

MEETING OF DECEMBER 5th, 1887.

ON SOME ERUPTIVE ROCKS FROM CUSTER COUNTY,
COLORADO.

BY WHITMAN CROSS.

All of the rocks to be described in this paper occur within the district adjacent to the mining towns Silver Cliff and Rosita, which has been studied by the writer under the supervision of Mr. S. F. Emmons, in charge of the Rocky Mountain Division of the U. S. Geological Survey. The report upon the district, to be published in monograph form, with a map, is now being prepared.

The particular rocks chosen from a considerably larger number for description at this time, are either very characteristic examples of their respective types, or they are rare forms with unusual mineral combinations.

One of the chief points in the definition of a *rhyolite* has been the preponderance of potash feldspar over soda-lime or plagioclase feldspars. Seldom is this difference more strongly shown than in the first rock I shall describe. In fact there is nothing about this rock which could lead to its classification in any other group.

Trachyte is the favorite term used in designating nearly all light colored eruptive rocks, by those who have no means of making close examinations, and yet there is no one of the prominent rock types which is so rare, in the Rocky Mountains, at least, as this. In composition a trachyte is the equivalent of a rhyolite without its excess of silica, which appears as quartz in the latter rock. It is very rich in feldspar and that is chiefly orthoclase, while its triclinic feldspar has but little lime and is rich in soda.

Syenite is another name which is commonly but very seldom correctly used. It is also a rare rock in this State and the example found near Silver Cliff is the best one I know of, for its variety.

In opposition to the extremely acid rhyolite of Silver Cliff there is found near Querida a very interesting representative of one of the most basic eruptives, namely: *peridotite*. But few occurrences of rocks of this group are known in this country, and the type is nowhere abundant. While the rock in question is not exactly like any other described in petrographical literature, it nevertheless serves very well to illustrate the characteristics of the group.

The other rocks are interesting as presenting exceptions to the common rules of mineral association and development upon which modern types are founded.

1. *Rhyolite*.

Occurrence.— The rock here to be described is the country rock of the famous silver-bearing deposits whose wonderful richness, when first discovered, caused a town to spring up with mushroom-growth at the base of the low rhyolite bank, the first claim in which was named the "Silver Cliff." The rock-type forms the low irregular group of hills extending for two miles northward from Silver Cliff, and named from the color of their constituent rock, "The White Hills." This area represents the surface flow of the rhyolite, while in "Round Mountain," which rises some 700 feet above the town on the northeast, the rock is found cutting up through the Archæan gneisses. To the southward from Round Mountain are remnants of the surface flows of this rhyolite, and near Rattlesnake Hill, some three miles southeast of Silver Cliff, are small dikes of the same rock. No doubt there is an intimate relationship between this and other rhyolites of the Rosita Hills, but the latter rocks are so diversified in structure that their description cannot be entered into at this time.

The rhyolite of the White Hills is found in places to be a stratified fragmental rock passing on the one hand into fine mud flows, and on the other into brecciated masses which in turn grade into the predominant massive rock. These diversified structures show the eruptive period to have included several outpourings of this rhyolite, which were accompanied by varying quantities of water, and were in themselves of different intensities. The same phenomena have been observed in still more striking manner in some of the rhyolitic eruptions of the neighboring Rosita Hills, and also in other rocks of the latter region.

Macroscopical Description. — The local structural variations in the Silver Cliff rhyolite are many, but the rock as a whole is earthy or felsitic in appearance; white, light gray, pinkish or pale yellowish in color; possesses no macroscopically visible crystals in many places, but usually contains a few smoky quartz grains and some minute sanidine crystals. No biotite, hornblende, or pyroxene is developed in this rock. In some white fragments minute reddish specks are visible and the lens shows these to be garnet. Irregular cavities are sometimes developed lined by small quartz crystals and occasional garnets.

The various structures exhibited are all due to the more or less complete separation of the quartz and feldspar in layers or patches.

