

## THE LEUCITE HILLS OF WYOMING\*

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## GENERAL REVIEW OF THE OCCURRENCE OF LEUCITE.

The mineral leucite is not a rock-maker of the first magnitude, but it has nevertheless attracted special interest because of its abundance where found. This latter characteristic places it in the group of feldspathoids, which in a minor way have the same important relations to the classification of igneous rocks as do the feldspars themselves. It is the general impression that up to 1868 but three leucite localities were known,†

\* In the field-work on which this paper is based the writer has been assisted by Mr Charles A. Fulton, one of his students, and by Mr O. A. Kennedy, of Ogden, Utah, to both of whom acknowledgments are here made.

† It is stated by E. Kalkowsky in a review of a paper by V. Steinecke, entitled "Ueber einige jüngere Eruptiv-gesteine aus Persien," which was published in the Zeitschrift für Naturwissenschaften, iv Folge, Band vi, pp. 1-71, Halle, 1887, and which is not accessible to the writer, that Loftus had made known the occurrence of leucite near lake Urmia, in Persia, in 1850. ("Aus dieser Gegend hatte bereits Anfangs der fünfziger Jahre Loftus das Vorkommen von Leucit erwähnt.") This would modify the above sweeping statement. See Neues Jahrbuch., 1889, vol. i, p. 438.

namely, the Italian volcanoes, especially Vesuvius, the Laacher See, and the Kaiserstuhl in the Black Forest. Humboldt described the mineral as essentially a European one. The introduction of the microscope, and especially its employment by Zirkel in the preparation of his work on the basaltic rocks,\* brought to light a number of other localities in Saxony, Bohemia, Thuringia, and the Rhön mountains,† all of which were, however, European. In 1874 it was discovered by Vogelsang in a basaltic rock from the small island of Bawean, north of Java, and the announcement was made the next year by Zirkel, ‡ the literary executor of his friend Vogelsang, who had passed away in the meantime. Its next discovery was in rocks from the locality that furnishes the subject of this paper, and was announced in 1876 § by Zirkel, since which date the following additional localities have been successively made known: By Doelter, || from Monte Ferru, Sardinia, in 1878, in a basaltic lava; by Lorié, from the volcano Ringgit, in eastern Java, in 1879; ¶ on Sao Antao, one of the Cape Verde islands, by Doelter, \*\* in 1882, in a leucite; from the volcano Moeria, in central Java, by Verbeek and Fennema, †† in 1882; in northwest Persia by Pohlig, ‡‡ in 1884, in a leucitophyre; from the Cerro de las Virgines, in Lower California, by von Chrustschoff, §§ in 1884; in Argentina by G. Lallemand, |||| in 1884. So-called pseudomorphs of feldspar, after leucite, were reported from Magnet Cove, Arkansas, by G. F. Kunz, ¶¶ in 1885, and were afterward investigated by J. Francis Williams in 1890, by whom they were called pseudoleucites.

\* Untersuchungen über die mikroskopische Zusammensetzungen und Struktur der Basaltgesteine. 2 vols., Bonn, 1870.

† These statements are chiefly taken from volume vi of the Survey of the Fortieth Parallel, p. 259.

‡ Neues Jahrbuch, 1875, p. 175. Compare also later citations of Verbeek and Fennema and of Behrens.

§ Survey of the Fortieth Parallel, vol. vi, p. 259, Microscopical Petrography. See also vol. ii, p. 236, Description of occurrence, by S. F. Emmons. Zirkel gives the essentials of its microscopic characters also in Berichte der Sächs. Gesellsch. der Wissenschaften, 1877, p. 238.

|| Denkschriften der Wiener Akad. der Wissenschaften, vol. xxxix, 1878, p. 40.

¶ Bijdrage tot de Kennis der javaansche Eruptief-gesteenten, Rotterdam, 1879, p. 247. See also Behrens, Neues Jahrbuch, vol. ii, 1883, p. 60, and Natuurk. Verh. Kon. Vet. Akad., Amsterdam, vol. xxiii, 1887.

