ART. XXVIII.—*The Granitic Rocks of the Pyramid Peak District, Sierra Nevada, California;* by WALDEMAR LINDGREN.

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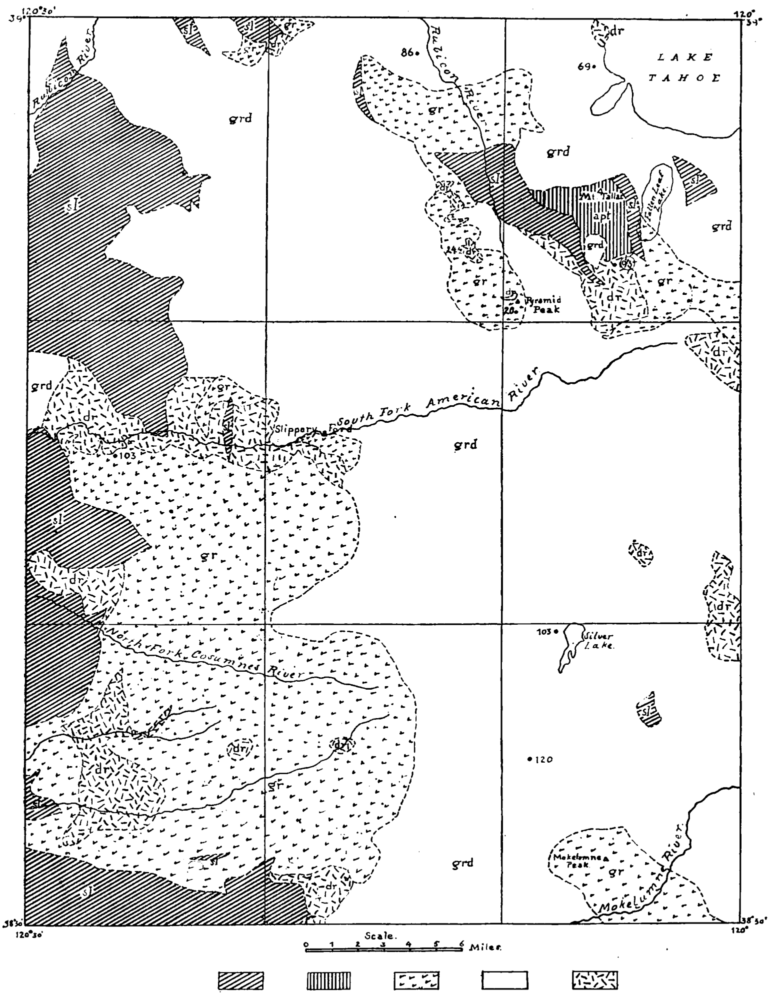
IT has long been known that the summit region of the Sierra Nevada is occupied by an enormous mass of granitic rocks, and that a large part of it consists of granodiorite, a rock intermediate between a granite and a diorite, but no detailed maps have thus far been made of the granitic areas. An opportunity was offered for the study of these granitic rocks during the survey of Pyramid Peak atlas sheet, which was undertaken in the summer of 1894 by the writer, assisted by Mr. H. C. Hoover. The results are shown in the accompanying map (p. 302), compiled from the Pyramid Peak folio now in press.

The region embraces half a degree of latitude by half a degree of longitude, and contains 927 square miles. The southern end of Lake Tahoe falls within the northern corner, and the main divide of the mountain range runs near the eastern boundary of the sheet. While the western part is occupied by an approximate plateau deeply trenched by canyons and gulches, the crest of the Sierra Nevada rises in the eastern part to lofty snow-capped mountains. The drainage of the western part is toward the Sacramento and San Joaquin rivers, while the drainage toward Lake Tahoe eventually finds its way to the deserts of the Great Basin.

The older bed-rock series consists of slates, schists and granitic rocks. These are extensively covered by Tertiary eruptives, andesite, rhyolite and basalt, which have not been indicated in the map accompanying this paper. To the west the slates, schists and accompanying basic eruptive rocks continue down to the foothills of the range and contain several small masses of granitic rocks. Toward the east the latter continue over to the eastern escarpment of the Sierra Nevada. The range in this vicinity contains two summit-ridges. The westerly, dividing the Pacific from the Great Basin, is found on this sheet, while the easterly summit divides the drainage flowing into Lake Tahoe from that running into the Carson River.