A banded or wavy mottled appearance is usually caused by bluish gray bands rich in quartz which stand in contrast to earthy parts of lighter shade rich in feldspar. The banded fluidal structure is seldom sharply defined. Certain masses are compact, dull porcelain-like in aspect, with white or bluish color, and sharp conchoidal fracture. Others are white, soft and crumbling. A tendency to a spherulitic structure is often seen and in some portions there are many of these bodies, which sometimes reach a diameter of one foot or more. These spherulitic

is assumed to be feldspar, though its nature cannot be demonstrated. The development of these minerals varies from specimen to specimen, no two being alike and yet all are similar. Quartz can be very positively recognized where it appears in clusters of irregular grains of considerable size. In one modification of the rock there were many little shot-like grains which a lens showed to be quartz, and these resolve in polarized light into aggregates allied to the more lenticular clusters of certain bands rather than to the larger crystals. From its development in clusters quartz may be traced to less distinct forms. The bluish gray bands and patches seen in the rock are found to contain much quartz as compared with the more earthy parts.

Where quartz can no longer be identified, the mass is cryptocrystalline. There seems to be no isotropic matter, but individual characteristics of form and optical action are lost through the minute size of the grains which overlap and overlie each other in the thinnest attainable sections. This mixture is irregular in many cases, but in others a mottled appearance is produced, in that one substance attains a uniform optical orientation in certain areas but is filled by inclusions of the other substance. No regular intergrowth of the two can be discovered. In some spots it was clearly quartz which was the enveloping mineral, and probably it is always so in this rock, for the feldspathic material of this groundmass has never been found developed in grains of determinable size. As to the formal development of the feldspar it can only be said that it appears in irregular particles as flakes and leaves, interlocking and overlapping in a manner rendering their study very difficult. As this aggregate is usually more or less clouded by products of beginning decomposition, or by films of yellowish brown iron oxide, it is doubly difficult to obtain a clear insight into its composition.

A micro-spherulitic structure was observed only in certain bands of the felsitic rhyolite from the Racine Boy mine-quarry at Silver Cliff. Here are many minute color-

less spherulites with a round isotropic centre about which a radiate structure is indistinctly visible with a high power, and this is further shown by a fixed black cross seen between crossed nicols.

An imperfect concentric shell structure seen in some rock specimens is due to a more or less perfect separation of quartz and feldspar in alternate layers.

Chemical Composition.—The extremely simple mineralogical composition is explained by the result of the rock analysis. Silica, alumina, potash and soda make up more than 98 per cent. of this rhyolite. The analysis, by Mr. L. G. Eakins, is as follows :

SiO ₂	75.20
Al ₂ O ₃	12.96
Fe ₂ O ₃	0.37
FeO	0.27
MnO	0.03
CaO	0.29
MgO	0.12
K ₂ O	8.38
Na ₂ O	2.02
H ₂ O	0.58
P ₂ O ₅	trace
	<hr/>
	100.22

The rock analyzed came from the summit of Round Mountain.

2. *Trachyte.*

Occurrence.—The latest of the series of eruptive rocks in the Rosita Hills is a fairly good representative of this type. It occurs in the massive hill called Game Ridge, near Rosita, and in a number of dikes which extend to the westward, cutting through all other eruptives of the region and cut by none. In Game Ridge itself we apparently see a mass which is partially an overflow and in part is seen cutting up through the Archæan and andesitic breccia.

cia. The dikes illustrate some of the changes possible in mineral constitution as a magma of this composition solidifies at increasing distances from the main eruptive channel, and in gradually narrowing bodies.

Macroscopical Description.—The trachyte of Game Ridge is a very light-gray porphyritic rock the most conspicuous constituent of which is sanidine in characteristic glassy crystals, much fissured and occurring both in tabular and in stout forms, with a length rarely exceeding one centimetre. Plagioclase is seldom identifiable and always occurs in very small crystals. Biotite, in a few small leaves, represents the only dark silicate of the rock.

The strongly predominant groundmass is of a uniform, very light ashen-gray color, and is not resolvable into distinct mineral grains with a strong lens.

Microscopical Description.—The microscopical study of the porphyritic crystals simply shows the sanidine to be unusually free from inclusions except in the outer zone; the plagioclase is found to be an oligoclase; and the biotite leaves have a ragged border containing much magnetite; apatite and zircon are present but in less amounts than is usual in such rocks.

