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CHARLES D. WALCOTT, DIRECTOR

SOME LAVA FLOWS

OF THE

WESTERN SLOPE OF THE SIERRA NEVADA, CALIFORNIA

BY

F. LESLIE RANSOME

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., June 19, 1897.

SIR: I have the honor to transmit herewith an illustrated paper by Dr. F. L. Ransome on some lavas from California that are regarded as intermediate between trachytes and andesites. It may be noted that these rocks occupy the same position among the effusives that certain of the rocks called monzonite by Brögger do among the granolites.

It is recommended that the paper be published as a bulletin.

Very respectfully, yours,

H. W. TURNER,
Geologist.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

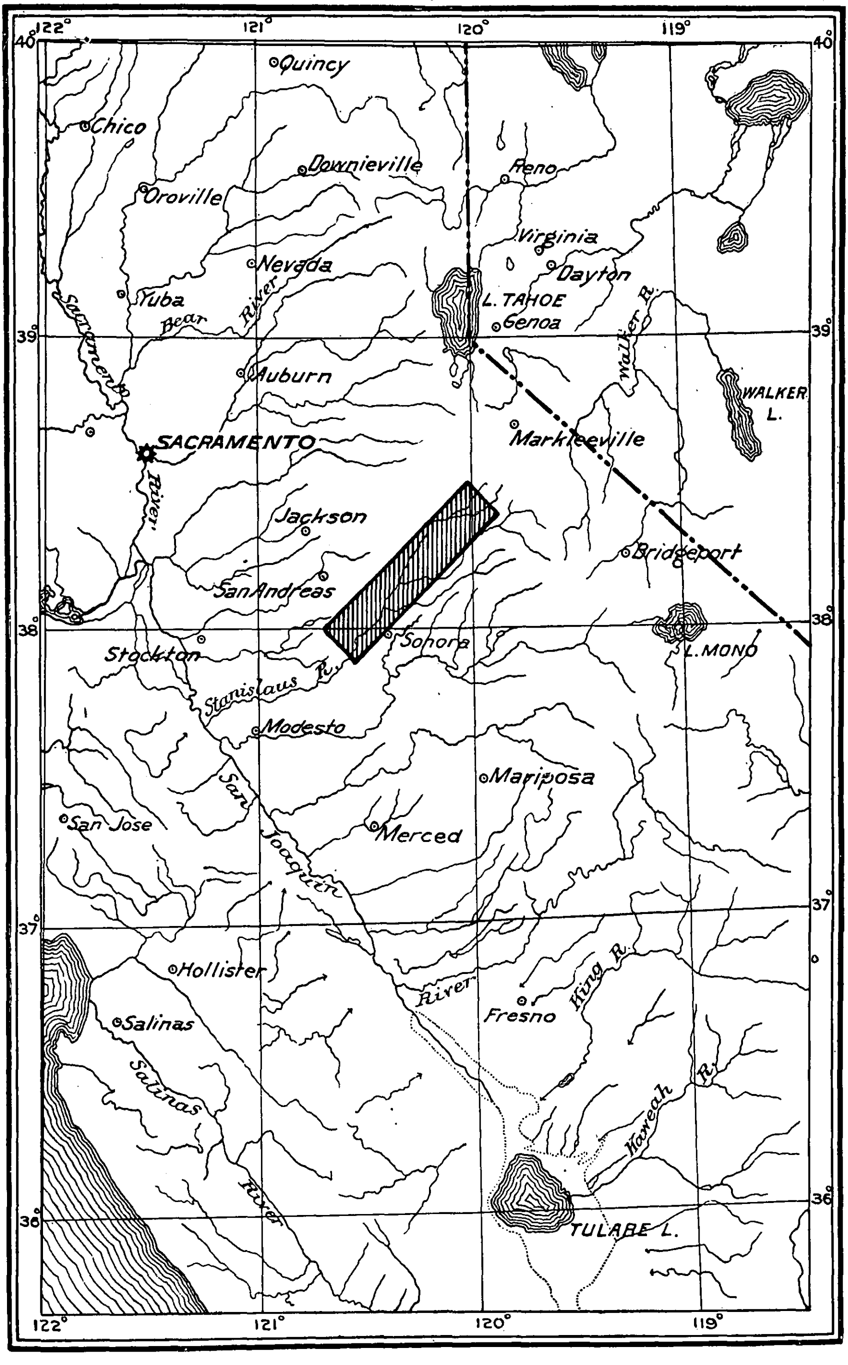

DIAGRAM SHOWING THE POSITION OF THE AREA EMBRACED BY THE MAP (PL. II).

SOME LAVA FLOWS OF THE WESTERN SLOPE OF THE SIERRA NEVADA, CALIFORNIA.

By F. Leslie Ransome.

INTRODUCTION.

The field relationships of the rocks described in the following paper were studied during the summers of 1895 and 1896, while I was engaged in geologically mapping portions of the Sonora and Big Trees quadrangles, under the direction of Mr. H. W. Turner. It was seen that this particular set of lavas offered a promising field for more detailed work than could be given to the region as a whole, and Mr. Turner kindly suggested that I should undertake their investigation as a special problem, to be carried along in conjunction with the regular areal work of the quadrangles. It was found that, in addition to the andesitic tuffs and breccias (designated upon the completed folios of the Gold Belt of California "Neocene andesite-tuff," or "Neocene andesite"), which are so widely and monotonously developed over the broad western slope of the Sierra Nevada, there occurs within the district studied another series of lavas in the form of massive flows, of much more limited distribution. They are in some cases closely associated with the breccias and tuffs, but are always readily recognized by their prevailingly massive character and by certain very distinctive lithological features. Taken as a whole, they form a series of superimposed flows, extending in a southwest direction from some as yet unknown source near the crest of the range in Alpine County down to the little village of Knights Ferry, in Stanislaus County, on the border of the Great Valley—a distance of more than 60 miles as the crow flies. Only one of the flows is known to have extended the whole distance, and they have all suffered considerable dissection through the very incisive gashing of the present streams, but in a general way the line of flow may be said to follow the course of the Stanislaus River. These flows were poured out within the period of eruptive activity, during which the andesitic breccias and tuffs were spread for hundreds of square miles over the western slope of the Sierra; but their eruption was immediately preceded by an interval of sharp erosion, which cut out the channels down which they flowed toward the valley. Subsequently they were again partly covered by fresh andesitic breccia, especially in the higher portions of the range.

The distinctive chemical feature of these rocks is a rather high percentage of total alkalies, with the potash somewhat in excess of the soda. Chemically they stand between typical andesites and typical trachytes, and belong to a general chemical group of the effusive rocks which it seems necessary to classify under a new name. Without anticipation of a discussion which has its proper place after the rocks themselves have been described, the name *latite* (derived from the Italian province of Latium or Latia, where rocks closely related to those described in the present paper occur abundantly), may be considered for the present as used merely to indicate the group of lavas which form the subject of the present paper, for the purpose of avoiding confusion with the ordinary clastic andesites abundant in the same field.

The laboratory work embodied in the preparation of this paper was carried on in the petrographical laboratory of Harvard University, and my thanks are due to Professor Wolff for the excellent facilities there enjoyed. I am also indebted to Mr. Turner not only for the original permission to undertake the work, but for generously aiding it in many ways and for furnishing field notes of such occurrences of the latites as fell within his own portions of the general area.

GENERAL OUTLINE OF THE PHYSIOGRAPHY OF THE REGION.

The accompanying map (Pl. II) embraces a rectangular strip of country 63 miles in length and 14.5 miles in width, with its longer dimension lying very nearly northeast and southwest. It includes portions of the Oakdale, Sonora, Jackson, Big Trees, Dardanelles, and Pyramid Peak atlas sheets, and the general position of the district covered is indicated in the annexed diagram (Pl. I). Considerably more than half the area lies within the Big Trees sheet. The extreme southwestern portion, lying west of longitude 120° 30′ and south of latitude 38°, is from the northeast corner of the unfinished Oakdale sheet. The topography is here only partly indicated, and the areas of latite are drawn with approximate outlines subject to revision when the region is examined in detail with a finished topographical map. A similar explanation should also be made with regard to the corner of the map lying east of longitude 120°, which is a part of the Dardanelles sheet. The work in this area was limited to a rapid reconnaissance, before the completion of the topographical base, and the areas of Neocene lavas will require slight modifications and considerable additions when the areal geology of the Dardanelles quadrangle is worked out in full.

The elevations on the map range from a general altitude of about 500 feet, near Knights Ferry, to 9,529 feet, on the summit of Dardanelle Cone, in Alpine County, corresponding to an average grade of 150 feet per mile for this portion of the Sierra slope. As a whole, this area is practically destitute of alluvial valley bottoms, and is drained by streams of torrential character. It is traversed from end to end by the comparatively young consequent Stanislaus River, with its two principal branches, the North and the Middle forks, and may be regarded as a thoroughly typical transverse strip of the great tilted and dissected peneplain which forms the western slope of the Sierra Nevada. The rocks upon which this somewhat uneven peneplain has been carved are those of the so-called "Bed-rock series" of the Gold Belt folios, and are of Juratrias and earlier age. In the foothill region they consist of closely compressed clay slates, schists, limestones, quartzites, and various igneous rocks, while in the higher portions of the slope gneissoidal and granitic rocks prevail.

Toward the end of the base-leveling process, which, as shown by Diller[1] and Lindgren[2] for other portions of the Sierra, lasted at least into the Miocene, the series of volcanic eruptions began which continued through the Pliocene, and which ended by covering the old surface far and wide with a blanket of clastic andesitic material in the form of breccias, rolled gravels, and fine tuffs. At the same time began the differential elevation which has given the peneplain its present slope of about two degrees to the southwest. According to Lindgren,[3] there is still recognizable a peneplain of Cretaceous age in the common altitude of many of the higher peaks of the middle Sierra, but no survival of such an intermediate stage of base-leveling has been detected in this region of the Stanislaus drainage.

The old surface revealed to-day by the stripping off of a great part of its andesitic cover is by no means a perfectly even one. If the sharp V-shaped canyons of post-Tertiary date were all filled up, and the remnants of the Tertiary volcanic cover quite removed, there would still remain a surface of gentle relief surmounted by occasional monadnocks. On the whole, though, it would be a topography of greatly subdued relief when contrasted with the possibilities for alpine types of form suggested by the nearly vertical schistose rocks and batholithic plutonic masses out of which it was carved.

The peneplain character has not been equally well preserved in all portions of the region. In the foothill districts it is recognizable only in a very general way, erosion having largely obliterated the old surface or obscured it by the etching out of later and local lowlands. The reason for this is threefold: The foothill regions are not only composed of belts of highly tilted heterogeneous rocks, originally unfavorable to the production of an ideal peneplain, but in addition to this they were probably never so thoroughly covered by the coarse andesitic breccias as were the higher portions of the slope. Moreover, the lack of homogeneity in the underlying rocks has led to the rapid development in Pleistocene time of small subsequent streams along belts of weaker

[1] Topographical revolution on the Pacific coast: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, pp. 419–421.

[2] Age of the auriferous gravels of the Sierra Nevada: Jour. Geol., Vol. IV, 1896, pp. 893 and 898.

[3] Loc. cit., p. 897.

rocks, and thereby effected a far more widespread degradation of the surface than in the higher region presently to be described, where the underlying rocks are not only more homogeneous, but have been more thoroughly protected from attack.

Nowhere within the area of the map is the old peneplain character better preserved than in the region included between the North Fork and the Middle Fork of the Stanislaus River. All the higher ridges are capped by andesitic breccia, and as a rule present flat, even tops, with a very gently ascending grade to the northeast. As these ridge tops are generally bare, or covered only with patches of low-growing shrubs and scattered trees, they are the natural routes of travel through the district and are followed by the sheep and cattle herders, who make use of the higher mountain meadows during the summer months. In contrast with the bare or open character of the ridges, the intervening slopes and canyons are generally heavily forested with noble trees, including the famous "mammoth trees" (*Sequoia gigantea*), the more graceful and scarcely less majestic "sugar pine" (*Pinus lambertiana*), and the massive "yellow pine" (*Pinus ponderosa*).

Following one of the ridges the traveler may ride for hours on a scarcely perceptible grade toward the northeast, with a wide prospect over the treetops on either hand and a view of similar ridges in the distance. But if, as Whitney says, speaking of the mining regions of the Sierra, "he turn and attempt to make his way across the country, in a line parallel with the crest of the range, he will discover that this apparent plain is cut into by the gorges or canyons in which the present rivers run in a most extraordinary manner; he will find it several hours' work to descend into one of these and rise again to the general level on the other side, even if he be assisted by a well-beaten trail."[1]

The drainage of the middle portion of the slope differs from that of the foothill region in the absence or insignificance of purely subsequent streams. The larger tributaries show a tendency to flow straight down the tilted peneplain, entering the main trunk streams obliquely, and frequently after running for a long distance nearly parallel with them, as in the case of Beaver Creek and the North Fork of the Stanislaus, the former being at one point apparently in imminent danger of capture by the latter. As a result of this consequent system of drainage, the deep canyon of the Middle Fork receives practically no tributaries from its southern side, the brink of its canyon wall being the divide. The North Fork shows a similar poverty in tributaries on its northwest side, streams frequently heading close up to the brink of its gorge, but generally diverging from it at a small angle toward the west and running finally into the Mokelumne River to the northwest. In other words, the general direction of consequent flow roughly bisects the angle made by the two main forks of the Stanislaus. The whole area is characterized by very active but concentrated erosion. The larger

[1] Auriferous Gravels of the Sierra Nevada, Cambridge, 1880, pp. 63–64.


MAP
OF A PORTION OF THE REGION DRAINED BY THE
STANISLAUS RIVER
CALIFORNIA
SHOWING THE DISTRIBUTION OF THE LATITES
AND OF THE ASSOCIATED NEOCENE VOLCANIC ROCKS
BY F. L. RANSOME
1898
Scale 1/125,000
Contour Interval 500 feet
LEGEND
Rhyolite and rhyolitic tuff
Biotite-augite-latite
Augite-latite
Andesitic breccias and tuffs
Olivine-basalt
Altaville
Angels
Murphy
Big Trees
Vallecito
Douglas Flat
Carson Flat
Robinson Ferry
Knights Ferry
Tuttletown
Columbia
Springfield
Rawhide
Saw Mill
Jamestown
SONORA
Montezuma
Phoenix Res.
Ellis
CLOVER MEADOW
Dardanelle Cone
Bloods Toll
Gianna
Godie
NORTH FORK STANISLAUS RIVER
MIDDLE FORK STANISLAUS RIVER
GRADE PROFILES OF THE NEOCENE AND PRESENT
CHANNELS OF THE STANISLAUS RIVER
VERTICAL SCALE TWICE HORIZONTAL
KNIGHTS FERRY
DARDANELLES
JULIUS BIEN & CO. LITH. N.Y.

streams, having cut through the Neocene cover of andesitic breccia, are still energetically sinking their steep-walled, V-shaped canyons into the underlying granitic rocks. These canyons as yet show little tendency to widen out into valleys, and remnants of the former extensive covering of andesite are often preserved on their very brinks. The vigorous nature of this trenching is well shown in the deep canyon of the Mokelumne River, of which a small portion comes within the map just north of Bear Valley, and also in the whole canyon of the Middle Stanislaus. There are probably few better illustrations of a young V-shaped canyon than can be seen by looking westward from a point about halfway down the trail which is shown descending into the gorge a mile and a half west of Mount Knight.

From Clover Meadow eastward the character of the country changes, although the change is not an abrupt one. The various residual andesitic ridges which have converged just west of Clover Meadow extend eastward as a single main ridge into the area of the Dardanelles quadrangle, between Highland Creek on the north and the Middle Stanislaus River on the south. About 2 miles east of Clover Meadow the ridge ends in a steep bluff about 400 feet in height. The brink of this declivity affords a view (Pl. III) which, aside from its somewhat stern beauty, is of considerable interest. For many miles to the northeast the eye overlooks a wild, hummocky surface of bare and glaciated granite,[1] stretching up toward the crest of the range, its dazzling whiteness being only partly relieved by a sparse growth of pines. In the near foreground the bald hummocks are interspersed with small, bright-green meadows, fringed with quivering aspens, and usually inclosing a lakelet. Immediately to the east, and just across the low, hummocky foreground, the dark and rugged peaks of the Dardanelles rise to an altitude 9,529 feet above the sea. The nearest peak, which may be conveniently called the West Dardanelle, can be plainly seen to be made up of a series of nearly horizontal volcanic layers, resting upon the granite and capped by a heavy flow of dark columnar lava, forming vertical cliffs several hundred feet in height. Beyond the Dardanelles appear the higher peaks forming the crest of the Sierra, also in part capped by volcanic rocks in nearly horizontal attitudes. These embrace some well-stratified andesitic tuffs, as observed by Turner[2] on the summit of Arnot Peak at an elevation of 10,000 feet.

This higher portion of the Sierra slope can not, then, like that west of Clover Meadow, be characterized as a series of more or less linear lava-capped ridges, separated by narrow canyons. The possibility of riding easily along the flat ridge-tops has ended with the bluff upon which the observer stands. From here on to the summit the Neocene volcanic covering has been so thoroughly dissected and carried away that only a few scattered remnants testify to its once great extent.

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[1]The term granite is used throughout this paper in a general sense, including all the "granodiorite," quartz-mica-diorite, etc., as well as true granite.

[2]Geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, p. 708.

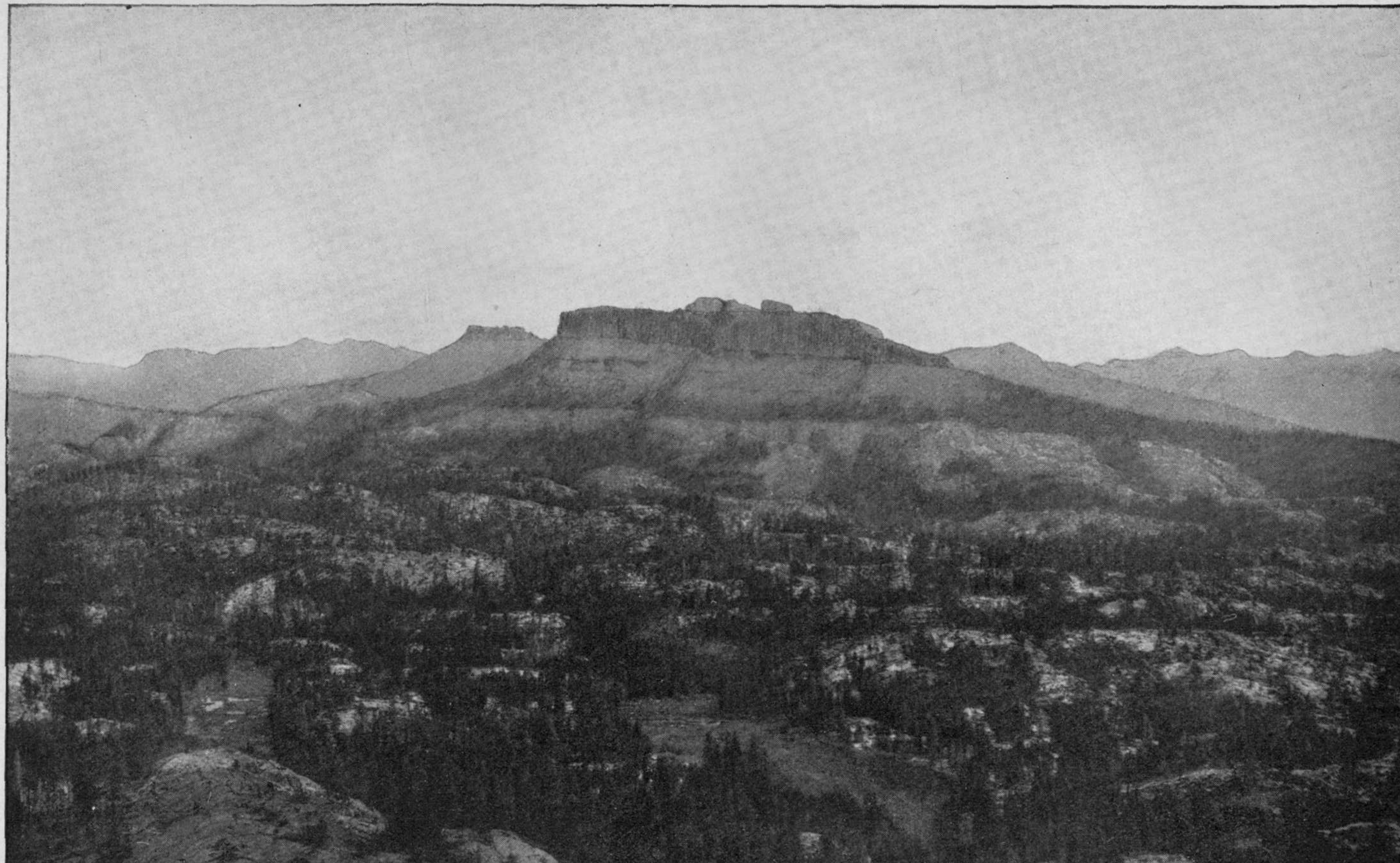
The region is best described as a rolling and hummocky granitic slope—a portion of the old peneplain modified by ice action and by recent erosion. Above this old surface stand isolated peaks and clusters of peaks, often true flat-topped buttes, composed of volcanic materials. Distinctly below it are the deep trenches of the larger streams, their character being well shown in the fine gorge of the Middle Stanislaus, 4 miles southeast of Clover Meadow. An idea of the general character of the region may be gained from Pl. X (p. 32), which is a view of the Dardanelles from the south, looking across the canyon of the Stanislaus.

The foregoing account of the physiography of the region embraced in the accompanying map (Pl. II) is little more than a bare outline, intended to present some picture of the old uneven peneplain, with its Neocene cover of fragmental andesite, down which the latitic lavas flowed, and of the general character of the erosion by which it has since been modified. No reference has been made to the influence of ice action upon the drainage, for the reason that there is no patent evidence that the important streams have retained any traces of ice interference. Definite moraines are rare, and although a few morainal patches occur on some of the ridges as low down as 5,500 feet, they are not shown on the present map. Various details of topography which are closely connected with the occurrence and distribution of the latites can be more intelligibly discussed under that head than in a general preliminary sketch, and will be for the present deferred.

THE OCCURRENCE AND DISTRIBUTION OF THE LAVAS (LATITES).