\*\* Die Vulkane der Capverden und ihre Produkte, Graz., 1882, p. 19.

†† Neues Jahrbuch, Beilage-Band. ii, 1882, p. 169.

‡‡ Sitzungsberichte der Niederrheinische, Gesellsch. in Bonn, 1884, p. 98. See also regarding leucite from Choi, Steinecke, Jungere Eruptivgesteine aus Persien, Inaugural Dissertation, Halle, 1887.

§§ Tschermaks Mittheilungen, vol. vi, p. 160.

|||| Apuntos mineralógicos de la república oriental, An. Soc. Cient. Argent., vol. xvii, p. 49, sqq., Buenos-Ayres, 1884. The reference is on the authority of v. Chrustschoff as under 1890, later cited, the original not being accessible to J. F. K.

¶¶ Proc. Am. Assoc. Adv. of Science, vol. xxxiv, 1885, pub. 1886; Am. Jour. Sci., vol. xxxi, 1886, p. 74; analyses by Genth; microscopic examination by G. P. Merrill. The same occurrence was reported to Rosenbusch by H. Carvill Lewis, Mikroskop. Physiographie, 1887, p. 631. J. Francis Williams, Annual Rep. Ark. Geol. Survey, vol. ii, 1890, p. 267, and elsewhere in volume. Compare also subsequent references under Derby, Hussak, and v. Graeff.

Derby found it,\* in 1887, in leucitite from the vicinity of Rio Janeiro, Brazil. For the leucite from Choi, Persia, described by Steinecke in 1887, see the reference above under Pohlig. In 1887 J. W. Judd † announced the discovery of leucite at Byrock mountain, in New South Wales, by T. W. Edgeworth David, who with W. Anderson described it in full in 1889. A boulder of leucite rock from Ishawooa canyon, Absaroka range, Wyoming, was described by Arnold Hague ‡ in 1889, since which date the rocks have been discovered in place and have been treated at length by J. P. Iddings under the name of leucite-absarokite. § In 1889, also, J. Shearson Hyland || detected leucite in a leucite-basanite from the volcano of Kilima-Njaro in Africa, making the first announcement of it from the African mainland. In 1890 A. Lacroix ¶ made known its occurrence at Trebizond, Asia Minor, and in the same year v. Chrustschoff\*\* announced a new occurrence on the banks of the Tunguska river, in Siberia. In 1892, from some newly discovered material presented by J. F. Kemp to O. A. Derby, Hussak †† described a leucite-tephrite from New Jersey, although only alteration products were present in the specimen. The locality was later described in detail by Kemp, †† who in time identified actual leucite. Bäckström §§ reported leucite in 1896 from the Lipari islands. The greatest interest in connection with this present paper attaches to the work of Weed and Pirsson in the outlying ranges of the Rocky mountains in Montana. Leucite rocks have been met by them in the Bearpaw mountains, ||| and a very peculiar leucitic, plutonic rock called missourite has been described by them from the Highwood mountains. ¶¶ Dr Hoffmann, of the Canadian Geological Survey, as cited by Weed and Pirsson, has reported leucite in boulders from the Horse-

\* Quarterly Journal of the Geological Society, August, 1887, p. 463. The determinations were made by Rosenbusch. Compare also O. A. Derby, idem, May, 1891, p. 261, and F. von Graeff, Neues Jahrbuch, vol. ii, 1887, 258, and E. Hussak, Idem, vol. i, 1890, p. 160, regarding pseudo-leucites.

† Mineralogical Magazine, vol. vii, 1887, p. 190. Also T. W. Edgeworth David and W. Anderson, "The Leucite basalts of New South Wales," Records of the Geological Survey of New South Wales, vol. i, pt. 3, p. 153, Sydney, 1890.