The groundmass is almost entirely a granular mass of orthoclase particles, which seldom show crystal form. Locally there is a development of prismatic or stave-like forms and in all such cases these are arranged in streams or bands through movements in the partially solidified rock. Such movements, unless very marked, are naturally not easily identified by such structures in the more even-grained parts of the groundmass. Quartz is present in small quantity throughout the groundmass and is clearly distinguishable from feldspar in all but the thinnest sections. It occurs in clusters of irregular grains as the latest formed constituent and feldspar grains adjoining it are often partially developed in crystal form.

No glass base is now visible but there are minute angular spaces distributed through the groundmass, and

now occupied by a pale yellowish cryptocrystalline aggregate, which may be devitrification products of residual glass particles.

In structure and composition this rock is closely allied to the so-called sanidine-oligoclase trachytes of the Siebengebirge, near Bonn, in Germany.

A small mass of trachyte allied to the preceding in origin occurs in the small rounded hill south of Game Ridge, and this rock possesses a peculiarity which emphasizes the resemblance just mentioned between this occurrence and several rocks in the Siebengebirge. The trachyte here has a darker gray color than in Game Ridge, and its sanidine crystals are smaller and much more numerous.

The peculiarity referred to is a porous structure of secondary origin. All through the rock one sees small irregular cavities lined by dark brown ochre. A careful examination shows most of these cavities to be surrounded by sanidine, although this is in some cases only a mere shell. The microscopical study of this rock makes it clear that these cavities were once occupied by irregular inclusions which may yet be seen in various stages of alteration in some of the sanidine crystals. Where freshest these are pale yellowish in color and in polarized light are seen to be composed of an aggregate of very small, distinctly doubly refracting particles, a typical cryptocrystalline mass. They are irregular in shape and according to the degree of alteration are mottled or stained by dark-brown oxide of iron. Apparently the original inclusion contained iron in the ferrous state which by the change to ferric oxide and hydration produces the ochre.

Inclusions in the trachyte from Khlsbrunnen, in the Siebengebirge, have been described by Rosenbusch and are apparently almost identical with those of the rock just considered.

Dikes.—The dikes running west from the Game Ridge mass present some interesting changes. In Pringle Hill there are four dikes and the rock of these has in general a somewhat altered appearance. Sanidine is the only porphyritic constituent now remaining, and its crystals are pink in color and less glassy than in the Game Ridge rock.

From Pringle Hill westward the fresh rock is usually dark brown in color from its strongly predominant groundmass. Many small glassy sanidines and a few black biotite leaves are imbedded in this groundmass. Plagioclase crystals, which are always dull and seldom show good cleavage planes, are locally developed more prominently than the sanidine, and the latter is, indeed, almost wholly lacking in many places, the conditions of final consolidation having prevented its formation in distinct crystals and confined it to the microscopic grains of the groundmass.

Contact zones in some of the smaller dikes present an almost black finely porphyritic rock having no resemblance to the type found in Game Ridge and yet possessing very nearly the same mineralogical and chemical composition.

Microscopical examination of the dark dike rocks shows that the darker shade is due to the development of the magnetite, which is here evenly disseminated in very minute grains instead of occurring in a few larger individuals, as in the light colored varieties. Biotite has been as a rule much attacked by the magma in which its early-formed leaves were suspended, and where this destruction of biotite has been most complete there is usually a formation of augite, both in prismatic crystals and in round grains in the groundmass. The grain of the groundmass is sometimes so coarse in these dark rocks that most of the particles can be identified as orthoclase, and quartz is found as in the Game Ridge rock. Plagioclase is the predominant feldspar developed in crystals as was inferred from the macroscopic appearance. From optical behavior this plagioclase is an oligoclase poor in lime.

Chemical Composition.—Two complete analyses of this trachyte have been made by Mr. L. G. Eakins; one of the Game Ridge rock, and the other of a dark brown dike rock. The former is given under IV, the latter under V, below.

