NOTES ON SOME ERUPTIVE ROCKS FROM GALLATIN, JEFFERSON, AND MADISON COUNTIES, MONTANA.

By George P. Merrill,

Curator of the Department of Geology.

The rocks described below were collected by Dr. A. C. Peale and the writer, mainly during the seasons of 1887, 1888, and 1889. The writer's own observations were limited to two brief seasons in 1887 and 1889. The region covered is quite extensive, comprising upward of 200 square miles as shown on the Three Forks sheet of the U. S. Geological Survey, and much of it difficult of access. In many instances doubtful points regarding the occurrence and association of certain masses could have been decided only by a second visit to the locality, after the first series of specimens collected had been submitted to study in the laboratory and we were in a condition to avail ourselves of the knowledge thus gained. Unfortunately, this we have been unable to do, and while in many instances we are led to infer that somewhat variable rock types are but widely separated facies of the same magma, we have no absolute proof of the same. Eruptive rocks of a wide geological range and of widely varying character are abundant throughout the region. Here I shall attempt to describe only those of greatest petrological interest. A few of them have been noted in a preliminary way in Bulletin No. 110, U. S. Geological Survey, 1894.

In describing the rocks they will be taken up as found along the main routes traveled, in the following order: (1) From the foothills north of Gallatin Peak, along the valley of the Gallatin and East Gallatin to the Horse Shoe Bend of the Missouri River; (2) from Three Forks southward, up the Madison Valley and into the foothills on either side as far as the Wedge and westward to Virginia City; (3) from the same point, southwestward, up the Jefferson River as far as South Boulder Creek. The numbers referring to specimens are those given in the catalogues of the U. S. National Museum.

Enstatite andesite.—Head of small creek west of Salesville, west side of Gallatin River. A dense, dark-brownish, nearly black rock, without macroscopic constituents of such dimensions as to be evident to the unaided eye. In thin sections, a dense, partially devitrified base filled with opaque granules of iron ore, pyroxene, and feldspar microlites, and carrying abundant small elongated phenocrysts of nearly colorless pyroxenes. These without evident pleochroism, and orthorhombic in crystallization. Hence, doubtless, enstatite. Rarely small augites occur. In a few instances the latter mineral occurs in the form of a narrow zone about the enstatites, as described by Iddings.* The feldspathic constituents are confined wholly to microscopic forms in the ground mass.

Basalt (?).—Small outcrop in Cretaceous, some 2½ miles southeast from Bozeman, east side of Bozeman Creek.

Macroscopically the rock (No. 38598, U.S.N.M.) is compact, dull, dark-green, almost black, thickly studded with rounded olivine in sizes up to 5mm. in greatest diameter, and numerous smaller green augites; none of these porphyritic constituents are prominently noticeable, owing to the similarity of their colors to that of the rock containing them. A chloritic alteration has set in, attacking both the minerals mentioned as well as the groundmass, and this, together with the other features mentioned, imparts to the stone the appearance of an olivine rich peridotite in which the process of serpentinization has far advanced. The olivines in alteration have sometimes given rise to deep red ferruginous products which are visible to the unaided eye.

As viewed in the thin section and by ordinary light the rock consists of a clear, colorless, groundmass with an illy defined radiate structure, often pierced in every direction by innumerable minute needle like colorless forms, and bearing abundant black granules of iron oxides, through which are interspersed countless small, idiomorphic, very light-greenish pyroxenes. Abundantly distributed throughout this groundmass are the larger olivines and less abundant augites already noted. A chloritic alteration has set in, attacking the augites, olivines, and colorless groundmass alike, though the augites are the least attacked. The most striking feature of the rock is this colorless groundmass, which appears under a low power (80 diameters) and between crossed nicols, as illy defined fan-shaped aggregates of elongated crystals, over which the dark wave sweeps gradually as the stage is revolved. There is apparently little, if any, true amorphous, glassy, or felsitic base, or microlitic matter. The field, on the contrary, between crossed nicols, breaks up into somewhat illy defined polygonal areas, which become light and dark as the stage is revolved, but in no case give satisfactory extinction angles or interference figures. The structure, in short, is that of an imperfect radial spherulitic aggregate, such as is common

*Eruptive Rocks of Electric Peak and Sepulchre Mountain. Ann. Rep. U. S. Geol. Survey, 1890–'91.

in the quartz porphyries and liparites, but such as I have never seen in rocks so basic in composition as is this.

Under a power of 390 diameters the individual columns of the aggregate were found in some instances to be almost wholly without action or polarized light, or again polarized in light and dark colors, some of the better defined giving extinctions parallel with or ranging but a few degrees from the axis of greatest elongation, and eminently suggestive of feldspars; in a few instances indefinite interference figures were obtained, but only such as might be due to tensile strain on isometric or amorphous bodies.

The results of purely optical investigation proving thus unsatisfactory, an attempt was made at a separation of the mineral by pulverization and precipitation in the iodide of mercury and potash solution.

This proved a work of great difficulty, owing to inclusions of iron ore and the chloritic alteration which had set in. After repeated attempts a powder coming down at a density of 2.56 was obtained in sufficient quantity for analysis. This yielded Mr. Eakins, of the U. S. Geological Survey, results as follows:

	Per cent.	Ratio.
SiO_2	65.23	1.02
Al_2O_3	17.48	.17
Fe_2O_3	.98	....
CaO	3.08	.05
MgO	2.02	.05
K_2O	4.63	.05
Na_2O	3.79	.06
H_2O	1.90	.11

Such a composition is evidently that of a mixture, and may perhaps be explained on the assumption that it consists of two feldspars (sanidin and a soda-lime variety) and an aluminous pyroxene.

The pyroxenic constituent, as above noted, occurs both in porphyritic forms and as a constituent of the groundmass, sometimes in good idiomorphic forms and again as rounded and irregular granules scattered singly and in clustered aggregates. Except in the matter of size the individuals of the two generations are indistinguishable from one another, are of a light greenish color, not noticeably pleochroic, and give extinction angles on clinopinacoidal sections as high as 41°. The larger porphyritic forms are sometimes 3 or 4 mm. in diameter, while those of the groundmass are, as a rule, not over 0.05 mm., and at times sink to 0.02 mm.

By pulverization and separation by the iodide of mercury and potash solution, and subsequent digestion in hydrochloric acid and potassic carbonate, a sufficient supply of the pryoxenic constituent was obtained for a complete analysis. This, submitted to Mr. Eakins, yielded results as given in column I, below. In columns II, III, and IV are given for comparison, chrome diopsides out of the peridotites of (II) Lake of Lherz, (III) Dillgegend, and (IV) Piedmont, as given by Teall.*

	I.	II.	III.	IV.
SiO_2	52.50	53.63	50.443	54.25
Al_2O_3	2.26	4.07	5.105	6.07
Cr_2O_3	1.07	1.30	1.403	1.48
Fe_2O_3	2.05	} 8.50	9.696	7.49
FeO	2.47			
MnO	Trace.	....	....	....
CaO	21.70	20.37	14.629	17.75
MgO	17.11	12.48	17.418	13.63
K_2O	.07	....	....	....
Na_2O	.35	....	....	....
H_2O	.64	....	....	....
	100.22	100.35	98.694	100.67

A bulk analysis of the rock yielded Dr. Chatard as follows:

	Per cent.		Per cent.
SiO_2	46.90	MgO	20.98
TiO_2	0.41	K_2O	2.04
P_2O_5	0.44	Na_2O	1.16
Al_2O_3	10.17	H_2O at 120° C	1.04
Cr_2O_3	0.33	H_2O at red heat	4.38
Fe_2O_3	1.22		
FeO	5.17		100.54
MnO	0.10	Specific gravity	2.86
CaO	6.20		

The composition, as above indicated, is quite unlike that of any rock I have yet seen described. So far as indicated by the silica percentage, the rock might belong to the diabase or basalt group, but the magnesia percentage is far higher than I have ever seen reported in rocks of this class, and from either of which it differs structurally. It is equally difficult to consider the rock a peridotite, since not only is the silica percentage above that of a normal peridotite, but the high percentage of potash and soda (confined wholly to the minerals of the groundmass) indicate a very considerable quantity of sanidin and soda-lime feldspar.

To gain a further insight into the composition of the rock, fragments from the same mass as that used in the above bulk analysis were subsequently sent to the laboratory with the request that an analysis be made of that portion soluble in hydrochloric acid. The results are given below.

Amount of rock soluble in HCL 48.7191 per cent. This yielded:

	Per cent.	Ratio.	
SiO_2	42.87	....	.714
Al_2O_3	7.98	.077 }	.105
Fe_2O_3	4.53	.028 }	
FeO	8.78	.122 }	
MnO	Trace.	....	1.001
CaO	2.07	.037	
MgO	33.69	.842 }	
Alkalies	Trace.	....	
	99.92		

*British Petrography, p. 89.

It is evident that this is essentially olivine with a mixture of iron oxides and decomposition products.

In the summer of 1889, while working on Bear Creek, in the foothills just east of and overlooking the Madison Valley, some 45 miles in a direct line to the southwest, inconspicuous outcrops of an intrusive were discovered, which were at once seen to be nearly identical. On returning to Washington thin sections were prepared, from an examination of which the first impressions were abundantly confirmed. Certain of the slides were indistinguishable from those of the Fort Ellis rock; others differ in showing a groundmass more crystalline and a somewhat smaller proportion of the porphyritic olivines. The base proper is here a nearly colorless glass occurring only in the interstices of a crowd of small, lath-shaped feldspars, mainly a plagioclase variety, though certain nonstriated forms may be sanidin.

Throughout this groundmass are scattered innumerable black granules of iron ore and the olivines and augites as already described. The rock has an aspect more nearly like that of normal basalt, but differs in the character of its pyroxenic constituent and the abundance of its olivines. A bulk analysis of the rock by Dr. Chatard yielded results as in I below. II is the Fort Ellis rock reproduced for the purposes of comparison.

	I.	II.		I.	II.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
SiO_2	49.13	46.90	CaO	5.68	6.20
TiO_2	.42	.41	MgO	17.21	20.98
P_2O_5	.38	.44	K_2O	2.24	2.04
Al_2O_3	9.05	10.17	Na_2O	2.01	1.16
Cr_2O_3	.39	33	BaO	.05	....
Fe_2O_3	3.57	1.22	H_2O at 110° C	.84	1.04
FeO	5.05	5.17	Ignition	3.50	4.38
MnO	.15	.10			

The close relationship of this rock to the dark eruptive between South Boulder and Antelope Creek is mentioned on page 673.

Augite andesite.—Hills east of Fort Ellis. As here displayed, this is a coarse, dark-gray rock (No. 38597, U.S.N.M.), full of vesicles and amygdules of all sizes up to an inch or more in diameter. Its only macroscopic constituent, aside from the secondary minerals comprising the amygdules, is a dark-greenish augite which occurs as scattering crystals, at times four or five millimeters in diameter.