‡ Am. Jour. Sci., vol. xxxviii, 1889, p. 47.

§ Journal of Geology, vol. iii, 1895, p. 938.

|| Tschermaks Mittheilungen, vol. x, 1889, p. 261.

¶ Comptes Rendus, vol. cx, 1890, p. 302. More fully described in the Bulletin de la Société géologique de France, (3), vol. xix, 1891, p. 737. M. Lacroix also announced probable leucite from Mont Doré, in France, in 1891, but the identification is not absolute, Comptes Rendus, vol. cxiii, 1891, p. 751.

\*\* Bull. Imp. Acad. of Sciences, Saint Petersburg, vol. xxxiv, 1891, p. 225. Also in Neues Jahrbuch, vol. ii, 1891, p. 224.

†† Neues Jahrbuch, vol. ii, 1892, p. 153.

‡‡ Am. Jour. Sci., April, 1893, p. 298; May, 1894, p. 339.

§§ Geol. Fören. i Stockholm, Förhandl., vol. xviii, p. 155.

¶¶ Am. Jour. Sci., August, 1896, p. 143; Sept., 1896, p. 194. The latter reference refers to pseudo-leucites.

¶¶ Am. Jour. Sci., Nov., 1896, p. 315.

fly mine, Cariboo district, British Columbia.\* The writer has received from his friend, Professor F. C. Smith, of Rapid City, South Dakota, a suite of rocks from west of Terry peak, in the Black hills, which contains abundant leucites and which is now being studied for fuller description.

In résumé, it may be said that aside from the occurrences in Italy, Germany, and Bohemia, on the European mainland, leucite is known on the Lipari islands. In Asia it is found in Persia, Asia Minor, and

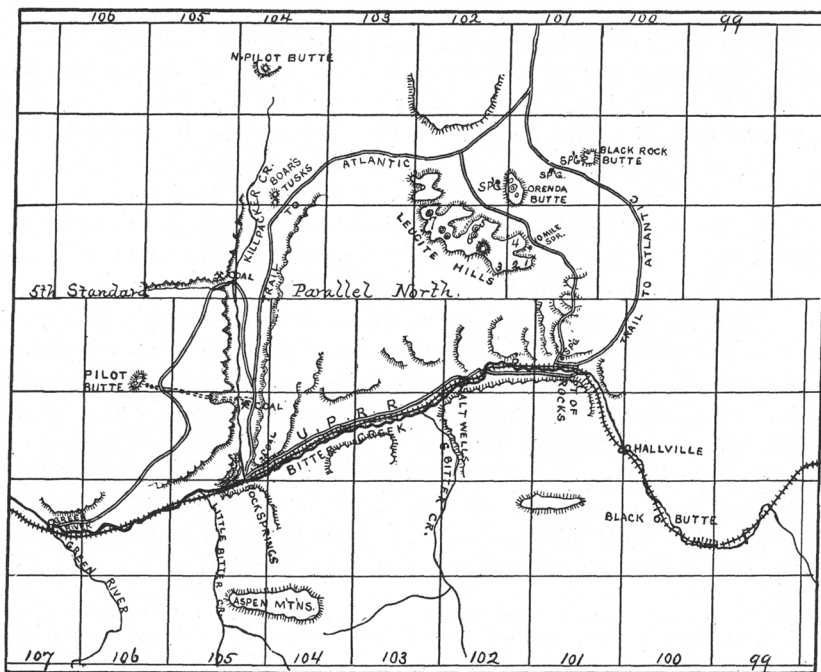


FIGURE 1.—Sketch-map of the Leucite Hills and Environs.

It is based on map 11 of the Survey of the Fortieth Parallel and on the Land Office maps. The squares are townships, 6 miles on a side. The Leucite hills, Orenda butte, Black Rock butte, Pilot butte, the Boar's tusks, and probably North Pilot butte are igneous. The other escarpments, so far as known, are sedimentary strata.

