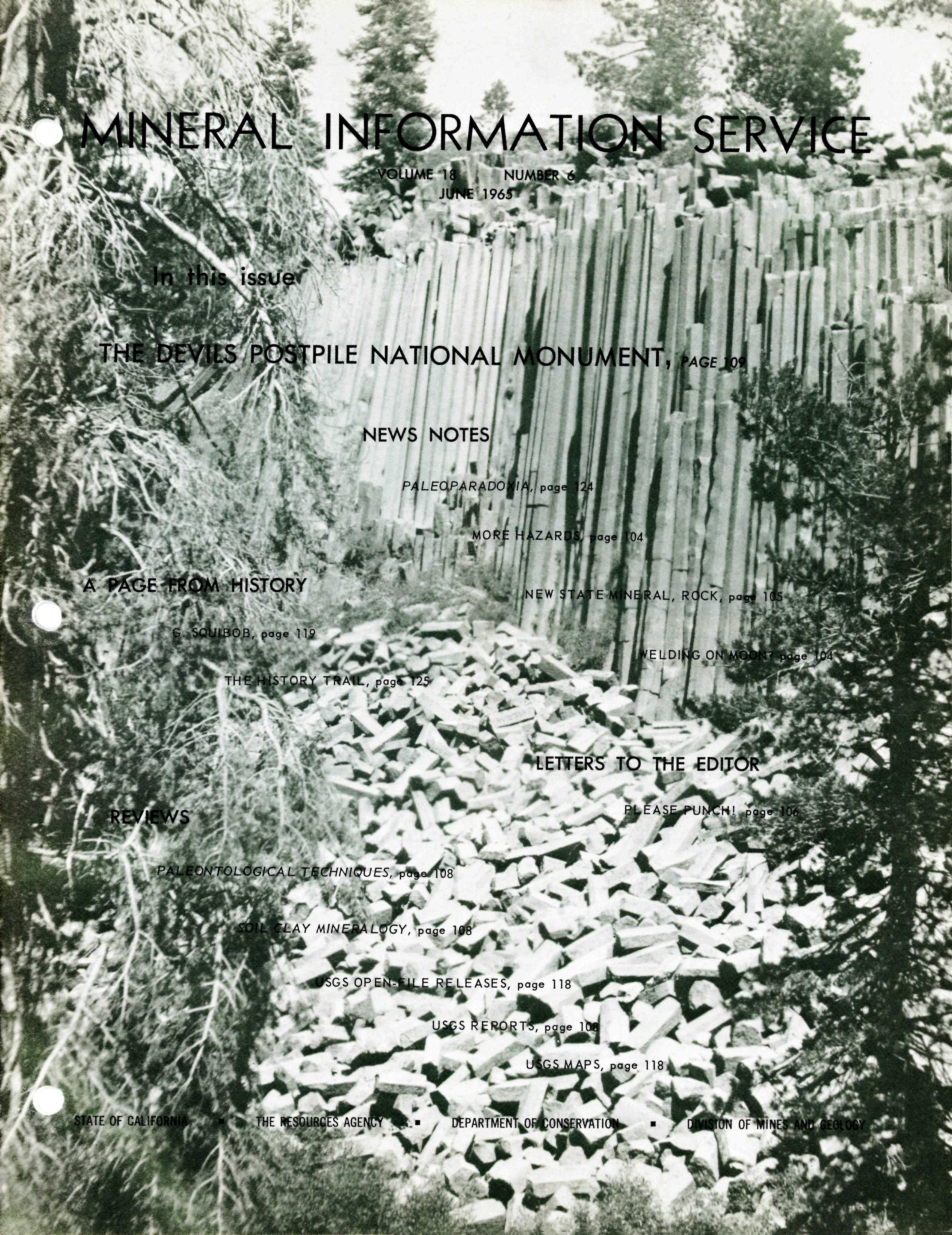

# MINERAL INFORMATION SERVICE

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In this issue



STATE OF CALIFORNIA ▪ THE RESOURCES AGENCY ▪ DEPARTMENT OF CONSERVATION ▪ DIVISION OF MINES AND GEOLOGY

# THE DEVILS POSTPILE NATIONAL MONUMENT

By N. KING HUBER and C. DEAN RINEHART[1]

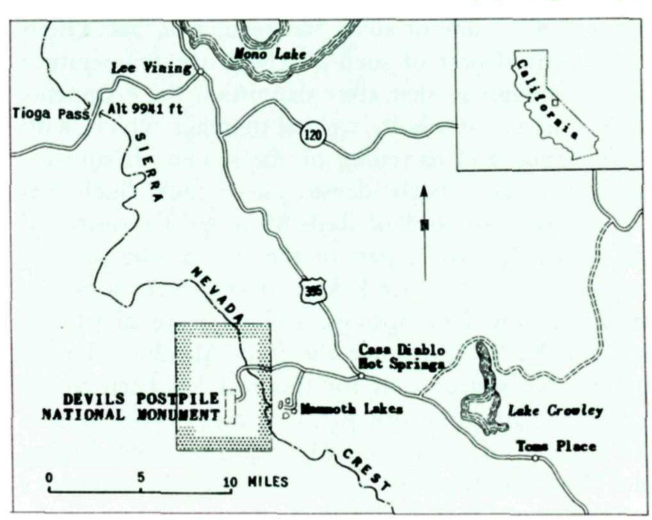
The headwaters of the Middle Fork of the San Joaquin River originate within one of the most scenic parts of the central Sierra Nevada, a region of glacially sculptured peaks, numerous lakes, and fascinating geology. The Middle Fork basin is flanked on the west by the jagged Ritter Range, culminating in peaks ranging in elevation from 10,000 to 13,000 feet, and on the east by the somewhat more subdued Sierra Crest, which reaches elevations of over 11,000 feet. Within this setting, partly forested, partly alpine, lies the Devils Postpile National Monument—a monument dedicated to the preservation of the Devils Postpile itself, a striking example of columnar jointing in a lava flow.