	IV.	V.
SiO ₂	66.03	65.41
Al ₂ O ₃	18.49	18.78
Fe ₂ O ₃	2.18	.94
FeO	.22	.72
MnO	tr.	tr.
CaO	.96	1.58
MgO	.39	.16
K ₂ O	5.86	5.41
Na ₂ O	5.22	5.91
H ₂ O	.85	1.38
P ₂ O ₅	.04	tr.
CO ₂	tr.	—
	<hr/>	<hr/>
	100.24	100.29
S.G.	2.592	2.621
at	29°C.	24°C.

The rock on the hill south of Game Ridge has 66.36 per cent. of silica.

Comparing the two analyses with each other no marked differences appear. The dike rock is slightly more basic than the other as shown by the silica, lime and alkalis, but it has less iron than the light colored rock. The percentages vary less for any single constituent than in many duplicate analyses of the same rock, where the mass is not unusually homogeneous.

The composition found is very near that of the trachyte from Kùhlsbrunnen to which reference has been made.

3. *Syenite.*

Occurrence.—The rocks belonging in this division are exposed as narrow, vertical dikes extending for consider-

able distances, and cutting through gneiss. The dikes are noteworthy for their straight courses, constant width, and uniform mineralogical composition. This rock is only known to cut Archæan schists and is distinctly older than any other eruptive of the district excepting, perhaps, the diabase of certain small dikes, and the peridotite of Cottonwood gulch, near Querida.

Macroscopical Description.—The rock is composed of a predominant dull red feldspar with minute green prisms and grains of hornblende.

Rarely there appear porphyritic crystals of red orthoclase, of tabular form, 1–3^{mm} in thickness with a length of 1^{cm} or more. These usually include long narrow prisms of hornblende. In the mass of the rock the feldspar is also developed in rudely tabular individuals seldom exceeding 2^{mm} in greatest diameter, and are sometimes in approximately parallel position, producing a very imperfect schistose structure. As for the green prisms, evenly distributed through the mass, their identification as hornblende is only made clear with the aid of a lens, and then particles of pale green epidote become also visible.

Microscopical Description.—The microscope shows two feldspars, a monoclinic and a triclinic, both developed as a rule in tabular crystals of imperfect form. They are equally filled by very minute ferritic particles causing the red color, and are much alike in appearance in every way. The orthoclase is usually twinned according to the Carlsbad law while the plagioclase exhibits the albite twinning, and both act quite feebly on polarized light. It would seem from the appearance of the field in polarized light that plagioclase predominates slightly, but the species is clearly one poor in lime, both from the low angle of extinction in the zone of the twinning axis and from the small percentage of lime found in the rock, a large portion of which must be reckoned to the hornblende and calcite. Extinction in the zone named is never more than 3 or 4 degrees from the twinning line.

Besides the hornblende the microscope reveals a green mica, and there are seen to be two varieties of hornblende occurring in very intimate relationship. The hornblendes are often found together in single crystals, and so irregular are the formal relationships that it is difficult to prove either one to be of secondary origin however strongly this may be suspected. Both varieties are massive; one has a general brownish color, the other a dark bluish green. Both are strongly pleochroic; the brown having *a* greenish, *b* chestnut brown, *c* dark brown; the green, *a* yellowish green, *b* dark green or opaque, *c* bluish green. Both extinguish within a few degrees of *c* in the clinopinacoidal section. The brown variety seems sometimes to be surrounded by the blue, but the reverse relation has also been seen. Both pass directly into decomposition products. The hornblende individual is usually prismatic, but good terminations never occur and even the prism faces are seldom perfect. Perhaps a part of this irregularity is due to alteration.

The mica of this syenite occurs in irregular forms unlike any other development of this mineral ever seen by the writer. It seems to have been one of the last instead of the first of the silicates to form. It is penetrated by feldspar crystals and has in many instances the appearance of having filled in angular spaces. Thin leaves are hence rare and the development parallel to the *c* axis is often the greatest. In color this mica is dark green in ordinary light. It is strongly pleochroic, showing *a* strong yellowish brown, *b* and *c* dark green, or opaque, from strong absorption.

Apatite is the only original accessory constituent now remaining, and it is present in very small quantity.