The Sedimentary Areas.

No fossils have been found in any of the sedimentary rocks of the bed-rock series within the limit of this sheet, and the age assigned is in all cases tentative only. The determinations are, however, based upon a comparison with formations of approximately known age in adjoining areas, and they therefore possess a strong degree of probability.



A, Sedimentary slates and schists. B, Augite porphyrite. C, Granitite. D, Granodiorite. E, Diorite and Gabbro.

Under the name of the Calaveras formation the beds of Paleozoic age have been comprised which cannot at present be further subdivided. The larger part of them probably belong to the lower or middle Carboniferous. To this formation all of the sedimentary rocks along the western boundary of the sheet belong. The sedimentary rocks are separated from the granite by an extremely irregular contact line. The bays of granitic rocks reach far into the schists and slates, and all along this contact the sedimentary rocks have been subjected to an intense contact metamorphism, but of fusion or absorption there is absolutely no evidence.

The whole of the Calaveras formation on the eastern part of the Placerville sheet and on this sheet has a pronounced siliceous character; it consists of altered sandstones, grading into quartzite, and clay slates grading into micaceous schists. The cause of the metamorphism is partly of a regional character and caused by dynamic movements affecting a large part of the Sierra Nevada, chiefly prior to the great granitic intrusions, partly of a local character, and caused by the heat and the emanations from the intrusion of enormous massses of granitic magmas. While the latter metamorphism is superimposed upon the former, and the phenomena resulting from each not always easy to discriminate, it is clearly seen that the extremely altered sediments are found only at the contacts with the granitic rocks, and that the degree of metamorphism gradually decreases away from it. The contact zones are here very wide, typical contact metamorphic rocks often being found two miles from the contacts, or even more in case of projecting masses of sedimentary rocks surrounded on all sides by granite. It does not appear probable that any of these rocks are old, pre-Carboniferous or Archean schists.

Less altered rocks, the clastic character of which is clearly apparent, occur at a few places near the western border of the sheet. They are principally dark clay-slates and quartzitic rocks, which under the microscope show their fragmental origin. Thus on Silver Creek, near the western boundary of the sheet, on Sly Park Creek, at Fort Grizzly and southeast of Tar's Sawmill. But the larger part of the Calaveras formation in this sheet is occupied by the contact metamorphic schists. In places especially exposed to the action of the granitic magma, the rock is converted to normal, medium-grained gneiss or mica-schist, and at these places the contacts with the granite, usually sharp, are liable to become indistinct. Somewhat farther away the schists are finer-grained, generally of a brownish color, from the biotite contained, or of a silvery lustre caused by scales of muscovite on the planes of schistosity. The surface is frequently knotty, changing to normal "Knotenschiefer." They often carry andalusite, characteristic for contact rocks, in well-developed crystals, and such rocks may be found more than one mile distant from the contact.

Excellent exposures are found in the deep canyons of Silver Creek, Camp Creek and the north fork of the Cosumnes, but they are accessible only with difficulty. The schistosity is indicated on the outcrop by lines, straight on the whole, but delicately wavy in detail; heavy benches alternate with streaks, in which the lamination is very fine. Nodules and nests of apparently segregated quartz are common. On the ridges and slopes satisfactory outcrops are rarely seen, as the rock here weathers to a dark-red soil.

A part of the area in the southwestern corner, is also intensely altered; micaceous schists and a striped green and white schist, consisting of pyroxene, quartz, feldspar and wollastonite, evidently a product of contact metamorphic action on limestone, appear in this vicinity.

The stratification can only rarely be observed beyond doubt, as for instance where quartzite and black clay-slate alternate, but it is probable that in most cases the stratification approximately coincides with the superimposed schistosity. In the northern area the strike of the schistosity is generally due north and the dip either about vertical or westward at a steep angle, this being contrary to the general rule further down the slope. South of the south fork of the American River the strike is more irregular, but generally east-west, while the dip is always within 20° of the perpendicular and usually to the north. Comparing with the S.E. part of Placerville sheet and the N.E. part of Jackson sheet, it will be seen that the series in these regions also has an abnormal east-west strike; the cause may possibly be sought in the mechanics of the intrusion, the slates in this vicinity being especially torn up by deeply incised bays of granitic rock. Horizontal and inclined joints also traverse the schists, separating them into rhomboidal fragments. The contact of the schists with the granitic rock is usually best defined where that line runs parallel to the schistosity. Wherever the contact cuts across the strike a stronger metamorphism, accompanied by a feathering out of the schists and by an injection of granitic magma, is often noted. The cleavage of the schists has not been produced by the pressure of the intruding magma; it existed before the granitic irruption.