The Devils Postpile National Monument is reached by a 12-mile graded and partly paved road that connects with the Mammoth Lakes road 5 miles west of U. S. Highway 395, the main north-south route along the eastern side of the Sierra Nevada. At Minaret Summit the road crosses the main Sierra drainage divide (Sierra Crest) and descends into the Middle Fork canyon. Although the Ritter Range is higher, streams on its eastern side are tributary to the Middle Fork of the San Joaquin River, which cuts across the south end of the range and flows down the western slope of the Sierra to the San Joaquin Valley. The topography of the Sierra drainage divide is greatly subdued compared to that of the Ritter Range, for the former is underlain chiefly by more easily erodable volcanic rocks of Pliocene and Pleistocene age, whereas the Ritter Range is composed of more resistant metamorphic and granitic rocks of Mesozoic age that make up the bulk of the Sierra Nevada.

## Geologic Setting

The history of the Sierra Nevada prior to the outpouring of the Tertiary volcanic rocks is beyond the scope of this article; the bibliography lists several papers dealing with the earlier geologic history of the range. Suffice it to say that by late Tertiary time, the metamorphic and granitic rocks of the Sierra Nevada were deeply eroded, and the range had attained approximately its present configuration, except for modifications related to later faulting, uplift, and increased dissection. Beginning somewhat less than four million years ago, the Mammoth Lakes region has become the site of recurrent volcanic activity that has continued essentially into the present. The Devils Postpile was formed in a lava flow erupted during this extended period of volcanism, but before considering the Postpile itself, it is of interest to see how this par-

Map showing location of Devils Postpile National Monument. Shaded outline shows area covered by geologic map.




[1] U. S. Geological Survey. Publication authorized by the Director, U. S. Geological Survey.

ticular flow fits into the larger picture of volcanism during the late Tertiary and Quaternary Periods.

The first volcanic activity was the eruption of andesitic lava, ash, and cinders (andesite of Deadman Pass) in the late Pliocene Epoch from vents scattered throughout a large part of the Middle Fork basin and adjacent areas to the east. The flows range in thickness from a few feet to 25 feet and generally are separated by layers of andesitic blocks and reddish cinders. Relatively soon after the andesite was deposited, new eruptions of more silicic material poured out vast quantities of pyroclastic (fragmental volcanic) rocks and flows of quartz latite composition on top of the andesite. These deposits may have been less extensive than the andesite, as none have been found on the west side of the Middle Fork.

