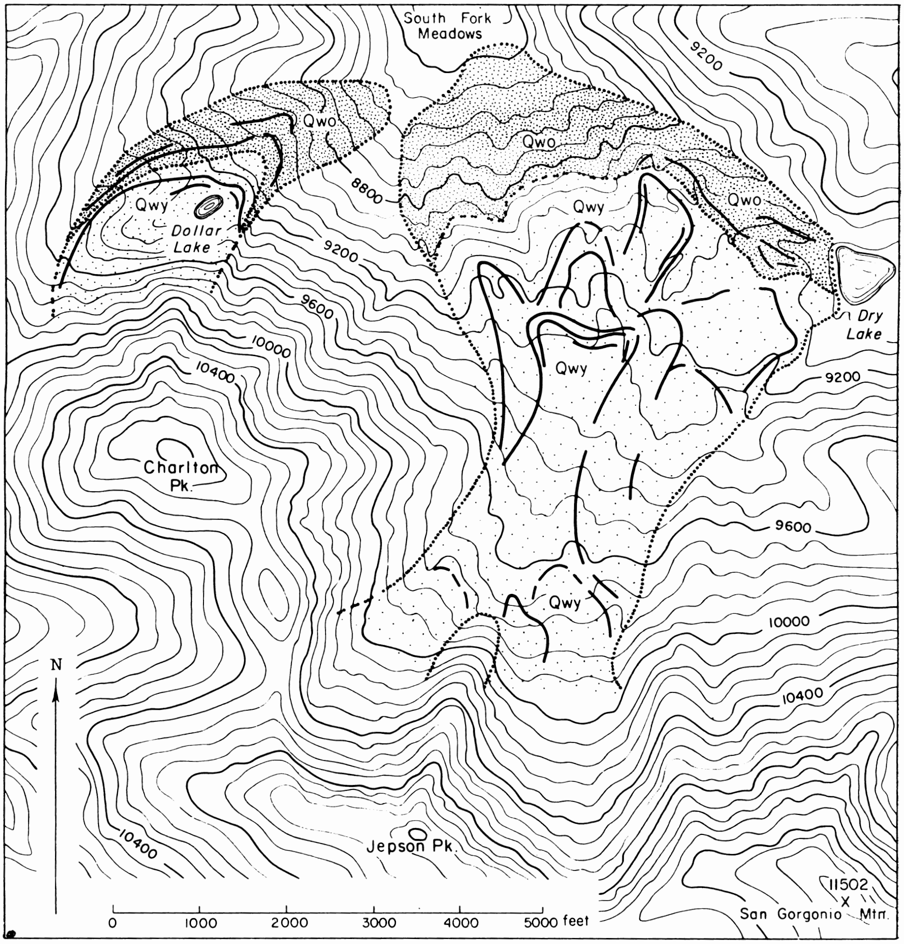


Fig. 4. Glacial deposits in the Dry and Dollar lakes area.

is terminated by a distinct but breached end moraine with springs at its base. The uppermost part of the embankment consists of younger deposits including an exceedingly blocky terminal moraine enclosing a marked axial depression that extends upvalley a quarter of a mile to a recessional moraine. Deposits of the two glaciations are clearly distinguished here by physical appearance and vegetative cover.

Viewed from the air the accumulations on Barton Creek are suggestive of rock glaciers. That the deposits are truly glacial is indicated by: (1) the elongate axial depression enclosed by the terminal and its associated lateral moraines of the younger episode, (2) the well-defined recessional moraine higher up the valley, and (3) the long east-side lateral moraine of the older glaciation.

TABLE 1

Data on Pleistocene Glaciers of the San Bernardino Mountains

Locality	Estimated elevation at head of glacier in feet	Lowest elevation attained	Length in miles	Approximate area square miles*	Principal direction of exposure
South Prong, North Fork of Whitewater River	11,000	8700 (1) 9100 (2)	1.0 (1) 0.7 (2)	0.17 (1) 0.14 (2)	E and N
North Fork of Whitewater River	11,300	9120 (1) 9440 (2)	1.3 (1) 1.0 (2)	0.36 (1) 0.30 (2)	N and NE
Dry Lake area	10,900	8800 (1) 9000 (2)	1.7 (1) 1.6 (2)	0.84 (1) 0.74 (2)	N
Dollar Lake	10,400	8960 (1) 9240 (2)	0.7 (1) 0.5 (2)	0.16 (1) 0.12 (2)	N and E
Tributary of South Fork Santa Ana River	10,300	8960 (1) 9000 (2)	0.8 (1) 0.7 (2)	0.19 (1) 0.16 (2)	NE
East Fork Barton Creek	10,300	8800 (1) 9050 (2)	0.8 (1) 0.6 (2)	0.11 (1) 0.09 (2)	N
Forsee Creek	10,300	8960 (1) 9060 (2)	0.6 (1) 0.5 (2)	0.12 (1) 0.10 (2)	NW

(1) = older episode
(2) = younger episode

* Second figure beyond decimal point is reported to indicate approximate difference in size.