Decomposition products are: quartz, calcite, epidote and a dark green fibrous mineral which is probably serpentine. Calcite and quartz occur in clear grains, often associated, and, as for the greater part of the epidote, one cannot trace a direct connection with the mineral whose

decomposition furnished the material for the new formation. Epidote is sometimes derived immediately from hornblende or mica. The dark green fibrous mineral with strong polarization is poorly shown and deserves no special notice.

Chemical Composition.—Analysis of the rock described, from a prospect hole on the south slope of the Blue Mountains, yielded Mr. L. G. Eakins the result given below :

SiO ₂	59.78
Al ₂ O ₃	16.86
Fe ₂ O ₃	3.08
FeO	3.72
MnO	0.14
CaO	2.96
MgO	0.69
K ₂ O	5.01
Na ₂ O	5.39
Li ₂ O	none
H ₂ O	1.58
CO ₂	0.75
	<hr/>
	99.96

Sp. Gr. 2.689 at 30°C.

Of the 2.96 per cent. CaO, 0.95 goes with CO₂ to form the granular calcite, seen in the sections. Of the 2.01 per cent. remaining a considerable portion must be assigned to the hornblendes, leaving a very small amount for the feldspars. The anorthite molecule must therefore be very subordinate in the plagioclase of this rock. The low percentage of MgO would indicate that the mica contains much FeO, a constitution very probably explaining the dark green color.

4. *Peridotite.*

The name peridotite embraces a group of very basic eruptive rocks, free from feldspar, and containing olivine as the most essential element. Subdivisions of this group

are made according to the other minerals prominently developed in association with the olivine. Diallage and rhombic pyroxene are the most common of these associates, while ordinary augite, hornblende, or biotite, may assume important positions. The peridotite found near Querida presents an unusual combination in that brown hornblende and hypersthene are developed in about equal prominence beside the olivine.

But little can be said concerning the occurrence of this rock. It forms a small oblong outcrop in the Archæan on the north bank of Cottonwood gulch, just above the Mountain Boy mine. It lies in the main parallel to the stratification of the finely schistose hornblende gneiss, but parts of the mass distinctly cut sharply across this stratification. A coarse pegmatitic vein traverses both gneiss and peridotite.

Macroscopical Description.—This dark brown coarsely granular rock contains as its most prominent constituent a brown hornblende which presents brilliant striated cleavage surfaces that are often 2^{cm} in diameter. These surfaces are very irregular and are interrupted by numerous inclusions of other constituents, the only clearly recognizable one being brown biotite. This latter mineral is also developed in large leaves which are still more frequently interrupted by penetrations of other substances than is the hornblende. The mica is usually brown in color and very lustrous, but the color often grades off into a clear green.

A careful examination with a lens shows the presence of a second mineral with bright striated cleavage faces. This is very abundant but in smaller individuals than is the rule for the hornblende. Splinters of this mineral are light reddish brown in color and inclusions of biotite are rare. Flakes of such grains, examined microscopically, are found to belong to a rhombic pyroxene. The remainder of the rock is dull green in color though possessing a semi-vitreous lustre, and resembles partially altered olivine,

which the microscope shows it to be. It is not developed anywhere in macroscopically determinable individuals.

The large cleavage surfaces of hornblende, with their interruptions, present in some degree the peculiar structure called "lustre mottling" by some petrographers, and "pœcilitic" structure by Williams,* and which is shown so much more prominently in allied rocks.

Microscopical Description.—The constituents of this rock revealed by the microscope are: olivine, hypersthene, hornblende, biotite, plagioclase, magnetite, apatite, pyrrhotite, sillimanite, serpentine, calcite. The rôles played by these minerals are expressed in the following scheme:

Primary Constituents	{ Essential { { Accessory	{ Olivine { Hypersthene { Hornblende.
		{ biotite { plagioclase { apatite { pyrrhotite { sillimanite.
Secondary Constituents		{ serpentine { hornblende { calcite { magnetite.