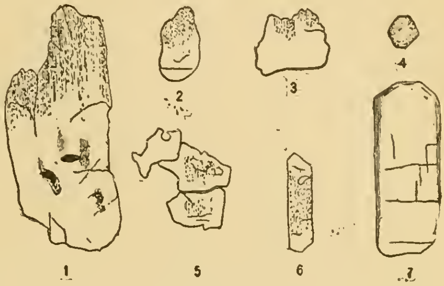
Under the microscope the rock presents an exceedingly dense microlitic groundmass of lath-shaped plagioclases, augites and iron oxides in which are embedded widely-scattered porphyritic plagioclases, and more numerous augites with an occasional dusky apatite. The augites, although comparatively fresh appearing, are rarely in well-developed crystals, but occur as very irregularly corroded and rounded forms full of inclosures of the base and of magnetite particles. In the section they are of a light-greenish color. The porphyritic plagioclases are small and widely scattered.

As already noted, the rock is quite vesicular, the vesicles being wholly or in part filled by white, dull red, and greenish zeolites. There is also a smoky-brown, undetermined mineral which occurs only as a narrow border of minute radiating fibers projecting inward from the cavity wall and visible only with the microscope. The white mineral is by far the most abundant of all the secondary constituents. When viewed in the section and between crossed nicols this is in some cases quite isotropic, and in others polarizes faintly in dull colors, the field being divided into polygonal areas over which the shadows play, alternately as the stage is revolved. The appearance is such as to suggest at once the anomalous analcite described by Ben-Saude,* although in the present case the optical peculiarities are less pronounced. An examination of the hand specimen reveals in the larger cavities many small, nearly colorless trapezohedra of the mineral which have a specific gravity of 2.7, as determined by a Westphal balance, and which fuse quietly to a clear, colorless glass at 2.5 of Dana's scale. These characteristics demonstrate the mineral as analcite beyond doubt. The dull-red zeolite is quite colorless and isotropic in thin sections; examined in the hand specimen, with a pocket lens, it shows a rhombohedral cleavage, and the small splinters obtainable were found to give the blowpipe reactions of chabazite. Other of the amygdules, from 1 to 3 mm. in diameters are filled by a hard and very brittle dull, dark-brown mineral which always breaks away during the grinding of the section, but which gives blowpipe reactions for hematite.

Hornblende andesite.—From small outcrops on ridge east of Fort Ellis. This is a compact, light-gray rock (No. 62400, U.S.N.M.) with macroscopic brown hornblendes and whitish feldspars. Under the microscope it shows a compact groundmass of feldspar microlites and opacite grains carrying abundant porphyritic hornblendes, plagioclases, and smaller light-green augites. The hornblende is by far the most abundant of the porphyritic constituents, and is readily recognizable by its well-defined crystallographic outlines, though in nearly every case its substance has completely changed to the characteristic opacite granules. The plagioclases are very muddy through impurities and decomposition. The most interesting feature of the rock is the abundant sprinkling of large brick-red pleochroic apatites, as shown in figs. 1–7. These occur in all sizes up to 0.6 mm. The colors vary from colorless through yellow to brick-red, the deeper color being due to innumerable inclosures, which are represented by black dots in the figures. The distribution of the color is not uniform through the whole mass of the crystal, but, as in figure 2, a crystal may be bright yellow at one end and red at the other, or, as in figure 6, red in the center and fading out gradually to colorless at the ends. In the cross section shown

* Neues Jahrb. Vol. II. 1882, p. 41.

in figure 4 the red color is zonal, while the interior is yellowish. Prismatic sections are all plainly pleochroic, being red when the light passes through parallel to the vertical axis and light yellow when at right angles to this axis. A not less interesting feature is the amount of corrosion from the fluid magma which the larger crystals have undergone and which is shown in the figures, especially Nos. 1, 2, 3, and 5. From the fact that the apatite is one of the first minerals to separate out, such results are not unexpected, but, so far as I am aware, have before not been observed to the extent here indicated. This is presumably due to the small size of the crystals, as usually occurring.



Figs. 1–7.

APATITES IN HORNBLENDE ANDESITE.

From specimen No. 38597, U. S. N. M

The large forms, like figure 7, show a faint cleavage parallel with the prism.

Intrusive rocks: Lamprophyrs.—From the lower part of the Flathead shales, north of the East Gallatin River. The rocks described below outcrop at the base of the sandy shales that lie just above the basal quartzite of the Flathead formation, as exposed in the hills about one mile north of the East Gallatin River. They have been traced eastward about three miles from the most western exposure, where they pass beneath the lake beds, but show again where the Flathead shales cross Dry Creek, three miles farther to the northwest. In all these outcrops they hold the same relation to each other. The upper rock is usually from six inches to a foot in thickness, but sometimes thins out to even less than six inches. It lies in close contact with the shales, is dark gray, nearly black, in color, tough, fine grained, and compact, and shows to the unaided eye only occasional small black crystals evidently belonging to a mineral of the pyroxene group, and numerous small reddish amygdules. This is succeeded by, and seems to pass gradually into, a zone of decomposed material, which carries numerous scales of black mica, and which is traversed in a direction parallel with the sheets by several veins from one to two inches in width of a light pinkish feldspar. The lower or underlying rock, which also seems to pass into this zone of decomposed material, appears to the unaided eye as a holocrystalline mass composed essentially of elongated light pink feldspars and abundant small, often radiating, folia of black mica. The microscopic and chemical properties of this rock are given below. Although the upper and lower rocks belong apparently to two quite distinct types, their constant association, even when in sheets but a few inches thick, is somewhat confusing. Geologically they appear as one and the same body; from a petrographic standpoint they differ radically. It is useless to speculate on their possible relationships until further outcrops are found, or until, by digging or blasting, the nature of the intermediate zone of decomposed material is made apparent. The total thickness of the eruptive sheet or sheets is about 45 feet.*

Porphyrite (?).—The upper sheet. Macroscopically, this (No. 38599, U.S.N.M.) is a very tough and hard dark gray, nearly black, aphanitic rock bearing abundant small pseudo-amygdules of a dull red or yellowish green color, and with but rarely a black porphyritic mineral sufficiently developed to suggest a member of the pyroxene or amphibole group. In the thin section the rock was found so completely altered that it was only after repeated sections had been cut from samples from various portions of the outcrops that anything like a satisfactory idea of its original nature could be learned. Sections of the freshest samples obtainable show under the microscope a nearly colorless devitrified base, impregnated with innumerable small, sometimes mere dust-like particles of opacite and elongated yellowish mica-like needles in places so abundant as to form a truly feltlike groundmass.

Scattered thickly throughout this groundmass are numerous pseudo-amygdules of calcite, chloritic, and ferruginous substances, and occasional badly shattered, imperfect, and greatly decomposed augites.

The amygdules are due wholly to the decomposition of porphyritic augites and olivines, as can be determined by occasional still quite perfect crystal outlines in the least decomposed portions of the rock, and are in no case true gas cavities filled with secondary minerals. In a few instances the outlines of these cavities were such as to suggest that the decomposed mineral may have been a feldspar, but this can not be determined for a certainty. Sections from the more highly altered portions of the rock exhibit interesting changes. The groundmass here (No. 38599, U.S.N.M.), as above, consists of the colorless base so filled with the mica (?) needles as to be almost felsitic, but the porphyritic augites are replaced wholly by a light greenish-blue, faintly dichroic, somewhat fibrous hornblende. Although optically these secondary forms are undoubted hornblendes giving maximum extinctions on clinopinacoidal section of 15°, their outlines, when sufficiently perfect for measurement, are still, in part at least, those of augite. In a number of cases the prism outlines on cross sections were measured with results varying from 87° to 89°. The cleavage in such cases was somewhat imperfectly developed, but I was able to obtain measurements of the obtuse angle varying from 123° to 125.5°, which is, perhaps, as close as can be expected in sections cut at haphazard. Although the hornblendes are so plainly paramorphic, I have found in no case traces of an augitic nucleus, the change being in all cases complete.

Chemical analysis of so highly altered a rock can be regarded as

* Bull. U. S. Geol. Survey No. 110, pp. 49, 50.

merely suggestive. The following results were obtained by Mr. Eakins on a sample in which the augitic alteration thus described was complete:

	Per cent.		Per cent.
SiO_2	49.47	CaO	9.30
TiO_2	.21	MgO	10.86
Al_2O_3	12.15	K_2O	2.42
Cr_2O_3	Trace.	Na_2O	2.08
Fe_2O_3	1.93	H_2O	4.14
FeO	4.07	P_2O_5	.37
MnO	.10	CO_2	3.31
BaO	.03		

Making due allowances for the various changes attending decomposition, the rock, it will be noted, agrees closely with that from Cottonwood Canon (No. 38596, U.S.N.M.) and Boulder Creek (No. 62409, U.S.N.M.), to be noted later (p. 670).

The association of this rock with that next to be described is peculiar and needs further investigation.

Mica syenite.—Underlying the above. In the hand specimen the rock (No. 38600, U. S. N. M.) appears to the unaided eye as a holocrystalline mass of pink lath-shaped feldspars interspersed with very numerous long, slender, and at times radiating needle-like folia of black mica. As seen under the microscope the structure is quite simple, consisting of a holocrystalline aggregate of badly kaolinized sanidins, lath-shaped plagioclases, scales of mica, scattering granules of iron oxide, apatite needles, and in the interspaces, secondary calcite, plagioclase, and, rarely, quartz.

The most interesting feature of the rock is the almost constant intergrowth of the sanidins with plagioclase, the effect being in the section as if each crystal of plagioclase was set in a frame of orthoclase, as already described and figured in Bulletin 110, U. S. Geological Survey. Unfortunately, in the sample at hand, both feldspars are so badly decomposed that their optical properties are greatly obscured. The plagioclase alteration gives rise to innumerable minute flecks of a silvery white micaceous mineral, and in many cases the twin structures have become entirely obliterated; the potash feldspar has become brown muddy, and opaque, resembling the orthoclase of granitic rocks, and at times acts scarcely at all upon polarized light. A partial analysis of as fresh a sample of the rock as could be obtained, yielded Dr. Chatard results as follows: Silica, 58.88 per cent; potash, 5.18 per cent; soda, 3.46 per cent. The rock is undoubtedly a phase of the syenitic lamprophyre, which was later found in the vicinity of Antelope Creek (p. 671).

Porphyrite.—Intrusive sheets between Dry Creek and Nixons Basin. The rock here is evidently identical with that of the lower sheet of Cottonwood Creek, though the sample collected by Dr. Peale is so badly decomposed that little can be made from it.