The latites were early differentiated in the field into three varieties, belonging to at least three distinct flows. These are, in the order of their geological sequence: (1) a dark, compact augite-latite of somewhat basaltic aspect, with conspicuous tabular crystals of labradorite and smaller phenocrysts of augite, which for convenience will be referred to as the Table Mountain facies; (2) a moderately dark-gray biotite-augite-latite, in which glistening tablets of biotite are the most conspicuous phenocrysts; (3) a dark, very compact augite-latite, with small, scattered phenocrysts of labradorite and augite, which may be called the Dardanelle facies from its occurrence on the extreme summit of the West Dardanelle.

The Table Mountain facies forms the longest flow of the series, having been traced from the West Dardanelle, where its surface attains an elevation of about 8,600 feet, down to Knights Ferry, where it forms plateaus, with black, bowlder-strewn surfaces, about 500 feet above sea. The rough, bowlder-like masses, from a foot to 2 feet in diameter, locally known as "nigger-heads," which are frequently abundant on the surface of the flow near Knights Ferry, are of the same character as the solid lava beneath them; and as the latites rarely show any



THE DARDANELLES FROM THE WEST, SHOWING THE HUMMOCKY GRANITIC SURFACE IN THE FOREGROUND AND THE CREST OF THE SIERRA NEVADA IN THE DISTANCE.

signs of weathering into soil, these were possibly originally loose fragments borne along on the surface of the lava stream.

My information concerning this portion of the Table Mountain flow is incomplete. It is known to extend almost continuously for 7 miles up both banks of the river, to Byrnes Ferry, forming irregular, plateau-like areas which break off abruptly on the river side in vertical columnar cliffs. These areas were evidently continuous at one time, but have been dissected by the river, now flowing several hundred feet below them. Andesitic breccia is reported by Turner[1] beneath the Table Mountain flow at Byrnes Ferry, and a considerable bed of similar breccia occupies the same relative position just south of McCartney Creek, about 4 miles northeast of Knight's Ferry.

Near Byrnes Ferry the flow turns eastward, leaving the river and entering the edge of the Sonora quadrangle just west of Montezuma, or about latitude 37° 53′. Here it again resumes a northeasterly course, running generally parallel with the Stanislaus River at an average distance of about 5 miles to the southeast, until it enters the southern border of the Big Trees quadrangle, just west of Shaws Flat. It is this section of the flow that is known as the Tuolumne Table Mountain, a physiographical feature of considerable natural and historical interest. The old river gravels in the Neocene channel, beneath the so-called basalt, being auriferous, were actively exploited during the earlier days of mining activity. The line of famous Mother-Lode veins, passing through Angels, Carson Hill, Rawhide, and Quartz Mountain, runs beneath the lava near Rawhide, and reappears on the southern side as a heavy vein, determining a small southeast spur shown on the map. Being thus in the center of one of the most productive mining districts in the State, several references to the Tuolumne Table Mountain are found in the older geological literature of California. Trask,[2] writing in 1856, says:

This celebrated locality, of which so much has been said and written of late, is one of the most remarkable and interesting places to be found in this State.

That portion of the mountain which has so recently attracted attention on account of the placer deposits found beneath its surface is situated near the towns of Sonora and Columbia, being about equidistant from either locality. A portion of Shaw's Flat is situated immediately at its base. The superior portion of the mountain is composed of basaltic rock having the prismatic form; but in a few instances, at different points, it assumes the pentagonal shape so common to the columnar form of this rock.

I have traced this basaltic overflow in an east and west direction for the distance of nearly 40 miles on its course, and it is probable that it will be found to extend to a much greater distance eastward than at present known.

. . . .

Its breadth is very variable throughout its course, in no instance, I believe, less than 400 feet, and often one-fourth of a mile. It seems to have followed the course

[1] The rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, Part , 1894, p. 491.

[2] Report on the Geology of Northern and Southern California, Sacramento, 1856; State Senate Doc. 14, p. 20.

of a stream, filling its bed and banks, and to have flowed in this course for the entire length that it is now observable upon the surface.

To the east [*sic*] of Columbia it crosses the present bed of the Stanislaus at two different places, but what its position beyond this may be is at present unknown with any degree of certainty. From the relative position of the Stanislaus at the present time, the evidences are almost demonstrative that at the period of its occurrence it flowed into and down the former bed of this river, displacing the latter and filling up the space between its banks. The depth of the banks to the bed may be pretty accurately measured by the thickness of the basalt above that bed, which is about 100 feet on a general average.

Professor Whitney, in his volume on the geology of California, devotes several pages to a description of this portion of the flow, and of the auriferous gravels beneath the lava, accompanying his report with illustrations and sections. His account is too long to quote entire, but the following portions are pertinent to the lava flow itself, and are characterized by Whitney's usual graphic descriptive power:

One of the most striking features in the topography and geology of Tuolumne County is the so-called "Table Mountain," a name given throughout the State to the flat table-like masses of basaltic lava which have been rendered so conspicuous by the erosion of the softer strata on each side, and which now exist as elevated ridges, dominating over the surrounding country and remarkable for their picturesque beauty, but still more so on account of the important deposits of auriferous detritus which lie beneath them.

The Table Mountain of Tuolumne County is a flow of lava originating in the lofty volcanic region beyond the Big Trees of Calaveras. . . . . It comes down on the north side of the Stanislaus, forming a nearly continuous ridge, elevated more than 2,000 feet above the river. Just below Abbeys Ferry ("Abbott Ferry" on map) the Stanislaus has broken through the once continuous basaltic ridge, which has been irregularly worn away for some distance from the river, but which reappears as a continuous mountain a little southwest of Columbia and continues on the south side of the river, forming a conspicuous feature of the scenery as far as Knights Ferry, a distance of about 20 miles from the point where it crosses the river and enters Tuolumne County. As seen from a distance, this Table Mountain reveals its origin at once in the contrast between the long straight line of its upper edge and the broken and curving ones which eroded hills of the auriferous slates everywhere exhibit. Its dark color and the comparative absence of trees or shrubs on its top and sides also indicate very clearly that the material of which it is composed is very different from that of the surrounding hills.

. . . .

On approaching Table Mountain and examining the material of which it is composed, and the position which it occupies, it is seen at once that it is a vast lava flow, of which the upper surface remains very nearly at the level and with the form which it originally had at the time of its consolidation, while the edges and the surrounding country have been denuded and washed away, so that the topography of the region is entirely different from what it was; in fact it is almost the reverse of it. No one can deny that a stream of melted lava, running for 40 miles down the slope of the Sierra, must have sought and found a depression or valley in which to flow, for it is impossible that it should have maintained, for any distance, a position on the crest of a ridge. Nor could the valley of the Stanislaus, now 2,000 feet deep, have existed at that time, for this flow of lava is clearly seen to have crossed it at Abbeys Ferry. The whole face of the country must, therefore, have undergone an entire change since the eruption took place during which this mass of lava was poured out. . . . .

The summit of Table Mountain is occupied by a heavy bed of basaltic lava, of a very dark color and dense texture. It is occasionally distinctly columnar, and appears to have all been poured out in one flow, as there are no partings or divisions perceptible in the mass, which in the vicinity of Sonora is from 140 to 150 feet in thickness. Its width, at a point near the Buckeye Tunnel, was found to be about 1,700 feet. The surface of the basalt is very nearly level, with a gentle slope down the valley.[1]

In his volume on the auriferous gravels,[2] the same writer summarizes his earlier account of the mountain, adds some further notes, and appends an outline map showing the approximate extent of the dissected lava flow between Abbeys Ferry and Knights Ferry. He also gives several transverse sections showing the structure of the mountain as revealed by mining operations. He speaks of the "basalt" overlying the andesite breccia, a relation which both Mr. Turner and I have confirmed at several points.

To the descriptions quoted there is little to be added concerning this portion of the flow, save to note that it attains a width of three-fourths of a mile northwest of Montezuma, and that the columnar structure is a decidedly noticeable feature of the dark crags which surround the mountain in this region, rendering it an almost impassable barrier, and its level top a secure resort for hawks and eagles. Roads skirt the cliffs on either side, but a practicable route across the line of the flow is found only where the volcanic cap has been cut through by erosion, effected by an undermining of the softer underlying rocks. The main stage road, connecting Sonora with the Great Valley, passes through such a gap about three-fourths of a mile northwest of Shaws Flat.

The extent of the general erosion that has transformed the old Neocene lava stream into the most imposing and continuous mountain mass in the vicinity is well shown in one of Whitney's wood cuts,[3] which pictures the Table Mountain from the southeast, probably near Chinese Camp, with the Bear Mountains (monadnocks) rising in the distance above its even crest line.

North of Shaws Flat, the Table Mountain flow turns westward toward the Stanislaus River. Just west of Springfield it appears to rest in a shallow trough eroded in andesitic breccia, but this relation could not be definitely established. It terminates a mile to the south of Parrott Ferry in a columnar cliff overlooking the canyon of the Stanislaus, the stream flowing a thousand feet below the bottom of the lava. Looking northward, across the river, the continuation of the flow can be seen as a dark capping upon the summit of a granite peak rising precipitously from the water's edge, just west of the ferry. The base of the latite is here 1,100 feet above the bottom of the canyon and rests directly upon the granite. The distance between the two dissevered portions of the flow is just under 1¼ miles.

From Parrott Ferry northward the flow has been dissected into a chain of separate but closely contiguous areas, which extends for 8

[1] Geological Survey of California, Vol. I, Geology, 1865, pp. 243-246.

[2] Auriferous Gravels of the Sierra Nevada: Mem. Mus. Comp. Zool. Harvard Coll., Vol. VI, 1880, pp. 131-137.

[3] Geology of California, 1865, p. 244, fig. 36.

miles along the west bank of the Stanislaus, regularly gaining in elevation, until the base of the flow at the end of this distance has an altitude of 3,000 feet above the sea and about 1,800 feet above the bed of the Stanislaus, giving a grade of about 125 feet to the mile.

Along this 8 miles the Table Mountain latite reposes upon a variety of underlying rocks. At the southern end, near Parrott Ferry, it rests upon granite. About three-quarters of a mile farther north the underlying rock is a limestone, belonging to the Calaveras formation.[1] The chief evidence for regarding this limestone as of Carboniferous age is the occurrence of Fusulina at Hites Cove.[2] A portion of the lava also rests upon the nearly vertical edges of a lenticular area of quartzose Calaveras schists inclosed in the limestone. Between the latite and the schists is a thin layer of breccia made up of fragments of the underlying schist. Still farther north the third area shown on the map is separated from the limestone by a thick deposit of auriferous gravel. Due east of the town of Vallecito the latite rests upon a bed of white rhyolitic tuff 200 feet in thickness, which in turn rests upon gravels. The rhyolite, although very plainly a tuff, is frequently divided into small columns by a rather regular prismatic parting. In one case where these columns were measured they were found to average 4 or 5 inches in diameter and about a foot in length between the joints. Columnar structure in tuffs, while not common, is not unknown. Moderni, as cited by Washington,[3] describes a columnar trachytic tuff in the Bolsena region.

To the east and southeast of Douglas Flat the relation of the latite flow to the ordinary andesitic breccia of the region and to the rhyolitic tuff is very interesting. The main ridge which separates Douglas Flat from the canyon of the Stanislaus is made up chiefly of andesitic breccia in a succession of nearly horizontal beds of great aggregate thickness, in places at least 700 feet, resting sometimes on the Bed-rock series and sometimes on an underlying bed of rhyolitic tuff. The latite flow occurs, not as a rule on the crest of this breccia ridge, but on its eastern side, overlooking the deep canyon of the Stanislaus, in characteristic flat-topped benches. These thin out on the west and overlap unconformably upon the andesitic breccia, while on the east they are terminated abruptly by perpendicular cliffs, frequently over 200 feet high, from whose edges are obtained grand views into the canyon below. At the base of these cliffs there is a bed of white columnar rhyolitic tuff, which appears to be at least 100 feet in thickness, and beneath this again a bed of auriferous gravel, varying in thickness and sometimes locally lacking. By a rather curious coincidence these benches of latite hang upon the slope at just the proper altitude to conceal the base of the andesitic breccia upon which they partly rest, the latter not appearing at the bottom of the cliffs at any point visited.

[1] See Gold Belt folios; also Lindgren, Am. Jour. Sci., 4th series, Vol. III, 1897, p. 302.

[2] Turner, Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 446; also Seventeenth Ann. Rept., Part I, 1896, p. 660.

[3] Italian petrological sketches: Jour. Geol., Vol. IV, 1896, p. 543.

From the northern end of this chain of dissected areas there is a gap of 3 miles before another remnant of latite is met with, capping a small hill just south of Mill Creek. The structure of this hill is rather complicated. On its western side the massive augite-latite is separated from the Bed-rock series by three beds of soft, light-colored tuff, while on the eastern side the place of the tuffs is taken by a sheet of gray, highly glassy lava with a pitchstone-like luster, which has been found to be a vitrophyric biotite-latite, somewhat resembling petrographically certain facies of the biotite-augite-latite forming the second flow of the series, and which is generally found resting *upon* the Table Mountain flow when the two lavas occur together. Chemical evidence seems to indicate, however, that it is perhaps a remnant of a distinct and earlier flow which preceded the Table Mountain flow.

Between the vitrophyric lava and the augite-latite cap occurs a very thin layer of reddish lava, of somewhat uncertain affinities, which has been found at only one other point, near Clover Meadow, and is there apparently beneath the Table Mountain flow. There is thus an indication that the long Table Mountain flow was not really the first of the latitic eruptions, but may have been preceded by a vitrophyric lava very similar to the biotite-augite-latite which preceded the Dardanelle flow. The field studied, however, affords no certain evidence on this point, and it must be left as a possible contingency that may meet with confirmation or denial when the geology of the Dardanelles quadrangle is fully investigated.

Immediately to the north of Mill Creek there is a small mass of the vitrophyric lava hanging upon the slope of a small spur overlooking the Stanislaus. It is evidently a continuation of the fragment south of Mill Creek, but here occurs alone, resting upon the edges of the Calaveras quartzite.

Following up the western bank of the North Fork of the Stanislaus, a small remnant of the Table Mountain flow is found about a mile and a half east of Manuel's, perched on the brink of the canyon at an elevation of about 3,200 feet and resting immediately on the granite.

A quarter of a mile farther upstream an interesting portion of the flow is encountered, which extends along the river almost continuously for 3½ miles to Squaw Hollow. The comparatively shallow drainage area of Love Creek is separated along this distance from the deeper canyon of the North Stanislaus by an even, flat-topped ridge, capped for the greater part of its length by andesitic tuff and breccia. The Table Mountain flow not only occupies the greater part of the valley of Love Creek, but also forms a distinct bench on the river side of the ridge, just below its crest. The outer edge of this bench is nearly always a vertical cliff, and the latite can generally be seen resting upon the granite. The relation to the andesitic breccia at the rear of the terrace is not easily determined. It is not always plain whether the andesite breccia is the later and rests upon the latite, as the mapping at first sight suggests, or whether the latter is really the younger rock, which, having flowed down a channel cut through the breccia, has by a curious coincidence left its remnants lying unconformably upon both granite and breccia in such a way as to conceal their contact. In spite of its inherent improbability, there are indications which point to the latter hypothesis as the true one, especially as a similar relationship was observed east of Douglas Flat. That such a condition does obtain only a short distance away is shown at a point 1⅛ miles south of Squaw Hollow. (Pl. IV.) Here the nearly horizontal beds of light-gray andesitic breccia, with an aggregate thickness of 700 feet, are well exposed in a steep, bare slope, the lowermost bed reposing on the granite. The base of the Table Mountain flow is also very well exposed, and can be seen resting in striking uncomformity upon the eroded edges of the horizontal breccia beds, the plane of contact sloping down toward the river at an angle of about 20 or 25 degrees. The bottom of the flow is separated from the breccia by a thin layer of andesitic rubble or conglomerate, evidently derived from the underlying beds. Above this somewhat angular conglomerate comes the vesicular and more or less brecciated under surface of the massive latitic flow, passing, a little higher up, into a horizontally platy structure, which in turn is succeeded by a rude columnar parting. Although the base of the flow slopes down toward the bottom of the canyon at a considerable angle, its upper surface is more nearly level and forms a gently sloping bench, which breaks off abruptly toward the river in cliffs from 100 to 150 feet in height.

There is thus proof at this point, not only that the Table Mountain flow rests unconformably above a considerable thickness of the andesitic breccias, but that, at the time of its extrusion, the latter beds had been extensively eroded and a channel cut in them, which, here at least, was closely coincident with, though not so deep as, the present canyon of the North Stanislaus.

Near the crest of the ridge the Table Mountain flow becomes quite thin, and is overlain by biotite-augite-latite about 100 feet in thickness, which in turn is capped by about 75 feet of augite-latite, here occupying the summit of the ridge. This upper flow is lithologically nearly identical with the Table Mountain flow, but has somewhat smaller plagioclase phenocrysts, and on account of its position is correlated with the Dardanelle flow. The biotite-augite-latite occurs in three other places on the river slope of the ridge, in every case in small patches resting upon thicker masses of the Table Mountain flow. It is best seen, however, to the west of the ridge, in the little valley of Love Creek.

A few yards east of McKay's mill the attention is arrested by a low, gently arching lobe of dark-gray lava, which rises from the narrow floor of the valley with so clean and bare a surface that it appears to have been erupted within historical times. Its surface shows no sign of weathering, and is divided by cracks into rough polygonal blocks from

TABLE MOUNTAIN FLOW RESTING UNCONFORMABLY UPON BEDS OF FRAGMENTAL ANDESITE SOUTH OF SQUAW HOLLOW.

The view is taken from the east. The steep, bare slope in the foreground is andesitic breccia in nearly horizontal beds, upon whose edges the rudely columnar augite-latite can be seen resting in the upper left-hand portion of the illustration.

a foot to 2 feet in diameter. The rock cleaves most readily transverse to these rude vertical columns, the cleavage faces showing the characteristically abundant, glistening biotite crystals of the biotite-augite-latite. Upstream from McKay's mill the latite is found to fill most of the bottom of the little canyon, with a final isolated patch resting in the col at its head. As the ravine itself is excavated in granite, it is evident that it must have existed in substantially its present shape before the lava flow took possession of its stream bed. In other words, it is a remnant of a small Neocene valley. This result is startling when it is remembered that the main Stanislaus River has cut a gorge 1,000 feet deep directly across the Table Mountain flow upon which a portion of this biotite-augite-latite rests, while near Sonora the waste of the surrounding country has been sufficient to leave the same flow as a mountain mass, conspicuous for miles around. But, startling as it appears, there seems to be no avoidance of the conclusion here drawn. This survival explains why the old peneplain character is better preserved in this portion of the Sierra slope than in the foothill region; the rocks are more homogeneous and resistant, and the active erosion is largely concentrated in the deep canyon-cutting of the longer and more vigorous streams. This phase of denudation, although productive of striking results, is least calculated to obscure the peneplain character of the surface upon which it acts. It is quite probable that the present small stream of Love Creek has had its cutting power greatly decreased by the capture of its former head-water drainage by the deepening and widening of the North Stanislaus Canyon.

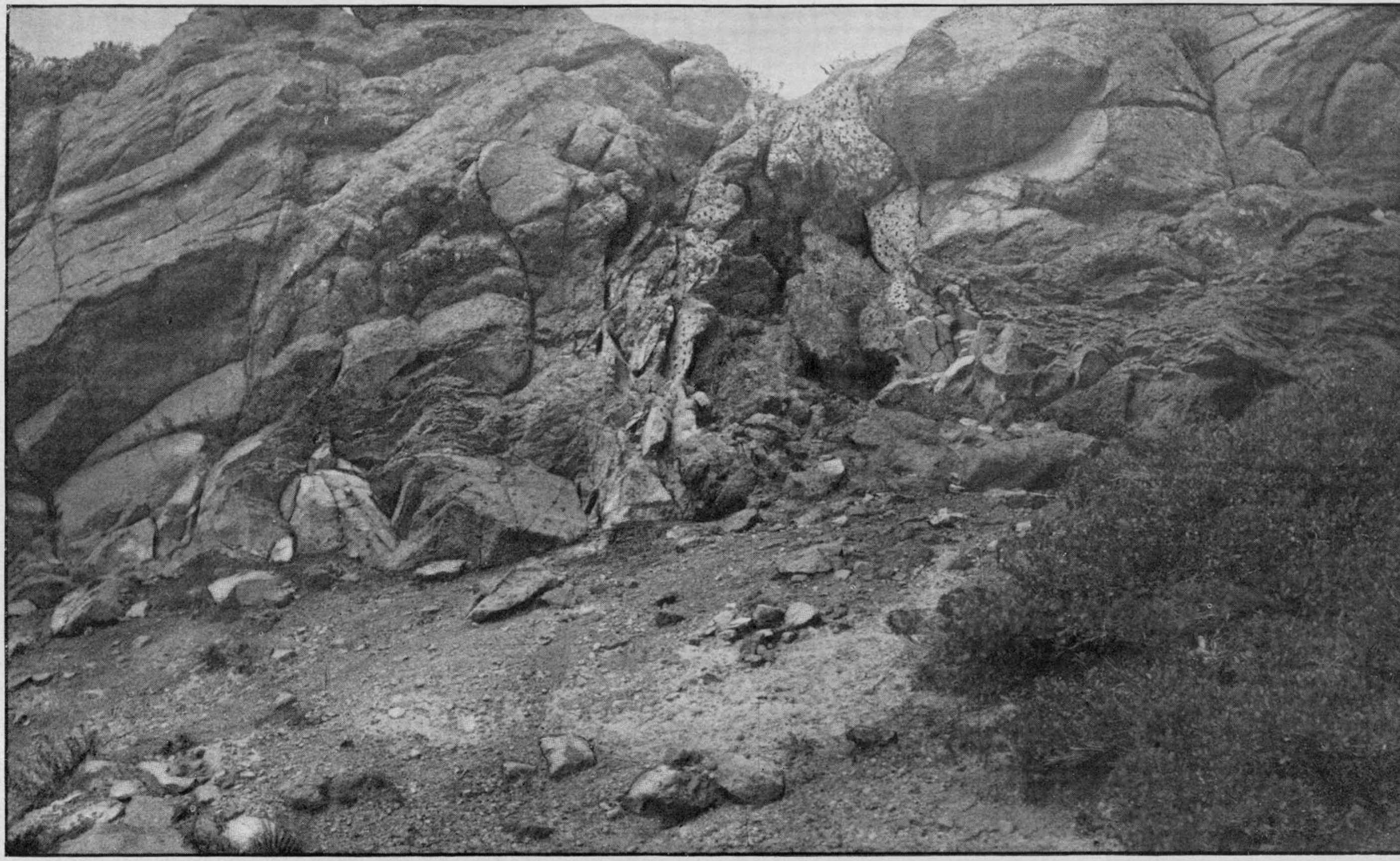
Near Squaw Hollow the line of the flow turns eastward and crosses the present canyon of the North Fork of the Stanislaus, another obvious instance of deep cutting since the eruption of the lavas. This canyon is not to be compared to that of the Middle Stanislaus, but some idea of its depth and the steepness of its walls may be gained when it is stated that the trail connecting the two groves of mammoth trees crosses at this point on a narrow bridge, and a horseman must travel more than 12 miles in a straight line up or down the stream before coming to another practicable crossing.