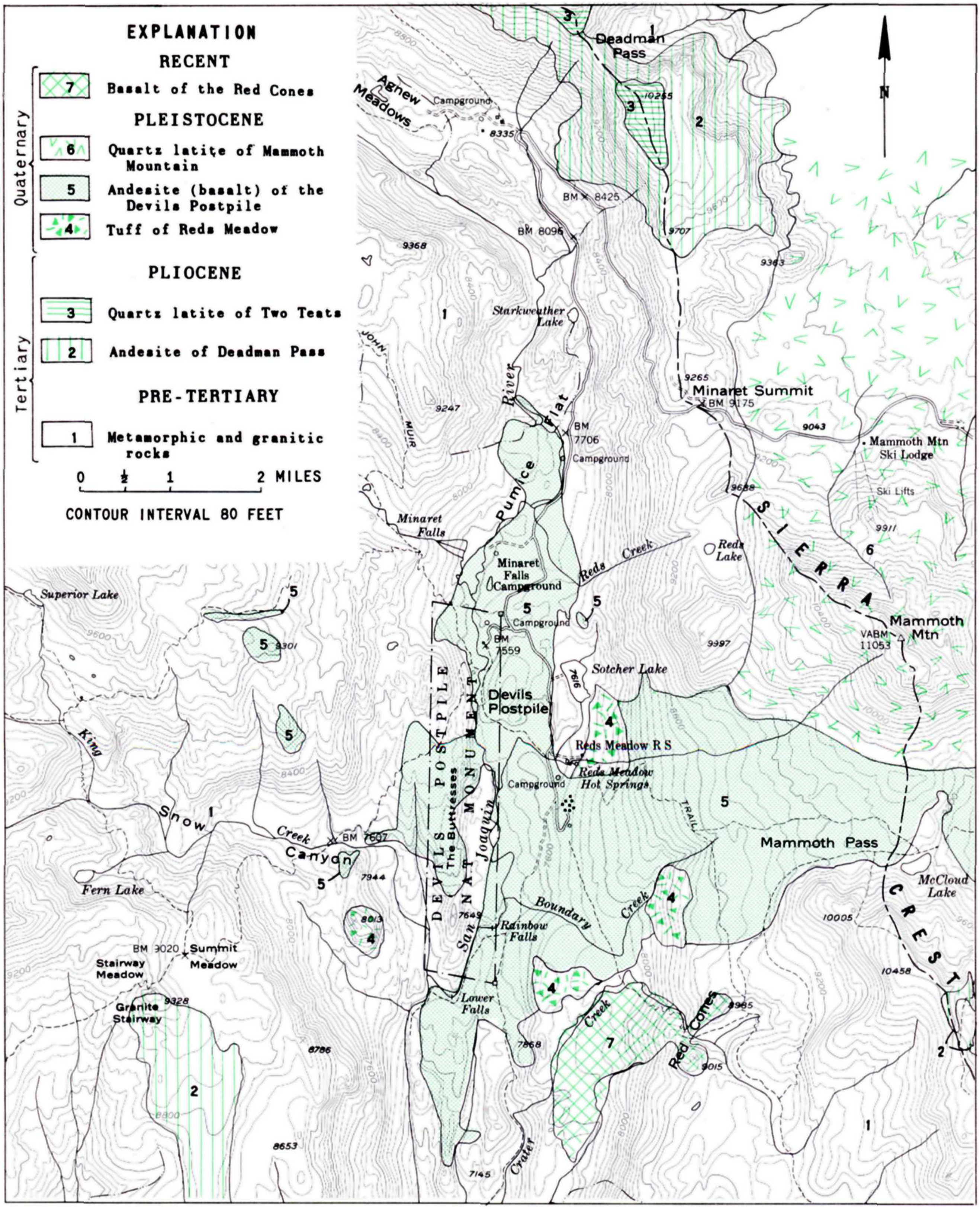
During the next two million years, stream erosion, probably aided by glaciation, stripped the andesite and quartz latite from most of the Middle Fork basin, leaving only the relatively small remnants on the Sierra crest and other old upland surfaces to the south and southwest (see geologic map). Exposures of the andesite can best be seen on the slopes above the road descending to Agnew Meadows just south of Deadman Pass; the quartz latite can be seen on Two Teats and San Joaquin Mountain, 2½ miles northwest of Deadman Pass.

After the Middle Fork canyon was reexcavated to approximately its present depth, probably somewhat less than a million years ago, new eruptions filled it in the vicinity of the Devils Postpile with a rhyolitic ash-flow tuff to an estimated depth of at least 1,000 feet. This tuff results from the consolidation of an ash flow—a turbulent mixture of gas and pyroclastic materials, ejected explosively from a crater or fissure at high temperature, that travels swiftly down the slopes of a volcano or along the ground surface. Often in the central part of such a deposit the temperature is high enough so that after deposition the fragments become partly or wholly welded together, which, with the deflation and flattening of the pumice fragments, tends to make a fairly dense, glassy rock. Such was the case with the tuff of Reds Meadow. Exposures of the nonwelded lower part of the tuff can be seen on the east side of Sotcher Lake and in the creek bed at Reds Meadow Hot Springs; welded material can be seen on the hillside above the Reds Meadow Ranger Station. No source vent for this tuff has been found within the Middle Fork basin; it most likely was in the vicinity of Mammoth Mountain or even farther east. The tuff is similar in all physical characteristics to the Bishop Tuff, which blankets a large area in the Owens River drainage to the east, and the two may be correlative in age and magmatic source.

The evidence for glaciation in the interval between the eruption of the andesite and quartz latite volcanics and the tuff of Reds Meadow is rather subjective and depends in large part upon the validity of age correlation between the tuff of Reds Meadow and the Bishop Tuff. Although there is no direct evidence for such glaciation within Middle Fork canyon, glacial deposits do occur beneath the Bishop Tuff. Similarly, no direct evidence indicates glaciation immediately following deposition of the tuff of Reds Meadow. However, before the next volcanic episode—the eruption of the andesite of the Devils Postpile—all but a few remnants of the tuff had been stripped from the Middle Fork canyon, and it seems unlikely that stream erosion alone, unaided by glaciation, could perform such a feat in a relatively short span, estimated to be about 100,000 years.

The main source for the andesite of the Devils Postpile seems to have been in the vicinity of Mammoth Pass, from which the lava flowed eastward into the Mammoth Lakes basin and westward into the Middle Fork valley. Measurements in the vicinity of the Devils Postpile, from the bottom of the flow to the tops of nearby erosional remnants, indicate that the lava was originally at least 600 feet thick. On the slopes of the valley the andesite rests upon the tuff of Reds Meadow, but in the center of the valley, as along the river next to the Postpile, the andesite rests upon granite bedrock from which the tuff had been previously removed. The Devils Postpile flow is usually described as basalt on the basis of its mineralogy; the flow contains phenocrysts of labradorite, pyroxene, and olivine in a micro-crystalline matrix. Although basalt is still a useful field term for rocks of this physical appearance, chemical analyses and other analytical data now show that the bulk of this flow is andesitic in composition; that is, the silica content is too high for basalt.