A few isolated areas of schists, quartzites and highly-altered tuffs referred to the Jura-trias are scattered on both sides of the crest in the northern part of the area of the Pyramid Peak sheet. One of the principal reasons for assigning them, with doubt, however, to the Jura-trias is their position in the continuation of strata known to be of that age in the area of the Truckee sheet adjoining northward; another is that the principal mass, near Mount Tallac, is intimately connected with large masses of dark-green diabase-porphyrite and porphyrite tuff, which is characteristic of the Jura-trias at Sailor Canyon (Colfax sheet) and northward. The color of the outcrops of these schist areas is usually reddish brown, contrasting strongly with the light-gray granodiorite.

The two small areas at the northern boundary consist of quartzite and black slate, the latter altered near the contacts to gneissoid micaceous schist; the contacts are usually sharp, extremely so where the road crosses the western area. At other places, as for instance, on the west side of Loon Lake, the contact is very unsatisfactory, the reddish granitic outcrops being everywhere mixed with schistose fragments.

The long and narrow area west of Tells Peak is strongly metamorphosed and composed of gneissoid schists, quartzites and mica-chlorite-andalusite schists.

The largest area of supposed Jura-trias lies in Rockbound Valley between Mount Tallac and the Pyramid Peak Range; it has a roughly triangular form and is distinguished by outcrops of dull gray or brown color. The rocks consist of a series of clearly stratified black slates and white quartzitic rocks; beautifully banded hard rocks, dark-gray and white, also occcur in Rockbound Valley. The normal strike appears to be N.N.W., with a dip of about 45° to the east; the schistosity is not prominent. In the western point of the area the rocks are disturbed and dip in different directions. In the vicinity of Suzy Lake white quartzitic rocks crop, less clearly stratified, often indeed appearing massive. The microscope shows that the banded rocks from Rockbound Valley and in the Suzy Lake region are porphyrite tuffs, probably deposited contemporaneously with the eruption of the large porphyrite mass of Mount Tallac. Dikes of typical diabase porphyrite were noted on the west shore of Suzy Lake; on the western slope of Rockbound Valley uralite-porphyrites appear which would seem to lie conformably in the sedimentary series and are made somewhat schistose by pressure.

The Granitic Rocks.

The granitic rocks exhibit a rather unexpected variety in composition and structure. They include granites, aplites, granodiorites, diorites, and gabbro, by far the largest areas being, however, occupied by the granodiorite. The structure is always massive, a well defined schistosity being nowhere observed. Joints are frequent, however, and near the summit the rocks are intersected by extensive fissure systems.

Granite.—A normal biotite-granite or granitite occupies several large areas along the Pyramid Peak Range at Echo Lake, at Mokelumne Peak, and about the headwaters of the Cosumnes River. Its outcrops are generally distinguished by a light-yellowish or reddish color, due to the sesquioxide of iron contained in the orthoclase. It is harder and of a firmer texture than the granodiorite, and its areas include the highest and roughest ridges in the region. For the same reason bowlders and cobbles of granitite are much more abundant than those of granodiorite. While it varies somewhat in appearance and constitution, yet it is a typical granite. The rock is coarse-grained and has often a decided tendency towards a rough porphyritic structure. The orthoclase appears as large grains and imperfect prisms of reddish gray color up to two or even three centimeters long; the quartz is very prominent in dark-gray rounded grains up to one centimeter in diameter, while the black mica and smaller quartz and feldspar grains lie between these larger constituents. Hornblende occurs only rarely; when it appears plagioclase usually also enters into the composition, and transition-forms to granodiorite result.

TABLE OF ANALYSES OF GRANITIC ROCKS.

Analyst: Mr. Geo. Steiger.