Augite porphyrite.—This rock (No. 38596, U.S.N.M.) as displayed in the deep ravine of Cottonwood Creek is dark-gray and coarsely porphyritic, consisting of large and very perfect coal-black augites embedded in a dark-gray, almost holocrystalline feldspathic groundmass. Toward the central portions of the sheet the mass is much the more coarsely crystalline, and through a kaolinizing of the feldspars falls away to a coarse sand. From this sand were picked out in considerable number, still fresh augites in sizes up to eight mm. in length. These are usually elongated in the direction of the vertical axis, though sometimes in short and stout forms of a diameter fully equal to their length, the crystals having the common form ∞P; $\infty P \bar{\infty}$; $\infty P \grave{\infty}$, and P. Twin forms are also common, the more abundant form being that in which $\infty P \bar{\infty}$ is the twinning plane; more rarely occur knee-shaped and clustered forms, evidently twinned after $-P \bar{\infty}$ and $P\grave{2}$.

Approaching both upper and lower contact, the rock gradually becomes firmer and more compact until at last the groundmass is quite aphanitic, though the porphyritic augites still retain their relative size and abundance, appearing on a freshly broken surface of a light, sage-green color. At the line of contact with the shale the rock has the appearance of a brownish, amorphous base, thickly sprinkled with porphyritic augites and feldspars closely cemented to the shale.

Under the microscope the coarser portion of the rock shows an almost holo-crystalline groundmass of lath-shaped feldspars, small augites, scales of brown mica, iron ores, and a large amount of secondary chloritic matter and calcite in which are embedded porphyritic plagioclase feldspars and the large idiomorphic augites already noted. The amount of unindividualized base is very small, and is represented only here and there by small, wedge-shaped areas of greenish, chloritic, decomposition products. In places these are wholly lacking, and the rock assumes the panidiomorphic structure of a diabase.

The porphyritic augites, as seen in the section, are of a very light-green color, not perceptibly pleochroic, and give extinction angles on clinapinacoidal sections as high as 43°. They carry inclosures of iron ore, brown mica, apatite, and glass. The feldspars belonging to the first generation, that is, the porphyritic forms, are all triclinic, with step-like ends and abundant twin striæ. They are somewhat decomposed, giving rise to chloritic and other secondary products.

The only other porphyritic constituent is a greatly decomposed olivine occurring in widely scattered forms, and evidently a nonessential constituent. The decomposition has gone so far that in the majority of cases the resultant forms are no longer recognizable. In a few instances the crystal outlines are still preserved and show steep domal faces and irregular fracture lines, unmistakably those of olivine. The product of the decomposition is in some cases a dull green, chloritic mineral; in others, a dull red, ferruginous amorphous product, accompanied in both cases by abundant calcite. The latter forms are frequently macroscopically evident on a freshly broken or a polished surface, appearing as dull red areas 1 to 2 mm. in diameter, surrounded by a narrow border of the white calcite. In none of the many sections examined am I able to find even a trace of unaltered olivine.

The feldspars of the groundmass are, in part at least, a plagioclase variety, as shown by the numerous twin striæ. There are, however, abundant clear glassy forms appearing in the section in the form of stout rectangular areas, which in some cases give extinction angles exactly parallel and in others inclined a few degrees from the axis of elongations. These are assumed to be orthoclase, an assumption apparently borne out by the large percentage of potash shown in the analysis. The augites of the groundmass have the same color as the porphyritic forms, but occur in idiomorphic, and also in imperfect, and often sharply wedge-shaped and angular forms filling the interstices of the feldspars. The brownish mica occurs only in small and very irregular shreds associated with secondary chloritic material.

Approaching the line of contact the groundmass becomes more dense, but still retains its largely crystalline character. The porphyritic augites here are of a light sage-green color and show very perfect crystal outlines. They are, however, much more decomposed than those in the coarser and less compact portion, presenting a mass of rounded and angular pale augite fragments, interspersed with calcite, iron oxides and undeterminable decomposition products of a dirty white color. At the immediate line of contact with both over and underlying shales there is a narrow band, from 3 to 6 mm. in width, of a brownish color, consisting of the augites and feldspars of the first generation imbedded in a wholly or partially devitrified base, which remains always light between crossed nicols, and shows a mass of illy defined rounded and elongated globules, over which play imperfect and distorted black crosses as the stage is revolved. Both the feldspars and augites are here replaced by calcite pseudomorphs. The shale itself is strongly injected with calcite for the distance of a few millimeters from the line of actual contact. The line of separation between the shales and eruptive rock is in all cases perfectly sharp, the fused material having flowed over and around the particles of quartz and feldspar in a manner implying a high degree of fluidity. Contact metamorphism of even so large a mass injected in a highly fluid condition, and cooling so slowly as to become almost holocrystalline, is here reduced almost to a minimum, owing to the refractory nature of the materials of which the shales are composed. Thin sections show these to be made up of small fragments of quartz and feldspar with but a small amount of intersticial space now occupied by secondary silica having the same crystallographic orientation as the adjacent quartz granules, and by very minute, needle-like flecks of silvery white mica, evidently developed from the small amount of original amorphous cement. The shale is, therefore, no longer at this point an agglomerate of fragments adhering by means of an amorphous cement, but is a true crystalline rock, the original fragments forming proportionally large nuclei to a mass of crystalline granules whose regular growth has been interrupted by mutual interference. How much or how little of this change is due to the injected rock it is impossible to say.

Chemical analysis of as fresh a sample of the eruptive as was obtainable from near the central portion of the sheet yielded Mr. Eakins results as follows:

	Per cent.		Per cent.
SiO_2	52.33	MgO	6.73
TiO_2	.14	K_2O	3.76
Al_2O_3	15.09	Na_2O	3.14
Fe_2O_3	4.31	H_2O	2.68
FeO	4.03	P_2O_5	1.02
MnO	0.09		
BaO	0.07		100.45
CaO	7.06	Specific gravity in mass	2.785

Considering all the potash in the above as belonging to the orthoclase and the soda to the plagioclases, these results can be reduced readily to the following proportions:

	Per cent.
Potash feldspar	22.24
Soda-lime feldspar	35.67
Augite, olivine, and mica	31.46
Iron ores, apatite, and decomposition products	10.63

Such calculations must, of course, be accepted only with a considerable degree of allowance. It is probable that a portion of the potash belongs to the plagioclase feldspars, and, without doubt, a small amount to the mica, for which no allowance whatever has been made. This last amount would, however, be trifling. A safer but less definite calculation is as follows:

	Per cent.
Feldspars	58.00
Augite, olivine, and mica	32.00
All other constituents	10.00
	100.00

The above, I believe, represents the proportional qualities of the various constituents as nearly as it is possible to obtain them.

To the west of the outcroppings of the sheet occur rather inconspicuous outcroppings of a darker, more compact rock with macroscopic olivines and augites in macroscopically recognizable forms. (No. 38516, U.S.N.M.) This is described in detail in connection with the basic eruptive overlying the mica syenite between Antelope and South Boulder creeks (p. 671).

During the season of 1886 Dr. Peale brought in from the northwest side of the lower valley of Cottonwood Creek, and labelled as from the "Upper dike," a small specimen of badly weathered, fine grained, light gray rock, thickly studded with small folia of black mica and minute augites. Under a low power the rock appears almost holocrystalline and composed of lath-shaped, short, stout interlocking feldspars, light greenish augites, and scales of brown mica. The feldspars are all muddied through decomposition and optical determinations are very unsatisfactory. A portion of them show twin striæ; others show none and are presumably in part sanidin.

The augites are all small (one-third mm. in greatest diameter), and as a rule in imperfect and fractured forms. Cross sections, however, frequently show quite perfect outlines. They are very light greenish in color in the section. The mica is reddish-brown, strongly dichroic, and occurs in irregular shreds, in very perfect hexagonal tablets, as a narrow border about the iron ores, and in a few instances was observed a like border about elongated augites.

A high power shows the interstices of the feldspars occupied by a colorless isotropic substance or a very light green chloritic material evidently derived therefrom. When an uncovered slide is treated with hydrochloric acid there are shortly produced abundant cubes of sodium chloride. So abundant were these cubes that careful search was made for nepheline or sodalite, but with unsatisfactory results. The cavities left in the slide after treatment with hydrochloric acid presented in no cases the outlines of any crystallized mineral, but are in all cases irregular areas scattered promiscuously throughout the mass of feldspars. For the time being the true nature of the isotropic mineral which gave rise to these was a mystery, but in the light of subsequent observations there seems little doubt but that they are of sodalite and the rock a phase of the mica and augite bearing syenitic lamprophyres, described later (p. 671). A partial analysis of the rock yielded Mr. Eakins results as follows:

	Per cent.
SiO_2	54.29
Al_2O_3	18.47
Fe_2O_3	5.67
CaO	3.69
MgO	3.98
K_2O	5.92
Na_2O	4.13
	96.15

Augite porphyrite.—Intrusive sheet some sixty feet in thickness just above Horse Shoe Bend of the Missouri River. In strike and dip it follows the Cretaceous sandstone in which it lies, cutting across the beds only very slightly, if at all. It is well exposed in the bluffs on the west side of and facing the river. Both upper and lower contact are here readily found.

The rock (No. 62410, U.S.N.M.) is evidently identical with the main eruptive at Cottonwood Creek, Gallatin County, some 6 miles to the southeast, and which was called an augite porphyrite in Bulletin No. 110, U. S. Geological Survey. (See above.) Like that rock, it is dark greenish and at times nearly black in the least decomposed samples and thickly studded with stout idiomorphic augites of all sizes up to 10 mm. in length. Near the line of contact the rock is almost aphanitic, but shows under the microscope abundant porphyritic augites and plagioclases in good idiomorphic forms in a felsitic base. Receding from the line of contact the rock grows gradually coarser, and thin sections show the rate of cooling to have been sufficiently slow for an abundant development of a second generation of plagioclases. Whether any glassy base remained can not now be determined, as everything is obscured by decomposition products. As with the Cottonwood Creek rock, there are abundant iron oxides in large grains, numerous small scales of dirty brown mica and occasional apatites. The augites occur in simple, and twinned and in clustered *glomero-porphyritic* forms.

Quite a number of the porphyritic feldspars show beautiful zonal structure and no twinning. Such are assumed to be sanidins, an assumption borne out in the Cottonwood Creek rock by the high percentage of potash shown in the analysis. The microstructure varies from hypocrystalline porphyritic to holocrystalline porphyritic with a panidiomorphic groundmass.

The only difference which can be considered at all essential between this rock and that of Cottonwood Creek lies in the development in the former of abundant olivines, which, however, are now recognizable only by the outlines of the dirty yellow brown chloritic decomposition products. A few of these were present in the Cottonwood Creek samples, but they were so scattering as to be deemed nonessential.

Hypersthene andesite.—Northwest of Red Bluff. This is a very fine-grained and compact nearly black rock (No. 66929 U.S.N.M.) breaking with an irregular choncoidal fracture and in which none of the constituents are developed in such size as to be determined by the unaided eye.