Siberia, on the mainland; and in and near Java, of the East Indies. Off the coast of Africa it is met in the Cape Verde islands and on the mainland on Kilima-Njaro. It is known in one Australian locality. In South America it occurs in eastern Brazil and in Argentina. In North America it is known in Lower California, New Jersey, Arkansas, British Columbia, and in several places outlying from the eastern Rocky mountains.

\* Geol. Survey of Canada, vol. vii, 1896, pt. R, p. 13.

The wide extent of these richly alkaline magmas along the eastern Rocky mountains is a most interesting phenomenon, and is rendered more so by the presence of phonolites in the Black hills, at Cripple Creek, Colorado, and in the Davis mountains, Texas, showing that eruptions of related rocks have occurred over a wide area.

Additional interest has attached to leucite in the past because it was so long regarded as a distinctively pre-Tertiary mineral and as fortifying the now abandoned view that Tertiary and later volcanics should be separated from earlier ones. Its remarkable mineralogical and crystallographical mimetic properties have likewise attracted to it special attention.

#### GEOGRAPHICAL LOCATION OF THE LEUCITE HILLS.

The Leucite hills are situated in southwestern Wyoming, about 60 miles north of the Colorado line. They are within the drainage basin of Green river, from 10 to 15 miles north of Bitter creek, one of the eastern tributaries of Green river and the one which is followed by the Union Pacific railroad. The nearest station is Point of Rocks, from which a wagon road leads north past the hills to several mining camps in the Wind River mountains. The country is arid, with, however, several springs at intervals of 10 miles or less, and is on the western rim of the so-called Red desert. The accompanying sketch-map affords an idea of the location.

#### PREVIOUS DESCRIPTION OF THE LEUCITE HILLS BY S. F. EMMONS.

Mr S. F. Emmons describes the Leucite hills as follows: \*

"The Leucite hills consist of a number of little conical peaks protruded through the beds of the Laramie Cretaceous, which form the plateau country to the north of the railroad, near the Point of Rocks station. The form of some of these hills seems to indicate the outline of a former large crater, while to the north the lavas are spread out horizontally, capping the hills, and extend beyond the limits of our map, apparently forming the summit of North Pilot butte. Although no well defined Tertiary beds were found in actual contact with these eruptive rocks, it is evident, from their position directly over upturned Cretaceous sandstones and adjoining Green River beds, where the underlying, unconformable Vermillion Creek series is not seen, that they have been poured out not only since the deposition of the latter Tertiaries, but since their partial removal by erosion."

The observations of the writer corroborate this view of their late erup-

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\* Vol. ii of the Fortieth Parallel Survey, p. 236.

tion, because, so far as observed, float pieces are restricted to a zone, but one or two hundred yards broad, around the mesa itself. The Laramie sandstones on which the lava rests strike nearly east and west and dip from 10 to 15 degrees north. They are cream-colored sandstone with interbedded shales.

#### ADDITIONAL NOTES.

The leucite-rock forms several different and separated areas. The southerly one is much the largest, and extends about 10 miles, with its long axis running a little north of west. Its outline is irregular, so that it may be two miles wide in places and less than one mile in others. Its area is 10 or 12 square miles. About three miles to the north of its easterly end is Orenda butte, another flow of the lava, but of smaller area. It extends two or three miles in greatest length and varies from a maximum of two miles in width. Five miles northeast from Orenda butte is Black Rock butte, much smaller still. It is rectangular in outline, with reëntrant coves on the northwest and northeast, and is perhaps a quarter of a mile on a side. The sides are precipitous and the top is almost inaccessible.

Some 10 miles west of the west end of the Leucite hills proper, meaning by this the large south flow, are two small buttes in the valley of Killpacker creek, called the Boar's tusks, from which no material was obtained. Some 15 miles northwest of them and on the plateau west of Killpacker creek is Pilot butte, a small area of igneous rock, of which more will be said later on. It is about 1,500 feet from north to south and from 800 to 900 feet from east to west. North again from the Boar's tusks, a distance of about 10 miles, is North Pilot butte, presumably igneous, but from which no specimens were obtained.