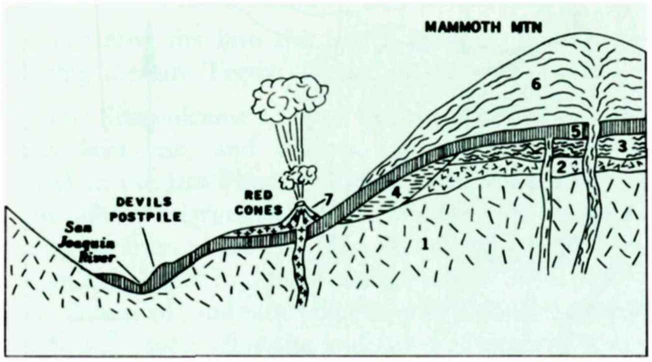
Somewhat less than half a million years ago, following the Devils Postpile volcanic episode, Mammoth Mountain grew as viscous lava formed a massive dome, chiefly by the piling-up of thick, stubby, glassy flows. The dome was probably modified several times during its growth by explosions that destroyed large parts of it, and no doubt at which times large quantities of pumice and ash were simultaneously disgorged. Scars from these explosions, although partly healed by later eruptions of thick flows and modified by glaciation, are still visible on the northern flank of the mountain. A pile of volcanic rocks as large as Mammoth Mountain takes a long time to cool and Mammoth Moun-




Base by U.S. Geological Survey

Geology adapted from Huber and Rinehart (1965)

Map showing distribution of volcanic rocks in the Devils Postpile area.




Idealized diagram showing the age relations, known and inferred, of all the geologic units depicted on the map.

tain still shows signs of thermal activity. Several fumaroles were active at the summit at least as late as 1957, and several on the hillside just north of Mammoth Pass were active in 1962. Recent (post-glacial) explosion pits occur on the north flank of the mountain, two of which can be seen in the woods just west of the ski lodge.

The last major glaciation (Wisconsin) in the Sierra Nevada was responsible for removing most of the andesite of the Devils Postpile from the Middle Fork valley. In so doing, the glaciers overrode outcrops that they did not completely remove, smoothing them off and producing the polish and striations that can now be seen on the top of the Postpile.

Following the retreat of Wisconsin glaciers (10,000–20,000 years ago), a new eruption about 3 miles southeast of the Devils Postpile built two basaltic cinder cones—the Red Cones—perched at the lip of a bench on the east side of the valley. A lava flow, originating chiefly from the base of the southernmost cone, cascaded down the slope and spread out on a lower bench. Although parts of this flow are at lower elevations than the Devils Postpile, the flow shows no evidence of having been glaciated and it thus represents the youngest major volcanic episode within the Middle Fork basin.

Pumice is ubiquitous in the entire Mammoth Lakes region. It is difficult to pinpoint the source of the pumice found at any given locality, for many sources of different ages all have produced pumice at one time or another, spreading it over much the same area. Mammoth Mountain was probably a source for much pumice, but much also probably was derived from more recent eruptions related to the Mono Craters, south of Mono Lake, and the chain of rhyolitic domes extending southward from them. Although the pumice was originally distributed as an air-fall, it has since been reworked and redeposited by streams. The extensive pumice deposit at Pumice Flat, just north of the Monument boundary, represents such a deposit which has been reworked by the Middle Fork of the San Joaquin.

Additional points of interest, some of which are definitely related to volcanic activity, can be seen in and near the Monument. A good example of carbonated springs, which are fairly common in the Sierra Nevada, can be seen at the brown-stained gravel bar just north of the footbridge that crosses the Middle Fork near the Postpile, where $CO_2$, associated with discharge of carbonated water, bubbles through a pool beside the river. Other small carbonated springs are near Soda Springs Campground, about a mile north of the Monument. The origin of carbonated springs is somewhat of an enigma, for it is not known whether the $CO_2$ is derived from a local volcanic source or whether it comes from a deeper seated igneous or metamorphic source. The Reds Meadow Hot Springs just east of the Monument are more directly related to volcanic activity for, although the spring water itself is probably of meteoric origin, the heat is undoubtedly from a volcanic source.

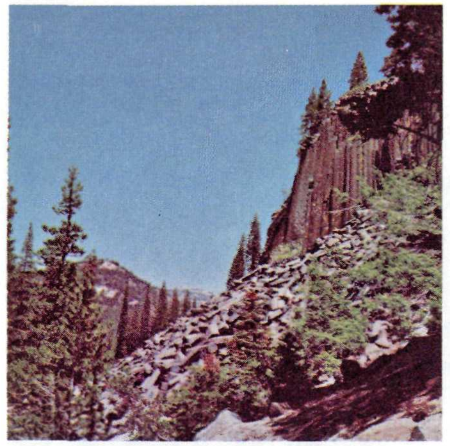


### Origin of the Devils Postpile

Columnar joints are common in lava flows of andesitic or basaltic composition, in which they tend to form if the flow is thick enough to maintain a relatively slow and uniform cooling rate. Long, regular columns are not particularly common, however, as the degree of uniformity of cooling necessary for their formation is not usually attained. The Devils Postpile, having approached "ideal" cooling conditions, ranks with other classic examples of columnar jointing, such as the famous Giant's Causeway of Northern Ireland. These cooling conditions were only locally attained in the Postpile, however, for only a small proportion of the columns are straight and parallel.