The rhombic pyroxene forming a principal constituent of this rock is very abundant in short prismatic grains. It is very fresh and contains few inclusions of any kind. Cleavage is strongly developed only parallel to the prism planes. The pleochroism is not very strong, indicating that the iron percentage is low, and possibly it might be more accurate to call it bronzite rather than hypersthene. Olivine is the most frequent mineral inclusion, and these two species seem as a rule to have formed at about the same time.

This hypersthene does not contain any of the microscopic plates or prisms found so abundantly in many

* Geo. H. Williams, *Am. Jr. Sc.*, 1886, xxxi, 30. *Ibid.*, 1887, xxxlii, 139.

instances in similar rocks, concerning the origin of which there has been so much divergence in opinion. But the greater part of the hypersthene does hold inclusions of secondary origin allied to some of those described by Prof. J. W. Judd* in his study of Scottish peridotites.

Olivine is next in abundance to hypersthene, and occurs in irregular grains often reaching several millimetres in diameter, but also appears in smaller, rounded particles. It is on the whole very fresh, the principal alteration having produced black films of probable magnetite on the curving fissures which form a net-work in most grains. Serpentinization has begun in some crystals but has in no case observed destroyed the greater part of any individual. The olivine is colorless and unusually free from inclusions. In a few grains minute gas pores and some possible glass-inclusions were noticed. A single grain of a dark spinel-like mineral was seen, and this may most probably be regarded as pleonast. Picotite seems entirely wanting in this rock. Particles of a metallic mineral with reddish lustre by reflected light are not uncommon in the olivine, and corresponding grains are also seen in other minerals. The determination as pyrrhotite is borne out by the presence of a small amount of sulphur in the rock. The sulphur found by Mr. Eakins in the magnetic ore extracted from the rock powder was only 0.011 per cent. of the rock. This would indicate about 0.03 per cent. of pyrrhotite in the rock.

The most prominent of the accessory constituents is brown biotite. It occurs in irregular leaves of dark brown color when fresh.

A very few small irregular areas of a soda-lime feldspar may be seen in each thin section. This occupies the position of the last formed mineral of the magma. Sections allowing a determination of the position of this mineral in the series were not found, although it is evidently quite basic. All feldspar grains are character-

* *Qt. Jour. Geol. Soc.*, Aug., 1885, p. 354.

ized by many colorless clear prismatic inclusions closely resembling the apatite crystals seen so frequently in eruptive rocks. Crystals corresponding to these are, however, not seen in any other constituent of the rock, not even in the mica. The apatite found occasionally in hornblende or pyroxene is always in large, stout crystals. The cross-sections of these prisms in the feldspar are rounded, as are the terminations. They are moreover seldom of the same thickness throughout. Transverse fissures normal to the prism are, however, characteristic. In view of these circumstances it has seemed to the writer probable that these prisms should be referred to some other mineral than apatite, and in this connection he would suggest that they may be sillimanite. In form and characteristics as far as can be determined these prisms agree very closely with the crystals of sillimanite occurring in many gneisses and schists. Rosenbusch* reports sillimanite as a prominent constituent of the dunite from North Carolina, and its formation here in the acid residue of this basic magma is much more natural than the assumption of a late generation of apatite.

All ordinary decomposition products are very subordinate. A few grains of calcite are present. Black films of magnetite are common on the curving fissures in olivine and a golden serpentine has also been formed from olivine, but to a very limited extent. Chloritic minerals do not seem to be developed.

The biotite bleaches to a pale green mica, and the brown hornblende to a green one. There is also a paramorphic development of hornblende from hypersthene.

Chemical Composition. — Analysis of the typical rock described, by Mr. L. G. Eakins, yielded the result given under I of the subjoined table. 22.53 per cent. of the rock was found to be soluble in hydrochloric acid. This portion is given under II and the percentage expression of this under III.

* *Massige Gesteine*, 2d Ed., p. 274.

	I.	II.	III.
SiO ₂	46.03	9.66	42.89
Al ₂ O ₃	9.27	0.64	2.84
Fe ₂ O ₃	2.72		
FeO	9.94	4.61	20.46
MnO	0.40		
CaO	3.53	0.27	1.19
MgO	25.04	7.35	32.62
K ₂ O	0.87		
Na ₂ O	1.48	tr.	
H ₂ O	0.64		
P ₂ O ₅	0.17		
S	0.01		
	100.10	22.53	100.00

Sp. Gr. 3.228 at 18° C.