#### GEOLOGICAL CHARACTERS.

Each of these buttes or mesas consists of a more or less dissected lava sheet, or aggregate of sheets, which presents an abrupt wall from 50 to 150 feet high, dependent on locality, and which is in the smaller buttes only accessible at one or two points. From the upper surface of Orenda butte and of the large south mesa arise cones of varying sizes, the apex of the largest being about 300 feet above the general surface. The others are smaller, some being quite low. They give the impression of craters from a distance, but all are solid, and they were evidently produced in the later stages of eruption by the welling up of a viscous lava,



FIGURE 1.—VIEW LOOKING NORTH FROM EAST END OF SOUTHERN MESA  
Orenda butte and its cones on left ; Black Rock butte on extreme right ; immediate foreground is southern lava sheet, and the interval is Laramie sandstone



FIGURE 2.—VIEW OF LARGEST CONE ON SOUTHERN MESA, LOOKING WEST  
The cone is about 300 feet high and was about 2 miles from the camera



FIGURE 3.—ESCARPMENT AT EAST END OF LEUCITE HILLS  
Showing lava sheet and talus. Lava sheet from 50 to 75 feet thick

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which did not flow far from its source. They doubtless indicate the location of the vents which supplied the earlier flows, as well. On the large, south mesa there are six cones, four of which are in pairs, while the other two are single. On Orenda butte there are one large and two or three smaller cones. Black Rock butte shows no cone, and Pilot butte has but a slight eminence or blister at its southern end.

These volcanic hills are therefore intermediate in type between the flat mesas such as the Table mountains, near Golden, Colorado, and the plugs of the Black hills.\* They have the flat sheet protecting the underlying sedimentaries, as in the former, and in the cones show the forms assumed by viscous upwellings, not, however, confined in dikes or columns nor brought out into relief, in the cases cited, by the removal of surrounding walls of sedimentaries, as in the outlying igneous buttes about the Black hills.

The Leucite hills are surface flows. No dikes have been met about them, nor are tuffs present in any case known to the writer. The rock is often, if not almost always, of pronounced cellular character, produced beyond question by expanding steam in a surface flow; but even this in the material collected by the writer hardly reaches the pumice stage. The observed phenomena seem to have been produced by the outpouring and lateral spread of a highly fluid lava in the early stages, followed in the later ones by a similar viscous extrusion which remained quite near the vent.

#### PETROGRAPHY.

##### INTRODUCTORY.

There is considerable variation in the rocks gathered at different parts of the south mesa, and also between them and the others collected to the north. Some of the former are extremely rich in leucite and correspond to the rock described by Zirkel. Others, and increasingly so to the north, are poor in this mineral, almost, if not quite, to its disappearance, while orthoclase (sanidine) appears in larger and larger amounts. Häüyne is also present in relatively large anhedral, and, as later described, fairly large phenocrysts of augite and olivine are found in material from Black Rock butte. These phenocrysts are clearly visible to the eye, and by the microscope are shown to be surrounded by rims of biotite. Inclusions of sandstone and impure limestone are very abundant and are met in all parts of the flows as studied. The rock from Pilot butte is almost lacking in leucite, but while its biotite and augite are

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\* I. C. Russell: On the Nature of Igneous Intrusions, *Journal of Geology*, vol. iv, pp. 23 and 176.

practically the same as those of the more eastern flows, it has an isotropic groundmass which is apparently glass.