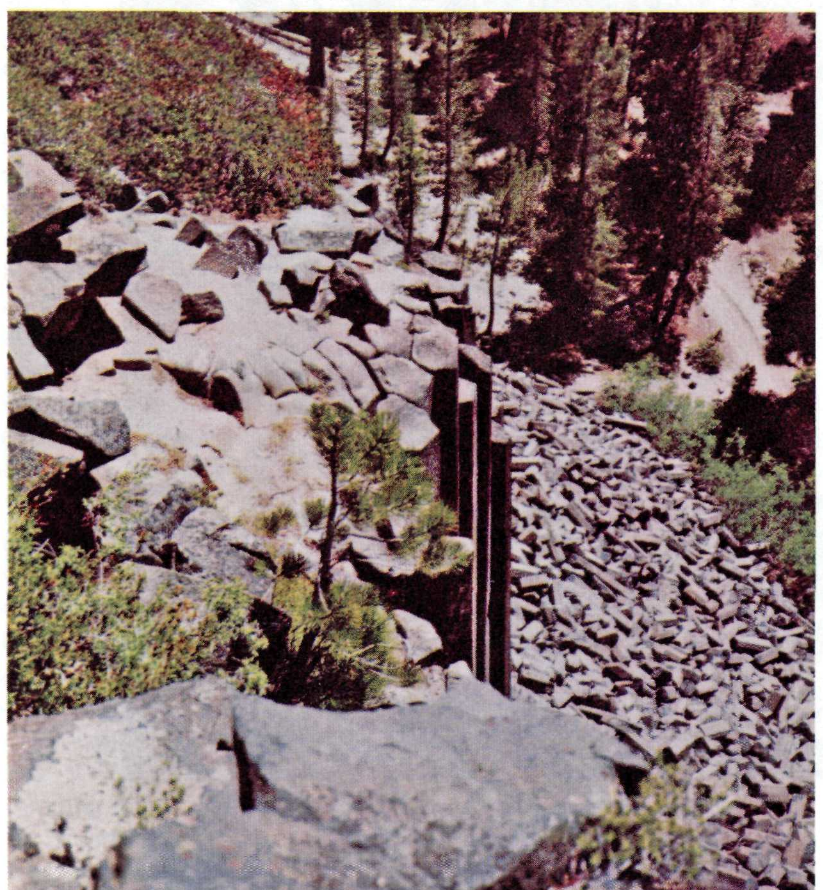
The columns or posts of the Devils Postpile are polygonal in cross section with six-sided ones slightly predominant over five-sided ones, and four- and seven-sided ones even less common. The cracks which bound the polygons usually meet at angles approaching 120°. The formation of polygonal structures such as these has long been considered a contraction process—the result of shrinkage due to cooling shortly after solidi-

The Grand Causeway from the sea. Giant's Causeway, Antrim County, Northern Ireland.



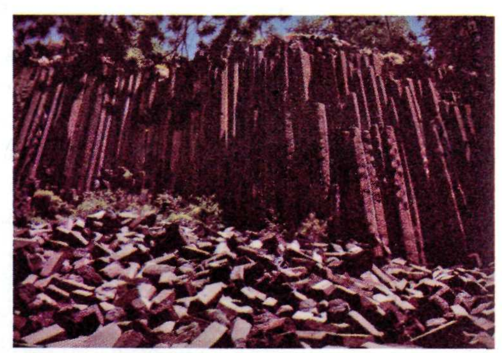
Devil's Postpile, Madera County, view north.

View from top of postpile, showing end grain of piles, vertical posts, and talus pile of broken posts.