In the thin section the rock shows an amorphous, glassy base so charged with opacite dust as to be itself almost black and opaque, and bearing very numerous irregularly lath-shaped plagioclases and abundant crystals of a colorless pyroxene. More rarely occur olivines which are in all cases altered to a greenish yellow chloritic product.

The plagioclases are many of them imperfectly secreted from the base and their borders are thickly charged with the black opacite. The pyroxenic mineral is in nearly colorless, very imperfectly outlined elongated forms, often broken transversely and rarely of such size as to show in basal sections prismatic cleavage lines cutting at nearly right angles.

The dichroism is very faint and in the larger forms only could it be made out with any degree of certainty: ċ, very light greenish; ǎ, very faintly reddish, and b̄, faint yellowish, scarcely at all reddish. The mineral shows extinction in all cases parallel and at right angle with the *c* axis; it is biaxial, negative, and sections cut at right angles to the *a* axis show the immergence of a bisextrix with the plane of the optic axes in that of the *a* and *c* axes. Dispersion $\rho > v$. These characteristics alone are sufficient to demonstrate the true character of the mineral.

Mr. J. S. Diller, of the U. S. Geological Survey, has kindly loaned me sections of the hypersthene basalt described by him from Mount Thielson, Oregon,* from an examination of which I am able to make the following comparisons: the two rocks have essentially the same structure, but differ in that the sample from Red Bluff shows a relatively smaller number of porphyritic plagioclases, a far larger proportion of hypersthene, and also a larger proportion of plagioclases in the groundmass, necessitating therefore a smaller proportional amount of glassy base. The feldspars of the Oregon rock are much better developed than in that of Red Bluff and the "opacite" particles much larger and more distinctly granular. Bulk analysis of the Red Bluff rock by Mr. Eakins yielded results as below. In column II is given that of the Mount Thielson rock, permission for the use of which has been kindly granted by Mr. Diller.

	I.	II.
	Per cent.	*Per cent.*
SiO_2	59.48	55.68
TiO_2	0.93	....
Al_2O_3	16.37	18.93
Fe_2O_3	3.21	....
CaO	4.88	7.99
MgO	3.29	4.86
FeO	3.17	8.73
BaO	0.13	....
Na_2O	3.30	2.12
K_2O	2.81	.48
P_2O_5	0.41	....
Ign	2.01	.60
	99.99	99.39

From this it would appear that the rock is much more nearly related to the andesites than the basalts, although on purely structural grounds it seems more like the latter.

Peridotite, var. Wehrlite.—Hills three miles northwest of Red Bluff. This rock (Nos. 70675 and 73162, U.S.N.M.) occurs intrusive in the gneiss and forms on the present surface only several small, nearly circular, inconspicuous outcrops, standing but a few feet above the surrounding gneiss and broken into rough, angular blocks weathering brownish. Two textural varieties are readily apparent. One, a somewhat coarse, distinctly crystalline rock, showing on fresh surfaces

* Am. Jour. Sci., XXVIII, 1884, p. 252.

mottled, deep bright green cleavage plates (sometimes 5 to 10 mm. across) of a mineral of the pyroxene group, and abundant small folia of brown mica. To the unaided eye these two minerals form the chief constituents of the rock. This variety weathers with peculiarily knobbed and deeply pitted surfaces.

The second variety differs only in being of finer grained and more uniform texture, its mineralogical nature being barely evident even with a pocket lens.

Both varieties are, however, essentially the same. Under the microscope the rock is found to be beautifully fresh and unaltered—a holocrystalline granular aggregate of pale green diallage, deep reddish-brown mica, colorless olivines, rarely small irregular areas of a basic plagioclase, and scattering patches and streaks of black iron oxides, which are evidently wholly secondary. None of the constituents present anything like perfect crystal outlines.

The structure is peculiarly jumbled and almost cataclastic. It resembles more the hasty and interrupted crystallizations characteristic of certain meteorites, like that of Estherville, Iowa, than that of terrestrial rocks. Diallages and olivines are crowded and jumbled together, the interstices of the larger forms being occupied by the same minerals in a granular condition.

The diallage has reached the most perfect stage of developement and often occurs in broad plates inclosing olivines and shreds of brown mica, and with a very pronounced pinacoidal parting. Feldspars, when they occur, are in short broad plates sometimes polysynthetically twined or again showing broad faces without trace of cleavage or twining lines and filled with small colorless and yellow interpositions of mica. (?) The prevailing mica is deep brownish-red and strongly pleochroic. The following shows the composition of the rock according to analysis by Mr. L. G. Eakins, of the U. S. Geological Survey:

	Per cent.		Per cent.
SiO_2	48.95	MgO	23.49
TiO_2	.81	BaO	Trace.
Al_2O_3	5.69	K_2O	.79
Cr_2O_3	.05	Na_2O	1.58
Fe_2O_3	1.20	H_2O	.18
FeO	12.11	P_2O_5	.12
MnO	.08		
NiO	.16		100.54
CaO	5.33	Specific gravity	3.37

Diorites.—Burnt Creek region. These rocks are apparently all diorites and presumably portions of the same geologic body, though differing somewhat in composition and in details of structure. Some are fine and evenly granular dark-gray rocks, showing under the microscope a holocrystalline, panidiomorphic granular structure, a portion of the plagioclases only showing idiomorphic developement. A green hornblende in very irregular plates and shreds is, next to the plagioclase, the predominating constituent. Shreds of brown mica, abundant granules of iron ore, occasionally a little interstitial quartz, and a few inconspicious apatites with rarely an irregular sphene complete the list of determinable constituents. Others differ mainly in being of coarser texture and showing a tendency toward a porphyritic structure through the development of occasional large plagioclases.

Two sections show peculiar modifications. The most abundant constituent is a pale green augite which has gone over to a considerable extent to chlorite and a uralitic hornblende. Both augites and plagioclases show a tendency to group themselves into granular aggregates, while the latter are in many instances so charged with globular, club-shaped or vermicular colorless inclosures as to almost obscure their true mineral nature.

The feldspar not infrequently appears as a ragged, irregular nucleal area, with or without twin striæ, and surrounded by a zone of varying width of the inclusions so as to appear, by a low power, like a very fine granular aggregate of colorless minerals. A single section shows all gradations from feldspars with no inclusions to areas no longer recognizable as such, but merely aggregates of the irregular inclusions described. The structure is at times pronouncedly cataclastic and the appearances such as to indicate that the above-mentioned peculiarities are due to dynamic causes.

Rhyolite and andesite.—Hills between North and South Meadow Creek, near Washington Bar. The eruptives here occur mainly on the eastern side of the creek and form the steep hills lying between the north and south branches. The predominant rock is a liparite overlying the gneiss and forming the main mass of the hill. This varies from purplish to gray or nearly white in color, sometimes pinkish. The ordinary type is faintly porphyritic, though sometimes quite aphanitic, and with so even and pronounced a flow structure as to closely simulate a compact, thin bedded, argillaceous limestone. On the eastern and upper slope of the hills, and particularly at the western end of the range, always near the contact between the liparite and gneiss there occur limited outcrops of a dense almost coal black andesite. (No. 72850, U.S.N.M). The contacts between the three rocks are never accessible, but the surface of the ground is simply covered with innumerable small joint blocks, rarely a foot in diameter, and which have been further reduced by the continual flaking off of small convex and concave chips by diurnal temperature variations. The rock on a weathered surface for perhaps the depth of a millimeter is of a brownish color. Beyond this it is always fresh, of a beautiful dense black color and satiny luster, and with only rarely small white porphyritic constituents sufficiently developed to be visible to the unaided eye.

A slight mottling sometimes seen on the surface is due to a spherulitic development. The field characteristic of the rock was such that it was supposed to be a basalt. The thin section, however, shows only a very dense aggregate of small feldspars and other colorless microlites, often with strongly marked fluidal structure and innumerable small opaque specks, assumed to be iron oxides. None of the magnesian silicates are sufficiently developed to be recognizable, even with the highest powers. The white porphyritic constituents mentioned above as occurring rarely, prove to be secondary segregations of quartz.

The microstructure of the rock is andesitic rather than basaltic; nevertheless, as I have never before seen any but the glassy andesites so dark in color and so compact, a test was resorted to which showed 64.42 per cent. of silica; specific gravity, 2.555.

Hornblende picrite.—North Meadow Creek. This rock (No. 73174, U.S.N.M.) in the hand specimen is of an iron-gray color and composed of very irregularly outlined crystal plates and fibers, from one to two centimeters broad, which to the unaided eye merge into one another without sharp lines of demarkation. The larger plates inclose rounded blebs of a deep green mineral, whereby is produced an indistinct and irregular luster-mottling. The rock weathers brownish on the immediate surface, but is apparently fresh and unaltered and so intensely tough and hard that a two-pound hammer quite failed to detach chips of any size, and recourse was had to the sledge.

The outcrops are few and rather inconspicuous, projecting in thin wedges but a few feet above the scanty soil, and ringing like metal when struck with the hammer. Although no contacts were visible, the strike is directly across that of the gneiss in the vicinity, and in the field no doubt was felt concerning its eruptive nature.

In the thin section, under the microscope, the rock shows a holocrystalline aggregate of light greenish to colorless hornblendes, abundant, beautifully fresh, and colorless olivines, irregular grains of pleonast, the usual sprinkling of iron ores, and occasional very imperfectly outlined areas of a faint brown, dichroic mineral, showing in an indistinct basal section a very irregular and interrupted nearly rectangular prismatic cleavage. Satisfactory determination of this mineral was impossible. It is evidently hypersthene. The hornblendes occur in broad ophitic plates of a green color, inclosing the rounded clear and fresh olivines, and also in colorless frayed-out asbestus-like forms. Were it not that the rock is so fresh and unaltered I would be disposed to regard such as secondary forms, perhaps after a rhombic pyroxene, but it seems scarcely probable that such an alteration could have taken place, leaving the olivines, which they inclose, so perfectly fresh and unchanged.

The rock belongs to the group of hornblende picrites, as defined by Bonney, and though a trifle more acid, seems to correspond fairly well with those described by him from Anglesea and figured by Teall on pls. V and VI, figs. 2 and 1, respectively, of his British Petrography. The rock is sufficiently rich in olivine to gelatinize readily in hydrochloric acid. Below is given the results of a bulk analysis of the rock as made by Mr. Eakins:

	Per cent.		Per cent.
SiO_2	46.13	BaO	Trace.
TiO_2	.73	K_2O	Trace.
Al_2O_3	4.69	Na_2O	.08
Cr_2O_3	.04	H_2O	1.38
Fe_2O_3	.73	P_2O_5	.07
FeO	16.87	S	.24
MnO	Trace.		
NiO	.09		100.63
CaO	4.41	Specific gravity	3.35
MgO	25.17		

Saxonite; Harzburgite.—From dike between North and South Meadow creeks. This rock (No. 62402, U.S.N.M.) was first noticed on the western side of the divide between North and South Meadow creeks, where it cropped out by the roadside in the form of a sheet not over 50 feet in width, of a plainly laminated deep green serpentinous rock lying in the gneiss, and apparently corresponding with it in dip and strike. The outcrop was traced in a southerly direction toward South Meadow Creek, finally disappearing at the lake branch of the creek. Everywhere the rock had the appearance of a highly tilted metamorphic schist, except at the extreme southern terminus, where it widened out into a bulbous enlargement which was serpentinous on the margins, but showed a nucleus of a dense dark gray, very tough, and hard rock made up of a macroscopically irresolvable groundmass thickly studded with imperfectly outlined phenocrysts of a pyroxenic mineral with a bronze luster. The conditions of the rock were such as to at once suggest that this nucleus represented the unaltered portion of an original eruptive mass from which the schistose serpentine had been derived by chemical and dynamic agencies. This suggestion was substantiated by chemical and microscopic examination.