*PREVIOUS OBSERVATIONS BY ZIRKEL.*

The descriptions by Professor Zirkel were based on several specimens gathered by Mr S. F. Emmons in the necessarily hurried reconnoissance of the great area covered by the geologists of the Survey of the Fortieth Parallel. They came, as the writer is informed by Mr Emmons, from the large south mesa, and yielded to Professor Zirkel the following results:\*

"They have a light yellowish gray, felsitic-looking, and very finely porous mass, in which the only macroscopical inclusion is some brownish yellow and reddish brown mica. This mica is not in six-sided or rounded plates, but in the form of remarkably long stripes and dashes, such as have seldom been observed. No other ingredients are visible to the naked eye, and the specimens do not disclose their rich secretions of leucite. At the first glimpse of the rock under the microscope the leucite appears, with its innumerable, very sharply outlined, colorless octagonal sections, .035 millimeter in diameter. None of the European rocks are as rich in leucite as these, and there is scarcely one in which the forms of the sections are so regular and so similar. As is the rule with all such small bodies, the sections are entirely dark between crossed nicols. . . . All of these leucite sections include quite pale green augite grains. . . . [The inclusions are described in detail.] . . . There are mixed with the leucites in this rock, as independent ingredients, pale green prisms, acicular needles, and microlites, which surely belong to augite, although their shape is indistinct, and larger, better crystallized individuals do not occur. In this fine aggregation and intermixture of leucite and augite the large biotite stripes are imbedded, and none of them of microscopical size was observed. This curiously colored mica, which resembles ormolu and whose long, thin streaks appear in surprising distinctness in the light rock mass, is remarkable for its comparatively very feeble absorption. . . . These plates seem for the most part to be scattered through the rock with some measure of parallelism, and hence the sections prepared parallel to the rock cleavage show no transverse sections of mica, but only basal ones. There is no trace of monoclinic or striated feldspar, and hornblende, olivine, mellilite, hedyne, and nosean are wanting. A small quantity of magnetite is present, and also a considerable number of comparatively thick apatites. . . . Occasionally indistinct colorless rectangular or oblong bodies appear, which possibly belong to nepheline. No corresponding hexagons are visible; but in any case this mineral must be relatively very rare. Some brownish black opaque microlites occur at intervals, and a few of them are included in the mica.

"The external aspect and the mineralogical composition of these rocks differ not a little from the other leucite-bearing masses. Their unusual light-gray color is produced by the extraordinary abundance of leucite and their comparative

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\* *Microscopical Petrography*, p. 260.

poorness in augite. Moreover, the augite occurs only microscopically. The European leucite rocks commonly bear thicker individuals of augite, and much more of it, and also more magnetite, so that their color is a great deal darker. The entire absence of feldspar is as remarkable as the abundance of large macroscopical biotites."

This extended quotation is made to avoid repeating many details already published and to bring out the bearings of the later and more extended observations. Professor Zirkel also gives a good colored plate of a micro-section\* and several drawings of individual leucites.†

*UNPUBLISHED OBSERVATIONS OF CROSS.*

After the specimens and observations for the present paper were gathered and fairly well worked up, the writer learned that his friend, Dr Whitman Cross, had visited the Leucite hills twelve years ago, and had made extended observations, amplified later by chemical analyses of the rocks, with the intention of some time publishing them. On consultation over the rocks it was evident that in general our observations are in harmony, but that each of us in important points had complemented the work of the other. The writer has sought, therefore, to leave untouched certain topics, such as the relations of the several flows, the chemical composition except as it is shown by the analyses already published, and, aside from one small sandstone fragment, the matter of inclusions or xenoliths, as Sollas uses the term, for on all these points Dr Cross' investigations are much more complete than my own, and their early publication will be looked for with great interest.

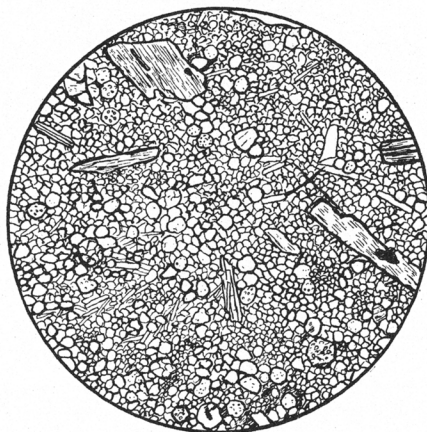


FIGURE 2.—Drawing from a Photomicrograph of a Variety of Rock rich in Leucite.