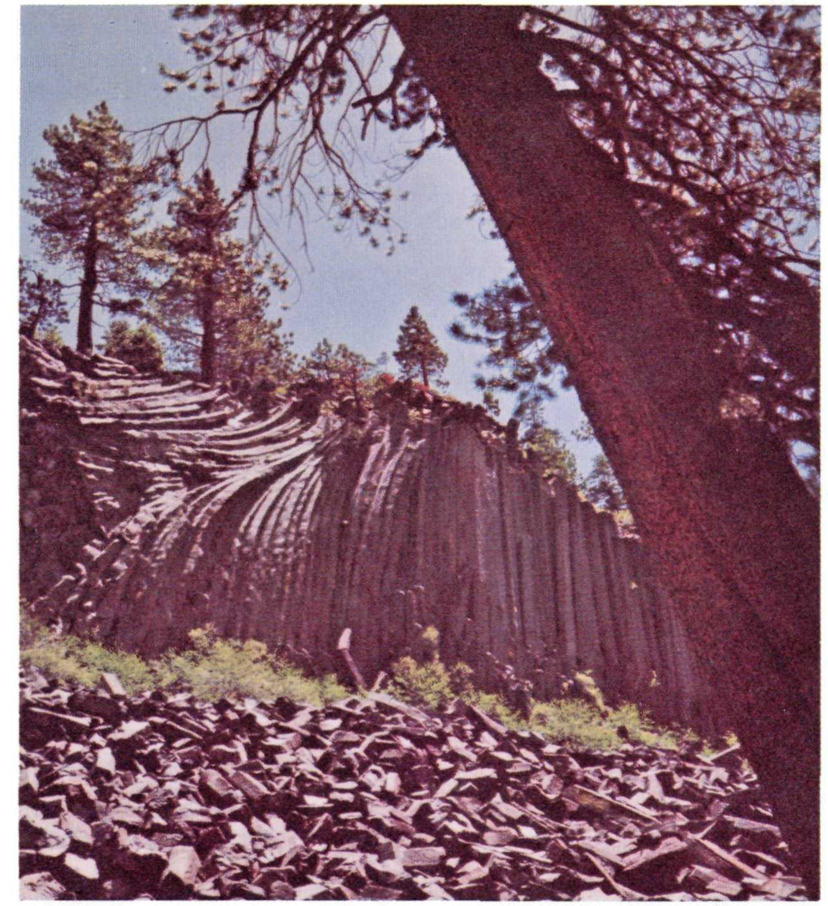


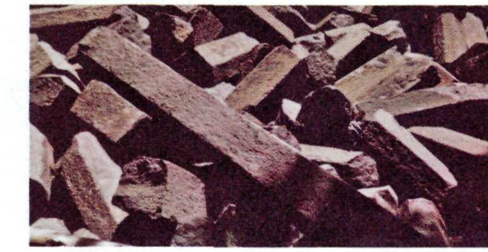
Some of the curving in photographs is due to steeply inclined perspective; however, in many places the piles themselves are sharply bent.

View of mosaic surface of top of pile blocks. Five and six sides are commonest, although four and seven may be found.



From the ground, the piles give an organ pipe effect.

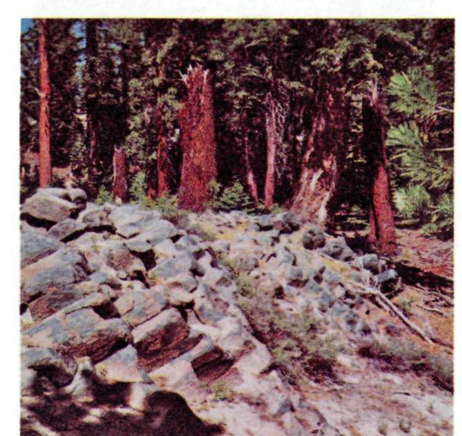


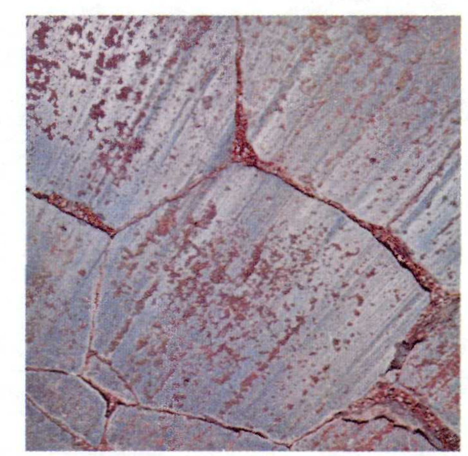


A jumbled mass of broken basalt posts photographed in the talus heap.

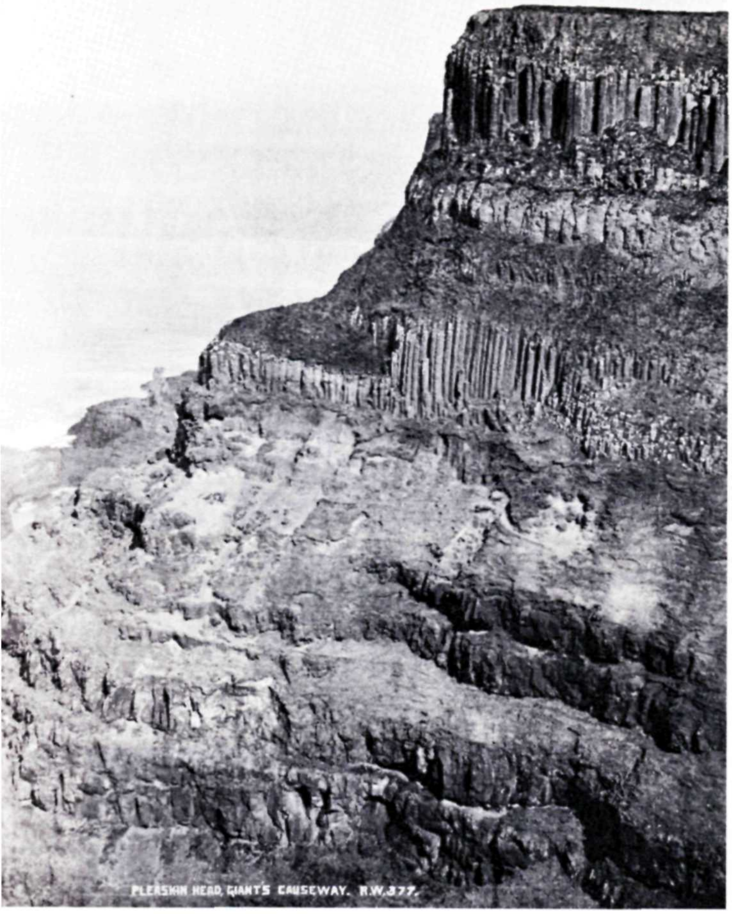
Close-up of the basalt, showing the texture. Whitish spots are plagioclase feldspar.

Along the top of the basalt outcrops, many stacks of posts are to be found, some vertical, some nearly horizontal.





The parquet-like pavement of the top of the pile still bears glacial polish and scratches.