The rock from the southern end of the dike, in its least altered conditions, shows under the microscope a dense groundmass of finely granular colorless rhombic pyroxenes and pale brown almost colorless hornblendes, interspersed with a few olivines, the usual sprinkling of iron oxides, and small rounded forms of dull green pleonast. Throughout this ground mass are scattered the bronzite phenocrysts above noted, more rarely irregular olivines, occasionally very irregular plates of faintly brownish or greenish hornblendes and more rarely shreds of a deep red-brown mica which show extinction angles of about 3°, when measured against cleavage lines in cross sections. In but one or two instances were observed small granules of a basic plagioclase feldspar. Bronzite and olivines make up the main mass of the rock.

The structure of the rock is quite variable and complex, and difficult to describe intelligibly. With the exception of certain of the hornblendes of the groundmass, none of the constituents show good crystallographic forms, but occur in comparatively broad, very irregularly outlined plates surrounding and inclosing blebs of olivine and portions of the groundmass. The bronzite phenocrysts show a very platy, at times almost fibrous, structure, and have as a rule bronze clouded interior areas surrounded by colorless margins.

This type of the rock passes quite abruptly into serpentine, the olivines succumbing first and the bronzite next, the hornblendes remaining intact to the last but finally going over to fibrous tremolite forms. Accordingly as olivine or bronzite predominated in particular instances, the sections show a serpentine of the well-known mesh, or bar and grating structure.

As the process of alteration is traced into the more schistose portions of the rock it is observed that the unaltered hornblendes assume an approximately parallel arrangement among themselves, their longer axes lying in one general direction, while a pale yellowish mica is in some cases developed, particularly in slides from specimens taken from near the contact with the gneiss. The appearance is such as to suggest that the apparent fissile structure is due to a lateral compressive or sheering force as in ordinary roofing slates, and that the force may have been produced by movements in the inclosing gneiss, or, as seems possible, to merely the expansion of the mass of rock itself during the process of hydration and while held firmly by the walls of gneiss. The sufficiency of this expansive force to produce a platy and slickensided structure in pyroxenic masses undergoing hydration the present writer has elsewhere alluded to.* The following analysis, by myself, shows the composition of the fresh, unaltered saxonite from the southern end of the dike, all the iron being determined as Fe_2O_3 and the rarer elements not looked for:

	Per cent.
SiO_2	46.35
Al_2O_3	16.41
Fe_2O_3	9.91
MgO	18.72
CaO	6.14
Ign	3.01
	100.54
Specific gravity	3.21

Pyroxenite.—Outcrop in gneiss. On divide between Meadow and Granite creeks. Macroscopically this (No. 73175, U.S.N.M.) is a massive holocrystalline granular rock in which stout, deep dark-green, nearly black, crystals of a hornblendic mineral in sizes up to five and eight mm. in length are interspersed with larger indefinitely outlined areas, sometimes 40 or 50 mm. in diameter, of a brownish eminently cleavable mineral, suggestive of a pyroxene. These two minerals, so far as can

* On the Serpentine of Montville, New Jersey. Proc. U. S. Nat. Mus., XI, 1888, p. 105.

be determined macroscopically, made up the entire mass of the rock. Its appearance may perhaps be better understood by comparing it to a conglomerate in which the large pyroxenic portions represent pebbles and the hornblendes the interstitial cement. The rock is very massive, and I am inclined to believe an eruptive, though definite proof is lacking. Eruptive or otherwise, it seems to cover a very limited area. The country rock is gneiss with a pronounced banded or foliated structure. Passing along through the woods one comes suddenly upon an exposure of this rock utterly different in mineral nature and structure, and occupying an area so far as exposed scarcely a hundred feet in diameter. Like so many other undoubted eruptives in the region, it occurred in the form of what we after a time dropped into the habit of facetiously calling *pustules*. Inasmuch as I have never seen any such sudden transitions in gneissic rocks, but have observed basic undoubted eruptives occurring in just this manner, I am naturally inclined to regard this also as an eruptive, though contacts are wholly obscured. It is apparently the deeper lying portion of an old and very small volcanic neck.

Thin sections under the microscope show the rock to be made up wholly of large, irregularly outlined plates of hypersthene, pleochroic in faint reddish and brownish colors, and a light-green hornblende, as above indicated. These, with a scattering of opaque granules of iron ore, comprise the entire list of recognizable constituents. The rock is beautifully fresh and unaltered. The crystallization of the two chief constituents must have been nearly contemporaneous. The hypersthenes never show good idiomorphic forms, but the borders are irregularly indented by the smaller hornblendes, which are also found in quite perfectly outlined forms wholly inclosed by the hypersthenes. As a rule, as noted above, these hornblendes occupy the position of a binding constituent, but at times both hornblendes and hypersthenes occur intimately associated in small, imperfect granular forms. Of the two minerals the hornblendes are the better developed. These show on cleavage plates parallel to $\infty P \grave{\infty}$ extinction angles as high as 14°. An analysis yielded results as below, all the iron being determined as Fe_2O_3:

	Per cent.
SiO_2	46.14
Al_2O_3	17.07
Fe_2O_3	8.45
CaO	11.70
MgO	15.01
K_2O	.10
Na_2O	1.11
	99.58

The rock belongs evidently to the group of pyroxenites as described by Williams,* but can not be classed under any of the varietal names

* Am. Geologist, July, 1890, pp. 40–49.

as given by him. *Hornblendite* includes the closely related hornblende augites forms and *hypersthenite* the pure hypersthene rock. The compound name hornblende-hypersthenite, while sufficiently descriptive, is too cumbersome, but it seems scarcely advisable to coin a new name until rocks of this type shall be shown to have a wider geographic distribution.

Below is given the results of a bulk analysis as made by Mr. Eakins (I). In II is given the composition of a bronzite diallage rock (Websterite) from near Webster, N. C., as described by G. H. Williams.*

	I.	II.		I.	II.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
SiO_2	51.83	55.14	MgO	24.10	26.66
TiO_2	.29	....	BaO	....	....
Al_2O_3	7.98	.66	K_2O	.06	....
Cr_2O_3	.31	.25	Na_2O	.25	.30
Fe_2O_3	1.48	3.48	Ign	.29	.38
FeO	8.28	4.73	P_2O_5	.09	.23
MnO	Trace.	.03			
NiO	.11	....		100.43	100.25
CaO	5.26	8.39			

Between South Meadow and Moore Creek was found a second inconspicuous outcrop of what is evidently a varietal form of the same rock (No. 62401, U.S.N.M.). As in the last case, the outcrop is in the gneiss, nearly circular in outline, and of very limited area, not over 100 feet in greatest diameter. The actual contact between the eruptive and the gneiss was obscured by a zone, some three or four feet wide, of decomposed material, and here again there may be some reason to doubt the eruptive nature of the rock. To consider it as an eruptive is certainly the easiest way out of the difficulty, since it is more difficult to explain how mineral aggregates of this nature could segregate out of gneissic rocks of entirely different mineralogical composition than it is to account for the coarse and uniform crystallization in eruptive masses of so small size.

The rock in the hand specimen is dense, dark greenish in color with a serpentinous look and flecked with abundant cleavage plates of dark-green hornblende. On the immediate surface the rock weathers to a rusty red and shows not infrequently small rounded garnet-like protuberances, which closer examination shows to be large hypersthenes left projecting, owing to their superior durability.

In the thin section the rock shows plates of faintly greenish, to almost colorless hornblendes, interspersed with short, stout hypersthenes and occasionally olivines, and very abundant, comparatively large, irregular deep-green pleonasts with which is nearly always associated a magnetic iron ore which gives a chromium reaction when tested in the borax bead.

The rock is very fresh, although a slight serpentinization has begun

* Am. Geologist, July, 1890, p. 44.

with the olivines. The spinels are so abundant as to be the most striking feature of the slide and are readily recognizable by the unaided eye, in the form of irregular opaque granules a millimeter or so in greatest diameter.

From the powdered rock the spinel was separated out by digestion with hydrofluoric acid. The material thus obtained yielded Mr. Eakins results as below:

	Per cent.	
SiO_2	0.55	
Al_2O_3	62.09	ratio 1
Cr_2O_3	2.62	
Fe_2O_3	2.10	
FeO	17.56	ratio 1
MnO	Trace.	
CaO	.16	
MgO	15.61	
	100.69	
Specific gravity at 32.3° c	3.89	

This reduces readily to the spinel formula $(Mg,Fe)O.Al_2O_3$, which is that of the variety pleonast, to which the mineral has already been referred.

A bulk analysis of the rock yielded me results as below, no attempts being made at determining the rarer constituents:

	Per cent.
SiO_2	44.01
Al_2O_3	11.76
Fe_2O_3*	15.01
MgO	25.55
CaO	4.06
	100.39

Diabase.—Granite Creek, Madison County. These are coarsely crystalline rocks (No. 62403, U.S.N.M.), in most cases readily recognizable in the field as diabases, though in some instances the uralitization of the augitic constituent had gone so far that in the hand specimen the rock might easily be mistaken for a diorite. In the thin section they present nothing of special interest. The ophitic structure characteristic of diabases is not prominently developed. There are broad areas of badly kaolinized plagioclases interspersed with augites, iron ore, and occasional quartz granules and shreds of brown mica, together with more or less uralitic hornblende and chlorite.

Basalt.—The high flat-topped plateau northeast and east of Virginia City is composed exclusively of basalt with interbedded tuffs, the whole being underlaid by andesites, which are exposed only in the dry gulches down well toward the level of the town (Nos. 62405 and 62406, U.S.N.M.). The basalts vary in color from dull reddish to

* All iron determined at Fe_2O_3.

nearly black, and in structure from coarsely vesicular to compact, and, as a rule, showing olivines developed in such sizes as to be recognizable to the unaided eye.