5. Augite-Diorite.

Occurrence.—The rock here to be described appears in the central area of the Rosita Hills and is particularly well developed in the mass of Mt. Fairview. The fresh type, as there seen, is all that is included in this present discussion. Local variations and more gradual transitions to other types of the region present very interesting studies which must be left for the complete report upon the Silver Cliff region.

The mass of the Fairview diorite is now so surrounded and penetrated by bodies of other later eruptives that the relations to the underlying Archæan are entirely concealed. From all available evidence, however, the body must be considered as a massive effusion the form and extent of which were greatly changed by erosion prior to the successive eruptions of andesite, rhyolite, and trachyte, now found about it. The general structure and the development of the constituent minerals of the rock now seen are not specially characteristic either of intrusive masses or of the common lava flows.

Macroscopical Description.—The fresh, normal rock as seen, for example, in some projecting cliffs on the eastern slope of Mt. Fairview, is a dark, fine grained rock with no tendency to a porphyritic development. The granular structure is plain, although all the constituents cannot be determined. Reddish brown mica surrounding dark green

grains of augite is distinctly seen, and a striation upon the plagioclase may be detected. None of the constituents ever reaches a diameter exceeding one-half centimetre.

Microscopical Description.—The essential constituents of the rock are : augite, biotite, and plagioclase ; accessory are : orthoclase, olivine, magnetite and apatite. The chief element is a soda-lime feldspar occurring in imperfectly tabular crystals with a fine lamellar twin structure. The optical properties of the plagioclase indicate that it must be quite basic,—probably labradorite. In addition to the triclinic feldspar there is a little orthoclase, never found except in irregular particles, though quite frequently surrounding the labradorite in regular position, the two having the clino- and brachypinacoids parallel, and the vertical axes are probably as nearly coincident as is possible. The labradorite contains many small irregular glass inclusions most of which are at least partially devitrified. These are not comparable in form or arrangement to the glass-inclusions often seen in feldspar crystals imbedded in the groundmass of surface flows of andesites of corresponding chemical composition.

Augite is next in importance to the plagioclase. It occurs in imperfect prismatic crystals and in small irregular grains. It is frequently full of irregular glass inclusions, with apatite, and magnetite and occasionally olivine and biotite as mineral inclusions. This augite is apparently of the variety common in trachytic rocks. Distinctly older than the plagioclase it emphasizes most clearly the difference between this rock and the normal diabase to which one might consider the occurrence to belong from a simple enumeration of the constituents.

The biotite of this diorite appears more often as a fringe about magnetite or augite grains than in separate leaves, and the latter are seldom regularly formed. It is sometimes intergrown with augite, the foliation being parallel to a pinacoidal plane of the latter mineral. The development of biotite is here very similar to that seen in other augite-diorites and in diabases.

The next most important mineral is olivine, which is here found in rather unusual associations. In the type rock of Mt. Fairview it is scattered through the mass quite uniformly, in small grains which seldom reach .5 centimetres in diameter. It is rarely of good crystal form, but is fresh and of characteristic appearance in many grains, while the various stages of decomposition are represented so well that no doubt exists in the mind of the writer as to its identity. The mineral in question has surely not been confounded with a rhombic pyroxene, as has been done in many published rock descriptions, where decomposition products alone have been taken as evidence of the nature of the original mineral. In some specimens of the Fairview diorite the alteration product of olivine is blood red by reflected light, though usually green in color. Inclusions are rare in this olivine. The amount of olivine developed varies greatly. It is never quantitatively important and is entirely wanting in many places. It is here considered as an abnormal formation and not an essential constituent. The remaining minerals, apatite and magnetite, occur in the usual manner.