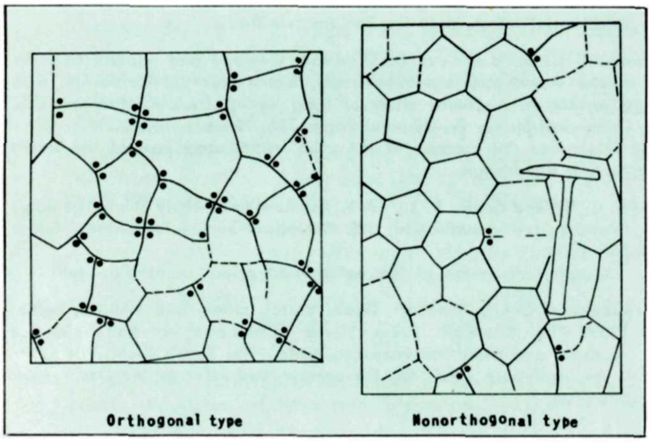

Upper flow of columnar basalt, Pleaskin Head, Giant's Causeway. The sloping area between vertical columnar sections is occupied by tuff.

*Photos from J. C. Branner collection.*

Columns of the Middle Causeway, showing vertical jointing and ball and socket cross joints. In upper left are the exposed ends of more nearly horizontal columns.

fication of the lava, in much the same way as polygonal forms are developed in drying mud.

Polygonal fracture systems are usually of two main types, orthogonal or nonorthogonal, depending on whether or not the contraction cracks tend to intersect at right angles (see illustration). A. H. Lachenbruch, who has recently studied the mechanics of



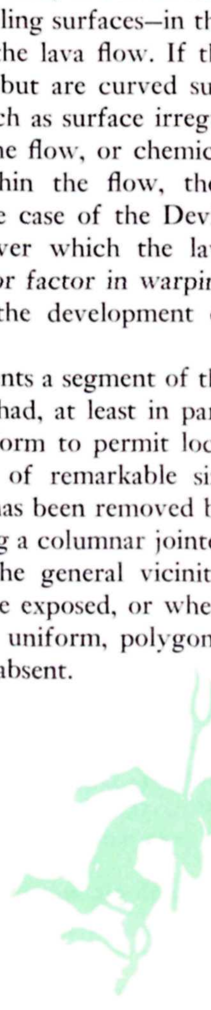

Cooling joints in lava. Dots denote orthogonal (right-angle) intersections. *After Lachenbruch (1962).*

thermal contraction cracks, has concluded that nonorthogonal systems are favored by factors which tend to cause rapid crack propagation and initiation of cracking at relatively few isolated points, and that orthogonal systems form by slow propagation and numerous points of fracture origin. According to this view, nonorthogonal systems, of which the Devils Postpile is an example, would be expected only in relatively homogeneous media subjected to uniform stress; they are believed to be much less common in nature than are orthogonal systems. Orthogonal joint systems, in addition to having right-angle intersections, commonly have numerous curved surfaces, examples of which can be found on many of the "rubbly" outcrops in the Devils Postpile area. Since long, regular columns such as those of the Devils Postpile are invariably of the nonorthogonal type, it is perhaps of interest to consider the formation of this type of jointing in a little more detail.

It can be shown mathematically that the surface of a homogeneous medium should be divided by a crack system defining regular hexagons when it is subjected to sufficiently intense uniform tension because a hexagonal system releases the maximum strain energy per unit crack area, and thus provides the greatest stress relief. Deviations from regular hexagons result from inhomogeneities in the medium or from other causes of nonuniformity of the local stress field. Once the applied thermal tension exceeds the tensile strength of the medium, a crack will start to form. Once started, the crack will propagate laterally, for a distance dependent upon various physical properties of the medium, and then will bifurcate or branch, forming angles approaching 120°. Each branch will again bifurcate when it reaches a prescribed length and, together with other simultaneously forming cracks, will generate a polygonal pattern. As cooling proceeds the cracks will deepen and, if the proper conditions prevail, will form long columns.

The foregoing "ideal" cooling conditions are never reached at the surface of a flow. However, as a progressive front of cooling, solidification, and cracking proceeds from either the top or bottom surface into a flow, a point may be reached where the thermal stress field is uniform enough for earlier irregular, usually orthogonal, jointing to give way to the formation of nonorthogonal columnar joints. Because cooling conditions usually are more uniform near the bottom of a flow, columnar jointing tends to be more pronounced and better developed in the lower part of the flow. The long axes of columns formed in this fashion will be oriented perpendicular to cooling isotherms or planes of equal temperature, which in turn will be roughly parallel to the cooling surfaces—in this instance, the top and bottom of the lava flow. If the cooling isotherms are not planes but are curved surfaces instead, owing to factors such as surface irregularities in the top or bottom of the flow, or chemical or physical inhomogeneities within the flow, then curved columns can result. In the case of the Devils Postpile, the irregular surface over which the lava flowed seems to have been a major factor in warping the cooling isotherms and thus the development of curved columns.

The Devils Postpile thus represents a segment of the basal portion of a lava flow that had, at least in part, a cooling history sufficiently uniform to permit local development of columnar joints of remarkable size and regularity. Most of the flow has been removed by stream and glacial erosion, exposing a columnar jointed portion to view. Elsewhere in the general vicinity, where higher parts of the flow are exposed, or where the local cooling history was less uniform, polygonal jointing is poorly developed or absent.