The large irregular crystals are biotite. The small rods are augite. The round crystals are leucite. The actual field was 1.2 millimeters. The specimen came from the west end of the Leucite hills, at locality number 7.

*VARIETY OF ROCK RICH IN LEUCITE.*

The specimens richest in leucite of those gathered came from the west

\* Plate v, figure 4.

† Plate i, figures 21, 22, 23.

end of the south mesa, at locality number 7, as shown on the map (figure 1). The leucites are also the largest, and are illustrated in figure 2, which is simply a reproduction of an inked-in photomicrograph.\* There is hardly any other mineral except the leucite and biotite in the slide. A little apatite, a rare needle of augite, and a grain or two of magnetite are the only ones recognizable. All the other slides from the Leucite hills have more or less sanidine.

VARIETIES OF ROCK WITH MORE OR LESS SANIDINE.

From the variety rich in leucite referred to above a series may be established through those with more and more sanidine, until at the extreme leucite is quite rare. In the intermediate varieties the leucites tend to



FIGURE 3.—*Augite Phenocryst with Rim of Biotite, from Black Rock Butte.*

The actual field is 2.5 millimeters. The ground-mass is a dense aggregate of sanidine, leucite, and augite, but no attempt has been made to differentiate them. The white spaces are holes, either amygdaloidal or produced in grinding.

An isotropic mineral is also present in one or two of the slides and in anhedral up to a millimeter in cross-section. This is undoubtedly haüyne,

be aggregated in swarms of minute crystals, while the sanidine makes up the chief portion of the remainder of the rock. The sanidine in ordinary light sometimes resembles a clear colorless glass, occurring as it does in the very cellular varieties, but the moment the upper nicol is put on its true character is evident. It has an extinction on its long side up to 8 or 10 degrees, and is occasionally once-twinned, although twinning is uncommon. The sanidine contains a network of minute augite needles which cross one another in every direction, and when it is well crystallized it has the form of rather stout rectangular rods.

\* Figures 2 and 3 have been prepared by a method which combines the fidelity of a photograph with the distinctness of a drawing. Photomicrographs of rock sections are seldom of much significance. A negative was taken immediately from the eyepiece by a vertical camera. A blue print was made from this and inked in with water-proof ink. The blue color was then bleached out with a soda or ammonia solution, the print was washed, and the tendency to turn brown was neutralized by immersion in very dilute hydrochloric acid. In this way a line drawing, black on white, is afforded suitable for photoengraving, and much more quickly, accurately, and easily prepared than with a camera-lucida.

for microchemical tests of it with hydrochloric acid yield but few cubes of sodium chloride.

In specimens from the south mesa, the augite shows occasionally a tendency to develop larger crystals than the minute rods and needles in the groundmass. One was noted of perhaps 0.5 of a millimeter in diameter, but in Black Rock butte the large augites are more frequent and may reach 2 millimeters. They are colorless and are surrounded by a rim of biotite crystals as is shown in figure 3. Olivine is also met less commonly forming the interior core. In one or two slides an opaque decomposition product was noted, apparently limonite in largest part, that in one case had some unaltered strongly pleochroic strips still remaining. It corresponded in pleochroism to biotite or hornblende, but the dark color and almost opaque character prevented its sharp determination. If biotite, it must be of a different kind from the common light brown variety, which is perfectly unaltered. The light brown biotite, which is the most widespread and uniformly present mineral, has been quite fully described by Zirkel. Hexagonal plates do, however, appear in sections taken parallel to the flow, and exhibit a marked biaxial character.

The amygdaloidal cavities are almost invariably empty. In only two cases were fillings detected, and in each they were chalcedonic silica. Although often rusty and more or less weathered the rocks show surprisingly few secondary minerals of this character.