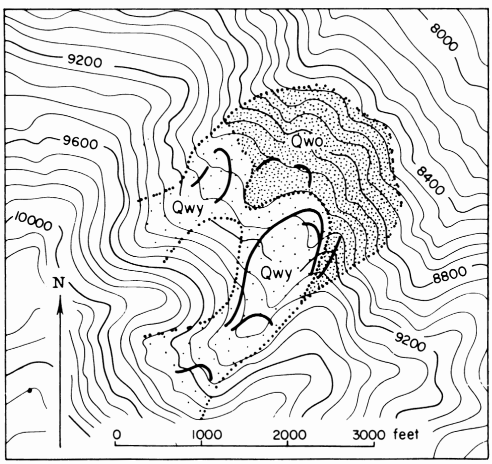


Fig. 5. Glacial deposits in the West Prong of the South Fork of Santa Ana River.

Forsee Creek.—The ice in Forsee Creek lay largely on the south side of the valley under a steep north-facing wall and flowed more across the valley than down it (fig. 7). This glacier built 3 distinct morainal ridges on the north side of the valley and a terminal embankment a short distance downstream. The north-side ridges are too far from the south valley wall to be protalus ramparts.

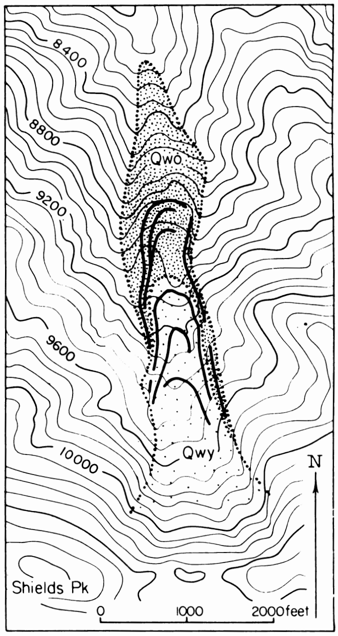


Fig. 6. Glacial deposits in the East Fork of Barton Creek.

Criteria of Age Differentiation

The older and younger glacial deposits of the San Gorgonio Mountain region are differentiated by the following criteria:

1. *Topographic position.*—Older deposits are farther down the valley and higher on the valley walls.

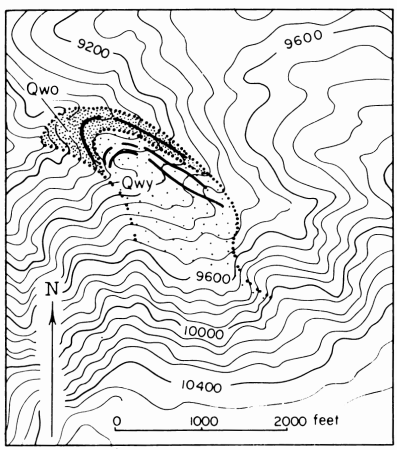


Fig. 7. Glacial deposits in Forsee Creek.

2. *Topographic expression.*—Landforms on the older deposits are rounded and subdued compared to sharp angular features on the younger deposits.

3. *Topographic unconformity.*—In some localities older morainal ridges disappear beneath the younger moraines with a marked difference in trend.

4. *Weathered color.*—Many of the older deposits are yellowish-brown in contrast to a predominantly grayish cast in the younger materials.

5. *Abundance of gruss.*—Gruss formed by disintegration of granitic boulders is more abundant and finer grained on the older deposits. It fills depressions thus helping to create a more subdued topography.

6. *Boulder relations.*—(a) Boulders on younger moraines are more angular and sharp edged because of recent fracturing without much subsequent rounding by other weathering. (b) On older deposits the surfaces of boulders are more roughened by pitting and disintegration. (c) More large boulders are found on younger moraines (table 2). (d) Boulder frequency is higher on the younger deposits (table 2). (e) Spalls and shattered boulders are more abundant on younger moraines composed of granitic rocks, for disintegration has largely destroyed such fragments on older deposits (table 2).

7. *Vegetation cover.*—Forests are relatively dense on the older deposits compared with scattered trees and heavy brush on younger moraines.

TABLE 2

Boulder Size, Frequency, and Condition on Older and Younger Moraines

Location	Predominant rock type	Age	Number of boulders 3 feet diameter in a strip 10 feet wide and 100 feet long	Number of boulders 1 ft. in diameter in a similar strip	Fractured boulders
Dry Lake	Quartz Monzonite	Younger	20	195	49%
		Older	8	75	39%
North Fork of Whitewater River	Quartz Monzonite	Younger	—	120	—
		Older	—	90	—
East Fork of Barton Creek	Gneiss	Younger	74	196	20%
		Older	17	108	20%
Dollar Lake	Quartz Monzonite and Gneiss	Younger	6	96	18%
		Older	4	48	15%

Episodes of Glaciation

By means of the criteria listed, two episodes of glaciation have been distinguished at all sites in the San Gorgonio area. The impression is gained that the older deposits have an age at least twice and possibly several times as great as the younger.