	I	II	III	IV	V	VI	VII	VIII	IX
SiO_2	77·68	72·95	67·45	68·13	67·14	68·32	65·88	51·47	57·11
TiO_2	·14		·58						
Al_2O_3	11·81		15·51						
Fe_2O_3	·72		1·76						
FeO	·51		2·21						
MnO	trace								
CaO	·72	1·16	3·60	3·51	4·07	3·21	4·11	10·18	5·32
MgO	·18		1·10						
K_2O	5·00	5·43	3·66	3·58	2·70	3·37	2·88	1·08	4·11
Na_2O	2·96	3·74	3·47	3·13	3·09	2·51	2·41	2·86	3·06
Water 100−	·04		·14						
Water 100+	·27		·63						
P_2O_5	·10		·12						
	100·13		100·25						

I. 164 Pyramid Peak collection; granitite: Placerville Ditch, ⅓ mile north of Ditch-camp 7. Lat. 38° 45·5′; Long. 120° 36·1′.

II. 20 Pyramid Peak collection; granitite; south side Pyramid Peak, 1,200 feet below summit. Lat. 38° 50·2′; Long. 120° 9·5′.

III. 103 Pyramid Peak collection; granodiorite; road, ¼ mile west of Silver Lake House. Lat. 38° 39·8′; Long. 120° 7·7′.

IV. 69 Pyramid Peak collection; granodiorite; trail Emerald Bay to Rubicon Point, 1½ mile south of latter. Lat. 38° 48·6′; Long. 120° 6·3′.

V. 86 Pyramid Peak collection: granodiorite; 1 mile E.S.E. of Rockbound Lake. Lat. 38° 58·8′; Long. 120° 13·7′.

VI. 120 Pyramid Peak collection; granodiorite; Big Mud Lake bears N. 30° W. and is 1½ mile distant. Lat. 38° 35·6′; Long. 120° 9′.

VII. 177 Pyramid Peak collection; granodiorite; Meek's Creek, 2 miles up from mouth at Lake Tahoe. Lat. 39° 0·8′; Long. 120° 9′.

VIII. 24 Pyramid Peak collection; diorite; Pyramid Peak bears S. 50° E. and is 3 miles distant. Head of Blakeley Creek. Lat. 38° 52·3′; Long. 120° 12′.

IX. 93 Pyramid Peak collection; Glen Alpine Spring bear N. 40° W. and is ¾ mile distant. Lat. 38° 51·9′; Long. 120° 5·2′.

Under I in the table of analyses is given one of these granites of an unusually fresh type. It is a light-gray, hard, granular rock with an approximation to a porphyritic habit. Macroscopically are noted large quartz grains up to five millimeters in diameter, large grains and imperfect prisms of feldspar up to ten milimeters in length. Between these larger grains lie the remaining feldspar-quartz mass with somewhat finer grain. Biotite in foils up to three millimeters in diameter are scattered through the rock. Microscopically, the structure is almost allotriomorphic, the rock being principally made up of large, irregular and very interlocking grains of microcline, microperthite, and quartz. In the microline lie imbedded smaller grains and prisms of an acid plagioclase, as well as some quartz. Between the larger grains lie in places aggregates of quartz, microcline, albite, and oligoclase, also with interlocking structure. Biotite is sparingly present. The analysis may be calculated as follows:

		Per Cent.
SiO_2	18·23	
Al_2O_3	5·18	
K_2O	4·76	
$K\,Al\,Si_3O_8$		28·17
SiO_2	17·24	
Al_2O_3	4·89	
Na_2O	2·96	
$Na\,Al\,Si_3O_8$		25·09
SiO_2	1·05	
Al_2O_3	·93	
CaO	·49	
$Ca\,Al_2\,Si_2O_8$		2·47
P_2O_5	·10	
CaO	·13	
Cl	·02	
Apatite		·25

TiO_2	·14
SiO_2	·11
CaO	·10

Titanite	·35
Biotite	3·10
Magnetite	·61
Quartz	39·80
Water	·31
	100·15

From the total amount of potash 0·24 was tentatively subtracted for the biotite. The total lime, after subtraction of amount needed for titanite, was counted to $CaAl_2Si_2O_8$; the total soda as $NaAlSi_3O_8$. On basis of remaining Al_2O_3 a portion of the silica was referred to the biotite and half the amount of iron oxide and sesquioxide subtracted as magnetite. There remains then for the biotite:

SiO_2	1·25	40·32
Al_2O_3	·81	26·13
Fe_2O_3 / FeO	·62	20·00
MgO	·18	5·81
K_2O	·24	7·74
	3·10	100·00

This corresponds fairly well with a normal biotite.