Two miles east of Squaw Hollow a remnant of the Table Mountain flow occurs resting upon a ridge of granite and surmounted by a small patch of the biotite-augite-latite. Another fragment occurs on the same ridge a little farther east. From these small areas there is a considerable gap in the continuity of the lava flows, until they are met with again, some 3 miles to the east, in the upper drainage of Griswold Creek. The most interesting occurrence here is about 1¼ miles south of Fennessy Meadow, on the divide between Griswold and Skull creeks, where a portion of the biotite-augite-latite can be plainly seen resting upon the andesite breccia, and in turn covered by a second bed of the latter. The volcanic rocks at this point cap a small elliptical hill and rest upon the basal granite of the region. At the eastern end of the hill the latite is about 40 feet thick, and well exposed on the southern side, resting upon the breccia. Above the latite is a bed of soft, light-colored tuff, about 15 feet thick, which in turn is overlain by the ordinary andesitic breccia which caps the hill. At the west end of the hill a similar sequence is exposed, only here the latite is not more than about 25 feet thick, and rests directly upon the granite. Just to the east of the hill is a strip of augite-latite which appears to underlie the biotite-augite-latite, but the relation is not clearly shown. Other considerable masses of augite-latite occur on Griswold Creek above Fennessy Meadow, but they were somewhat hastily examined, and it is not known whether they should be correlated with the Table Mountain flow or with the Dardanelle flow.

Near the head waters of Beaver Creek the andesitic breccia surrounds an area of granite, portions of which are higher than the bottom of the breccia, indicating a considerable irregularity in the old peneplain at this place. The biotite-augite-latite occurs at three points about the edge of this inclosed area, resting on the granite at the base of the breccia, and apparently overlain by the latter. The southernmost of the three patches is overlain by a portion of the Dardanelle flow.

The line of the latitic flows crosses the main breccia ridge at this point and appears on its eastern side in the drainage area of the Middle Stanislaus. Whether the flows are really continuous under a portion of the andesitic breccias is a question that was not determined with absolute certainty. The mapping indicates such a continuance, and the hypothesis is strengthened by the fact that on the eastern side of the ridge a portion of the sloping terrace formed by the Dardanelle flow and the underlying biotite-augite-latite is occupied by a small meadow, with strong springs issuing from beneath the andesitic breccia at its rear. As such springs are not common along the sides of these ridges, save where the porous breccia beds rest upon an impervious foundation, the presumption is that the massive Dardanelle flow here passes beneath a portion of the clastic series.

To the south and east of Clover Meadow the latites are well exposed. They occupy in general the crest of the ridge already described as running eastward toward the Dardanelles, and rest with evident unconformity upon the andesitic breccias and tuffs, or directly upon the granite, as seen about a mile to the south of Clover Meadow. All three of the flows are represented on the ridge. The earliest or Table Mountain flow is the most extensive, and rests upon a rather uneven surface of the clastic andesites. It varies greatly in thickness from point to point, and has a warped and twisted surface, rendering its mapping difficult on a small scale. At the western end of the ridge, about half a mile due east of the small pond in Clover Meadow, occurs an insignificant patch of the red lava, identical with that found south of Mill Creek, and occupying a position below and apparently geologically beneath the Table Mountain flow. Near the



CONTACT BETWEEN THE MASSIVE LATITE OF THE TABLE MOUNTAIN FLOW AND THE UNDERLYING ANDESITIC BRECCIA 1½ MILES EAST OF CLOVER MEADOW.

eastern end of the ridge the contact of the latite with the clastic andesite is finely shown (Pl. V). The lower portion of the massive flow is usually highly vesicular, and at the point shown in the illustration there is a cavity about 3 feet in height in the under side of the flow, its interior being lined with exceedingly frothy lava. At a short distance from the bottom the latite becomes less vesicular and takes on the usual platy structure, passing with increasing thickness into columnar parting. The character of the underlying andesite at this place is shown in Pl. VI. The material shows a rude stratification and the fragments are rounded or subangular, indicating that they were water deposited.

As already noted, the eastern end of the ridge falls off abruptly in a high bluff, in which are exposed over 400 feet of nearly horizontal beds, composed of andesitic sands and gravels partly consolidated. They form a part of the andesitic tuff series, but are somewhat more waterworn and better stratified than usual in this region. (Pl. VII.) The craggy masses in the upper right-hand corner of the illustration are composed of an andesitic breccia, which lies at a considerable angle and unconformably upon the stratified andesitic beds and underlies the Table Mountain flow. It appears to belong to the period of latitic eruptions, and to have immediately preceded the first of these. It has very little horizontal persistence, but is probably the equivalent of the conglomerate noted in a similar position beneath the lower latite flow, east of McKay's mill.

At the western end of a little meadow lying on the crest of the ridge, near its eastern end, the Table Mountain flow exhibits the interesting rounded forms shown in Pl. VIII. These recall certain spheroidal structures occurring in the Mesozoic basalts at Point Bonita,[1] in the Coast Ranges, although they are not so perfect as the latter. They are clearly not due to weathering and exfoliation, as the surface shown is perfectly bare of soil and exhibits only the merest traces of superficial decomposition. It is undoubtedly a structure produced during the cooling of the molten mass, and is replaced a few yards away by the ordinary columnar structure (Pl. IX). The surface shown in the illustration, Pl. VIII, is probably but little different from that of the original flow, and exhibits well its locally rolling character. That the ice at one time surmounted the ridge is indicated by the granitic bowlders which occur perched here and there upon the lavas, but it does not appear to have acted as an effective eroding agent.

At various places on the ridge the biotite-augite-latite rests upon the Table Mountain flow with an average thickness of something less than 50 feet, while on top of it again are masses of the Dardanelle flow, with an observed thickness of 100 feet. This latter rock generally shows a smaller columnar structure than the Table Mountain flow, the columns being rarely a foot in diameter and usually short and irregular.

[1] Univ. of Calif., Dept. Geol., Bull., Vol. I., 1893-96, pp. 71-114.

Probably no known area in the Sierra Nevada presents a more interesting succession of volcanic rocks than the cluster of peaks known as the Dardanelles. As a whole they have never been closely studied, and the present information has been derived merely from a short reconnaissance of the western peak, and an ascent to its summit. This peak is made up of a series of volcanic flows resting upon the granite as a basement, at an elevation of about 7,500 feet above sea. On the west side (the side shown in Pl. III) the lower member of the volcanic series is composed of several flows of olivine-basalt, aggregating from 500 to 600 feet in thickness. This basalt has suffered greater decomposition than the latites, and forms a steep, weathered slope, leading up to the base of the lofty cliffs which give the peak its striking outline. That the rocks composing this slope are true surface flows is indicated by the frequent vesicular and amygdaloidal bands from 10 to 40 feet in thickness, which are exposed in the small gullies channeling the weathered rock. The vesicles are usually lined with zeolites in the form of thin incrustations.

Resting sometimes directly upon the olivine-basalt, sometimes separated from it merely by a thin layer of volcanic conglomerate, is a thick mass of dark, columnar augite-latite, forming a vertical cliff over 400 feet in height. The lower 25 or 30 feet of the cliff face shows a very vesicular facies, becoming compact and columnar higher up. A short distance away from the mountain it could be seen that the columns became much larger some distance up the cliff, but it was not possible to determine whether this difference in size was significant of any division into an upper and lower flow, or whether the whole cliff face consisted of the Table Mountain flow. Hand specimens from the base of the cliff show a facies much like the typical Dardanelle flow, while fragments fallen from the upper portions exhibit the thoroughly characteristic features of the Table Mountain facies. The difference, however, is not greater than might easily obtain between the middle and basal portions of a single thick flow.

The conglomerate, mentioned as occurring between the olivine-basalt and the base of the latite, is composed chiefly of waterworn volcanic pebbles, some of which are identical with the underlying basalt, while others appear to be andesitic, or possibly latitic, in character. The bed is a lenticular one, about 12 feet in thickness and of small lateral extent.

Rhyolitic material was not observed on the west side of the peak, but an area of massive rhyolite is shown on the map just west of the peak and crossed by the trail going down to Highland Creek. This is the only area of undoubtedly massive rhyolite met with in the district embraced by the map. It rests immediately upon the granite, and, like the rhyolitic tuff of the region, is probably older than the andesites and latites.

Above the heavy columnar Table Mountain flow, and forming the extreme summits of the West Dardanelle, some rounded, dumpling-

ANDESITIC CONGLOMERATE UNDERLYING TABLE MOUNTAIN FLOW 1½ MILES EAST OF CLOVER MEADOW.

The illustration shows the imperfect rounding of the volcanic fragments and the rude stratification of the whole. These are outlying pinnacles left by differential erosion upon the steep hill slope.

shaped masses could be seen, which the glass showed to have the smaller columnar structure generally associated with the uppermost, or Dardanelle flow.

On the southeast side the ascent to the top of the peak is not difficult. It was found that the lowermost member of the volcanic series on this side is a rhyolitic tuff, inclosing foreign waterworn pebbles, and about 50 feet thick, probably resting on the granite, although the base was not seen. Above the tuff the same olivine-basalt already mentioned is exposed for a thickness of 150 feet. The succeeding 300 feet of vertical elevation is occupied by a very rough talus slope, composed of fallen columns from the cliffs above, which on this side show a height of nearly 500 feet by aneroid barometer. The lower 200 feet of the cliff exposed is coarsely and somewhat irregularly columnar; toward the top this passes gradually into a zone characterized by a horizontally platy structure, which in turn is succeeded by an irregularly jointed and vesicular upper portion, becoming a flow breccia at the extreme top. No evidence was found on this side of the mountain to indicate that this thickness of 500 feet is made up of any more than the single Table Mountain flow. Its bottom, however, was not seen.

On the top of this thick flow, exposed in the saddles between the three summits shown on the map, lies the biotite-augite-latite of the second flow, here 50 feet in thickness.

The summits themselves are composed of remnants of the Dardanelle flow, which on the western knob has a thickness of at least 160 feet. It shows the usual small columns and fresh bare surface, its dissection being due rather to an undermining and falling away of the columns than to its own weathering. The entire thickness of the latites here exposed is at least 710 feet, and of the entire volcanic accumulation above the granite 1,210 feet. These figures, however, are from aneroid readings, while the topographical map would indicate a total thickness of 1,400 feet. It is noteworthy that this thickness does not include any of the ordinary andesitic breccia which elsewhere occurs in such volume beneath the latites.

The Dardanelle Cone, 9,529 feet, the highest peak of the group, was not visited. It owes its name to its sharp conical summit as seen from the west, but, like the West Dardanelle, appears to be made up of horizontal volcanic rocks resting upon the granite. The lower beds are light in color, suggesting rhyolitic or andesitic tuffs.

The view from the summit of the West Dardanelle is in many ways an exceedingly interesting one. In the immediate foreground, to the west and north, lies a broad basin of bare, glaciated granite, rounded and polished by the ice, and dotted here and there with lakes or grassy meadows. To the south lies the gorge of the Middle Stanislaus—too deep and narrow for its bottom to be seen, even from such a vantage point. But if the eyes are withdrawn from what lies just below them and allowed to sweep the horizon, the attention is at once attracted by the several peaks of similar structure to that upon which the observer stands; that is, they are made up of nearly horizontal flows or breccia beds, resting upon a granitic basement. Not only are they of similar structure, but they stand with their tops close to an imaginary plane having a noticeable slope to the southwest, the general western slope of the range, which is rendered more apparent when seen from so high an altitude. Toward the west the ridges are lower, and, as has been shown, are composed in part of the same latitic flows. To the east and northeast they are higher and less continuous, being frequently isolated peaks, and less is known of the nature of their volcanic caps. It is probable that they are in part composed of latite, as Whitney[1] mentions the occurrence of lava similar to the Table Mountain flow south of Hermit Valley. But they are probably largely made up of the ordinary andesitic breccia of the range.[2] This appears to be especially true of the ridges to the southeast across the main Stanislaus River. It is evident that in Tertiary times this portion of the range was a peneplain, or a surface of comparatively gentle relief, which at the end of the Neocene was covered by volcanic tuffs and flows. Moreover, the latite now crowning the Dardanelles can not mark the upper limit of this accumulation, for, as has been shown in the preceding pages, these lavas flowed down channels in the andesite, and were in turn covered by fresh accumulations of the same breccia. The only remnants of all this volcanic covering now visible from the summit of the West Dardanelle are a few residual peaks and ridges which, owing to a more resistant capping, or to other causes, have survived the general degradation. The picture of profound denudation, shown in the uncovering of the old granite surface and its deep trenching by such streams as the Stanislaus, would be impressive in any case, but it becomes doubly so when it is remembered that all this has taken place in post-Tertiary times.

Thus far the latitic lavas have been described as if they were confined in their distribution to the main line of flow outlined in the preceding pages. But this is not entirely the case. As shown on the accompanying map, the biotite-augite-latite occurs in small isolated areas at considerable distances from the main flow-axis, even appearing in the drainage area of the Mokelumne River, to the north of the Stanislaus Basin. It is possible that there may be a few more of these patches than have been indicated, as they frequently occur very unobtrusively near the contact of the andesite breccias with the underlying granite, and are often concealed in the heavy timber. In such situations it is generally impossible to determine positively whether the latite really underlies the andesite or vice versa. South of the Middle Stanislaus are several small areas of the biotite-augite-latite which plainly rest upon the andesitic breccias and tuffs, in most cases with evident uncon-

[1] Auriferous Gravels, 1880, p. 131.

[2] See Turner, Geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, pp. 708-709, for some interesting notes on this region, with views of the andesite breccia (Pl. XXXVI).

VIEW OF BLUFF WHICH TERMINATES THE RIDGE ABOUT 2 MILES EAST OF CLOVER MEADOW, SHOWING THE STRATIFICATION OF THE ANDESITIC BEDS.

The pinnacles on the left are composed of a coarse andesitic breccia resting unconformably upon the stratified tuffs and conglomerates and underlying the Table Mountain latite, which is not shown.

formity. This relation is well shown about 2 miles southeast of Mount Knight, where the latite, beginning with a point on the top of the ridge overlooking the Middle Stanislaus, runs obliquely down over the beveled edges of the nearly horizontal clastic andesite, resting finally on the schists of the Bed-rock series just above Rose Creek.

As will be seen in the section devoted to the petrography of the latites, the biotite-augite-latite has characteristics that render its distinction from a tuff not always easy. The fact that it has a wider distribution than the two undoubted massive flows, also suggests that it may have had a different origin. But the field evidence does not support the view that it is in any sense a water-deposited tuff. It is entirely devoid of the horizontal bedding characteristic of the known tuffs of the region, and on the other hand it possesses the more or less uneven upper and lower surfaces, and the ability to lie upon perceptible slopes, which are characteristic of true lava streams. It also resembles lavas in being coarsely columnar in structure, although, as has been shown, this structure may also occur in undoubted tuffs. The basal contact of the biotite-augite-latite was nowhere seen sufficiently well exposed to give a decisive answer to the question whether it is tuffaceous or massive in character.

PETROGRAPHY OF THE LATITES AND OF THE OTHER VOLCANIC ROCKS ASSOCIATED WITH THEM.

As frequently emphasized in the preceding account of its distribution, the lava composing the Table Mountain and Dardanelle flows is dark in color and basaltic in general appearance. The earlier writers, without exception, referred to it as basalt, and until very recently no reason had appeared for revising their determination. In 1895, however, Turner wrote as follows:

> The basalt of the Tuolumne Table Mountain is also a dark, heavy rock, but as may be noted below [referring to an accompanying chemical analysis] has an unusually high percentage of silica for a basalt. It is also characterized macroscopically by containing numerous cavities and tabular porphyritic feldspars which are sometimes half an inch long.[1]

In a later paper, published after the field seasons of 1895 and 1896, occurs the following paragraph:

> Tertiary trachytes are known thus far only in the area of the Big Trees sheet. They occur both as tuffs (?) and massive flows, the latter strongly resembling basalt in macroscopic appearance. They are placed with the trachytes chiefly on the basis of their chemical composition. Indeed, the Tuolumne Table Mountain basalt has so high an alkali content that it is placed in the table with the trachytes for comparison. This flow can be traced from Knights Ferry, in Stanislaus County, across the Sonora area into the Big Trees district, not far from where specimens 85 and 86 Tuolumne were collected. As the writer has only cursorily examined these trachytes, the matter of their classification will not be further considered at present.[2]

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[1] Rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 491.

[2] Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, p. 729.

By way of preliminary explanation, it may be stated that both the "trachytes" and the "basalt" referred to in the foregoing citation are portions of the latitic flows which form the subject of the present paper. This separation into trachyte and basalt, it will appear, was not without excuse so long as hand specimens from somewhat widely separated localities were made the basis for such distinction, and the mere fact that lavas belonging to one chemical and mineralogical type, if not, in some cases, to one flow, could be tentatively classed as trachytes in one place and basalts in another, is not without its bearing on the question of their proper classification.

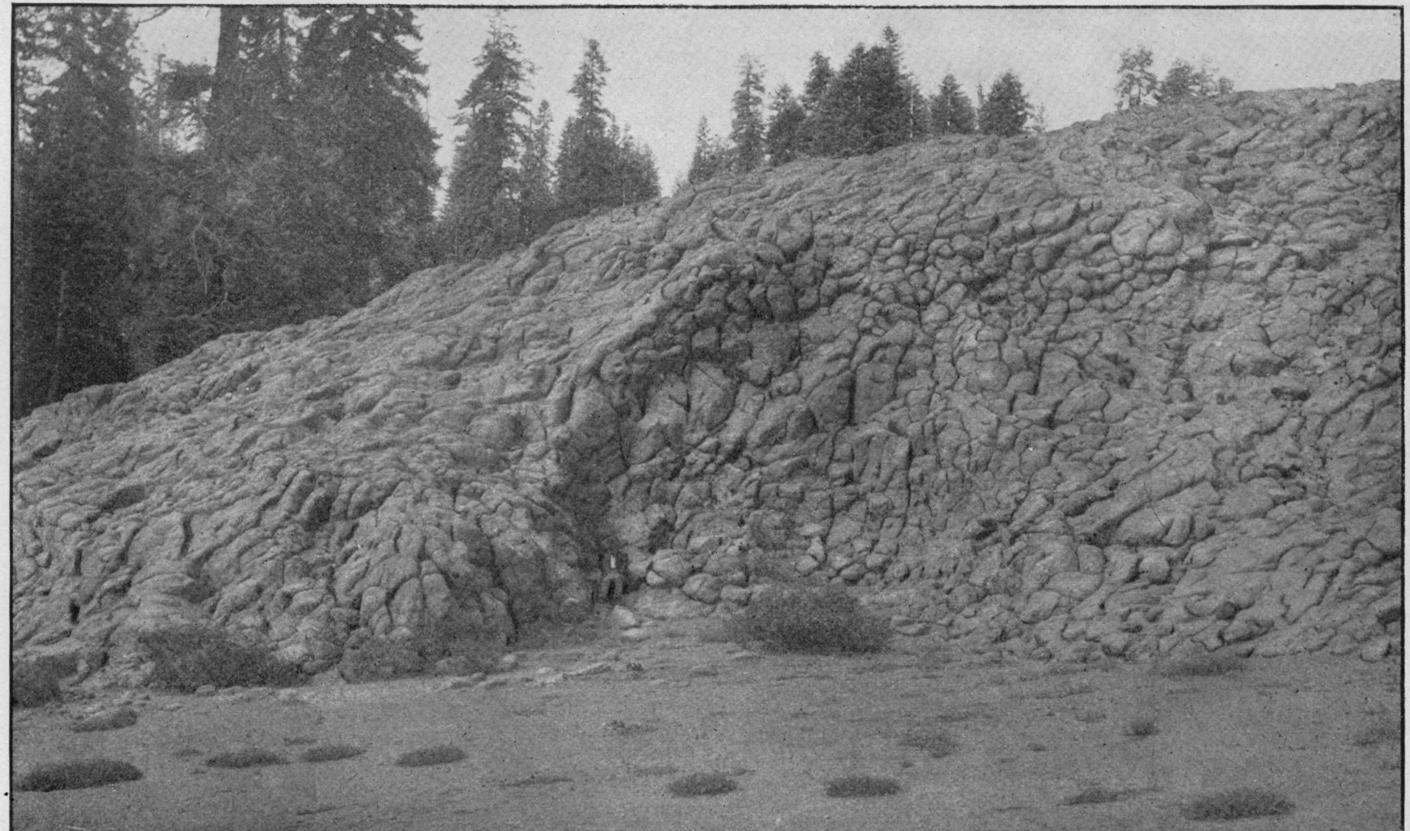
THE TABLE MOUNTAIN FLOW.

Megascopically the Table Mountain latite shows great uniformity, from the end of the flow, near Knights Ferry, to the Dardanelles, the highest point at which it has been studied. It may become locally vesicular, especially at the top and bottom of the flow, or show slight variations in the number and size of the phenocrysts, but in general the description of any one hand specimen will apply with but slight modification to any portion of the 60 miles of flow.

A specimen (1820 S. N.) from just west of Parrott Ferry, at the point where the river has cut its gorge across the line of the lava stream, may be considered as typical. This is a dark rock, of compact texture and basaltic aspect, characterized by an abundance of large glassy plagioclase phenocrysts lying in a dense, nearly black groundmass. The plagioclases are tabular parallel to the brachypinacoidal faces, a common size being about 2 ^{mm} in thickness, 8 ^{mm} in breadth, and 10 ^{mm} in length. A length of 15 ^{mm} may, however, be frequently observed. The cleavage faces, on the freshly fractured rock surfaces, always show twinning according to the albite law, and not infrequently an additional twinning following the Carlsbad law. Dark olive-green augite can be distinguished in the form of phenocrysts, but it is neither an abundant nor a conspicuous constituent as compared with the plagioclases. The rock is somewhat vesicular, the vesicles being usually elongated in the direction of flow, and occasionally filled with calcite.

Under the microscope the large plagioclase crystals are by far the most conspicuous mineral in the slide. Augite is much less abundant, but occurs in phenocrysts of considerable size and usually of irregular outlines. Olivine is moderately abundant in small, more or less idiomorphic phenocrysts up to 0.5 ^{mm} in length. The groundmass is hyalopilitic.