As a rule the samples collected present no points of exceptional interest, though from an outcrop on the divide between the two south branches of Moore Creek a quartzose variety was found which needs mention. Macroscopically the rock is dense, compact, of a dark-gray color, and studded with numerous rounded or oval spots, 2 to 3 mm. in diameter, showing a whitish center surrounded by two narrow zones, the inner greenish in color, and the outer, an irregular and imperfect one, whitish. In the thin sections these spots show a rounded nucleus of quartz surrounded by a zone of pale-green augite, and these in turn surrounded by a zone of nonstriated feldspars (?). The nature of this last constituent could not be made out beyond doubt in the sections at hand. The mineral is biaxial and gives inclined extinctions, the general behavior being that of a potash feldspar. With the exception of this imperfect outer zone the occurrences are apparently in every way similar to those described by Diller* and Iddings,† and are to be accounted for in a similar manner.

Hornblende andesite.—Old Tollhouse on road leading from Postlewaite Creek toward Virginia City (No. 72867, U.S.N.M.). This is a gray andesite of ordinary type, showing to the unaided eye coal-black hornblendes, hexagonal folia of black mica from one to two mm. in diameter, and abundant small plagioclase phenocrysts. The microscope brings to light no points of unusual interest. The rock is finely exposed in the hillside at the tollhouse, and is found to underly the basalt forming the plateau to the west. The same rock occurs again at Virginia City, where it has been used in the construction of several buildings. On the east side of Alder Gulch, also underlying the basalt, a similar rock occurs, but in which the hornblende seems to have been wholly replaced by the black mica.

Liparites.—Cherry Creek on west side of Madison Valley. The only eruptives here (No. 72945, U.S.N.M.) are liparites and diabases, the first occurring only in remnants of thin sheets on the slopes north of the creek, and in isolated patches for several miles to the southward. The prevailing type is a light reddish or gray and but slightly porphyritic rhyolite, sometimes coarsely spherulitic. The material is of such slight density as to have been transported by spasmodic streams clear to the opposite side of the valley in masses of even 10 feet in diameter. Wind-blown sand has in many cases hollowed these out into a mere shell. Older eruptives in the form of dikes of diabase occur well down in the edge of the valley, outcrops running parallel with the prevailing schists. These in the hand specimens are holocrystalline granular rocks, dark gray in color, and in which an

* Am. Jour. Sci., XXXIII, Jan., 1887, p. 45.
† Am. Jour. Sci., XXXVI, Sept., 1888, p. 208.

abundant sprinkling of a dark-greenish black hornblendic mineral in a gray feldspathic base is readily recognized.

In the thin sections the most abundant constituent is hornblende, in broad plates of green color and fibrous aspect such as to at once suggest that they are wholly secondary, that is, uralitic; accompanying these are small, irregular flecks of brown mica, which is also secondary. The groundmass of the rock is composed of badly kaolinized feldspars, in part at least plagioclastic, and granular quartz. Frequent patches of a dirty brownish amorphous matter, acting between crossed nicols like a gum, are evidently residual products from the decomposition of titaniferous iron. Mineralogically the rocks may be classed as quartz diorites, but I am inclined to regard them as altered diabases.

Porphyrite.—On the eastern side of the valley, in the upper valley of Bear Creek, the eruptives occur in the form of three sheets of porphyrite, a liparite, and two inconspicuous outcrops of a dense greenish basaltic rock closely related to that described as occurring near Fort Ellis. Between Bear and Indian Creek, to the southward, are extrusions of basalt. The most conspicuous eruptive on this side of the valley is that forming the mass of Lone Mountain, and which is found in the form of sheets and dikes in the Cretaceous and older beds of the surrounding hills. As exposed in the canon of Cedar Creek (Nos. 72866 and 72880, U.S.N.M.), the mass is evidently laccolitic in Cretaceous sandstones. The entire thickness of the mass as exposed can not be less than 3,000 feet. In its most conspicuous development the rock is a compact light-gray hornblende porphyrite, with both hornblende and feldspars sufficiently developed to be recognizable by the unaided eye. Black mica is commonly present, and near the lower contact this mineral prevails, to the entire exclusion of the hornblende. (No. 72880, U.S.N.M.) This variety of the rock is further characterized by abundant rounded blebs of quartz.

In the thin section the prevailing type shows a groundmass varying from densely microlitic or felsitic in samples from near upper contact to finely microgranular in specimens more remote. Phenocrysts of striated feldspars and green hornblendes are abundant, and occasionally rounded blebs of quartz occur. The feldspars are in most sections opaque through decomposition, and an abundance of secondary calcite indicates that they belong to a lime-rich variety. The mass, as shown by specimens collected at various points, is very uniform throughout in structure and mineral composition. Near the lower contact, as found in the canon of Cherry Creek, it becomes a dense, almost porcelain-like rock, breaking with a beautiful conchoidal fracture (No. 66928, U.S.N.M.). This variety shows under the microscope a dense felsitic groundmass, with many small, rounded, and wedge-shape bits of quartz and feldspars. Through weathering, the upper portion of the peak has become hollowed out so as to resemble a volcanic crater broken down on the side facing the valley. The rock is also exposed in the upper portion of Jackass Creek, together with dikes of diabase.

Pyroxenite; Websterite.—Well up on the hills north of the first basin of Jackass Creek was found another inconspicuous outcrop of a doubtfully eruptive rock somewhat similar in its mode of occurrence to the pyroxenites already described. In the hand specimen the rock (No. 62442, U.S.N.M.) shows to the unaided eye a granular aggregate of dark bronze, gray, and green minerals suggestive at once of a pyroxenite. Thin sections under the microscope show a fine granular aggregate of light-green diallage and colorless enstatite with included folia of brown mica, and occasional interstitial areas of lime soda feldspars and more rarely a colorless biaxial mineral, showing in polarized light the wavy banding characteristic of intergrowths of orthoclase and albite. An attempt at isolating this mineral for microchemical tests proved unsuccessful owing to its small quantity. The colorless mineral thus obtained gave always, when evaporated with hydrofluorsilicic acid, abundant beautifully perfect hexagonal forms of sodium silico-fluoride and stellate groups of calcium silico-fluoride, but no potash salts so far as could be observed. The percentage of potash shown in the bulk analysis is, however, suggestive of some other potash-bearing mineral than the mica, though it is of course possible it may come in part from the pyroxenes. The diallage is but faintly green and at times almost colorless in the section, and with difficulty distinguished at all times from the enstatite. Besides the usual prismatic cleavage it shows distinct partings parallel with both $\infty P \bar{\infty}$ and $\infty P \breve{\infty}$. In longitudinal sections it is at times quite fibrous, but carries no inclusions of note except the brown mica. The enstatite is almost perfectly colorless and never noticeably dichroic. Enstatite and diallage make up the main mass of the rock, the former being more conspicuous in the hand specimen.

The rock must evidently be classed with the pyroxenites, though showing transitional tendencies toward gabbro.

Bulk analysis yielded me results as below. The ignition with sodium carbonate indicated the presence of manganese, but which was not determined quantitatively. Chromium and other rarer elements not looked for. All iron calculated as FeO.

	Per cent.
SiO_2	54.12
Al_2O_3	7.91
FeO	12.87
CaO	6.21
MgO	16.64
K_2O	1.19
Na_2O	.44
	99.38
Specific gravity in bulk	3.30

Diorite porphyrite.—About six miles northwest from Three Forks, Jefferson County. The eruptives occur here in the form of three approximately parallel ridges. The outcrops are not continuous, but form a series of rounded knolls covered with scanty soils through which project the angular or rounded fragments into which the rock weathers.

The most easterly of the three ridges shows outcrops in large rounded masses of a coarse gray and pinkish granitic-appearing diorite in which black hornblende and pinkish or gray feldspars are easily recognized by the unaided eye. This, separated by wide ravines and benches, is succeeded by a compact dark gray fine-grained micaceous rock in which only small scales of black mica in a very finely granular base are recognizable, and this in its turn by a very typical diorite porphyrite, a dark gray very compact rock thickly studded with black hornblendes of all sizes up to 15 or 20 mm. in length, and often in stellate clusters of radiating individuals some 25 mm. in diameter. The field relationships of the last two varieties were somewhat obscure, but although never observed grading into one another, little doubt was felt at the time but that they were portions of the same mass.

In thin section the first mentioned (No. 73170, U.S.N.M.), the granite-like rock, is found to consist of large plates of muddy and impure orthoclase and plagioclase feldspars with interstitial quartz, deep green hornblendes, and occasional light-green augites, scattering apatites, sphenes, an occasional zircon (?), and the usual iron ores. The second variety, the compact finely granular rock with microscopic mica shows in the section a finely holocrystalline groundmass of stout idiomorphic plagioclases and orthoclase in broad plates with abundant sprinklings of green hornblende, paler green augites, brown mica, iron ores, apatites and sphenes. A part of the hornblendes are original and a part secondary after the augites. The rock is not distinctly porphyritic, and the structure as a whole is panidiomorphic. Occasional large plates of a nonstriated feldspar inclosing small augites and plagioclases give rise to ophitic forms. The third, the porphyritic variety, shows a similar mineral composition, but somewhat variable structure. Certain slides show a dense microgranular feldspathic base carrying occasional rounded blebs of quartz and phenocrysts of plagioclase and deep green hornblende and smaller augites in good idiomorphic forms; others show a structure almost granitic and with interstitial quartz. Hornblende occurs both as phenocrysts and as a constituent of the groundmass, but in the latter case is always an alteration product of the augite. Mica in this variety of the rock is much less abundant than in the last, and is at times almost wholly lacking. All intermediate grades of structure exists from the close-grained porphyritic to the granitic, and the mass as a whole, if as supposed all portions belong to the same magma, offers an interesting field for those who are disposed to make structural differences a basis for rock classification.

Quartzose hornblende porphyrite.—Willow Creek at Lower Canon. The eruptive here occurs as an intrusive sheet or boss through the Potsdam quartzites. On the east side of the creek the mass is practically a boss, throwing the quartzites on the north far out of position. Near the canon the mass begins to narrow and passes westward as a broad sheet or dike dipping with the quartzites which appear both above and below.

In the canon the eruptive is finely exposed in vertical cliffs a hundred or more feet in height and is broken by nearly vertical joints into rudely columnar masses from six to ten feet in diameter. By joints running parallel with the strike the rock is in places also broken into a series of sheets varying from an inch to a foot or more in thickness. East of Willow Creek the main sheet divides, forming two sheets, with the Potsdam quartzites and shales lying between them, and through which has been extruded a brownish coarsely porphyritic andesite.

The normal rock (No. 62407, U.S.N.M.) is a dense light gray, sometimes almost white or faintly yellowish, felsitic to microgranular mass with inconspicuous phenocrysts and imperfect needle-like hornblendes. No quartzes are microscopically apparent. Occasional bands are apparently holocrystalline, though this variety was so badly decomposed as to crumble and samples fresh enough for study were not obtained.