A specimen from the south side of Pyramid Peak was subjected to a partial analysis (II), which shows it to be of practically the same composition as (I), though a little more of the anorthite molecule is present. The granite is on the whole very constant in mineral composition and it is believed that these analyses well indicate its average composition.

*Granodiorite.**—As mentioned before, the granodiorite is the prevailing rock, occupying a broad belt extending across the whole area from north to south. It is of a crumbling nature, falling an easy prey to the destructive forces of weathering and

* The name of granodiorite was first proposed by Messrs. G. F. Becker, H. W. Turner and W. Lindgren in 1892. References to the rock may be found in the following places:

Geologic Atlas of the U. S., Folios 3, 5, 11, 18, 29.

W. Lindgren: The Auriferous Veins of Meadow Lake, this Journal, III, vol. xlvi, p. 201, 1893; U. S. Geol. Survey, 14th Ann. Rep., pt. 2, p. 243; U. S. Geol. Survey, 17th Ann. Rept., pt. 1, p. 35.

H. W. Turner: U. S. Geol. Survey, 14th Ann. Rept., p. 478; U. S. Geol. Survey, 17th Ann. Rept., pt. 1, p. 724.

erosion. The outcrops are of rounded form, often weathering into huge detached boulders; the color is very light gray. The granodiorite is a medium to coarse-grained rock, the average diameter of the grain being 2 to 3 millimeters. The grayish quartz and white feldspar grains are of about equal size. The quartz is decidedly less prominent than in the granite, and the feldspar does not reach the dimensions attained in the latter rock. Black mica and hornblende are usually present in about equal quantities. The foils of the former reach 2 or 3 millimeters in diameter, while the hornblende is roughly prismatic, the crystals sometimes attaining 1 centimeter in length. By reason of this development of the hornblende, a somewhat porphyritic aspect may occasionally be obtained. Titanite is nearly always present in small isolated brownish grains. A little magnetite is also a constant accessory mineral. The appearance and composition of the rock is very constant over large areas, with only small variations in grain and in the quantity of hornblende and biotite. In a few places the quantity of hornblende diminishes and the rock then assumes a habit more similar to that of granite; thus, for instance, at Buck Island Lake, between Rubicon Peak and Rubicon Point and in the area east of Fallen Leaf Lake. Microscopical and chemical investigation shows the rock at this point to be a granodiorite, though rather rich in orthoclase.

Analysis III shows the composition of a typical granodiorite from the northwestern shore of Silver Lake. It is a light-gray granular rock composed of white or yellowish feldspar in grains and imperfect prisms, grayish quartz, biotite foils up to 1 millimeter in diameter, and a rather abundant dark-green hornblende in well-defined stout prisms up to 8 millimeters in length. Grains of brown titanite are also present.

The microscrope shows the structure typical for granodiorites: Very plentiful, roughly idiomorphic prismatic crystals of an acid plagioclase, sharply outlined foils of yellowish brown biotite partly decomposed into chlorite, and grains of imperfect prisms of ordinary brownish green hornblende, accompanied by a few grains of magnetite. These constituents are cemented by anhedral quartz, orthoclase, and a little microline. Titanite occurs in small grains enclosed in biotite. On the borders of the plagioclase and orthoclase a little micropegmatite often occurs. Some slight evidences of crushing are present in this rock, though such phenomena are in general very rare in the granodiorites.

As neither the hornblende nor the biotite has been analyzed, it is clear that no exact calculation of this analysis can be made. It is, however, possible to arrive at the approximate composition by means of the following calculation:

		Per Cent.
SiO_2	11·48	
Al_2O_3	3·27	
K_2O	3·	
$KAlSi_3O_8$		17·75
SiO_2	20·20	
Al_2O_3	5·74	
Na_2O	3·47	
$NaAlSi_3O_8$		29·41
SiO_2	5·14	
Al_2O_3	4·37	
CaO	2·40	
$CaAl_2Si_2O_8$		11·91
SiO_2	·42	
TiO_2	·58	
CaO	·40	
Titanite		1·40
P_2O_5	·12	
CaO	·16	
Cl	·02	
Apatite		·30
Magnetite		·84
Hornblende and biotite		12·79
Quartz		25·71
		100·11

For the hornblende and biotite there remains:

SiO_2	(4·50)
Al_2O_3	2·13
Fe_2O_3	1·13
FeO	2·00
CaO	·64
MgO	1·10
K_2O	·66
H_2O	·63
	12·79

The estimation is made in the following way: A small amount of potash and soda being first subtracted for the biotite and hornblende, the remainder was calculated as orthoclase and albite. Further, 1·20 per cent lime was tentatively subtracted from the total as belonging to the hornblende, and 0·56 per cent for titanite and apatite, the remainder being calculated as anorthite. The amount of magnetite is estimated. From the remaining silica 4·50 per cent was subtracted to approximately correspond with the Al_2O_3, and MgO available for biotite and hornblende.

The analysis is entirely typical for granodiorite and is extremely similar to the analyses of the granodiorite from Nevada City and Grass Valley, Nevada County.*

Under No. IV a partial analysis is recorded of a rock near the shore of Lake Tahoe, not far from the northern boundary line of the sheet. The rock is coarse granular, consisting chiefly of slightly reddish feldspar with much quartz. Hornblende and biotite are present in about equal quantities, but the hornblende occurs in small grains and prisms only. It was thought that this rock presented a certain similarity to the granitite and it was therefore analyzed, but the figures obtained indicate it to be a normal granodiorite. The microscope shows a few large carlsbad twins of microcline and microperthite; an abundance of imperfect prisms of plagioclase imbedded in anhedral quartz, orthoclase, microcline and microperthite, the latter two often as Carlsbad twins; well-defined foils of biotite, a little hornblende and a few grains of titanite.

Analysis V shows the composition of a granodiorite from the valley of the Rubicon, 2 miles south of the northern boundary line of the sheet. Macroscopically the rock is very similar to IV. Under the microscope the same normal granodiorite structure is apparent. As in IV much of the potassium feldspar cementing the plagioclase prisms is microcline. The analysis indicates a normal granodiorite.

Analysis VI shows the composition of the granodiorite 6 miles south of Silver Lake in Bear River canyon. The rock is normal except for the fact that the quartz is rather prominent in grains up to 6 millimeters in diameter and that the biotite predominates over the hornblende.

Under the microscope it is evident that the cementing orthoclase and microcline are rather abundant, but the granodiorite structure is well-defined. Titanite is abundant. The analysis shows a closer approach to the granitite than in any other of the rocks here examined; this is expressed in the high percentage of silica and potash, as well as in the relatively low percentage of lime. Still there is a wide gap between this rock and a normal granitite.

Analysis VII shows the composition of the granodiorite of

* 17th Ann. Rept. U. S. Geol. Survey, pp. 38 and 42.

Meeks Creek, Truckee sheet, a few miles north of the northern boundary of the Pyramid Peak sheet. Both in appearance and composition the rock is a normal granodiorite.

Comparing the analytical and microscopical results with the field notes, it is clear that the granodiorite, as it appears in the High Sierra, is a rock of well-defined and fairly constant composition, structure, and appearance. It is neither a normal diorite, nor is it a granite; it is clearly an *intermediate* type, occupying a place between normal quartz-mica-diorite and quartz-monzonite (Brögger).* All transitions toward diorite and, more rarely, toward granitite, may be found, but they are local and do not cover large areas, while the normal granodiorite is the prevailing rock of the Sierras. Comparing the type here described with the granodiorites of the many smaller areas enclosed in the slates on the western flank of the range, it can be stated that the latter as a rule approach more closely to the quartz-diorites, the percentage of lime being higher and the percentage of potash more often smaller than equal to that of soda. A few of these smaller granitic areas could, in fact, almost as well be indicated as quartz-mica-diorites. In the general habit, however, in the percentage of quartz, hornblende, and biotite, and in the constant presence of titanite, they are entirely similar to the granodiorites of the High Sierra. Microcline, not common in the granodiorites of the foothill region, occurs abundantly in those of the High Sierra.