Chemical Composition. — A quantitative analysis of the rock from the cliff on the eastern slope of Mt. Fairview yielded Mr. L. G. Eakins the following result :

SiO ₂	50.47
TiO ₂	.51
Al ₂ O ₃	18.73
Fe ₂ O ₃	4.19
FeO	4.92
MnO	.11
CaO	8.82
MgO	3.48
K ₂ O	3.56
Na ₂ O	4.62
H ₂ O	.58
CO ₂	tr.
P ₂ O ₅	.10
Cl	tr.
	<hr/>
	100.09

S. G. 2.870 at 32° C.

It is plain from the analysis, taken in connection with the description, that the plagioclase must be rich in the anorthite molecule, while the percentage of potash indicates the presence of more orthoclase than one would feel assured of from the microscopical examination.

6. *Sanidine-bearing-andesite.*

Occurrence.— This rock occurs in the Rosita Hills and on their southern flanks. It is separated from the Fairview augite-diorite in period of eruption by at least a portion of the rhyolite outpouring, for it is found cutting the latter in numerous dikes, and resting upon it in sheets, while the rhyolite in turn cuts the diorite. The main development is in dikes and in adjacent masses which have poured out of them.

The chief dike runs from Rattlesnake Hill along the southern base of the Rosita Hills and practically connects with the mass of the same rock seen in Pringle Hill near Rosita.

Macroscopical Description.— This is a porphyritic rock having a largely predominant dark brown groundmass in which are imbedded many small feldspar crystals, and minute flakes of biotite. Of the feldspar crystals the largest and most conspicuous are pink, glassy tablets of sanidine, developed parallel to the clinopinacoid. These are never more than one centimetre in greatest diameter and are usually much less. More numerous than the sanidines are smaller, white feldspar crystals, upon the basal cleavage plane of which the striation characteristic of plagioclase can easily be detected. A few small wedge-shaped crystals of titanite may be seen scattered through the groundmass.

Microscopical Description.— The minerals seen in thin sections of this rock are as follows: plagioclase, orthoclase, quartz, biotite, augite and the accessory elements, titanite, magnetite and apatite.

The plagioclase crystals are well formed and show

fine polysynthetic twin structure. They are probably all referable to oligoclase, to judge from optical properties. Minute indistinct inclusions, some of which are fluid, render many of these crystals cloudy. No regular order is observable in the arrangement of the inclusions, and a zonal structure due to changes in acidity of the feldspar in different periods of growth is not here developed.

The oligoclase crystals are nearly always surrounded by a zone of orthoclase, which has itself a quite regular outline. The two feldspars are regularly oriented with clino- and brachypinacoids parallel. A peculiarity of the orthoclase zone is that it cannot be distinguished at all in ordinary light, as it contains inclusions of all constituents of the groundmass in such abundance. This zone is in fact merely the orthoclase of the groundmass brought into regular relations with the plagioclase by crystallographic forces, and the only unusual feature in this case is the uniform thickness of this zone about all crystals.

A pale green augite in imperfect prismatic crystals is subordinate to the biotite, which is present in brown leaves having a granular border rich in magnetite.

The groundmass varies in grain in different places. Where coarsest its constituent particles are distinguishable as orthoclase, plagioclase and quartz, with minute magnetite particles, titanite, and apatite, are scattered through it, the former very regularly. Quartz is never abundant and is regarded as representing a slight excess of silica in the magma.

Chemical Composition.—The rock subjected to quantitative analysis came from a knoll on the main dike passing through Rattlesnake Hill. It shows a goodly number of clear sanidine crystals, but its groundmass is so dark, from the great number of minute magnetite grains present that one would naturally expect a much lower percentage of silica than was found, a case comparable with the dike rock of the trachyte already described. The analysis is by Mr. Eakins.

250 ERUPTIVE ROCKS FROM CUSTER CO., COLO.

SiO ₂	63.49
TiO ₂	tr.
Al ₂ O ₃	18.40
Fe ₂ O ₃	2.44
FeO	1.09
MnO	0.16
CaO	2.30
MgO	.66
K ₂ O	4.62
Na ₂ O	5.70
H ₂ O	1.04
P ₂ O ₅	tr.
CO ₂	tr.
	<hr/>
	99.90

Li₂O was tested for but could not be detected by the spectroscope. Outwardly this rock seems as likely to be low in silica as many specimens of the Fairview diorite, whereas there is a difference of 13.02 per cent.