The large plagioclases generally show approximate crystallographic outlines, but they are often rounded and sometimes deeply embayed. Although perfectly fresh, they are apt to be crowded with inclusions of dark, glassy base, giving them a mottled appearance not unlike the



SPHEROIDAL FACIES OF AUGITE-LATITE OF THE TABLE MOUNTAIN FLOW.

At the western end of a little meadow on the crest of the ridge, about 1½ miles east of Clover Meadow.

crystal figured by Rosenbusch[1] from a Hungarian augite-andesite. They are invariably twinned in accordance with the albite law, but the resulting lamellæ are of very different widths, ranging from those just visible up to 0.5 mm or over. The frequent combination of Carlsbad with albite twins renders the determination of the feldspars by Michel Lévy's method comparatively easy. In a section at right angles to the plane of the brachypinacoid, angles of extinction were obtained on each half of the Carlsbad twin of 14.5° and 33.5°, indicating a labradorite with about the composition Ab_3An_4. A section cut approximately parallel to the brachypinacoid and revealing no twinning showed the emergence of a slightly oblique acute bisectrix and gave an extinction angle of about 16° with the basal cleavage, the angle varying somewhat for different portions of the crystal.

Pericline lamellæ are occasionally observed in conjunction with the albite twinning.

An attempt was made to determine the specific gravity of the plagioclase phenocrysts by suspending fragments in Thoulet solution. Some very small and apparently pure grains neither floated nor sank at 2.684, but the specific gravity of particles over a millimeter in diameter was found to be about 2.651. The latter figure is undoubtedly lower than the true specific gravity of the feldspar, as it is impossible to secure fragments that are free from inclusions and yet large enough to give satisfactory determinations by suspension in a heavy liquid.

The augite phenocrysts are generally irregular and rounded in outline, but are sometimes crystallographically bounded in the prism zone. They are very pale green in color, nonpleochroic, and resemble diopside; but the extinction angle on *c* is often over 40°, and sometimes as high as 45°, and they are more properly classed as pale augite. As Zirkel[2] points out, such pale-green augites are characteristic of rocks high in alkalies, while brownish augites are more common in basalts.

The olivine, like the other minerals in the slide, is perfectly fresh, and forms small crystals, usually less than 0.5 mm in length, and showing slightly rounded crystallographic outlines. Although occurring in much smaller crystals than the augite, it appears to be nearly as abundant in the thin section, and may be regarded as an essential constituent of the rock.

The groundmass, from which the phenocrysts are distinctly differentiated, shows a rather coarse hyalopilitic structure, made up of feldspar microlites, grains of magnetite, augite, olivine, and glass. Structurally, it is very similar to the olivine weiselbergite of Rosenbusch,[3] as seen in one of Voigt and Hochgesang's thin sections. The feldspar microlites usually show distinct albite lamellæ, which extinguish at considerable angles, indicating a labradorite but little, if any, less basic than the phenocrysts. As one of the distinctive characters of the latites

[1] Mikroskopische Physiographie (3d ed.), Vol. I, 1892, Pl. XXIV, fig. 3.
[2] Lehrbuch der Petrographie, 2d ed., Vol. I, 1893, p. 281.
[3] Op. cit., Vol. II, 1896, p. 954.

described in this paper is their relatively high potash content, and as Washington[1] has described orthoclase in rocks of almost identical chemical composition from Italy and Asia Minor, pains were taken to determine whether any of the microlites were potash feldspars. But microscopical study gives no ground for believing that any other feldspar than labradorite is present. Some of the labradorite phenocrysts were observed to be bordered by an extremely narrow zone of more acid feldspar—possibly orthoclase. This, however, is not common.

The glassy portion of the groundmass appears to make up less than half its bulk. It is light brown in color, and quite turbid from the presence of very minute globulites. The magnetite occurs in small but distinct grains, rather abundantly and evenly distributed through the section. The olivine and augite grains in the groundmass differ in no way but in their small size from the same minerals in the phenocrysts, and are not to be sharply differentiated from the latter. The olivine frequently occurs as inclusions in the augite, and the latter is sometimes included in the large labradorite phenocrysts. Apatite occurs in small prisms, commonly included in the augite.

Turner[2] has given a microscopical description of a specimen (36 S. N.) collected from Table Mountain near Shaws Flat. He says:

> Microscopically the Table Mountain basalt shows large tabular feldspars, smaller augites, and numerous olivine grains in a nearly opaque groundmass, in which are very abundant feldspar microlites. This groundmass doubtless contains a large amount of magnetite, and strongly resembles some of the sections of the older basalt. There is a good deal of brownish serpentinoid substance in the groundmass. The porphyritic feldspars are polysynthetically twinned and have a corroded appearance, due to the abundant inclusions of aggregates of opaque particles, with some glass inclusions. There is also some serpentine in the large feldspars.

An analysis of this specimen is appended to his description and has been quoted in Column I of the table of chemical analyses on page 58.

Mr. Turner having kindly allowed me to examine two thin sections of this rock, it was found that it differed from most of the specimens collected at other points along the Table Mountain in the slightly greater abundance of the olivine, in the presence of the serpentinous patches, and in a rather unusual opacity in the glassy base. A single rounded crystal of slightly pleochroic orthorhombic pyroxene was noted included within a large augite phenocryst, but this mineral is very rare in the Table Mountain flow. The groundmass is hyalopilitic. The opacity of the groundmass is seen with high powers to be due to the dense crowding of minute globulites of rather peculiar character. These globulites occur also in the Dardanelle flow, and as they have been there more studied their description will be for the present deferred.

A specimen (1016 S. N.) taken on the trail passing over the top of

[1] Italian petrological sketches: Jour. Geol., Vol. IV, 1896, p. 547 *et seq.*, and On igneous rocks from Smyrna and Pergamon: Am. Jour. Sci., 4th series, Vol. III, 1897, pp. 41-50.

[2] Rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 491.

COLUMNAR FACIES OF THE AUGITE-LATITE OF THE TABLE MOUNTAIN FLOW.

About 1½ mile east of Clover Meadow, on the crest of the ridge. The light-colored bowlders in the foreground and the larger masses on top of the lava columns are glacial erratics.

the mountain between Sonora and Tuttletown is thoroughly typical and shows particularly well the numerous inclusions in the large labradorite phenocrysts. These inclusions are usually composed of globulitic glass, with microlites of labradorite and augite, and are similar to the fine groundmass of the rock.

Northeast from Parrott Ferry the Table Mountain flow was investigated microscopically at many points, with the general result of showing great structural and mineralogical uniformity. In general, as the flow is followed higher up into the mountains the olivine becomes somewhat less abundant and sinks to crystals of smaller dimensions. The large labradorite phenocrysts, while preserving their size and characteristic mottling, seem to become progressively slightly more acid, numerous determinations by the Michel Lévy method indicating that in the more eastern portions of the flow a labradorite of the approximate composition Ab_1An_1 predominates. Apatite is a constant accessory, occurring in the groundmass and in the augites.

About $1\frac{1}{4}$ miles southwest of Collyer's a facies (1845 S. N.) occurs in which the labradorite phenocrysts are somewhat smaller than usual, the rock standing megascopically about halfway between the normal Table Mountain facies and the usually finer-grained rocks of the third, or Dardanelle, flow. A thin section shows the usual phenocrysts of labradorite, augite, and olivine. The labradorites are twinned with beautiful sharpness and vary considerably in the number of inclusions contained within them. One long crystal of irregular shape was observed to be a veritable sponge, inclosing glass and microlites of plagioclase and augite. The groundmass is hyalopilitic and contains a little carbonate scattered through it.

A specimen (1945 S. N.) from the portion of the flow 1 mile northeast of McKay's mill, shown in Pl. IV, also has somewhat smaller plagioclase phenocrysts than usual, and resembles in megascopic character the Dardanelle flow, which lies above it, separated by the biotite-augite-latite. Under the microscope, however, it shows no marked difference from other thin sections from the same flow. There are the same large labradorites mottled with glassy inclusions and showing albite twinning lamellæ combined with those of the Carlsbad and pericline laws. Augite is present in large, irregular phenocrysts and in smaller crystals with idiomorphic cross sections transverse to the prism. Olivine is distinctly less abundant and occurs in smaller crystals than in that portion of the flow near Shaws Flat already described. In this particular slide it has been almost wholly altered to serpentine, a rather uncommon condition in the Table Mountain flow. The groundmass is finer, less opaque, and typically hyalopilitic.

Across the north fork of the Stanislaus the small area $1\frac{1}{2}$ miles east of Squaw Hollow presents a thoroughly typical facies (1913 S. N.), both megascopically and microscopically. The large labradorites frequently show Carlsbad twins and give extinction angles corresponding to the mixture Ab_3An_4. They sometimes show deep and intricate embayments, and are full of the usual inclusions. The augite occurs in characteristic phenocrysts and also as small grains, which are sometimes heaped together in a manner suggesting the aggregates formed by the magmatic resorption of hornblende in many andesites. Like the Shaws Flat facies described by Turner, the glassy base is dark and semi-opaque, and the slide contains small irregular patches of greenish-yellow serpentine. The latter does not show definite outlines, and is not a pseudomorph after any crystalline mineral. It permeates portions of the slide irregularly, and may fill some small vesicles. Augite and olivine are less abundant than in the Shaws Flat rock, the latter mineral occurring only in small crystals in the groundmass.

The small mass (1794 S. N.) resting upon the andesitic breccia 2 miles northeast of Ashcraft's is megascopically halfway between the typical facies of the Table Mountain and Dardanelle flows. Under the microscope it shows an equally intermediate character, and may possibly belong to the latter flow. The labradorite (Ab_3An_4) phenocrysts are fresh and sharply twinned, pericline lamellæ being not uncommon. They show the basal and brachypinacoidal cleavages in systems of fine cracks, and are comparatively free from inclusions. The other phenocrysts are augite, magnetite, and olivine, lying in a hyalopilitic groundmass with considerable globulitic glass.

As the lava showing the spheroidal forms seen in Pl. VIII has been subjected to chemical analyses, it will be described somewhat at length. Megascopically the rock (1422 S. N.) forming these spheroids is indistinguishable from specimens collected from the Tuolumne Table Mountain, 40 miles to the southwest. It shows similar tabular phenocrysts of labradorite, with here and there an irregular crystal of augite, lying in a compact dark groundmass. The plagioclases are fresh and glassy, and their glistening cleavage planes are the most conspicuous features of the freshly broken rock, and even of the natural surfaces, for the weathering has been but skin deep. A common size for these phenocrysts is about 2 by 7 by 9^{mm}, the plane of greatest extension being the brachypinacoid. They invariably show the albite twinning on the basal cleavage planes, and not uncommonly Carlsbad twinning also.

Under the microscope the thin section (Pl. XI, *A*) shows the usual phenocrysts of labradorite and pale-greenish augite with small idiomorphic olivines, lying in a very fine, even groundmass, which is typically hyalopilitic, showing flow lines of the small lath-shaped microlites around the phenocrysts. The large labradorites show the usual rounded and embayed outlines, and are mottled with abundant inclusions. The latter are usually similar to the glassy base of the rock, but more rarely a greenish serpentinoid substance. Some of the labradorites have been broken in the magma and the parts displaced, and angular fragments, probably of similar origin, are common. The

VIEW OF THE DARDANELLES FROM A HIGH POINT TO THE SOUTH, LOOKING OVER THE CANYON OF THE MIDDLE STANISLAUS RIVER.

Photograph by H. W. Turner.

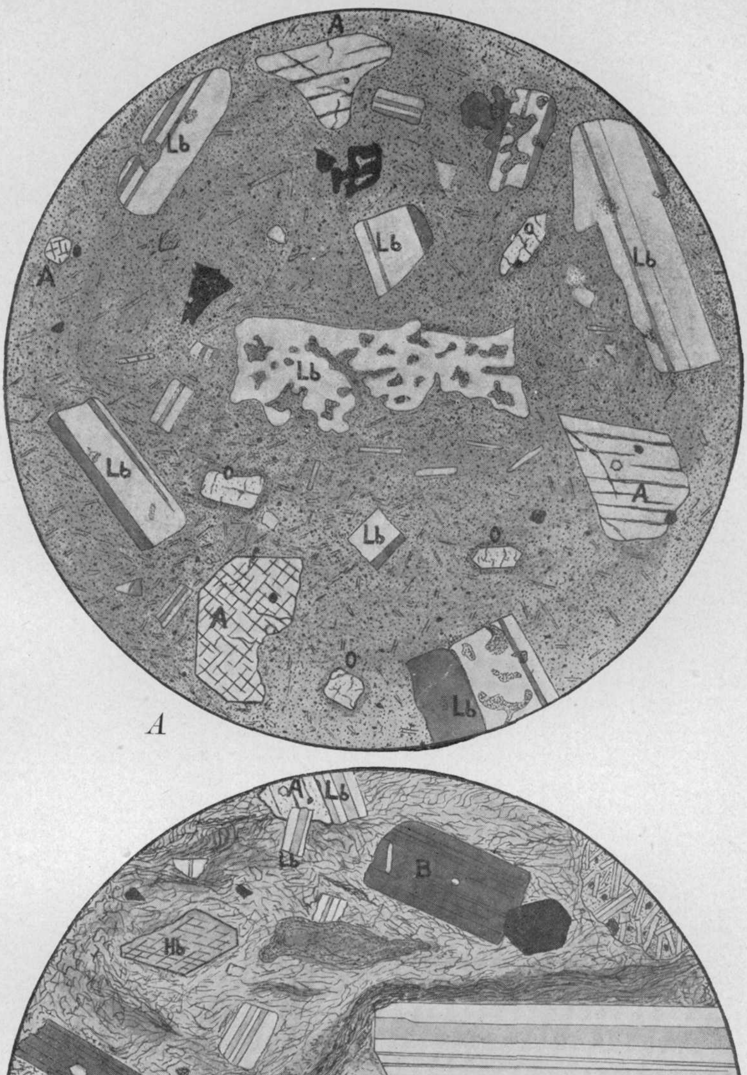
PLATE XI.

PLATE XI.

MICROSECTIONS OF LATITES (SEMIDIAGRAMMATIC).

A. Augite-latite (1422 S. N.), Table Mountain flow, showing general structure of the rock, with phenocrysts of labradorite (Lb), augite (A), olivine (O), and magnetite.

B. Biotite-augite-latite (1955 S. N.), showing eutaxitic or "piperno" structure. The drawing shows phenocrysts of labradorite (Lb), augite (A), biotite (B), hornblende (Hb), and magnetite, with included rock fragments, lying in a banded and partially brecciated microlitic glass.



MICROSECTIONS OF LATITES (SEMIDIAGRAMMATIC).

plagioclases show the usual combination of albite and Carlsbad twinning, with occasional pericline lamellæ. A determination of the extinction angles by Michel Lévy's method indicated a labradorite with the composition $Ab_1 An_1$. The specific gravity of a small, apparently pure fragment was found by means of Thoulet solution to be 2.648, which is rather light for apparently so basic a plagioclase. The augite, which is much less abundant than the labradorite, is very pale green in color, nonpleochroic, and identical with that already described. Sharply idiomorphic cross sections of the prism zone are rather more common than usual. It is frequently twinned polysynthetically on the orthopinacoid in the usual manner. The olivines are fairly abundant, but small. They are generally fresh, and show crystallographic outlines, but in somes cases they are changed to yellow serpentinous pseudomorphs. The groundmass around these olivine crystals is sometimes distinctly more finely crystalline than elsewhere, giving them the appearance of being surrounded by a faint halo. Some scattered crystals of magnetite are of sufficient size to be included among the phenocrysts.

The groundmass is truly hyalopilitic, and is made up of small slender feldspar microlites, minute crystals of magnetite, and globulites, all lying thickly crowded in a clear glass of faint brownish-violet tint. The microlites are often so crowded that it is difficult to find a portion of the section that will show no double refraction between crossed nicols. By using an immersion objective, however, and working on the thinnest edges of the section, it is possible to differentiate the glassy matrix from the feldspar microlites and to see that it is full of crystals of magnetite, ranging from those that show crystal outlines down to barely visible black specks. Associated with the magnetite grains are numerous globulites and globulitic granules of high relief and faint green tint, which are probably augite. From this it appears that magnetite, although not conspicuous with low powers, is yet quite abundant in the mass of the rock. Augite, also, is probably a more important constituent than would be indicated by its distinct crystals.

The feldspar microlites are generally too small to be determined optically, but the better-individualized ones generally show albite lamellæ with an obliquity of extinction corresponding to labradorite. Apatite occurs in rather stout, sharply hexagonal prisms.

A chemical analyses of this rock is given in Column III of the table of chemical analyses on page 58. Its specific gravity is 2.67, which is lower than one would usually expect in a rock of such dark color and compact texture.

A few hundred yards to the east of the spheroidal facies the bottom of the Table Mountain flow is exposed, resting upon clastic andesitic beds, as shown in Pl. V. The flow is here exceedingly vesicular in its lower portions, the large labradorite phenocrysts being held together by a paste of frothy red glass. The microscope shows the usual labradorite phenocrysts full of glass inclusions. Augite was observed only as an inclusion in one of the labradorites. The cementing material is a vesicular, semiopaque brown glass, with a few labradorite microlites. The turbidity of the glass is apparently due to the oxidation of the magnetite, contingent upon the highly spongy character of the rock. The inclusions in the large plagioclases are of the same glassy nature as the matrix, while in other occurrences already described the inclusions consist of more or less individualized groundmass, thus indicating that crystallization went on in the included portions as well as in the groundmass outside the labradorite phenocrysts.

At the West Dardanelle the latite of the Table Mountain flow (1023 S. N.) is megascopically identical with the spheroidal facies (1422 S. N.) just described, although its larger structure is columnar. Microscopically it resembles rather more closely the sections from the Table Mountain near Sonora, although with considerably less olivine. The large labradorites give extinction angles corresponding to a mixture $Ab_1 An_1$. They are full of inclusions of glass, with sometimes small crystals of augite and labradorite. The augite phenocrysts are larger and more abundant than usual. They are sometimes, like the labradorites, filled with inclusions, plagioclase laths and small patches of yellow serpentine being among the latter. The thin section also shows serpentinous patches like those described in the Tuolumne Table Mountain specimens. Olivine, however, is not so abundant, being confined to small idiomorphic crystals scattered through the groundmass. These are generally fresh, but are sometimes partly changed to serpentine.

A specimen (1030 S. N.) taken near the upper surface of the flow is rendered spongy by abundant small vesicles. Under the microscope it shows the same phenocrysts as the preceding rock, but the labradorite microlites in the groundmass are much smaller, and the rock as a whole is more glassy. With high power the glass is seen to be thickly dusted with magnetite and globulites and to show the faint violet-brown tint characteristic of the perfectly fresh glass of these rocks. In spite of the freshness of the other constituents, the olivine has all been altered to yellow serpentinous pseudomorphs.

The microscopic petrography of the Table Mountain flow has been described at some length on account of its interesting chemical character, and for the reason that such a course seemed desirable in dealing with a flow so greatly dissected. It is seen that in its superficial appearance and in the presence of olivine the augite-latite resembles the basalts; in the character of the augite and plagioclase, in the degree of preponderance of the feldspathic constituents, and in the hyalopilitic structure of the groundmass, it is more closely related to the andesites; lastly, in the fine dissemination of the magnetite, in the abundance of microtine phenocrysts, and, above all, in chemical composition, it shows certain analogies with the trachytes. No potash feldspar has been detected in any of the thin sections studied, except, possibly, as a very narrow fringe on some of the labradorite phenocrysts, and even this seems to be the exception rather than the rule.

THE BIOTITE-AUGITE-LATITE.

As already indicated in the account of its occurrence, considerable difficulty was experienced in deciding whether this volcanic rock was a true flow, like the Dardanelle flow above it and the Table Mountain flow beneath it, or whether it should be classed as a tuff. In spite of the fact that it frequently shows the presence of fragmental material the rock is regarded as constituting a flow, for reasons that can be better appreciated after a petrographical description.

The facies occurring within the drainage of Love Creek, about 3 miles south of Big Trees post-office, is a thoroughly typical one. A specimen (1882 S. N.) taken just north of the road, about a mile southwest of McKay's, shows a bright-gray rock, that sparkles brilliantly on fresh surfaces, from the numerous crystals of biotite. In contrast to the Table Mountain augite-latite upon which it lies, this rock has a harsh or trachytic feel and is somewhat porous. Besides the biotites, the fine, and evidently glassy, groundmass holds small phenocrysts of clear sanidine-like feldspar and fragments of dark glass and of glassy volcanic rock. Some of the black glass inclusions are irregular and somewhat angular in outline, while others appear to be drawn out into thin lenses. These lenses, together with the biotite crystals, have a tendency to lie horizontal, so that the lava cleaves most readily along a plane parallel with the top and bottom of the flow. This arrangement is by no means universal, however, for the biotite tablets are found in all positions. These latter are from 1 to 2 ^{mm} in breadth and sometimes 0.5 ^{mm} in thickness. They have sharp crystallographic boundaries, the narrow planes of the prism and clinopinacoid reflecting the light nearly as brilliantly as the basal planes.

The thin section shows that the greater part of the rock is made up of a light-brown glass, with a suggestion of violet in its peculiar tint. Scattered about in this glassy matrix are abundant phenocrysts of plagioclase and biotite, a few broken or irregular crystals of augite, crystals of magnetite and apatite, and fragments of more or less glassy volcanic rocks.

The plagioclases usually show beautifully sharp twinning in accordance with the albite law, and some show both albite and Carlsbad twinning, with occasional pericline lamellæ. The Carlsbad-albite twins give extinction angles corresponding to labradorite of the composition $Ab_3\,An_4$. There is no sanidine present, and the index of refraction of all the plagioclase, as determined by Becke's method, is distinctly greater than the balsam of the slide, which is about 1.540. The outline of the plagioclases is sometimes irregular and angular, sometimes rounded, and sometimes in part defined by crystallographic planes.

The biotite is abundant and in sharply bounded hexagonal tablets.

It is bright chestnut brown, with the usual strong absorption and small axial angle. It frequently includes prisms of apatite.

Augite is not abundant, and rarely shows crystallographic outlines. It is very pale green, and in no way distinguishable from that in the Table Mountain flow, already described.