In the section the rocks show a very dense microcrystalline groundmass ot quartz and feldspar particles, bearing abundant micro-phenocrysts in the form of dihexahedral quartzes and larger feldspars, a large portion of which are orthoclase, though a few striated forms are occasionally seen. The hornblendes, although recognizable macroscopically as fine needles, are scarcely visible at all in the section owing to a decomposition which has given rise to calcite and chloritic products. The only striking feature of the rock is the abundance of the small quartz phenocrysts and their peculiar skeleton-like forms, due to numerous empty cavities and inclosures. Partial analysis on a fresh compact sample yielded:

	Per cent.
SiO_2	67.43
K_2O	3.40
Na_2O (by difference)	5.87

The hornblende andesite mentioned above (No. 62408, U.S.N.M.) is macroscopically a somewhat dense, brownish or gray rock thickly studded with white feldspar phenocrysts in all sizes up to ten mm. in greatest diameter. In the thin section it shows a dense feldspar microlitic groundmass with strongly marked fluidal structure, and which bears only the porphyritic feldspars above noted, and numerous badly decomposed and corroded areas which form their outlines are assumed to have been hornblendes. Subjected to chemical tests the rock yields 2.5 per cent. of potash (K_2O).

Lamprophyres.—Between South Boulder and Antelope creeks. The intrusives here are a gray to pinkish micaceous syenite and a dark gray, basic porphyritic rock immediately overlying it. Both are intrusive in Cretaceous sandstones. The basic rock (No. 62409, U.S.N.M.) occurs in a sheet apparently fifteen to twenty feet in thickness, though this could not be determined for a certainty owing to lack of exposures. This rock in the hand specimen shows a gray and apparently crystalline groundmass thickly studded with deep greenish black very perfectly formed augites and olivines and very numerous minute flecks of brown mica. The augites in extreme cases are ten mm. in length and half as broad; forms five mm. in length are common.

As seen under the microscope and with a power of eighty diameters the rock presents a colorless feldspathic, holocrystalline (?) groundmass, carrying scattering granules of iron ore, numerous greatly elongated dusky apatites, a few small augites, abundant elongated and very irregularly outlined shreds of brown, strongly dichroic mica and the porphyritic augites and olivines above noted. The rock is beautifully fresh and unaltered.

The porphyritic augites show very perfect crystal outlines of the ordinary type; twin forms are rare. Inclosures are minute and limited to what is apparently portions of the groundmass, iron oxides, and mica scales; a faint zonal structure is sometimes apparent. The olivines are also at times in very perfect crystal forms, though more frequently rounded with extremely irregularly toothed or etched outlines closely bounded by small shreds of the brownish mica. This feature is likewise occasionally shown by the augites. The mica itself never shows hexagonal outlines, but is always in very irregular and greatly elongated folia.

The groundmass.—Revolved between crossed nicols no portion of the field remains entirely dark, but breaks up into irregularly bounded areas showing at times an almost granular structure, but more commonly one imperfectly columnar-radiating, the dark wave merging from one portion to another, and in few cases showing crystal outlines sufficiently well defined for determination. Occasional elongated forms show a maximum extinction paralled and at right angles with the axis of elongation. In rare instances still others occur showing twin striæ characteristic of plagioclase feldspars, but beyond this the microscope fails to give satisfactory results. No interference figures are obtainable nor are cleavage lines apparent. An attempt was made at separating the minerals of the groundmass by means of specific gravities, but results were not particularly satisfactory owing to inclosures of mica and iron ores. After repeated attempts a small amount coming down at 2.6 and showing under the microscope no admixture of augites, olivine, or iron ores was obtained, which yielded me on analysis as below.

The determinations were not duplicated, and can be regarded little more than suggestive.

	Per cent.
SiO_2	60.68
Al_2O_3 and Fe_2O_3	21.71
CaO	3.03
K_2O	7.31
Na_2O (by difference)	6.63
	99.36

Evidently a mixture of potash and soda-lime feldspars. A bulk analysis of the rock as made by L. G. Eakins, of the U. S. Geological Survey, yielded the results given in column I, on p. 670.

In the dry ravines and gulches near by, and on the north side of the road leading from Antelope to South Boulder Creek were found obscure outcrops of what from its position was assumed to be the same rock, but which in a state sufficiently fresh for examination could be found only in small rounded bowlders, the main mass of the rock having so thoroughly rotted as to be easily dug out with the hand pick. The freshest nodules obtained showed on a broken surface a deep dark greenish gray indistinctly porphyritic rock in which olivines and augites, with occasional flecks of brown mica, are determinable by a pocket lens. In the thin section this variety is nearly if not quite holocrystalline but its structure badly obscured by decomposition. A clear glassy sanidin intergrown with plagioclase is readily made out, green augites, brown mica, and badly altered olivines.

During a previous season (1886) small outcrops of a somewhat similar rock were found near Cottonwood Creek and east of the Gallatin River in Gallatin County. These on comparison proved to be undoubtedly portions of the same magma, but offer some interesting peculiarities. I find these described as follows in my notes of the winter of 1886–'87:

Macroscopically this rock (No. 38596, U.S.N.M.) consists of a compact aphanitic, dark gray or nearly black, sometimes brownish, groundmass in which are embedded abundant dark green porphyritic olivines and augites of all sizes up to five millimeters in greatest diameter.

Microscopically the rock is both unique and beautiful. In a dense groundmass of a light gray, sometimes brownish color, consisting of a colorless or gray undeterminable mineral, augite microlites, small scales of brown mica, and grains of iron ore, are embedded beautiful large clear grains of olivine and augite, these two minerals alone constituting the porphyritic ingredients.

The olivines occur in clear, colorless, rounded, and irregularly corroded forms, scattered singly or in polysomatic groups, as shown in figure 8, and often in close juxtaposition with the augites. They are beautifully clear and fresh, with but few inclosures of magnetite and glass cavities. A chloritic or serpentinous alteration has set in and the crystals are traversed by the characteristic irregular canals of bright greenish blue secondary matter and scattering grains of iron ore. The augites occur in sizes fully equal to those of the olivines, and are of a clear light green or faint yellow color in section. They contain very numerous inclosures of the groundmass, a brown dichroic mineral, evidently mica, grains of iron ore, and glass. As a rule, the crystal outlines are far from perfect, the mineral having suffered from the corrosive action of the magma even more than the olivine. The mineral is perfectly fresh and clear, shows sharply developed prismatic cleavages and gives maximum extinctions on clinopinacoidal sections of 43°. Like the olivine, it occurs both in scattered and isolated single crystals and in groups. Twin forms are common after the ordinary type. Augite and olivines often occur in such close juxtaposition as to have mutually interfered in process of growth (see figure 9). So marked an interference between minerals belonging to the earliest stages of consolidation and occurring in widely scattered groups in an unindividualized groundmass can be accounted for only on the supposition that neither mineral is a direct secretion from the magma, but that they are residuals of an earlier crystallization in which consolidation had proceeded so far that free growth was no longer possible. The present rounded, scattered, clustered, or isolated conditions being due to

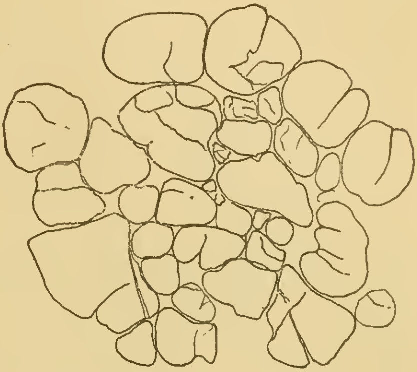


Fig. 8.

POLYSOMATIC OLIVINES.

From specimen No. 38596, U. S. N. M.

Fig. 9.

INTERGROWN OLIVINES AND AUGITE.

a.—Olivines. *b.*—Augite.

From specimen No. 38596, U. S. N. M.

refusion, such as almost completely destroyed original structures without wholly obliterating the minerals belonging to the first stages of consolidation. The mere rounding alone of either mineral could not be considered as indicative of other conditions than are so frequently shown by those minerals which belong to the earliest generation and which, owing to reelevation of temperature or diminution of pressure have become again partially dissolved by the molten magma. Among crystals which develop freely in a more or less viscid magma, however, no such interference as here shown could have occurred, and we must conclude that their first crystallization took place under more restricted circumstances.

The gray material constituting the greater portion of the groundmass is here not sufficiently crystalline for optical determination. Under a power of 170 diameters it shows only a scaly, granular aggregate of a colorless mineral or minerals, polarizing in light and dark colors, with the individual granules blending into one another as the stage is revolved; often an imperfect, spherulitic structure is developed. The appearance suggested that nepheline or melilite might be one of the constituents, but micro-chemical tests failed to show a trace of either mineral, though an analysis of the portion soluble in hydrochloric acid (p. 670) is very suggestive. From the high percentage of silica and potash shown by the complete analysis it must be inferred that an acid feldspar is a prominent constituent. Occasional areas of colorless glass are seen, but by far the greater part of the groundmass is composed of the white substance, presenting always the peculiar scaly-granular structure above described, and which is unlike anything I now recall, excepting as sometimes displayed in rocks of the phonolite or trachyte groups. Very evenly distributed throughout the entire groundmass are innumerable small flecks of brown mica and augite microlites. These last are peculiarly beautiful and interesting, showing every stage from mere skeleton outlines inclosing areas of groundmass, elongated, needle-like forms with crenate and undulating borders, to quite perfectly outlined crystals.

As shown in the section they are faintly greenish, or nearly colorless. Between crossed nicols the larger forms show cores giving lively bluish or purple polarizations colors, while the borders are very faint yellow.

Although small and imperfect, the optical and crystallographic properties are readily determined, and agree with those of normal augite. No microlites were observed which could with certainty be referred to olivine. The abundant small scales of brown mica are scattered singly and in small clusters quite uniformly throughout the groundmass. It is noticeable, however, that in the immediate vicinity of the corroded augites they often occur in greater abundance, and in particular where augites and olivines lie in close juxtaposition. The space is then often filled with a perfect cloud of the small mica scales, as I have attempted to show in figure 10. I think that there can be no doubt that these, and perhaps all the micas, and augite microlites as well, result from a recrystallization of the material derived by refusion mainly from the older olivines and augites. The residual augites are not separated from the groundmass by a sharp line, as might be imagined from an examination of the figure alone, but pass into it by slight gradations.

The above-described minerals, together with small grains of iron ore and innumerable minute, greatly elongated, needle-like crystals of a brownish color, and which occur singly or radiating in every direction from an indefinite nucleus, complete the list of recognizable constituents.