In cirques at the head of North Fork of Whitewater River, on the north face of San Gorgonio Mountain above Dry Lake, and at the head of East Fork of Barton Creek are blocky morainal loops which look fresher than most moraines of the younger episode. Upon some, grow stunted lodgepole pines which increment borings show to be 300 to 500 years old. These accumulations must be older than the 1850 moraines of the Sierra Nevada (Matthes, 1942, p. 197), but they may be due to an earlier phase of the "little ice age" (Matthes, 1942, p. 212-214; Holmes and Moss, 1955, p. 642-643) or to some other post-Wisconsin glacial episode. Since definite evidence is lacking, they are provisionally treated as recessional phases of the younger glaciation.

Correlation of the San Gorgonio Mountain sequence with glacial stages in other western mountains is purely speculative, but all the San Gorgonio deposits appear young enough to be Wisconsin. To some degree, they resemble Blackwelder's (1931) Tahoe (early Wisconsin) and Tioga (late Wisconsin) glacial stages of the Sierra Nevada. Thick deposits of boulder-rich, poorly sorted debris filling the canyon of Santa Ana River north of the areas of recognized glaciation may possibly be related to pre-Wisconsin glaciations. Since no proof of a glacial origin has been found, these deposits may actually be the product of accelerated mass wasting related to late Pleistocene episodes of refrigeration.

SUPPOSED GLACIATION OF THE SAN GABRIEL MOUNTAINS

Landforms and deposits at several localities in the San Gabriel Mountains (fig. 1) have been attributed to glaciation (Miller, 1926; 1928, p. 226-227). Skepticism concerning this interpretation arises from the fact that many of these glaciers would have formed at elevations as low as 5000 to 6000 feet. Even though they may have been pre-Wisconsin (Miller, 1926, p. 81), this seems much too low in view of the fact that Wisconsin glaciers in the San Gorgonio area required elevations 5000 to 6000 feet higher.

Not all of Miller's localities were visited, but at those inspected the relations do not require glaciation. Bear Canyon (Mt. Lowe quadrangle), a tributary of the Arroyo Seco, was described as a glacial U-shaped valley (Miller, 1926, p. 78-80). Upper Bear Canyon is indeed relatively open and lacks the narrow crookedness and overlapping spurs of lower Bear Canyon. However, this seems to be due principally to differences in bedrock, the upper part being in readily disintegrating Mt. Wilson diorite (Miller, 1934, map) and the lower part in more resistant Lowe granodiorite and San Gabriel Formation. Supposed glacial deposits on the floor of upper Bear Canyon have all the appearances of an alluvial accumulation.

The same explanation applies for similar relations in Big Santa Anita Canyon (Mt. Wilson quandrangle) near Sturtevant's Camp (Miller, 1928, p. 227). The upper open part of this canyon is in homogeneous Wilson diorite that is susceptible to relatively rapid granular disintegration.

The most intriguing locality is the Crystal Lake area at the head of North Fork of San Gabriel River (Crystal Lake quadrangle). Here, the deposits and topography are of a type that one might readily attribute to either glaciation (Miller, 1957, p. 212) or mass movements. However, the topography is, if anything, too chaotic, and it lacks the morainal loops and ridges so characteristic of glacial accumulations on San Gorgonio Mountain. Furthermore, none of the topographic features show any relations to possible sources of ice. If of glacial origin, these deposits could hardly be older than Wisconsin. The peaks and ridges enclosing this area attain a maximum elevation of 8500 feet, and the exposure is south. In view of altitude relations on San Gorgonio Mountain, this seems much too low for Wisconsin glaciers. These deposits and the peculiar topography are attributed to landslides and rock falls. Features on the north side of Strawberry Peak (Miller, 1928, p. 227) farther west in the San Gabriels are also judged to be of this origin.

The highest peak in the San Gabriel Range is Mt. San Antonio (10,080 feet). Inspection of the north, northeast and northwest faces of this peak disclosed no evidence of glaciation. The elevation is below that at which glaciers formed on San Gorgonio Mountain, and there is no reason to expect more favorable conditions such as heavier precipitation here. South of the peak, massive bouldery deposits that choke parts of San Antonio Canyon have been mapped as landslides (Ehlig, personal communication).

It is concluded that the San Gabriel Mountains escaped glaciation in the Wisconsin stage, and no evidence of glaciation during pre-Wisconsin stages has been seen.

SAN JACINTO PEAK

This relatively isolated peak, at 10,831 feet, is high enough for Wisconsin ice to have formed, given precipitation comparable to the San Gorgonio area and suitable sites for snow accumulation. Much of the north face of San Jacinto Mountain is so precipitous that snow would avalanche to lower slopes and glaciers could not form. Some topographic features of the summit area suggest glaciation, but definite proof of ice work has not yet been found. A tongue of bouldery debris extends northeast into Round Valley from an amphitheater heading in the saddle south of San Jacinto Peak. This deposit terminates as a bulbous mass at about 9800 feet and shows evidence of two episodes of development, but it lacks the morainal loops and closed depressions so typical of glacial deposits on San Gorgonio Mountain. Still the general relations incline one to regard it as more likely of glacial origin than not.

ACKNOWLEDGMENTS

Oblique air photographs were obtained with the aid of Paul MacCready. J. H. Birman kindly criticized the manuscript.

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