A green hornblende is quite charactistic of this rock, occurring in nearly every slide of the biotite-augite-latite, but always in strictly accessory amount. It is usually in small shreds or irregular fragments, of which not more than two or three are found in any single thin section. In only two cases were prismatic cross sections seen with anything like idiomorphic outline, the best of these being shown in Pl. XI, *B*. The optical orientation is: $\mathfrak{a} = a$, $\mathfrak{b} = b$, and $\mathfrak{c}: c =$ at least 11°. The pleochroism is: $\mathfrak{a}$, faint yellow; $\mathfrak{b}$, dark brownish green, and $\mathfrak{c}$, dark green. The absorption is: $\mathfrak{a} < \mathfrak{b} < \mathfrak{c}$.

Magnetite occurs in good-sized grains in the glass, sometimes attached to the anhedra of labradorite and augite, and frequently including prisms of apatite. The latter mineral also occurs isolated in the brown glass in well-developed prisms.

The sharply bounded rock inclusions, as seen in the slide, are usually of small size, less than 0.5^{mm} in diameter, and rounded in outline. They consist of fragments of andesitic or latitic groundmass, generally indistinguishable, in such small areas, from facies of Table Mountain and Dardanelle flows. They sometimes contain phenocrysts of labradorite like those occurring in the inclosing rock. The glass base of these inclusions is usually gray and globulitic, but sometimes clear and pale brown, like that making up the mass of the section. In one case a rounded inclusion was observed with a central portion composed of labradorite microlites and gray glassy base, and a peripheral zone of similar microlites lying in a clear, light-brown glass.

An examination of the isotropic matrix which makes up the mass of the rock shows it to be by no means homogeneous. It is a confused mixture of shreds and strings of light-brown, translucent glass, with other portions which are rendered dark and turbid by microlites and globulitic dust. Sometimes these lighter areas are sharply bounded and resemble inclusions, at other times they fray out imperceptibly into the groundmass, or are drawn out in long flamboyant tongues. Some of the light-brown patches contain plagioclase microlites, and such portions are not always sharply separated from the nonmicrolitic areas. The whole aspect of the thin section suggests that the development of a fluidal structure was followed by flow brecciation on a minute scale, giving as a result a rock that is in some respects not unlike a tuff. That the rock is not an ordinary tuff is indicated by the close affinity shown between the inclusions and the including matrix, by the absence of distinctly foreign material, by the inclusion within areas of homogeneous brown glass of labradorite phenocrysts exactly like those which occur in the finely brecciated portions, and, lastly, by inclusions of the same light-brown glass within such phenocrysts.

On the supposition that the rock, if a clastic tuff, must owe its present induration to the presence of a considerable proportion of opal among the isotropic material, a weighed portion of the finely powdered rock was boiled in a platinum dish for two hours with a 10 per cent solution of sodium carbonate. The dish was allowed to stand for nineteen hours, again heated, the liquid filtered off, and the silica determined in the usual way. The amount soluble under these conditions was only 1.6 per cent.

A specimen (1877, S. N.) from the coulée-like mass half a mile north of McKay's, already described, is slightly darker in color than the foregoing, and, while plainly containing inclusions, has every appearance, both in the field and in the hand specimen, of being a glassy lava and not a tuff.

At first glance the thin section looks tuffaceous, but closer examination shows that the shreds of violet-brown glass, instead of behaving as rigid clastic fragments, frequently curve around the phenocrysts and inclusions in well-marked flow lines, or conform to their shape. The glass has a rather more distinct violet tint in this section, and is a little more abundant, than in the one just described. There is also a little more augite. The specific gravity of the rock is 2.47.

One mile northeast of McKay's, on the river slope of the ridge, the biotite-augite-latite (1944 S. N.) resembles megascopically that first described (1882 S. N.), but shows many long-drawn-out lenses of dark glass. Under the microscope it shows comparatively few phenocrysts or inclusions and a large proportion of the faint violet-brown glass. One small fleck of green hornblende occurs in the slide.

The latite of the elliptical area (1977 S. N.) shown on the map 1¼ miles a little west of south from Fennessy's, and overlain by andesitic breccia and tuff, is light gray in color, with a somewhat more earthy texture than usual, and less biotite. Under the microscope it shows the usual characteristic features, although the biotite is not quite so abundant. There are a few fragments of the green hornblende present. The shreds of pale-brown glass show some flow structure and are bent around the phenocrysts and included fragments.

A specimen (1955 S. N.) taken near the southern end of the inclosed area of granite, about halfway between Fennessy and Clover meadows, is a light-gray facies with abundant feldspar phenocrysts, but not much biotite. In thin section (Pl. XI, *B*) this rock appears thoroughly typical. The glass, which makes up the greater part of the slide, is brown and turbid, but shows eutaxitic banding, with excellent flow structure. In this glass lie the phenocrysts of plagioclase, biotite, and augite, with the usual fragments of volcanic rock. The plagioclases are twinned with beautiful sharpness, and several readings on albite-Carlsbad twins indicated a labradorite a trifle more basic than Ab_3An_4. The biotite is rather more abundant than the hand specimen indicates, and occurs in the usual tablets with inclusions of apatite. The augite occurs sometimes in isolated fragments, or anhedra, and sometimes intergrown and partly surrounded by the labradorite crystals. One sharply idiomorphic section of the green hornblende occurs in the slide, being cut transverse to the prism and showing the usual amphibole outline and cleavage. Magnetite is in crystals and aggregates up to 0.5^{mm} in diameter, and, like the augite and biotite, frequently includes apatite crystals.

At a point 3¾ miles southwest of Clover Meadow, and a little over 1 mile west of the bold spur marked *7100* (feet) on the map, occurs a dark-gray facies (1420 S. N.), with the usual phenocrysts of microtine and biotite. It contains small rock fragments, but has on the whole the appearance and consistency of a lava rather than a tuff. The microscope shows the usual structure of these rocks, with the characteristic brecciated eutaxitic glass. The latter is brown and more turbid than is generally the case, and is probably somewhat weathered. Phenocrysts of feldspar are fairly abundant. They are sometimes broken and angular and occasionally slightly embayed, but they often preserve their original crystallographic outlines. Combination twins, according to both albite and Carlsbad laws, are common, and the plagioclase is labradorite. The phenocrysts are generally rather free from inclusions, and show the basal and brachypinacoidal cleavages unusually well. The other phenocrystic minerals are biotite, augite, and magnetite. Apatite occurs in small prisms included in all the other minerals.

Some of the bands and shred-like patches of brown glass show a striking mottled appearance, produced by thickly crowded round spots of shadowy outline, surrounded by darker-brown rims. The lighter central portions of these spots show an obscure radial arrangement, as if from a very imperfect spherulitic structure. No distinct microlites can be made out, however, although there is some slight double refraction between crossed nicols. The usual inclusions of latitic (?) groundmass with lath-shaped plagioclases occur in this facies, but the character of the surrounding matrix, with its fluxion phenomena, precludes the idea of the rock being a tuff. An analysis of this facies is given on page 58, Column VI of the table.

A mile southwest of the little pond in Clover Meadow is a remnant of the biotite-augite-latite (exaggerated on the map), resting upon the andesite breccia. It is very similar in appearance to the facies just described, but shows marked flow structure, which is brought out by atmospheric etching on exposed surfaces. Long-drawn-out and parallel lenses of nearly black glass are noticeable in the hand specimen (1948 S. N.). Under the microscope it is noteworthy for its fine large phenocrysts of labradorite (Ab_3An_4) and biotite and the wavy and contorted areas of clear, light-brown glass. Augite is also present among the phenocrysts, and, what is not known elsewhere in this rock, a few crystals of orthorhombic pyroxene and some scattered grains of olivine. The orthorhombic pyroxene occurs in stout prisms, rounded at the ends, and up to 0.5 ^{mm} in length. It is distinctly pleochroic, with strictly parallel extinction and low double refraction, and is readily distinguished from the pale-green, nonpleochroic augite. It is probably enstatite or bronzite, and it appears to be identical in pleochroism and double refraction with the orthorhombic pyroxene in the so-called enstatite-porphyrite of the Cheviot Hills. The olivine is in small irregular grains, and not abundant; but its presence is interesting, as it is rare to find biotite, orthorhombic pyroxene, and olivine all present in an effusive rock of intermediate composition. The green hornblende, frequently referred to as a characteristic accessory in the rock of this flow, occurs both in the glassy part of the section and in one of the included volcanic fragments. There are also present the usual prisms of apatite and a little magnetite.

The large labradorites are often intergrown with the augite, showing that the latter mineral is the younger. All the phenocrysts occur both in the clear brown glass and in the turbid, confused, and microlitic matrix between the clearer streaks. The apatite is included in the glass and in all the larger phenocrysts save the olivine. The more or less rounded fragments of volcanic rock in the section are plainly locally inclusions, but they show a mineralogical resemblance to the rock in which they are inclosed and may not have been derived from a wholly foreign source. Some of them show only very small feldspar microlites embedded in a brown glass like that so abundant in the inclosing rock. One compound inclusion was noted which consisted of several small rounded fragments of microlitic brown glass inclosed in a similar fine groundmass of slightly different color. This strongly suggests that the greater part of the inclusions in the biotite-augite-latite are not foreign material, but represent portions of the magma, which, having attained a certain degree of crystallization, were brecciated by the movement of the lava stream and disseminated through its more glassy portions.

A specimen (1435 S. N.) from the ridge just south of Clover Meadow is a light-gray rock with phenocrysts of biotite and microtine and small rounded fragments of volcanic rock, lying in a fine light-gray and somewhat porous groundmass. This is probably the most tuffaceous facies in external appearance of the whole flow. Under the microscope it shows the usual phenocrysts of labradorite, biotite, and augite in a matrix made up of light-brown glass. The proportion of glass in the slide is larger than usual and has a fine shred-like character. It would perhaps be impossible to determine satisfactorily from a microscopic examination of this slide whether it should be classed as a tuff or not. Some of the shreds of glass, however, are molded to the form of the phenocrysts. A small fragment of green hornblende was observed isolated in the glass, while another crystal, partially resorbed and surrounded by a dark granulated border of augite and magnetite, was seen in one of the fragmental inclusions.

An inclusion (1436 S. N.) of much larger size than any observed by me was found by Mr. H. W. Turner in the biotite-augite-latite just described. It measures about 6^{cm} in diameter and is rather angular in outline. It is a hard, compact rock, light gray in color, showing small phenocrysts of plagioclase and augite, and is apparently an andesite. Under the microscope it shows phenocrysts of plagioclase, augite, and orthorhombic pyroxene, with moderate-sized grains of magnetite, lying in a very fine hyalopilitic groundmass. The plagioclases are labradorite, apparently a little more basic than $Ab_3 An_4$. The albite twinning is not so regular as in the latites, and the combination with the Carlsbad law not quite so frequent, but with the pericline law more so. They frequently show zonal structure with undulatory extinctions, especially in brachypinacoidal sections. The phenocrysts are usually small, few in the section being over 1^{mm} in length.

The orthorhombic pyroxene occurs in nearly colorless crystals of prismatic habit up to about 0.75^{mm} in length, usually with more or less rounded or irregular ends. Cross sections of the prism show rectangular outlines with slightly truncated corners, due to the dominant development of the brachypinacoid and macropinacoid. The prismatic cleavage is well developed, while the macropinacoidal cleavage is indicated only by a few fine cracks. The extinctions are always parallel to the traces of the pinacoids. Sections transverse to the prism show the emergence of a bisectrix, with a large axial angle. By comparison with the interference figures given by longitudinal sections, and by using the method given by Michel Lévy,[1] it was determined that this is the acute bisectrix. The optical orientation is: $a = \mathfrak{a}$, $b = \mathfrak{b}$, and $c = \mathfrak{c}$. The mineral is therefore optically positive. The index of refraction is not noticeably different from that of the monoclinic pyroxene in the slide, but the double refraction is much lower, ranging from gray to pale straw-yellow. The pleochroism is distinct: $\mathfrak{a}$ = very pale brown $\mathfrak{b}$ = very light yellow, and $\mathfrak{c}$ = pale green.

From the foregoing description it is seen that the pyroxene has the optical orientation of enstatite or bronzite; but the distinct pleochroism and large axial angle point rather to bronzite than to enstatite.

This inclusion is accordingly a bronzite-augite-andesite, identical with specimens that will be described from the underlying andesitic breccia, and was probably caught up (with other similar ones noted at the same locality) by the latite from the clastic beds over which it flowed.

The general microstructure of the biotite-augite-latite appears to approach very closely to the *eutaxitic* structure as the term was first employed by Fritsch and Reiss,[2] who applied it to certain facies of phonolites, andesites, and trachytes possessing some resemblances to

[1] Les minéraux des roches, Paris, 1888, p. 95.

[2] Geologische Beschreibung der Insel Tenerife, Winterthur, 1868, pp. 414–422; also abstract in Neues Jahrbuch für Min., etc., 1868, pp. 752, 849–852.

clastic rocks and inclosing undoubted clastic fragments. They distinguished *agglomerate lava*, in which the structure was supposed to be due to a partial refusion of clastic material, from *piperno*, in which portions of the magma in different stages of crystallization are brought into juxtaposition by the motion of the flow. Common usage, however, has somewhat altered the original application of the term *eutaxitic*, so that it frequently implies merely a fluidal banding brought about by alternating streaks of microfelsitic and clear glass,[1] or is even used as "a general name for banded volcanic rocks."[2] That such can hardly have been the earlier application of the word appears from the discussion that has centered about the original *piperno* of Pianura in the Phlegræan Fields, near Naples, a rock that Fritsch and Reiss took as the second type of eutaxitic structure, and which appears to resemble in some ways the biotite-augite-latite of California. Luigi dell' Erba[3] considers this rock a tuff, but the greater number of petrographers have regarded it as a lava flow. Zirkel[4] refers to it as a sanidine trachyte with eutaxitic structure, remarking that Luigi dell' Erba's view is not even probable, while Rosenbusch[5] cites it as an example of his Ponza type of the trachyte family. Such a discussion could scarcely have arisen were the structure concerned a simple banding such as is observed in many vitrophyres, and which no petrographer could for a moment regard as indicating a tuffaceous origin. Küch,[6] following the terminology of Reiss, describes both kinds of eutaxitic structure, the agglomerate lava and the piperno, as occurring in the dacites and andesites of Colombia. The latter form is particularly abundant, and Küch remarks that it is at times impossible to distinguish the two varieties, as the piperno often contains included fragments of other andesites. Wichmann,[7] in describing an augite-mica-andesite from the Indian Archipelago having a structure apparently nearly identical with that of the biotite-augite-latite of the preceding pages, refers to it as having piperno structure; and there seems to be little doubt that this latter name, as used by the petrographers cited, expresses accurately the structure of the second flow of the Sierra Nevada latites.

When, on the other hand, a thin section of the last-named rock is compared with that of a lava having typical flow banding—as, for example, the beautiful vitrophyre of San Lugano, in the Tyrol, or the pitchstone-vitrophyre occurring between Lake Lugano and Lago Maggiore, both of which, according to Rosenbusch,[8] often show eutaxitic

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[1] Zirkel, Petrographie, 3d ed., Vol. I, 1893, p. 465.

[2] Kemp, Handbook of Rocks, New York, 1896, p. 136.

[3] Giornal di Mineralogia, etc., Vol. III, 1892, pp. 23–54.

[4] Loc. cit., Vol. II, p. 796.

[5] Mikroskopische Physiographie, 3d ed., Vol. II, 1896, p. 766.

[6] Geologische Studien in der Republik Colombia, I Petrographie, 1. Die vulkanischen Gesteine, Berlin, 1892, pp. 84–86.

[7] Petrographische Studien über den indischen Archipel, abstract in Neues Jahrbuch für Min., etc., 1897, Vol. I, p. 283.

[8] Loc. cit., p. 698.

facies—the chief difference seems to lie in a greater irregularity and brecciation of the bands in the latite, and in the presence of included rock fragments.

In looking over the large collection of volcanic rocks brought from Asia Minor by the Assos Expedition, and now at Harvard University, it was found that the peculiar structure of the biotite-augite-latite was exactly reproduced in a specimen (A. E. 310) from near the Hot Springs of Touzla, in the southwestern part of the Troad. This specimen, as Mr. J. S. Diller very kindly informed the writer, "belongs to the lower portion of a flow of rhyolite, near its contact with the underlying tuff. The rhyolite some distance away from the contact is deep flesh red. Near the contact it is frequently black and glassy, inclosing many fragments of the tuff over which it flowed." The hand specimen shows a light-gray, very glassy rock, with streaks of dark glass and abundant angular glassy inclusions of light-buff color, together with small, slightly rounded volcanic fragments, resembling superficially those in the latite.

Under the microscope the similarity of structure is remarkable. The light-brown glassy streaks, alternating with microlitic patches, show the same confused and brecciated appearance as in the latite. Phenocrysts of biotite and feldspar are abundant, and there are numerous small rounded inclusions of some andesitic rock. The structural resemblance between the Touzla rock and the biotite-augite-latite is so close that only a critical investigation of the phenocrysts and inclusions would serve to distinguish an unlabeled thin section of the former from one of the latter. To make the resemblance still closer, no sanidine was seen in the Asia Minor rock, all the phenocrysts in the thin section being plagioclase (andesine or labradorite).

Another specimen (A. E. 531) which, according to Mr. Diller, is from "one of the large flows of rhyolite forming the plateau that lies between the Touzla River and the southern coast of the Troad, west of Assos," shows a very similar structure, while specimens from near Baba-galessi (A. E. 559 and A. E. 560) exhibit gradations into nearly or quite typical unbrecciated flow-banding.

The object of this comparison is not to show that these specimens from the Troad are chemically or mineralogically identical with the biotite-augite-latite, but merely to draw attention to their *structural* identity, and the fact that they occur as true flows and not as tuffs.

As an historical illustration of the difficulty that sometimes exists in distinguishing a tuff from a massive lava may be recited the case of the so-called "peperino" near Viterbo, in Italy, which, according to Washington,[1] is probably a tuff, although it possesses some apparent flow structures, and has been by earlier investigators frequently designated a massive rock.

There has been mentioned the occurrence near Mill Creek of a vitro-

[1] Italian petrological sketches, II: Jour. Geol., Vol. IV, 1896, pp. 838-840.

phyric lava which, though underlying some augite-latite belonging apparently to the Table Mountain flow, yet resembles the biotite-augite-latite that usually rests *upon* the latter flow. Megascopically this rock (1866 S. N.) is a gray, extremely brittle glass with a pitchstone-like luster. It is speckled with a few minute feldspar phenocrysts and shows streaks of black glass and also lighter-colored glassy patches resembling inclusions.

Under the microscope the thin section, consisting chiefly of pale violet-brown glass, shows the eutaxitic structure already fully described, but, as might be expected from the megascopic appearance of the rock, approaches a little more nearly the ordinary flow structure of the vitrophyres. This glass contains numerous angular (rarely rounded) fragments of labradorite (Ab_3An_4), less abundant anhedra of pale-green augite, a few flakes of biotite, and an occasional prism of orthorhombic pyroxene. Most of the slides examined also show one or two shreds of green hornblende. Apatite occurs in small prisms, especially as inclusions in the augite, and there are also a few grains of magnetite present. Like the typical biotite-augite-latite, this facies frequently shows small rounded inclusions of volcanic rock consisting of small microlites of plagioclase in a glassy base, but it differs from all the known occurrences of the former in being more glassy and in the paucity of biotite. A chemical analysis of this rock will be found in Column VII of the table of analyses on page 58; it will be seen to have more silica, and less lime, magnesia, iron oxides, and alumina, than the other latites.

Immediately above the facies just described, and also at Clover Meadow, is a rather peculiar lava (1867 S. N. and 1428 S. N.) of light brick-red color, containing a few small empty cavities, but of generally compact texture and speckled with small phenocrysts or fragments of glassy feldspar. In its general aspect the rock is rhyolitic, although differing from the ordinary white rhyolites of the district, which, as far as known, are all older than any of the andesitic breccias. Under the microscope the rock shows phenocrysts of feldspar, frequently broken and angular, with occasional flakes of biotite, lying in a reddish, turbid, microfelsitic groundmass. The feldspars are all plagioclase, and some of the sharply twinned individuals give extinction angles indicating labradorite as basic as Ab_3An_4. The matrix in which they lie has its original structure obscured by secondary silicification and by the separation of ferric oxide, but appears to show some remnants of the vitrophyric structure observed in the preceding rock. There are apparently the same patches of bent and contorted glass, with occasional small rounded inclusions of volcanic rock. A partial chemical analysis of this red lava is given in Column IX of the table of chemical analyses, page 58. It is higher in silica than any of the latites, but too low for a typical rhyolite. The amount and relative proportions of the alkalies, too, give no very definite information as to its proper position, and it is uncertain whether it should be classed as a somewhat weathered superficial portion of the vitrophyric latite below it, or whether it is a very thin flow belonging rather with the rhyolites. The former supposition, however, seems much more probable, as in the latter case it would indicate a rhyolitic eruption of much later date than that of the normal white rhyolites and rhyolite tuffs which lie at the base of the whole Neocene volcanic series. For this, however, there is no evidence other than the two widely separated and insignificant patches of red lava just described, which is certainly not a typical rhyolite, and does resemble the rather acid latite (1866 S. N.) just beneath it.

THE DARDANELLE FLOW.

The rock of the youngest of the three flows resembles very closely that of the oldest or Table Mountain flow, and this resemblance is in a few cases so close that it would be impossible to say to which flow a given hand specimen belonged. Considered in their typical development, however, the two facies are fairly distinct. The augite-latite (1260 S. N.), forming the extreme summits of the West Dardanelle, may be taken as a typical facies of the Dardanelle flow. This is a dense, nearly black rock, ringing clearly under the hammer and breaking with a clean, slightly conchoidal fracture. The broken surfaces show clear glassy phenocrysts of plagioclase, resembling those of the Table Mountain flow, but smaller, sharper, and less abundant. Their basal cleavage faces show albite lamellæ, frequently combined to form Carlsbad twins. Close inspection will generally reveal a few small phenocrysts of augite, but the plagioclases are the only conspicuous megascopic crystals. They lie in a very compact, nearly black groundmass, in which a good lens can detect only a few feldspar microlites.

The microscope shows phenocrysts of labradorite, augite, and olivine, with apatite and magnetite, lying in a light-brown hyalopilitic groundmass. The labradorites are the largest and by far the most abundant phenocrysts in the slide, but are rarely more than 5^{mm} in length. They are fresh and sharply twinned, but often carry inclusions of glassy base, much as do the larger phenocrysts of the Table Mountain flow, and occasionally include small augites. They are usually tabular parallel with the brachypinacoid, and the prevailing section is lath-shaped. Observations on albite-Carlsbad twins by Michel Lévy's method gave extinction angles indicating a labradorite of the composition Ab_1An_1. The outlines of the phenocrysts are generally sharper and less embayed than in the Table Mountain flow.