## Bibliography


Bateman, P. C., Clark, L. D., Huber, N. K., Moore, J. G., and Rinehart, C. D., 1963, The Sierra Nevada batholith—a synthesis of recent work across the central part: U.S. Geological Survey Professional Paper 414-D, p. D1-D46.
*Considers the pre-Tertiary history of the Sierra Nevada with emphasis on the Sierra Nevada batholith.*

Beard, C. N., 1959, Quantitative study of columnar jointing: Geological Society of America Bulletin, v. 70, no. 3, p. 379-381.
*Compares polygonal shapes of columns in Devils Postpile with those from other localities.*

Dalrymple, G. B., 1964, Cenozoic chronology of the Sierra Nevada, California: California University, Publications in Geological Sciences, v. 47, 41p.
*Provides radiometric age data for some of the volcanic rocks in the Mammoth Lakes area.*

Hartesveldt, R. J., 1963, Your guide to Devils Postpile National Monument: Yosemite Natural History Association, Yosemite National Park, Calif., 22 p.
*Includes wildlife data and historical aspects of the Monument area in addition to a brief description of the geology.*

Huber, N. K., and Rinehart, C. D., 1965, Geologic map of the Devils Postpile quadrangle, Sierra Nevada, California: U.S. Geological Survey Map GQ-437. (In press.)
*Includes brief description of geologic map units.*

Lachenbruch, A. H., 1962, Mechanics of thermal contraction cracks and icewedge polygons in permafrost: Geological Society of America Special Paper 70, 69 p.
*Technical discussion of the mechanism of formation of contraction-crack polygons.*

Matthes, F. E., 1960, Reconnaissance of the geomorphology and glacial geology of the San Joaquin Basin, Sierra Nevada, California: U.S. Geological Survey Professional Paper 329, 62 p.
*Covers the Cenozoic geomorphic development of the Sierra Nevada with special reference to the San Joaquin Basin.*

Rinehart, C. D., and Ross, D. C., 1964, Geology and mineral deposits of the Mount Morrison quadrangle, Sierra Nevada, California, *with a section on* A gravity study of Long Valley, by L. C. Pakiser: U.S. Geological Survey Professional Paper 385, 106 p.
*Describes the geology of the area immediately east of the Devils Postpile quadrangle.*

Ross, C. S., and Smith, R. L., 1961, Ash-flow tuffs—their origin, geologic relations, and identification: U.S. Geological Survey Professional Paper 366, 81 p.
*Detailed discussion of the nature and origin of ash-flow tuffs.*

Schumacher, Genny; Rinehart, Dean; Vestal, Elden; and Willard, Bettie, 1959, The Mammoth Lakes Sierra [California]—a handbook for roadside and trail: San Francisco, Calif., The Sierra Club, 145 p.
*An invaluable guide for the camper and hiker in the Devils Postpile area.*


FROM U.S.G.S. (continued from page 108)

*New Maps*

★ *Geology of the Manzanita Lake quadrangle, California.* By Gordon A. Macdonald. U.S. Geological Survey map GQ-248. Price $1.00. Available from various offices of the U.S. Geological Survey. *Geology of the Prospect Peak quadrangle, California.* By Gordon A. Macdonald. U.S. Geological Survey map GQ-345. Price $1.00. Available from various offices of the U.S. Geological Survey.

These geologic maps cover the northern part of Lassen Volcanic National Park and adjoining Lassen National Forest. The maps are printed in color and are accompanied by geologic cross sections and a descriptive legend.

The prominent peaks in the area are the eruptive vents of presently inactive volcanoes and the lava which poured out from these covers the surrounding terrain. The volcanic rocks have been disrupted by recently active faults which trend in a northwesterly direction.

The volcanic rocks are predominantly basalt, dacite, and andesite in composition and range in age from Pliocene to Recent. The youngest are the most recently formed rocks in contiguous United States; they resulted from the explosive eruptions of Mt. Lassen during May of 1915.

★ *Geologic map of the San Gorgonio Mountain quadrangle, San Bernardino and Riverside Counties, California.* By T.W. Dibblee, Jr. U.S. Geological Survey Miscellaneous Geologic Investigations Map I-431, scale 1:62,500. Price 75¢. Although this report was prepared in cooperation with this Division, it is available only from the various offices of the U.S. Geological Survey.

Includes the geology of a strip 15 miles wide extending south from Big Bear Lake to the south foothills of the San Bernardino Mountains north of Banning.

★★

*Open-File Releases*

★ *Suitability of irrigation water and changes in ground-water quality in the Lompoc subarea of the Santa Ynez River basin, Santa Barbara County, California,* by R.E. Evenson. 57 p., 8 figs. Available at the U.S. Geological Survey, Room 8024, Federal Bldg., and U.S. Court House, 650 Capitol Mall, Sacramento, and at the U.S. Geological Survey, 121 West de LaGuerra St., Santa Barbara.

★ *Water levels in observation wells in Santa Barbara County, California, 1963,* by K.S. Muir. 30 p., 11 figs. Available at the U.S. Geological Survey, Room 8024, Federal Bldg. and U.S. Court House, 650 Capitol Mall, Sacramento, and at the U.S. Geological Survey, 121 West de LaGuerra St., Santa Barbara.