Diorite and gabbro.—When the amount of hornblende and biotite in a granodiorite increases, it is usual to find the quartz and orthoclase relatively diminished in quantity and rock types more closely allied to normal diorites result. At the same time pyroxene frequently appears, and transitions into gabbro are formed. These more basic rocks in places form smaller areas enclosed in granodiorite or granite; more frequently they lie between the two rocks or on the contacts between granite or granodiorite and the schists. The rock in these areas is of a very variable structure and composition, ranging from a quartz-diorite to a gabbro, almost approaching a peridotite. The latter type is, however, rare. The normal diorite, such as occurs in the canyon of the south fork of the American River, is medium to coarse-grained, composed nearly entirely of hornblende and plagioclase. A little quarz, however, very frequently enters into the composition. Typical coarse-grained gabbros with large reddish gray basic feldspars and dark green

* Though it is often difficult in practice to separate the normal quartz-mica-diorite from the granodiorite, it would seem suitable to restrict granodiorite to the following limits: SiO_2 59—69 per cent, Al_2O_3 14—17 per cent. Fe_2O_3 1½—2¼ per cent, FeO 1½—4¼ per cent, CaO 3—6½ per cent, MgO 1—2½ per cent, K_2O 1—3¾ Na_2O 2½—4½.

uralitized pyroxene occur near Round Top and to the west of Slippery Ford, and are connected with the diorites by abundant transitions.

Normal syenites have not been recognized, but intermediate rocks of the composition of monzonites may occur in places; it does not appear practicable, however, to separate them from the diorites.

A normal diorite from the western slope of the Pyramid Peak range was partially analyzed (VIII). The rock is granular, dark grayish green, the grains, averaging two millimeters in diameter, consist of feldspar, dark green hornblende and a little biotite. The plagioclase, which does not exceed andesine in basicity, occurs in imperfect short prisms, occasionally cemented by a little orthoclase. There is no quartz. The mica is in well-defined yellowish brown foils, often including small feldspar prisms. The hornblende occurs in irregular grains, but is sometime roughly idiomorphic. Small grains of titanite are present. The structure is typically hypidiomorphic. The composition is that of a normal diorite, indicated by the high percentage of lime and soda and small amount of potash. The hornblende must contain much lime.

Analysis IX shows the composition of one of the intermediate rocks, occurring in a diorite area a couple of miles south of Tallac Peak. It is a coarse-grained, dark rock made up chiefly of hornblende, a little biotite and feldspar. It carries a considerable amount of orthoclase, and its composition corresponds nearly exactly to the monzonite from Mulatto, analyzed by Lemberg.*

The relation and succession of the granitic rocks.—The contacts of the granodiorite with the granite are sometimes sharp, but more commonly much pegmatite, diorite and granite-porphyry occur on them, making them indistinct. In other places transition forms may be observed, such as at the northern end of Pyramid Peak granite area. Especially interesting are the exposures along the Pyramid Peak range. Wherever branches or bays of granodiorite reach into the granite a great variety of lighter or darker dioritic rocks make their appearance, in places bordering sharply against the granodiorite, at other times forming extremely graded transitions into it. Near the contacts of the schist areas it is quite common to find the granodiorite gradually growing darker and changing to diorites. The contacts between the granite and the diorite are usually sharper, and south of the south fork of the American River abundant well-defined dikes of granite occur in the diorite.

* W. C. Brögger: Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Süd Tyrol, p. 62.

There is no doubt that all of the granitic rocks are later than the altered sedimentary rocks and the augite-porphyrite, but it must be confessed that in spite of good exposures the evidence as to the relative age of the granite, granodiorite, diorite and gabbro is not decisive, and even in some respects contradictory. There is some evidence, based on the general form of the Pyramid Peak granite area and the manner in which it includes the slate fragments, as well as on the occurrence in it of dikes of a rock allied to granodiorite, tending to show that the granite was intruded earlier than the granodiorite. On the other hand, it is unquestionably true that the granite of the southwestern corner sends out numerous dikes into the diorite of the south fork of the American River; this diorite again shows numerous local transitions to apparently normal granodiorite, so that if it be conceded that this diorite area is of approximately the same age as the main granodiorite mass, it would follow that the granite would be later than the granodiorite. The probability is that the intrusion both of the granite and of the granodiorite was accompanied by minor intrusions of acid and basic magmas, and that there are diorites, pegmatites and aplites of the age of the granodiorite and of that of the granite, the latter being the older rock; only on this supposition can the contradictory testimony be explained; the diorites of the canyon of the South Fork and in the smaller areas along the western boundary would then belong to the period of granitic intrusions, while those of Round Top and the Pyramid Peak range would belong to the granodiorite.

Washington, D. C., Jan., 1897.