The augite is identical with that in the latter flow, but is in smaller crystals and shows a greater tendency toward sharpness of crystallographic outline, especially in the prism zone.

The olivine occurs usually in idiomorphic crystals of small size scattered through the groundmass, but occasionally one of larger size is met with

The hyalopilitic groundmass shows sharp, clear feldspar microlites, with more or less flow structure, lying in a light-brown glass. These plagioclases usually show albite twinning with extinction angles corresponding to labradorite. Bifurcated ends are common. The brown semiopaque glass is quite abundant, and makes up a considerable part of the section. It shows a rather noticeable fine mottling, suggesting an incipient spherulitic structure and apparently produced by the crowding together of very minute brown globulites. The magnetite, instead of being minutely disseminated through the glass, as is common in these rocks, forms small crystals and aggregates readily seen with low power.

The specimen just described was taken from the highest point of the peak. A second (1024 S. N.) from near the bottom of the same flow was very similar in thin section, but is slightly weathered. The glass is gray instead of brown, is finely globulitic, and has the magnetite a little more finely disseminated. Apatite, in small prisms, occurs in both slides.

A hand specimen (1421 S. N.) from the summit of the ridge, one-half mile east of Clover Meadow, is megascopically identical with that just described. Under the microscope the chief differences to be observed are a more pronounced flow structure and a slightly greater abundance of augite, olivine, and apatite. The labradorite phenocrysts are more basic, readings on albite-Carlsbad twins indicating a composition near Ab_3An_4. The widths of the albite lamellæ are very variable. The augite phenocrysts occur in stout prisms, very pale green in color, generally crystallographically bounded in the prism zone, but rounded on the ends. Extinction angles were obtained, of $c:\mathfrak{c} = 45^\circ$. The largest augite phenocryst in the slide is less than 2 mm in length. The olivine is in small, sharply idiomorphic crystals, and in larger anhedra from 0.5 mm to 1 mm in diameter. Apatite is noticeably abundant in rather stout, well-formed prisms, both in the augite and in the groundmass. This is evidently a somewhat more basic facies than that on the summit of the West Dardanelle.

The most interesting facies (1419 S. N.) of the Dardanelle flow occurs 3¾ miles southwest of Clover Meadow, at the point where the latites pass under a portion of the andesitic breccias to the west. Megascopically the rock resembles very closely the rocks just described, but the groundmass is apparently slightly more crystalline.

Under the microscope it shows the usual phenocrysts, lying in a groundmass that is distinctly more crystalline than the preceding, and recalls certain facies of the Table Mountain flow. The plagioclases are beautifully twinned according to the albite, together with the Carlsbad, and occasionally the pericline, laws. The extinction angles (30° and 13.5°, 29° and 15°) on albite-Carlsbad twins, cut in a zone perpendicular to the twinning plane, indicate a labradorite somewhat more basic than Ab_3An_4. Some of the larger crystals have glassy inclusions, as in the Table Mountain flow. The specific gravity of these labradorite phenocrysts, determined by suspending a small fragment in Thoulet solution, is 2.667, which is rather low for a labradorite of such basicity as the extinction angles indicate.

The augite is identical with that already described. Sharply idiomorphic cross sections of the prism zone are frequent, and often show twinning on the orthopinacoid. Extinction angles were measured up to $c : \mathfrak{c} = 44^\circ$. Olivine is present only in very subordinate amount.

The groundmass consists of well-developed lath-shaped microlites of plagioclase and small crystals of augite, olivine, and magnetite, lying in a gray cloudy glass. The great preponderance of the feldspars, both in the groundmass and among the phenocrysts, is a striking characteristic of the slide. The lath-shaped feldspars, which are thickly crowded together, are generally twinned, and have extinction angles corresponding to labradorite. When the section is examined with low power and crossed nicols it is very difficult to make out any glass. The spaces between the distinctly lath-shaped plagioclases nearly all show more or less double refraction, the only parts remaining dark being such as are already rendered nearly opaque by thickly crowded globulites. By using an immersion objective, and focusing up and down in the section, it appears that the labradorites of the groundmass are really tabular parallel with the brachypinacoid, and that these faintly doubly refracting portions of the slide are the result of an overlapping of glass and approximately brachypinacoidal sections of labradorite. They generally show the emergence of an acute bisectrix or optic axis in convergent light, which, combined with the fact that they seldom occupy the full thickness of the thin section, is sufficient to account for their low double refraction and rather uncertain extinctions. Naturally they do not show the albite twinning. It was at first supposed that they might be orthoclase, or at any rate a different feldspar from the well-defined labradorite laths, but careful focusing showed that all gradations could be traced from sections of labradorite cut at right angles to the plane of greatest extension, and therefore showing sharp albite twinning and usually occupying the full thickness of the slide, to those cut at an oblique angle and showing more shadowy lamellæ and less distinct lath-shaped outline, and finally to sections cut at only a very small angle with the brachypinacoid, occupying but a fraction of the whole thickness of the section, or thinning out to a feather-edge, and consequently showing no twin lamination and low double refraction.

The glass in which these well-developed plagioclases lie is in itself clear and colorless, but is usually crowded with dark globulites which render it nearly opaque with low or moderate powers. By using Becke's method the clear glass shows a lower index of refraction than the balsam, although the observation is difficult to make on account of the abundant globulites. With a No. VII Seibert immersion lens these globulites, which appear like black, opaque dust particles with low powers, are in part transparent, and composed of a pale greenish substance of high refractive index. Within this substance is frequently a smaller black dot which remains opaque and is probably magnetite. In their general appearance the globulites with dark central spots recall the well-known cells seen in micro-preparations of hyaline cartilage. Not all the globulites, however, are compound. Some are wholly transparent, while others are wholly opaque. It is thought that the transparent greenish substance is probably augite.

A portion of this rock was finely powdered and passed through a No. 120 sieve. The fine dust was sifted out through a piece of linen and the remaining powder washed, dried, and placed in Thoulet solution of about 3.15 sp. gr. A powder at once fell which consisted of augite, olivine, and magnetite. Upon dilution to sp. gr. 2.626, about half the remaining powder came down. This portion was easily separated by a small horseshoe magnet into two parts, a magnetic black powder and a nonmagnetic white powder. The magnetic portion examined under the microscope was found to consist of fragments of the globulitic glass, in which were included microlites of the various minerals of the groundmass, particularly labradorite. The nonmagnetic portion consisted of fragments of labradorite free from glass.

Upon dilution of the heavy solution to sp. gr. 2.485, practically all the powder fell. This portion also was nearly all magnetic, and the magnet left only a small residue of white, nearly pure plagioclase powder. The black magnetic portion seen under the microscope resembled that just described. No great difference could be observed between the powder which fell at 2.626 and that which came down at 2.485, except that the nonmagnetic portion was smaller in the latter. This lack of distinctive difference was probably due to the unusual fineness of the powder and its tendency to float in the fluid. It is evident from the experiment, however, that the globulites consist in part of magnetite, and that the latter mineral forms an important, although not conspicuous, constituent of the rock. The specific gravity of the rock as determined by the chemical balance is 2.61. The glass in which the globulites lie must, accordingly, be light.

In an attempt to determine the part played by the considerable percentage of potash shown in the chemical analysis of the rock (Column IV, page 58), a few grains of the magnetic and of the nonmagnetic powder were treated with hydrofluosilicic acid. The magnetic powder afforded abundant crystals of potassium fluosilicate, as well as of sodium and other bases, while the nonmagnetic grains showed only the fluosilicates of sodium, calcium, and aluminium, indicating that the greater part of the potash is in the undifferentiated glass, a result that accords with its low specific gravity.

The other constituents of the groundmass consist of not very abundant grains and crystals of augite, olivine, and magnetite, some small patches of greenish-yellow serpentine, and an occasional small zircon.

A rock remarkably similar to the one just described was found in the Assos collection already referred to. This (A. E. 240) is a dark, compact rock with splintery fracture, resembling a basalt, and labeled as coming from Husseinfagy, Asia Minor. Under the microscope it shows phenocrysts of labradorite and pale-greenish augite. The groundmass shows the same structure as the preceding rock, the same well-developed plagioclase laths, and a glassy matrix thickly crowded with the same dark globulites. The thin section also contains numerous small serpentinous pseudomorphs, after a mineral that was apparently olivine.

In the absence of a chemical analysis it would be hardly safe to assert the practical identity of this rock with the Dardanelle latite; but the work of Washington[1] on the rocks of Smyrna and Pergamon shows that the chemical type of the latites is well represented in this region.

A specimen (1956 S. N.) from the other side of the andesitic ridge, about a mile from the preceding, stands megascopically halfway between the typical Dardanelle facies and the typical Table Mountain facies, showing phenocrysts of labradorite up to 10 mm in length.

Under the microscope the thin section shows the usual labradorite and augite crystals, with smaller ones of magnetite. The olivine is very inconspicuous and appears to be confined to scattered grains or small crystals in the groundmass. The latter, which is rather coarsely hyalopilitic, consists of well-developed laths of plagioclase lying in a light-brown glass. These laths, instead of having squarely truncated ends, show a great tendency toward skeletal forms, splitting up, and projecting long, delicate spines into the glass. Others consist of a thin rectangular shell filled with brown glass. This glass, which occupies a considerable proportion of the slide between the larger laths, has a beautiful frosted appearance, due to its being crowded with still more delicate forms of growth than those of the larger laths. All the latter are well twinned and show extinction angles corresponding to labradorite. Small prisms of apatite and grains of magnetite, augite, and olivine are the other constituents of the groundmass. The glass, when examined with an immersion lens, is seen to be full of minute globulites, which give it its brown color. Some of the larger of these are transparent.

Three-fourths of a mile northward from the locality of the foregoing specimen a remnant of the Dardanelle flow, too small to map without exaggeration, rests upon a larger and broader mass of the biotite-augite-latite. It is very frothy in places, especially near its base, and the specimen (1953 S. N.) taken from the more compact portion shows numerous small round vesicles. Megascopically it resembles closely some of the Table Mountain latite, the labradorite phenocrysts being a little larger and more abundant than in the typical Dardanelle facies. The microscope shows large phenocrysts of plagioclase and smaller ones of olivine and augite lying in a hyalopilitic groundmass.

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[1] Am. Jour. Sci., 4th series, Vol. III, 1897, pp. 41-50.

The plagioclases are twinned with beautiful sharpness, frequently combining both albite and Carlsbad laws. Determinations made on such compound twins by the method of Michel Lévy, using the convenient little apparatus devised by Jaggar[1] to tilt the section into the proper positions, indicated a mixture somewhat more basic than Ab_3An_4. These phenocrysts are notable for their frequently very irregular outlines and deep embayments. The bays often exhibit the flow structure of the groundmass more conspicuously than other portions, streams of parallel plagioclase microlites curving in and out of their open mouths, and contrasting with the finer stagnant groundmass caught in the deeper ramifications of the bays, and therefore out of reach of magmatic currents.

Next to labradorite, olivine is the most conspicuous phenocryst—an unusual thing in these latites. It forms well-bounded crystals, in the usual stout prismatic forms, sometimes nearly 0.5^{mm} in length. These phenocrysts are not very abundant, as only five were seen in an ordinary thin section about 1.5^{cm} square. The augite is still less abundant, and in smaller phenocrysts than the olivine.

The groundmass is made up of laths of labradorite, small augites and olivines, grains of magnetite, a few prisms of apatite, and brown glass. The labradorite microlites show a tendency toward skeletal forms resembling those described in the preceding slide.

The last specimen (1886 S. N.) of the Dardanelle flow to be described is from the area one-half mile northeast of McKay's, the most westerly point at which the lava belonging to this flow has been identified. It is here slightly vesicular, with the plagioclase phenocrysts arranged with their longer dimensions distinctly parallel. These are sometimes 10^{mm} in length, and show albite and Carlsbad twinning. Their size and number cause the rock to resemble the typical facies of the Table Mountain flow very closely.

Under the microscope it shows large labradorite phenocrysts with the usual abundant inclusions, lying in a groundmass that is something between hyalopilitic and intersertal. It consists of lath-shaped labradorite microlites, crystals of augite, olivine, and magnetite, and an occasional apatite, lying in a brown glass like that in the section just described. A little serpentine is also present in the groundmass, in part replacing grains of olivine and in part in irregular patches. No phenocrysts of augite or olivine were seen.

Fragments of labradorite, picked out from the powdered rock under the microscope, were found by means of Thoulet solution to have a specific gravity of 2.648, which again is low for a normal plagioclase of the basicity indicated by optical tests. But it is extremely difficult to get fragments that are free from glassy inclusions and at the same time large enough to give the best results when suspended in a heavy fluid.

[1] A simple instrument for inclining a preparation in the microscope: Am. Jour. Sci., 4th series, Vol. III, 1897, pp. 129-131.

From the foregoing descriptions it can be seen that the typical facies of the Dardanelle flow resembles that of the Table Mountain flow very closely indeed, while in certain facies they are practically identical. The general distinguishing features of the Dardanelle flow are quantitative rather than qualitative. Its phenocrysts are smaller, the groundmass is finer; olivine is not quite so abundant, and occurs in smaller crystals.

ASSOCIATED VOLCANIC ROCKS.

Olivine basalt, as already mentioned, has been met with only at the West Dardanelle, where it forms a thick series of flows, beneath the latites, and rests in part upon the granite and in part upon rhyolite tuff. It is a dark, even-grained rock, in which the only megascopic phenocrysts are some dark-brown crystals up to 0.5 ^{cm} in length, showing a distinct cleavage, and outlines suggesting pseudomorphs after olivine. A little fresh olivine can also be detected with the lens. This rock weathers much more readily than the latites above it, and is otherwise quite different megascopically.

Under the microscope (1007 S. N.) it shows a typical basaltic or intersertal structure, the well-developed plagioclase laths, averaging nearly 0.5 ^{mm} in length, lying in every direction, with the triangular interstices filled with a nearly opaque glassy base and abundant yellow pseudomorphs after olivine. The plagioclase is perfectly fresh and sharply twinned. Combinations of the albite and Carlsbad laws are frequent, and give extinction angles indicating a labradorite rather more basic than the mixture $Ab_3 An_4$, probably about Ab_2An_3. Olivine occurs with the usual characteristic outline, and is the only mineral that rises to the rank of a phenocryst. It is very abundant, but is rarely fresh, being usually more or less altered to a bright orange-yellow pseudomorphous mineral, which has received the name of iddingsite.[1] The alteration proceeds from without inward, and all stages may be observed from olivines which have just begun to be attacked to those which have been wholly transformed into yellow pseudomorphs. Occasionally there appears to be an intermediate stage, the olivine being bordered by an ordinary greenish serpentine, and this in turn surrounded by the iddingsite. This relationship, however, suggests the possibility that the iddingsite may be an early, or even a magmatic,[2] alteration, whereas the serpentine is the ordinary product of atmospheric weathering. A similar relation was noted in the diabase of Point Bonita.[3] The iddingsite preserves perfectly the sharp idiomorphic outlines of the olivine. In its cleavage, finely fibrous structure, pleochroism, and double refraction it agrees with the iddingsite described from the much older diabase of Point Bonita, which was regarded as being

[1] Lawson, Geology of Carmelo Bay: Univ. of Calif., Dept. Geol., Bull., Vol. I, 1893-96, pp. 31-36. See also Ransome, ibid., Vol. I, pp. 90-92; and Smith, Proc. Calif. Acad. Sci., 3d series, Geology, Vol. I, 1897, pp. 38-40.

[2] See Washington, Italian petrological studies, II: Jour. Geol., Vol. IV, 1896, pp. 835-836.

[3] Loc. cit.

probably derived from olivine, although the original mineral had all disappeared.

The augite is not abundant, and is rather unevenly distributed in the slide. It occurs in irregular areas between the labradorite laths, with no crystal form of its own, and has the pale-brown tint characteristic of basaltic augites, as opposed to the greenish augites and diopsides of the andesites. Patches of greenish-yellow serpentine are abundant. They are rounded in outline, and appear to fill small vesicles in the glassy base. The latter forms a considerable part of the rock, and is rendered nearly or quite opaque by a fine black dust, probably magnetite. The specific gravity of the rock is 2.78. A chemical analysis will be found in Column VIII of the table on page 58.

Andesitic breccia or tuff of the ordinary Sierra Nevada type is, as already stated, very abundant in this region. It is not, petrographically speaking, a particularly interesting rock, and in spite of its clastic origin the larger fragments show a fairly uniform character over the whole district. They are usually composed of a hornblende-pyroxene-andesite, in which the large brown hornblende phenocrysts are in various stages of resorption in different specimens, so that this mineral is sometimes a conspicuous and abundant porphyritic constituent, occasionally showing crystals up to 2.5^{cm} in length, and at other times has almost wholly disappeared. The other phenocrysts seen in thin section are labradorite, characterized by zonal structure and undulatory extinctions, pale-green augite, orthorhombic pyroxene, and occasionally olivine, all lying in a hyalopilitic groundmass with rather abundant glass. Although many specimens and thin sections have been studied from different parts of the area, three only, collected from the breccia just beneath the latite south of Clover Meadow, will be described in full as fair types of the whole.

The first of these (1437 S. N.) is dark gray in color and shows black phenocrysts of hornblende up to 5^{mm} in length, and a few small plagioclases, lying in a dark, fine-grained matrix. Under the microscope it shows large phenocrysts of brown hornblende with abundant smaller ones of plagioclase, rather less numerous augites, and still less abundant orthorhombic pyroxene. Among the smaller, less conspicuous phenocrysts might also be included olivine and magnetite. The groundmass is light brown in color and hyalopilitic.

The hornblende is the usual brown variety, and the large crystals are rounded in outline and surrounded by the opaque resorption rims common in andesitic rocks. There is frequently also an outer border which is distinguishable from the groundmass in being clearer and in the local abundance of augite and magnetite grains.

The plagioclase phenocrysts give extinctions of albite-Carlsbad twins corresponding to labradorite (Ab_3An_4). They are rather small, but very abundant, and are characterized by zonal structure and undulatory extinctions, particularly in sections approximately parallel to the brachypinacoid. In this respect they are well contrasted with the sharp regular twinning and definite extinctions of the labradorite of the latites.

The augite is pale green to nearly colorless, and gives extinction angles of $c : \mathfrak{c}$ = about 45°. It is frequently idiomorphic in the prism zone, and is in general like the augite of the latites.

The orthorhombic pyroxene occurs generally in smaller and more slender prisms than the augite. It is in every way similar to that described on page 42 in an andesitic inclusion in the biotite-latite, and, as shown by its faint pleochroism and double refraction, is probably bronzite rather than enstatite.

The olivine is in small grains and irregular crystals and is quite accessory in amount.

The groundmass consists of small microlites of plagioclase, usually showing albite twinning, and brown glass. The rock may be called a hornblende-augite-bronzite-andesite.

A second specimen (1438 S. N.) from the same breccia resembles the preceding, but is a little darker in color and shows numerous crystals of dark olive-green augite 2 or 3 ^{mm} in length. The microscope shows large phenocrysts of augite and smaller ones of plagioclase and olivine, lying in a microlitic glassy base. The large augites are very pale yellowish-green in color and nonpleochroic. They sometimes show crystallographic outlines, and are sometimes rounded. The angle $c : \mathfrak{c}$ was found to be at least 46°.

Brown hornblende in large rounded phenocrysts with black resorption rims also occurs in the rock, but only a single fragment was included in the thin section studied.

The plagioclases are prevailingly broad lath-shaped in outline, with a central portion full of small glass inclusions. They generally show twinning according to the albite law, not infrequently combined with the Carlsbad law. The measurements of the extinction angles of these two sets of lamellæ indicate a labradorite rather more basic than Ab_3An_4.

Olivine is rather abundant, in more or less idiomorphic crystals of small size, with occasional larger anhedra, and is quite fresh.

The groundmass is rather glassy, but contains grains of magnetite and abundant small microlites. Lath-shaped microlites of feldspar are, however, notably lacking, and the groundmass can scarcely be called hyalopilitic. Apatite is present in small amount as inclusions in the augite. The rock may be called a hornblende-augite-andesite, but the abundance of the olivine indicates a rather close relationship with the basalts.

A third specimen (1439 S. N.), much like the preceding, but less plainly porphyritic, is dark gray in color and somewhat basaltic in appearance. The lens reveals small plagioclases, with augite and olivine, in a fine dark groundmass. Under the microscope it shows the same general structure as the preceding rocks. The augite, however, is in smaller phenocrysts and not quite so abundant, and no hornblende appears in the slide. The olivine, on the other hand, is present in rather greater amount, often partly serpentinized. The plagioclase is labradorite (Ab_3An_4), frequently showing wavy extinctions and zonal structure. The inner portions of the crystals are usually the more basic. The rock would be classed as an augite-andesite.

Types of andesite other than those described may be found among the fragments of the breccia in different portions of the region. On the ridge just north of Beaver Creek a beautiful light-gray hornblende-andesite (1966 S. N.) was collected, in which the pyroxene present is confined to an insignificant amount in the groundmass. The hornblende in this facies is green in transmitted light, with the pleochroism $\mathfrak{a}$ = light greenish yellow, $\mathfrak{b}$ = olive green, and $\mathfrak{c}$ = dark yellowish green. The absorption is $\mathfrak{b} = \mathfrak{c} > \mathfrak{a}$, and $c : \mathfrak{c} = 16°$ at least. Another light-gray fragment (1975 S. N.) with conspicuous porphyritic hornblendes, taken from the breccia 3½ miles northeast of Fennessy's, shows the usual brown hornblende in thin section. The groundmass contains abundant small microlites, which appear to be enstatite. A thoroughly typical hornblende-andesite was collected 3 miles south of Big Trees in which the hornblende phenocrysts are abundant. Seen in thin section, they are surrounded by narrow black rims and show strong pleochroism, $\mathfrak{a}$ = light yellowish green, $\mathfrak{b}$ = bright chestnut-brown, and $\mathfrak{c}$ = deep rich mahogany-brown. The absorption is $\mathfrak{a} < \mathfrak{b} < \mathfrak{c}$. The groundmass is typically hyalopilitic and contains a little augite. Other andesites occur in which the hornblende, if, as seems probable, formerly present, has been wholly resorbed, giving pyroxene-andesites in which augite and orthorhombic pyroxenes vary in relative proportions. The rarer accessory minerals of the intermediate effusive rocks are not well represented in the Sierra Nevada andesites. A small crystal of zircon can occasionally be detected, and a single crystal of rutile (?) was noted in one thin section.