A second variety, found in inconspicuous outcrops a few rods away, was described as follows:

Macroscopically this rock consists of a compact aphanitic groundmass of dark brown color, carrying abundant greatly altered olivines and augites. Under the microscope the groundmass shows a brownish, partially devitrified base, traversed in every direction by innumerable, short, thin, yellowish or brownish flecks of a dichroic mica-like mineral, which are light yellowish when the plane of vibration of the light is at right angles to the axis of greatest elongation and brownish when it is parallel. Between crossed nicols these give maximum extinctions and become almost completely obscured when their longer axes coincide with the plane of either nicol, and are of a light yellowish color at intermediate points. They are too minute and with too imperfect outlines for a more accurate determination of their optical properties, but are undoubtedly of biotite or an allied mica. These flecks, together with innumerable light greenish elongated augite microlites, are so abundant as to form a dense, almost felt-like groundmass, in which are embedded the abundant porphyritic augites and olivines.

Fig. 10.

CORRODED OLIVINES, AUGITES, AND SECONDARY MICA.

a.—Olivines. b.—Augite. c.—Mica.

From specimen No. 38596, U. S. N. M.

As above noted, both these minerals are badly altered though the augite is still shown in a few sections in the form of broad, rounded plates of a light greenish color, with sharply defined prismatic cleavages, and containing very many large inclosures and embayments of the groundmass. The olivine has completely decomposed, and but for the characteristic crystal outlines of the pseudomorphs would be unrecognizable. The product of this decomposition is in part a very light greenish chloritic substance, and in part a colorless substance so thoroughly impregnated with minute specks of opacite as to give it a bluish hue, remotely resembling hauynite. This secondary substance acts faintly on polarized light, and, being insoluble in boiling acids, is presumably chalcedony. Were it not that the outlines of these pseudomorphs are plainly those of olivines, and the amount of this insoluble substance increases proportionally with the alteration the crystals have undergone, I should hesitate to designate them as olivine derivatives.

Although this rock shows certain structural peculiarities, differing from that just described, I am at present disposed to regard it as a portion of the same flow solidifying, it may be, under slightly different conditions, and having undergone greater changes since its eruption.

Below are given the results of analyses on the three types indicated, Nos. I and III being by Mr. L. G. Eakins, and No. II by Dr. Chatard, of the U. S. Geological Survey. No. I is the fresh porphyritic variety from South Boulder and Antelope Creek (No. 62409, U.S.N.M.); No. II the variety collected in 1886 from near Cottonwood Creek (No. 38596, U.S.N.M.); No. III the variety found in nodular masses in decomposed material as just described, and No. IV a rock from the Absaroka range, as described by Iddings.*

	I.	II.	III.	IV.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	50.82	*a*51.65	50.03	48.36
TiO_2	.59	.55	.61	1.18
P_2O_5	.20	.21	.42	0.84
SO_3	....	.19	....	....
Al_2O_3	11.44	13.89	14.08	12.42
Cr_2O_3	.03	.80	Trace.	Trace.
Fe_2O_3	.25	2.70	2.92	5.25
FeO	8.94	4.80	6.11	2.48
MnO	.19	.15	.08	0.13
CaO	8.14	4.07	7.46	8.65
MgO	14.01	11.56	10.73	9.36
K_2O	3.45	4.15	2.64	3.97
Na_2O	1.79	2.99	1.46	1.46
BaO	.06	.19	.04	0.29
H_2O	....	1.30	....	5.54 (H₂O and Ign)
Ign	.58	1.89	3.70	
	100.49	....	100.28	99.93
Specific gravity	2.96			

a An analysis of the portion of No. II soluble in hydrochloric acid subsequently yielded results as follows:

	Per cent.
Soluble	33.42
Insoluble	66.58

The soluble portion yielded:

	Per cent.
SiO_2	41.87
Al_2O_3	9.48
Fe_2O_3 and FeO	16.41
MnO	Trace.
CaO	3.10
MgO	26.79
K_2O	1.06
Na_2O	1.26
	99.97

* The Origin of Igneous Rocks, Bull. Philos. Soc. of Washington, Vol. XII, 1892, p. 169.

The rock, it will be observed, is somewhat anomalous as regards both structure and chemical composition. There is apparently little doubt but that the groundmass is in all cases a mixture of potash and soda lime feldspars, as the microscope showed to be the case in the badly decomposed but holocrystalline variety, and with the possible addition of sporadic nepheline. The most striking feature is, perhaps the high percentage of potash in basic rocks so rich in magnesia. Both on structural and chemical grounds one would at first be inclined to regard the rock as belonging to the leucite, nepheline, or melilite bearing series, but most careful tests have so far failed to establish the presence of either mineral, beyond a possible doubt. If the powdered rock is freed from the iron magnesian silicates by means of the electro-magnet, the residual white granules yield crystals of sodium chloride when treated with hydrochloric acid, and minute radiating crystals of gypsum when treated with sulphuric acid. It is probable, however, that these reactions are produced by the presence of zeolitic alteration products which the microscope shows to exist, but the exact nature of which can not be made out.

The underlying syenitic rock (Nos. 73168 and 73169, U.S.N.M.) is a gray to pinkish, finely to coarsely crystalline granular rock, consisting essentially of orthoclase and abundant spangles of black mica readily determinable by the unaided eye, while on closer inspection are seen abundant small deep greenish needle-like crystals of pyroxene. These last in forms not over one mm. broad by ten mm. in length.

In the thin section the rock is holocrystalline granular, and the feldspars so opaque and muddied that their optical properties are quite obscure. They resemble the orthoclases of the older syenitic and granitic rocks. Occasionally plagioclases occur, but which in nearly every instance have gone over into a very light, almost colorless decomposition product, at times almost wholly without action on polarized light and recognizable as a pseudomorphous substance by their sharp crystalline outlines. The mica occurs in broad (five mm.) patches made up of a large number of independent folia, none of which show hexagonal outlines, and also in long (five to ten mm.) spangles radiating in every direction. Under the microscope it is deep smoky brown in color, strongly dichroic, and shows extinction angles measured against the cleavage lines in cross sections as high as 8°. The folia are often crushed, bent, and distorted, and show between the plates inclosures of a finely granular colorless mineral aggregate, the nature of which can not be made out.

The augitic mineral occurs in beautifully perfect elongated forms, sometimes as much as ten mm. in length, as above noted. In the section it is only faintly greenish in color, not perceptibly pleochroic and gives extinction angles, c on $\mathfrak{c}$, as high as 41°. Although the prismatic faces are well developed the terminations, so far as observed, are never perfect but often jagged and full of inclosures or even broken into several disconnected pieces which, though extinguishing simultaneously, are separated from one another by narrow intervals of feldspathic groundmass. The usual prismatic cleavage is well developed.

Abundant long, needle-like light smoky crystals of apatite and the usual scattering of iron ores are also present. Scattered throughout the slide are numerous irregular, triangular, or occasionally, nearly rectangular areas of a colorless, isotropic mineral, without cleavage and traversed only by an irregular network of fracture lines along which a faintly greenish chloritic alteration had set in. The microscope alone proving insufficient for its exact determination, chemical means were resorted to. The powdered rock, treated on a slide with concentrated hydrochloric acid, shortly yielded abundant cubes of sodium chloride; when boiled with the acid it also yielded a jelly. That the mineral was not nepheline was indicated by its optical properties. A test was therefore made for chlorine by warming the powder in a platinum crucible with sulphuric acid and catching the fumes arising in a drop of water suspended on the underside of a covered glass. Tested with nitrate of silver this drop showed an unmistakably white cloud, proving beyond all doubt the presence of chlorine. The isotropic character of the mineral, together with its gelatinization and property of yielding sodium-chloride cubes with hydrochloric acid, and chlorine by the last test, all seem to point conclusively to a mineral of the sodalite group.

Although I have spoken of the rock as granitic this structure does not hold through all parts of the mass. Certain specimens (No. 38600, U.S.N.M.) from near the upper contact, and from distant outcrops (see p. 645), are fine grained and show in the thin section a groundmass with a pronounced plumose or dendritic structure more nearly like that of the trachytes.

Bulk analysis of this rock (No. 73169, U.S.N.M.) yielded me the results given in column I, below. In column II is shown the composition of a sodalite syenite from Square Butte, Montana, as given by Lindgren.*

	I.	II.
	Per cent.	*Per cent.*
SiO_2	54.15	56.45
Al_2O_3	18.92	20.08
Fe_2O_3	6.79	1.31
FeO		4.39
CaO	3.72	2.14
MgO	1.90	.63
K_2O	8.44	7.13
Na_2O	5.47	5.61
Cl	.42	.43
H_2O	Not det.	1.77
P_2O_5	Not det.	.13
TiO_2	Not det.	.29
MnO	Not det.	.09
	99.81	100.45
Excess	....	.10
		100.35

* Eruptive rocks from Montana. Proc. California Academy of Science, Vol. III, pp. 45–47.

Assuming that all the chlorine belongs to the sodalite, the above analysis indicates the rock to contain nearly six per cent of the mineral.

The composition of the two rocks just described, and their intimate association even in widely separated areas, are peculiarly interesting in the present state of petrographic knowledge. It is evident that on structural grounds, such may be best classed with the lamprophyres, though they differ from any thus far described in many important particulars. This is eminently true with regard to the more basic one of the two, and it seems impossible to give it a specific name without coining one entirely new, a proceeding which, in my present frame of mind, is quite objectionable. Considered as a lamprophyre it would seem to stand distinct from the monchiquites as described by Prof. Rosenbusch,* in the presence of a feldspathic rather than a glassy base, though such a distinction can scarcely be considered an essential, since such might result from merely slight differences in rates of cooling. On purely chemical grounds it is further separated from this group by the high percentages of silica and magnesia, and the fact that the potash preponderates over the soda. From other members of the lamprophyre group, as described by Chelius,† Goller,‡ J. F. Williams,§ Harker,‖ Doss,¶ and others, it differs in equally important particulars. Its closest homologue so far as shown by existing literature, appears to be among the rocks forming the "exceptional dikes and flows in the Absaroka range" of Wyoming, as described by Iddings, and to which reference has been made above. These are regarded by Professor Iddings as forming a part of a series "grading into the normal basalt of the region." So far as the Boulder Creek locality is concerned, there is nothing to suggest any such transition. It is, however, very probable that a further comparison of these with the rocks of Fort Ellis (p. 641), Cottonwood Canon (p. 666), Flathead Pass (p. 643), and Horse Shoe Bend (p. 649) might throw more light on the subject. Their general similarity in composition as well as association is certainly very suggestive.

At South Boulder the eruptives occur in the form of successive sheets of which the lower is a compact hornblende andesite which is succeeded by a semiglassy hypersthene andesite, and this, in its turn, by basalt followed by a small sheet of rhyolite.

* Min. u. Pet. Mittheilungen, 1890, p. 445.

† Neues Jahrbuch für Min., etc., 1888, II. Band, 1. Heft, p. 67.

‡ *Ibid.*, 1889, VI. Beilage-Band, p. 485.

§ Vol. II, Ann. Rep. Arkansas Geological Survey. 1890.

‖ Geological Magazine. May, 1890, p. 199.

¶ Min. u. Pet. Mittheilungen, XI. Band, 1. Heft, p. 17.