No chemical analyses have been made of the andesites of this area, but they probably do not depart from the ordinary Sierra Nevada type, in which total alkalies are generally less than 6 per cent, with soda in excess of potash. Some analyses of these andesites have recently been published by Turner.[1]

Massive rhyolite occurs within the area of the map only at the point previously mentioned, just west of the Dardanelles. It is a fresh, nearly white rock, showing small phenocrysts of sanidine and a pale-pink feldspar, with a few grains of quartz, lying in a cryptocrystalline groundmass. Under the microscope it shows phenocrysts of sanidine with an occasional acid plagioclase and small biotite scales in a nearly colorless, homogeneous, microfelsitic groundmass. The sanidine does not show good crystal outlines, and is without twinning. It has a lower index of refraction than the balsam, a specific gravity as determined

[1] Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, p. 731.

by Thoulet solution of 2.542, and yielded abundant octahedra of potassium fluosilicate with hydrofluosilicic acid. The quartz occurs in little nests of interlocking grains and not as distinct porphyritic crystals. The groundmass shows a few scattered grains of magnetite and a small crystal of zircon.

Rhyolitic tuff is much more abundant than the massive rhyolite within the district studied. It is usually white in color, fine grained, and somewhat friable, although secondary silicification has frequently indurated the exposed surfaces of the beds. The coarser, more crumbling facies generally show fragments of sanidine, microtine, and quartz, and sometimes, as on the south side of the Dardanelles, waterworn pebbles of foreign material. As mentioned in the preceding pages, this tuff sometimes shows columnar structure.

Under the microscope the rhyolite tuff usually shows more or less angular fragments of sanidine, plagioclase, and more rarely quartz, with scales of biotite, lying in a nearly colorless matrix. The latter is almost isotropic, but is generally somewhat chalcedonized. Most of the sections show the "aschen-structur" of Mügge[1] in great perfection, and all intermediate facies occur between those made up of the fresh crescentic glass spicules of a finely comminuted volcanic ash[2] (1823 S. N.) and those in which secondary silicification has in great part replaced the intricate reentrant curves of the glass shards by finely radial, concentric bands of chalcedony, polarizing feebly between crossed nicols, and giving rise to a kind of secondary axiolitic structure common in older rhyolitic tuffs and concerning whose origin there has been some debate (1973 S. N.).

Various tuffs occur within the area embraced by the map which differ somewhat from the ordinary gray andesitic tuffs of the region. They are generally finer, softer, and lighter in color than the latter and are found only in a few small patches. Microscopic investigation shows that they are either andesitic or latitic in character, the distinction between the two being not readily made in their tuffaceous forms.

A mile and a half south of Fennessy's a thin stratum of porous, light-gray tuff (1978 S. N.) rests upon the biotite-augite-latite and separates it from the overlying andesitic breccia. Megascopically this shows abundant small fragments of white pumice inclosed in a finely comminuted volcanic paste. Under the microscope it exhibits numerous areas of nearly colorless pumiceous glass, together with crystals of labradorite, augite, brown and green hornblende, biotite, and apatite. The biotite occurs both as isolated crystals and inclosed in the pumiceous glass. There are also abundant fragments showing microlitic glassy base, some of which appear to be andesite, while others resemble the fine groundmass of some of the massive latites. The apatite is in small prisms, and the slide also contains a little magnetite and epidote. The presence of biotite, which was not found in the andes-

[1] Neues Jahrbuch für Min., etc., Beilage-Band 8, p. 648. See also G. O. Smith, Geology of the Fox Islands, Maine, Skowhegan, 1896, p. 39.

[2] Diller, Science, Vol. IV, 1884, pp. 651–654.

ites of the region, and the absence of orthorhombic pyroxene, suggest that this tuff may belong to the latitic series.

Just south of Mill Creek, near its mouth, the augite-latite, capping the small hill previously described, is underlain by three beds of soft tuff. The lowest of these is light-yellow, friable tuff, containing fragments of fine white pumice and small rolled pebbles. Under the microscope it is seen to be made up of glass shards showing typical ash structure, with fragments of pumice and a few grains of clastic quartz, the whole being somewhat chalcedonized.

The bed just above this is a fine, white volcanic sand that was not microscopically examined, while the topmost bed is apparently an ordinary andesitic tuff, albeit somewhat finer than is common in this region.

CHEMICAL COMPOSITION OF THE SIERRA NEVADA LATITES.

In the accompanying table (p. 58) the chemical analyses of the latites form all three flows are brought together for comparison. In spite of a certain range in the silica percentages, they are all closely related members of a series. They are not far from the andesites in general composition, but are slightly higher in silica and distinctly so in alkalies, the potash being always slightly in excess of the soda.[1] Compared with typical trachytes, these rocks are higher in lime and magnesia and lower in silica and alkalies, while the preponderance of potash over soda is usually much more marked in the trachytes.

As would be expected from the microscopical study of the thin sections, the rock of the Table Mountain flow is somewhat more basic than the biotite-augite-latite, while the Dardanelle facies occupies an intermediate position. The Shaws Flat rock (Column I) shows the greatest basicity; the greater amount of lime and magnesia, as compared with the other analyses, being in harmony with the slightly greater abundance of olivine and augite as observed in the thin section. Titanic oxide is present in all the analyses, and usually in noticeable amount, indicating that the magnetite of the rocks is probably titaniferous. Analysis VI is exceptional in containing a small amount of carbon, which is doubtless due to some organic matter included in the lava.

The most noteworthy feature of the analyses, however, taken in connection with the mineralogical composition of the rocks, is the amount of potash shown. As already stated, by far the greater number of the thin sections (excepting, of course, the biotitic facies, which, however,

[1]It is important to note that this statement applies only to the percentage figures in the analyses. When the *molecular* proportions of soda and potash are compared it becomes apparent that, as far as the actual mineral-forming efficiency of these alkalies is concerned, it would be more accurate to say that they are very nearly equal; for the soda molecule may sometimes be present in slightly greater amount than the potash molecule, although the preponderance, when reckoned in percentages, is in the other direction. But as rock analyses are not yet, as a general thing, molecularly expressed and compared, the common mode of percentage comparison has been retained in the characterization of the latites. The petrographer accustomed to translate his chemical analyses into molecular proportions will not, when reading the following pages, lose sight of the suggestion embodied in this note.

are no richer in potash than the others) contain no characteristically potash-bearing mineral. Several of the analyses contain as much as 5 per cent of potash, which, if it were present in the form of orthoclase, would make up nearly 30 per cent of the rock. This amount is entirely too large to be accounted for by the assumption that it is present in the form of orthoclase microlites which have escaped detection among the plagioclases of the groundmass. It is fairly certain that nearly all of the potash in those facies which do not contain biotite is present in the residual glass of the groundmass. This conclusion harmonizes with the results of the micro-chemical tests described on page 49, and with the previously noted low specific gravity of the glass.

Frequently[1] in rocks of intermediate composition, like the latites, the orthoclase forms a thin envelope around the basic plagioclases, while in the plutonic monzonites the orthoclase was the last mineral to crystallize, forming a mesostasis for the earlier minerals. In the Sierra Nevada latites the conditions under which orthoclase (or some other potash-alumina silicate) would separate out were never reached. This indicates that the method sometimes employed of assuming the presence of orthoclase in the groundmass of an effusive rock from the character of the bulk analysis is one that requires caution in its use.

Table of chemical analyses of Sierra Nevada latites and associated volcanic rocks.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
SiO_2	56.19 .936	59.88 .998	56.78 .946	59.43 .990	61.09 1.018	62.33 1.039	65.81 1.096	48.76	67.57
TiO_2	.69	....	1.15	1.38	....	1.05	.54	1.26	....
Al_2O_3	16.76 .162	....	16.86 .163	16.68 .161	....	17.35 .168	15.11 .146	16.60	....
Fe_2O_3	3.05 .019	....	3.56 .022	2.54 .015	....	2.98 .018	1.85 .011	5.60	....
FeO	4.18 .058	....	2.93 .040	3.48 .048	....	1.63 .022	1.40 .019	5.01	....
MnO	.10	....	none	trace	....	.08	....	none	....
MgO	3.79 .094	....	3.41 .085	1.84 .046	....	1.05 .026	.37 .009	6.93	....
CaO	6.53 .116	5.09 .090	6.57 .117	4.09 .073	4.94 .088	3.23 .057	1.98 .035	8.79	....
BaO	.19	....	trace	.14	....	.24	.10	trace	....
Na_2O	2.53 .040	3.90 .062	3.19 .051	3.72 .059	3.69 .059	4.21 .067	2.59 .041	2.47	5.57
K_2O	4.46 .047	5.06 .053	3.48 .036	5.04 .053	5.27 .055	4.46 .047	5.24 .055	.66	4.33
P_2O_5	.55	....	.42	.58	....	.29	.23	.19	....
H_2O above 110°	.66	....	1.21	.72	....	.75	....	2.19	....
H_2O below 110°	.34	....	.15	.27	....	.44	....	1.49	....
	SrO, tr.		CO_2 .18	ZrO_2 .08		SrO .05			
	Li_2O, tr.			SrO, tr.		Li_2O, tr.			
						FeS_2 .08			
				Cl .05		C .11		CO_2 .42	
Total	100.02	....	99.89	100.04	....	100.33	....	100.37	....
Sp. gr	....	....	2.67	2.61	....	2.49	2.38	2.78	2.23

[1] See Washington, Jour. Geol., Vol. IV, 1896, p. 551, for several references.

I. Augite-latite (36 S. N.), Table Mountain flow, Tuolumne Table Mountain, near Shaws Flat. Turner, Rocks of the Sierra Nevada, Fourteenth Ann. Rept. U. S. Geol. Survey, p. 491. Hillebrand, analyst.

II. Augite-latite (86 Tuol.), Table Mountain flow, 3 miles southeasterly from Big Trees. Turner, Geology of the Sierra Nevada, Seventeenth Ann. Rept. U. S. Geol. Survey, p. 727. Fireman, analyst.

III. Augite-latite (1422 S. N.), Table Mountain flow, spheroidal facies, about 1½ miles east of Clover Meadow. Steiger, analyst.

IV. Augite-latite (1419 S. N.), Dardanelle flow, 4 miles southwest of Clover Meadow. Stokes, analyst.

V. Biotite-augite-latite (85 Tuol.), 3 miles southeasterly from Big Trees. Turner, Geology of the Sierra Nevada, Seventeenth Ann. Rept. U. S. Geol. Survey, p. 727. Fireman, analyst.

VI. Biotite-augite-latite (1420 S. N.), 4 miles southwest of Clover Meadow. Turner, loc. cit. Hillebrand, analyst.

VII. Vitrophyric latite (?) (1866 S. N.), just south of Mill Creek. Analysis partial. Steiger, analyst.

VIII. Olivine-basalt (1007 S. N.), west peak of the Dardanelles.

IX. "Red lava" (1867 S. N.), just south of Mill Creek. Ransome, analyst.

CLASSIFICATION OF THE LATITES.

With the great advance in methods of petrographical research during recent years there has come inevitably greater difficulty and complexity in the proper classification of the rocks themselves. The greatly increased accuracy of chemical analyses, particularly as regards amounts of the alkalies and minor constituents, and their more critical interpretation, together with the strides made in the optical investigations of the feldspars by Becke, Federow, Michel Lévy, and others, is leading to the gradual splitting up of some of the older and more comprehensive groups. A notable example of this tendency was Brögger's differentiation of the monzonite family from the syenites, while a similar process has been long reducing the once large family of the trachytes to a size more commensurate with the minor importance of their plutonic equivalents. With the establishment of new families there has come into the literature an enormous number of new names. In many cases these names are local, being based on mineralogical combinations and distinctions that may not be repeated in another region or be given the same value by other observers. The common custom of providing such facies with a name derived from the locality in which they occur is a useful one, but the local, and to a certain extent provisional, nature of such names should be borne in mind, and they should not be allowed to bury under their accumulating mass broader and more rational schemes of classification.

On the other hand, it is no part of pure petrographical science to aim directly at ease and simplicity in classification, however anxiously such an end may be desired by the general geologist. Petrography in its present stage is occupied rightly with critical distinctions. It is only by the recognition of such slight points of difference that they can ever be transcended and assigned their true value in a really rational scheme of rock classification.

Recognizing the fact that igneous rocks are, chemically, mixtures of practically infinite variability within certain limits, the refining tendency of modern methods makes more and more for precision of definition and consequent subdivision of the older groups. This gain in exactness by no means makes easier the classification of a given rock, for it is evident that the greater the number of families the more numerous will be the intermediate or transition rocks, since sharp lines of demarcation apparently nowhere prevail between closely related types. It is a question, of course, how far for purposes of practical description such subdivision of larger groups should go, but it is a question that may very well be answered by the facts of geological occurrence. If a magma of a certain intermediate type with reference to two or more well-established families is found to possess geological unity, and particularly if it is found to be represented by both plutonic and effusive forms, there can be little doubt of the advisability of giving it a distinctive name. Brögger's monzonite magma is an example of such a case, and he has shown very conclusively that the plutonic monzonites, being orthoclase-plagioclase rocks, should be separated from the orthoclase rocks, or granites and syenites, on the one hand and from the plagioclase rocks, or diorites and gabbros, on the other, the mineralogical distinction being the visible sign of difference in chemical composition. In his tabular classification[1] he has indicated the effusive equivalent of monzonite as *trachyt-andesit*, and it is here that the latites of the present paper belong, as will now be more fully shown.

It is plain from the descriptions of the latites in the preceding pages that, in spite of their superficial basaltic character, they are in no sense basalts, being far too high in silica and alkalies and too low in magnesia and lime, and differing from the latter rock in microscopical structure and in the proportion of the ferromagnesian constituents to the feldspars. Their specific gravity, too, is lower than that of basalts of equally compact texture.

Their relation to the andesites is much closer, and were it advisable to crowd them into one of the well-established older groups they would be placed with little hesitation in this family. Leaving out of consideration the glassy base, the particular latites here described possess practically the mineralogical composition of andesites. But they differ from normal andesites in chemical composition, being generally slightly lower in lime and magnesia and always higher in alkalies. In the andesites the total alkalies are as a general rule less than 6 per cent, with soda in excess of potash. In the latites the total alkalies range from 6 to 10 per cent, with the potash equal to or slightly in excess of the soda.

Rocks of this type can hardly be classed as trachytes if the latter name is to retain any precision of meaning. Not only are they decidedly untrachytic in color and texture, but they differ widely mineralogically from typical trachytes. Sanidine, instead of being the dominant feldspar, is entirely absent and the conspicuous feldspar is here

[1] Die Eruptivgesteine des Kristianiagebietes; II. Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol. Kristiania, 1895, p. 60.

labradorite. As already noted, Turner[1] has provisionally classed some of the latites with the trachytes on the basis of their chemical composition. The analysis upon which he bases his comparison is quoted from Zirkel's Lehrbuch der Petrographie,[2] and, as Turner remarks, "contains more lime and less silica than most of the analyses given by Zirkel." The analysis in question is one by Ricciardi[3] of the so-called "trachyte" of Bolsena, and is quoted in Column VI of the table of chemical analyses on page 66. Concerning this "trachyte" Washington writes:

> Vom Rath first called attention to the abnormal chemical character of the "trachyte" of Bolsena, though he speaks of it as containing no plagioclase, probably owing to the rarity of the multitude twinning. As will be seen from Klein's descriptions and my own, and from the analyses, the peculiar "trachytes" of the region are remarkable; mineralogically for their richness in plagioclase and the frequent occurrence of olivine as an essential constituent, and chemically for their low silica and high lime and magnesia. Therefore they are not trachytes proper, but correspond to the trachy-dolerites of Abich and Hartung, and to some of the andesitic trachytes of Rosenbusch, and we shall see that they may be regarded as effusive representatives of Brögger's abyssal monzonites. These olivine-free effusive rocks will be called by the name of *Vulsinite*, from the Etruscan tribe Vulsinii, formerly inhabiting this region.[4]

There is thus fresh confirmation of the result already stated, that the latites of the present paper belong neither with the normal trachytes nor yet with the normal andesites, but occupy a position chemically about midway between the two.

Effusive rocks with a chemical composition corresponding to this intermediate taxonomic position appear to be not uncommon, and on page 66 the chemical analyses of a number of such rocks are placed together in tabular form for comparison. Nos. I to XIX inclusive are analyses of latites (which in the table are given the names assigned them by the authors quoted), while No. XX is the mean of the 19 analyses which precede it. Nos. XXI and XXII in the second division of the table are a typical andesite and a typical trachyte respectively, being inserted to show the intermediate character of the latites. The latter as a whole form a fairly uniform chemical series, of which the mean agrees closely with the analysis in Column IX.

But when attention is directed to the names and descriptions of the various effusive rocks embraced in the table they are found to be remarkable more for variety than for uniformity. Thus, besides the latites described in the present paper, there occur such names as *ciminite*, *biotite-vulsinite*, *olivine-bearing andesitic trachyte*, *biotite-dacite*, and *sanidine-bearing anaesite*. At first glance such an abundance of names for effusive rocks of a single chemical type seems to indicate little else

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[1] Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, p. 729.

[2] Vol. II, 1893, p. 378.

[3] Klein, Petrographische Untersuchung einer Suite von Gesteinen aus der Umgebung des Bolsener Sees: Neues Jahrbuch für Min., etc., B. B. VI, 1889, p. 8.

[4] Italian petrological sketches: Jour. Geol., Vol. IV, 1896, p. 547.

than a state of hopeless confusion in rock nomenclature. But while a certain amount of confusion does undoubtedly exist, the multiplicity of names has its chief explanation suggested in two other facts—partly, as pointed out by Iddings,[1] that rock series as they occur in nature may traverse existing schemes of classification at practically any angle, but mainly, in this case, that the name of a rock is generally determined more by its mineralogical than by its chemical composition.

In the case of most igneous rocks, and of nearly all plutonic rocks, the principal mineralogical constituents can be deduced with a fair degree of certainty from an accurate bulk analysis, and, vice versa, from a microscopical examination of a thin section the chemical constitution can be predicted with sufficient accuracy to leave little doubt of the general position of the rock in any ordinary scheme of classification. But with the effusive latites this appears to be true only in a slight degree. In effusive rocks of intermediate chemical composition the circumstances which determine the crystallization of the different possible mineralogical combinations appear to depend upon a very delicate adjustment of physical and chemical conditions. This is already noticeable in the andesites, where a given magma cooling under certain conditions may give rise to a hornblende- or biotite-andesite, and under other conditions, by the magmatic resorption of these two minerals, may solidify as a pyroxene-andesite. The latites, being intermediate rocks par excellence, and containing more or less unindividualized glass in reserve, exhibit this apparent capriciousness of crystallization in an unusual degree.

Thus the vulsinites of Washington "are characterized mineralogically by the presence of alkali feldspar with a large amount of basic plagioclase (labradorite to anorthite), together with augite and diopside. Hornblende and biotite are not abundant in the type specimens, though they may be present in large amounts in other varieties. . . . Olivine is wanting, or if present is so in only accessory amounts."[2] It should be stated that the facies which Washington regards as his most typical vulsinite contains over 9 per cent of potash, and accordingly approaches somewhat nearer to the trachytes than do the typical latites of the Sierra Nevada.

The biotite-vulsinite from Monte Santa Croce (Column II) is particularly interesting with reference to the point under discussion, and the dilemma in which one is placed in attempting to adhere to a purely mineralogical classification of these rocks is well expressed in Washington's own words. He says:

> We have then a rock which is chemically a ciminite and mineralogically a biotite-vulsinite. In regard to the name by which they should be called there may be some doubt. From a mineralogical standpoint they are obviously not ciminite, nor chemically can they strictly be called vulsinite. Since, however, in the schemes of classification in general use at the present time, the mineralogical composition takes

[1] Jour. Geol., Vol. III, 1895, pp. 955-956.
[2] Jour. Geol., Vol. IV, 1896, p. 553.

precedence over the chemical, and bearing in mind the unadvisability of adding new names to the already overburdened nomenclature, I shall designate these rocks as biotite-vulsinite.[1]

The ciminites are "characterized mineralogically by the presence of orthoclase, with basic plagioclase, augite or diopside, or olivine."[2]

The andesite from Carbezo Felipe contains phenocrysts of feldspar and biotite. Sanidine occurs in crystals over a centimeter in length, but the main bulk of the feldspar is labradorite, or a plagioclase between labradorite and andesine. Both monoclinic and orthorhombic pyroxenes are present, and the rock is rich in zircon and apatite. Concerning the classificatory position of this rock Osann writes:

> The proportion of the alkalies shows that the rock stands close to the group of andesitic trachytes—a position which is indicated also by the presence of the large sanidine phenocrysts. The content in lime and potash, contrasted with the small amount of soda, is explained by the fact that basic plagioclase (labradorite) occurs as phenocrysts with the sanidine. If the analysis is compared with the analyses of other andesitic trachytes, in part olivine-bearing (Mte. Amiata, the Arso flow, Mte. Alfina), it is seen to be higher in magnesia. (The Arso rock, in spite of the presence of olivine, has only 1.77 per cent.) This is explained only by the abundance of both biotite and orthorhombic pyroxene.[3]

The augite-andesite from Mount Pagos is "composed of plagioclase, diopside, and biotite, with accessory magnetite, apatite, and zircon, lying in a glass base."[4] The plagioclases are labradorite ($Ab_1 An_1$), but there are possibly a few orthoclase microlites in the groundmass.

The Gleichenberg trachyte contains, according to Hussak,[5] large sanidine phenocrysts, fewer and smaller ones of oligoclase (with extinction angles of 12°–15°), biotite, and dark augite, in a globulitic base.

The augite-andesite from Kara Tash has numerous phenocrysts of labradorite (a little more basic than $Ab_1 An_1$), pale-green diopsides, some biotite, and grains of magnetite, in an abundant, trichitic, glassy base.[6]

The biotite-dacite from Pergamon[7] contains phenocrysts of labradorite, with fewer sanidines, biotite, and olive-green hornblende. The rock is called a dacite on the basis of its chemical composition, although containing no free quartz, thus again illustrating the difficulties attendant upon a consistent mineralogical classification of these intermediate rocks.

The sanidine-bearing andesite of the Rosita Hills is described by Cross[8] as containing plagioclase, orthoclase, quartz, biotite, augite, and

[1] Jour. Geol., Vol. V, 1897, pp. 250-251.

[2] Ibid., Vol. IV, 1896, p. 838.

[3] Beiträge zur Kenntniss der Eruptivgesteine des Cabo de Gata, II: Zeitschr. Deutsch. geol. Gesell., vol. 43, 1891, p. 720.

[4] Washington, On some igneous rocks from Smyrna and Pergamon: Am. Jour. Sci., 4th series, Vol. III, 1897, p. 44.

[5] Zirkel, Lehrbuch der Petrographie, Vol. II, p. 383.

[6] Washington, loc. cit., p. 44.

[7] Washington, loc. cit., p. 48.

[8] Proc. Colorado Sci. Soc., 1887, p. 248.

accessory minerals. This rock is said to have its chief development in dikes, although occurring also in effusive masses.

The foregoing citations are sufficient to show how great mineralogical variety may be presented by rocks having the peculiar intermediate chemical composition of the latites. It is possible, and perhaps desirable, to assign the more conspicuous and well-marked of these mineralogical combinations separate names, but the number of the latter is apt to be large, and they are of a distinctly lower grade of importance than those rock names which express not only a certain mineral constitution but a corresponding and characteristic chemical composition as well.

It accordingly seems advisable to attempt to bring into common use some more general name to embrace all the effusive rocks standing chemically about midway between the typical trachytes and the typical andesites—a name that can be used as the effusive equivalent of the increasingly important plutonic group of the monzonites. I should gladly have avoided the necessity of introducing a new name into a rapidly growing nomenclature; the more so, as Washington, by his admirable petrographical studies in the Italian volcanic regions, has added so greatly to an accurate knowledge of intermediate rock types which must be necessarily embraced by such a new term. But the Sierra Nevada lavas can not be classed with the typical toscanites, vulsinites, or ciminites, as defined by Washington, although, like the vulsinites and some of the ciminites, they are to be regarded as the effusive equivalents of the monzonites. There is thus a demand for some more comprehensive name to cover the mineralogically diverse forms which the monzonitic magmas, cooling under effusive conditions, may assume. For this reason, and in recognition of the importance and interest of the Italian types described by Washington, the name *latite*, derived from the Italian province of Latium, is proposed as a broader term, comparable in its scope with *monzonite*, to designate the effusive forms of the monzonite magma. Thus it will be seen that certain of the characteristic features of the Sierra Nevada latites, such as the absence of sanidine, the predominance of labradorite, and the presence of a residual alkali-rich glass base, are not regarded as essential in the definition of the general group of the latites as a whole. The latites described in the present paper are merely members of this group, possessing individual characters which would entitle them to names of the same order of importance as the vulsinites, toscanites, etc., of Washington. For the present, however, no such names are proposed.

Abich and Hartung have used *trachy-dolerite* for rocks which in part belong with the latites; Fouqué and Michel Lévy, *trachy-andesites;* Zirkel and Rosenbusch, *andesitic trachyte;* and Brögger *trachyte-andesite.* But all these compounds are open to objection when a name is required for an important group standing midway between the trachytes and the andesites. Such a name should consist of a single word, and should be free from the undesirable connotations adherent to compounds which have been variously employed.

Referring again to the table of chemical analyses on page 67, it will be seen that in Columns XXIII and XXIV are placed the analyses of two quartz-banakites, chosen as being the nearest known dike equivalents of the latites[1]. The correspondence, however, is not quite perfect, as the two analyses show a slight deficiency in lime and a small excess of alkalies as compared with the mean of the latite analyses. Iddings[2] states that the rocks of these two analyses belong to the banakite series "both mineralogically and chemically, but are somewhat more siliceous, having 5 to 9 per cent more silica. They might properly be given specific names, but at present we prefer to class them with banakite, under the name of quartz-banakite, the amount of quartz, however, being very small."

The banakites are intermediate rocks in the same sense that the latites are. Chemically they possess a rather close analogy with the latter rocks, although somewhat lower in silica, and thus tending through leucitic facies toward the truly alkaline groups of igneous rocks. It is interesting to note that Iddings[3] remarks in this series the tendency toward mineralogical diversity with nearly identical chemical composition, already emphasized in the case of the latites.

In the succeeding columns of the table are placed the analyses of several monzonites, quoted from Brögger, in order to show the close relationship between these plutonic rocks and the effusive latites. Washington has already pointed out this correspondence in the case of his vulsinites and ciminites,[4] and notes as well analogies with the absarokite-banakite series of Iddings.[5]

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[1] After the foregoing was in type my attention was drawn to the dike rock described by Hibsch as occurring in the Bohemian Mittelgebirge, which he has named *gauteite*. (Erlauterung zur geologischen Karte des böhmischen Mittelgebirges: Tschermaks min. u. pet. Mitth., vol. 17, 1897, pp. 84-87.) This rock also is perhaps a dike equivalent of the monzonites and latites, although the chemical analysis shows rather high alkalies.

[2] Absarokite-shoshonite-banakite series: Jour. Geol., Vol. III, 1895, pp. 949-950.

[3] Loc. cit., p. 951.

[4] Jour. Geol., Vol. IV, 1896, p. 832.

[5] Ibid., loc. cit., p. 838. Since the foregoing was written Washington's final paper on the Italian volcanic regions has appeared (loc. cit., Vol. V, 1897, pp. 349-377), in which he divides the rocks between the trachytes and the andesites into two series—the trachyandesites and the trachydolerites, using the former term in a more restricted sense than in his earlier papers, and without the previously employed hyphen. The Sierra Nevada latites would fall most nearly within his trachydolerite series, although not the strict equivalents of any of its individual members. Whether some such single term as that here proposed shall be used to designate the rocks midway between the trachytes and andesites, or whether it will be found practicable to divide them into two series as Washington has done, may, as the latter suggests in a slightly different connection, be left to the winnowing action of time and usage.

Comparative table of chemical analyses.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII	XIX.	XX.
SiO_2	55.44	55.69	56.19	56.76	56.78	57.97	58.67	59.41	59.43	59.88	60.03	60.88	61.09	61.44	61.93	62.33	63.17	63.49	65.81	59.81
TiO_2	.16	trace	.69	......	1.15	......	......	.01	1.38	......	......	......	......	......	......	1.05	......	trace	.54	......
Al_2O_3	18.60	19.08	16.76	16.69	16.86	17.65	15.07	17.92	16.68	......	17.05	16.19	......	17.08	18.47	17.35	17.15	18.40	15.11	17.18
Fe_2O_3	2.09	4.07	3.05	2.07	3.56	.63	......	1.71	2.54	......	1.83	5.37	......	3.67	1.93	2.98	2.84	2.44	1.85	5.99
FeO	4.48	3.26	4.18	6.95	2.93	7.50	8.35	2.40	3.48	......	4.15	1.58	......	2.42	2.23	1.63	1.31	1.09	1.40	
MnO	......	trace	.10	......	......	.09	......	......	trace	......	.09	......	......	......	......	.08	......	.16	......	......
MgO	4.75	3.41	3.79	1.63	3.41	1.71	2.97	2.99	1.84	......	1.12	2.96	......	1.14	2.66	1.05	2.17	.66	.37	2.27
CaO	6.75	6.87	6.53	6.01	6.57	5.53	8.07	4.65	4.09	5.09	6.58	5.88	4.94	6.21	4.31	3.23	4.17	2.30	1.98	5.25
BaO	......	......	.19	......	......	......	......	......	.14	......	......	......	......	......	......	.24	......	......	.10	......
Na_2O	1.79	2.89	2.53	2.43	3.19	1.50	3.36	2.63	3.72	3.90	2.31	3.11	3.69	4.06	2.92	4.21	3.08	5.70	2.59	3.13
K_2O	6.63	4.41	4.46	4.67	3.48	5.31	3.50	5.60	5.04	5.06	5.12	3.95	5.27	3.86	3.92	4.46	4.19	4.62	5.24	4.67
P_2O_5	trace	......	.55	.47	.42	.42	......	.87	.58	......	.42	......	......	......	......	.29	......	trace	.23	......
CO_2	......	......	......	......	.18	......	......	......	......	......	......	......	......	......	......	......	......	trace	......	......
H_2O above 110°	.25	.17	.66	......	1.21	......	.82	1.30	.72	......	......	.98	......	2.04	2.28	.75	2.51	1.04	......	......
H_2O below 110°			.34	......	.15	......			.27	......	......		......			.44			......	......
Ig	......	......	......	2.44	......	1.82	......	......	......	......	1.42	......	......	......	......	......	......	......	......	......
			SrO, t. Li_2O, t.						ZrO_2 .08 SrO, tr. Cl .05							SrO .44 Li_2O, tr. FeS_2 .08 C .11				
Total	100.75	99.85	100.02	100.22	99.89	100.13	100.81	99.49	100.04	......	100.12	100.70	......	101.92	100.65	100.33	100.59	99.90	......	
Specific gravity	2.70	......	......	2.47	2.67	2.451	2.765	......	......	......	2.543	2.640	......	......	2.601	......	......	......	2.38	

	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.	XXVIII.	XXIX.	XXX.	XXXI.	XXXII.	XXXIII.	XXXIV.
SiO_2	58.47	60.97	57.29	60.89	52.16	52.53	52.81	54.20	54.42	57.66	58.05	58.98	61.72	61.73
TiO_2	.51		.72	.49			.71	.40	.80					
Al_2O_3	18.80	20.92	18.45	17.14	22.11	19.48	15.66	15.73	14.28	17.23	17.71	17.34	13.57	17.45
Fe_2O_3	3.34	3.81	4.38	3.32	8.58	11.07	3.06	3.67	3.32	7.28	8.29	3.44	7.60	5.94
FeO	2.64		1.20	.95			4.76	5.40	4.13					
MnO	.13		trace	.09			trace	.70	.10				.33	
MgO	2.69	.29	2.08	1.16	2.64	1.53	4.99	3.40	6.12	2.20	2.07	1.64	3.33	2.29
CaO	6.60	.14	3.57	3.58	8.61	6.61	7.57	8.50	7.72	5.32	5.81	8.64	5.88	4.52
BaO	.09						.24		.32					
Na_2O	3.58	5.03	4.43	4.54	3.35	2.71	3.60	3.07	3.44	3.41	2.98	3.41	3.12	3.12
K_2O	2.01	8.88	5.43	5.71	2.00	3.17	4.84	4.42	4.22	4.61	3.24	5.34	3.37	3.88
P_2O_5	.22		.46	.27			.75	.50	.59					
H_2O	[1] .92	.83	2.18	1.61	.80	2.34	[1] .93	.50	[1] .38	.70	1.34	1.06	.95	1.16
	[2] .14						[2] .16		[2] .22					
	SrO .05		NiO .12	NiO .19			SrO .09		SrO .13	CO_2 .76				
	Li_2O, tr.						Li_2O, tr.		Li_2O, tr.					
							Cl .07							
							Fl, tr.							
							SO_3, tr.							
Total	100.19	100.42	100.31	99.94	100.25	99.44	100.24	100.50	100.19	99.17	99.49	99.85	99.43	100.09
							.02							
							100.22							
Specific gravity		2.605												

[1] Above 110°.

[2] Below 110°.

I. Ciminite, Fontana Fiescole, Viterbo, Italy. Jour. Geol., Vol. IV, p. 849. Washington, analyst.

II. Biotite-vulsinite, Monte Santa Croce, Rocca Monfino region, Italy. Jour. Geol., Vol. V, p. 252. Washington, analyst.

III. Augite-latite (36 S. N.), Table Mountain, near Shaws Flat, Tuolumne County, Cal. Hillebrand, analyst.

IV. Olivine-bearing andesitic trachyte, Sassara, Italy. Klein, Neues Jahrbuch für Min., etc., B. B. VI, p. 7. Ricciardi, analyst.

V. Augite-latite (1422 S. N.), Table Mountain flow, 1½ miles east of Clover Meadow, Tuolumne County, Cal. Steiger, analyst.

VI. Trachyte (Klein) or vulsinite (Washington), Bolsena, Italy. Klein, Neues Jahrbuch für Min., etc., B. B. VI, p. 8. Ricciardi, analyst.

VII. Ciminite, Monte Cimino, Italy. Jour. Geol., Vol. IV, p. 849. Vom Rath, analyst.

VIII. Andesite, Cabezo Felipe, Cabo de Gata, Spain. Zeitschr. Deutscb. geol. Gesell., vol. 43, 1891, p. 719. Osann, analyst.

IX. Augite-latite (1419 S. N.), 4 miles southwest of Clover Meadow, Tuolumne County, Cal. Stokes, analyst.

X. Augite-latite (86 S. N.), Tuolumne County, Cal., 3 miles southeasterly from Big Trees. Turner, Seventeenth Ann. Rept. U. S. Geol. Survey, p. 729. Fireman, analyst.

XI. Trachyte (Klein) or vulsinite (Washington), San Magno, Italy. Klein, Neues Jahrbuch für Min., etc., B. B. VI, p. 10. Ricciardi, analyst.

XII. Augite-andesite, Mount Pagos, near Smyrna, Asia Minor. Washington, Am. Jour. Sci., 4th series, Vol. III, p. 43. Washington, analyst.

XIII. Biotite-augite-latite (85 S. N.), Tuolumne County, Cal., 3 miles southeasterly from Big Trees. Turner, Seventeenth Ann. Rept. U. S. Geol. Survey, p. 729. Fireman, analyst.

XIV. Trachyte, Gleichenberg, near Steiermark. Tschermaks mineral. Mittheil., 1887, p. 277. Smita, analyst.

XV. Augite-andesite, Kara Tash, near Smyrna, Asia Minor. Washington, Am. Jour. Sci., 4th series, Vol. III, p. 45. Washington, analyst.

XVI. Biotite-augite-latite (1420 S. N.), 4 miles southwest of Clover Meadow, Tuolumne County, Cal. Hillebrand, analyst.

XVII. Biotite-dacite, Pergamon, Asia Minor. Washington, Am. Jour. Sci., 4th series, Vol. III, p. 49. Washington, analyst.

XVIII. Sanidine-bearing andesite, Rosita Hills, Colo. Cross, Proc. Colo. Sci. Soc., 1887, p. 250. Eakins, analyst.

XIX. Vitrophyric latite (?) (1866 S. N.), just south of Mill Creek, Tuolumne County, Cal. Partial analysis. Steiger, analyst.

XX. Mean of the important constituents of the 19 preceding analyses.

XXI. Hornblende-pyroxene-andesite (72 S. N.). Downieville area, Sierra Nevada, Cal. Turner, Seventeenth Ann. Rept. U. S. Geol. Survey, p. 731. Hillebrand, analyst.

XXII. Trachyte (domite), Puy de Dôme, Auvergne. Zirkel, Lehrbuch der Petrographie, II, p. 378. Lewinstein, analyst.

XXIII. Quartz-banakite, dike, near head of Stinkingwater River, Yellowstone Park region. Iddings, Jour. Geol., Vol. III, p. 947. Melville, analyst.

XXIV. Quartz-banakite, dike, locality and reference as above. Melville, analyst.

XXV. Monzonite, Predazzo, South Tyrol. Brögger, Eruptivgesteine des Kristiania-Gebietes, II. Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol. Kristiania, 1895, p. 25.

XXVI. Monzonite, Sasinathal, Predazzo. Brögger, loc. cit.

XXVII. Monzonite, Beaver Creek, Bearpaw Mountains, Mont. Weed and Pirsson, Am. Jour. Sci., 4th series, Vol. I, p. 357. Stokes, analyst.

XXVIII. Monzonite, Monzoni, S. Tyrol. Brögger, op. cit., p. 24. Schmelck, analyst.

XXIX. Monzonite, Yogo Peak, Montana. Weed and Pirsson, Am. Jour. Sci., 4th series, Vol. I, p. 357. Hillebrand, analyst.

XXX. Monzonite, Mulatto, Predazzo, S. Tyrol. Brögger, op. cit., p. 25.

XXXI. Monzonite, Malgola, Paedazzo, S. Tyrol. Brögger, loc. cit.

XXXII. Monzonite, Predazzo, S. Tyrol. Brögger, loc. cit.

XXXIII. Monzonite, Blansko, Mähren. Brögger, op. cit., p. 50.

XXXIV. Monzonite, Hodritsch, Hungary. Brögger, loc. cit.

THE EVIDENCE OF THE LAVA FLOWS AS REGARDS OROGENIC MOVEMENTS.

The length of the Table Mountain flow and its favorable position with reference to the present drainage system suggested the comparison of its grade profile with those of the Stanislaus River, including its North and Middle forks, shown in Pl. II. The upper curve in the diagram is that of the base of the Table Mountain flow. Below it are the curves of the main Stanislaus River with its two principal branches, the lower grade being that of the larger Middle Fork. All the profiles are projected upon a vertical plane parallel with the upper and lower edges of the map—a method which, while it exaggerates the actual grade of certain portions of the streams, has the advantage of referring them all to the standard of an ideal consequent stream running straight down the slope and allows the direct comparison of one with another.

The curves as drawn for the existing streams are dependent upon the accuracy with which the canyon contours are laid down on the topographic sheets, while the profile representing the bottom of the lava stream as now dissected is in general somewhat higher than the true bottom of the channel down which it flowed. But the possible error from both sources is probably not large enough to affect seriously the general results to be deduced from a diagram on the scale shown.

The most noticeable fact that appears upon a comparison of the different profiles is the remarkable regularity of the Neocene curve as compared with the curves of the present streams. When there is recalled the great variety of rocks upon which the Table Mountain latite rests, this even character of the curve indicates that the stream which the lava displaced had been highly successful in establishing itself upon a uniform grade. In contrast with this profile, the profiles of the modern streams show some irregularities. The curve of the North Fork is approximately parallel along its middle portion with that of the Middle Fork; but near its junction with the latter stream it becomes considerably steeper, probably on account of the fact that, owing to its greater volume, the Middle Fork has been able to corrade its channel more rapidly than the North Fork, so that the latter stream is at present being lowered near its mouth at a rate too rapid to allow of a corresponding compensation along its entire course. At its upper end, also, the curve of the North Fork departs from its parallelism with that of the Middle Fork, rising rather suddenly and becoming slightly convex. This is due, no doubt, to the weakening of the stream near this point by a splitting up into head-water ramifications which are individually too feeble to cut deep gorges. In the case of the Middle Fork there is no very decided convexity shown, as the stream is much longer and carries its gorge farther back into the range. It is interesting to note that the profile of the Neocene channel also exhibits a slight convexity in the upper regions, as if it, like the North Fork, were approaching its former head-water drainage. But too little is known of the extent and distribution of the latites to the eastward to draw any valuable conclusion from this change in curvature.

The curves, as they stand, give evidence that the Neocene stream bed, down which a portion of the lavas flowed, records the work of a more nearly graded stream than either of its modern representatives, the Middle and North forks of the Stanislaus. It probably flowed, therefore, on a lower grade than the existent rivers, and the present difference of 2,500 feet between the bed of the Middle Stanislaus and the bottom of the Table Mountain flow in the region of the Dardanelles is less than the minimum amount of elevation of this portion of the Sierra slope since the date of the latitic eruptions. Moreover, the great regularity of the Neocene curve indicates that the elevation of this region was effected by a movement or movements which have resulted in at least a superficial resemblance to a simple block tilting, without deformation of the old surface sufficiently great to be appreciable by the methods here used. Lindgren,[1] on the other hand, in his interesting study of the Neocene, Yuba, and American rivers, farther north, found that the elevation was accompanied by deformation, whereby the Neocene channels, instead of showing the regular grade profiles of their modern representatives, appear "to be composed of two curves, with the convex side upward." As the district studied by Lindgren is some hundred miles north of that here described, there is no necessary conflict in the different results arrived at in the two fields.

The channel down which the latite flowed was, as has been shown in the preceding pages, cut during the volcanic period as a whole, and belongs in time with the "intervolcanic channels" of Lindgren, and is therefore younger than the channels of the Neocene Yuba and American rivers, which antedate the main volcanic eruptions. It therefore records only a fraction of the differential uplift during Neocene time. According to Lindgren, the intervolcanic channels of the region described by him exhibit the marks of an erosive activity similar to that of the present day, and are marked by strong grades in whatever direction they flowed.[2]

The Table Mountain channel seems, however, to have been of a slightly different class, and to have been occupied by a long consequent stream of more nearly uniform grade than the present rivers, indicating a considerable interval of erosion between the different andesitic eruptions. The fact that it, on the whole, follows the course of the present Stanislaus, or bisects the angle of its two main branches, indicates that the tilting of the slope has been substantially constant in direction since the beginning of Neocene time.

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[1] Bull. Geol. Soc. America, Vol. IV, 1893, p. 297.

[2] Loc. cit, p. 295.

SUMMARY.

The contents of the preceding sections may be very briefly summarized as follows:

The area embraced by the map is a fairly typical transverse strip of the middle western slope of the Sierra Nevada, having been worn down to a rough peneplain during the interval between the close of the Juratrias and the beginning of the Miocene. During the Miocene the volcanic eruptions began, which, accompanied by elevation and tilting of the peneplain, lasted to the end of the Pliocene. The first eruptions were rhyolitic, followed by the laying down of a great cloak of andesitic breccias and tuffs. The deposition of the auriferous gravels both preceded and accompanied the deposition of the volcanic material.

The accumulation of the andesitic tuffs and breccias was interrupted by at least one period of considerable erosion, during which a long consequent stream, the predecessor of the present Stanislaus River, established its channel down the slope, cutting through the volcanic cover into the older truncated Bed-rock series along the greater part of its course, and ultimately attaining a very uniform grade. This stream was subsequently displaced by a heavy flow of augite-latite, the Table Mountain flow, which, coming from an as yet unknown source near the crest of the range, ran down the stream bed to the edge of the Great Valley, a distance of more than 60 miles. A second and thinner flow of biotite-augite-latite followed, attaining a greater lateral extent, but not reaching the length of the first flow. The third, or Dardanelle flow, of augite-latite closed the series of latitic eruptions. The volcanic period, as a whole, was brought to an end by fresh andesitic eruptions, as shown by andesitic breccias resting upon the latites, accompanied by a further tilting of the peneplain toward the southwest.

During Pleistocene time the present streams have dissected the Neocene lavas and tuffs, including the latite flows, and have deeply incised the Bed-rock series of Juratrias and older rocks.

The Sierra Nevada latites are mineralogically closely related to ordinary andesites, but chemically they stand between the andesites and the trachytes. They are higher in alkalies than the andesites; the potash is generally slightly in excess of the soda, and, *in the particular rocks described*, is present chiefly in the unindividualized glass when no biotite is present.

Rocks of this intermediate chemical composition are fairly widespread, but are characterized by considerable mineralogical variety. The name latite is proposed as a convenient designation for this entire group of effusive rocks standing chemically between the trachytes and the andesites, and corresponding to the plutonic monzonites of Brögger and possibly to some of the dike banakites of Iddings and the gauteite of Hibsch.

A comparison of the grade profiles of the Neocene stream, down which the latites flowed, with those of the present Stanislaus River, shows that the elevation of the crest of the Sierra Nevada in this region has been such as would be produced by a simple block-tilting without perceptible warping.

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