#### INCLUSIONS.

As stated above, inclusions of foreign rock, especially sandstone, are common. In thin section the biotite flakes eddy around them and produce very pretty flow-lines and similar phenomena. An inclusion of orthoclase was also noted, showing strongly undulatory polarization apparently from strains. In the specimens studied practically no contact effects were observable.

#### PETROGRAPHY OF PILOT BUTTE.

Fresh specimens from Pilot butte are not readily obtainable, and are in most cases seamed with veinlets of secondary minerals. The rock has a dense, massive texture, gray in the least altered specimens, and giving to the unaided eye but slight clue to its composition. It is a difficult one to make transparent in thin sections, and of these only the outer edges are, as a rule, available for fine determinations. The light brown mica of the Leucite hills is present in considerable amount, but augite is much more in evidence and is the predominating mineral in the rock.

It forms small, stocky rods in the groundmass and larger micro-phenocrysts up to one millimeter in length and .25 of a millimeter in diameter. It is colorless, often twinned on (100), and has the high extinctions of common augite. The felt of little rods makes up the chief part of the ground mass and exhibits flow phenomena of marked excellence. The biotite contains many little augites. Small, rounded leucites can be detected with high powers, but are in small amount. Much of the interstitial filling of the felt of augites is isotropic and homogeneous and is regarded as glass, although Pirsson's suggestive observations on the isotropic groundmasses of basic rocks makes one suspicious of the presence of analcite.\* This, however, in lack of an analysis, does not impress one as a particularly basic rock. Its color is light and its whole macroscopic appearance suggests trachyte. It was described as trachyte by Mr Emons,† but from the mineralogical details given by him it is clear that there must have been some confusion of slides, probably in the preparation of them. In its systematic relations the rock is mineralogically nearest the augitites, but it is clearly a variant from the group of rocks of the Leucite hills, with which, however, it has the mica and augite in common.

#### CHEMICAL COMPOSITION.

The only analyses yet published are two, one made by R. W. Woodward with silica and the alkalis in duplicate, as given under I and its reference below, and the other by Pawel, made in Germany for Professor Zirkel. With it are placed several other analyses of western leucitic rocks.

|                                      | I.    | II.    | III.  | IV.    | V.     | VI.    | VII.   | VIII.   | IX.    |
|--------------------------------------|-------|--------|-------|--------|--------|--------|--------|---------|--------|
| SiO <sub>2</sub> .....               | 54.32 | 56.30  | 54.04 | 52.91  | 51.93  | 46.51  | 47.28  | 52.11   | 55.11  |
| Al <sub>2</sub> O <sub>3</sub> ..... | 13.37 | 12.63  | 20.27 | 19.49  | 20.29  | 11.86  | 11.56  | 23.01   | 16.07  |
| Fe <sub>2</sub> O <sub>3</sub> ..... | 0.61  | 6.92   | 4.66  | 4.78   | 3.59   | 7.59   | 3.52   | 8.41    | 3.04   |
| FeO.....                             | 3.52  | .....  | 0.64  | 2.05   | 1.20   | 4.39   | 5.71   | 1.75    | 8.46   |
| CaO.....                             | 4.38  | 5.63   | 2.75  | 2.47   | 1.65   | 7.41   | 9.20   | 3.40    | 6.46   |
| MgO.....                             | 6.37  | 5.08   | 0.16  | 0.29   | 0.22   | 4.73   | 13.17  | 2.18    | 3.10   |
| K <sub>2</sub> O.....                | 10.73 | 11.50  | 6.79  | 7.88   | 9.81   | 8.71   | 2.17   | 3.10    | 5.07   |
| Na <sub>2</sub> O.....               | 1.60  | 2.21   | 8.56  | 7.13   | 8.49   | 2.39   | 2.73   | 5.37    | 1.58   |
| H <sub>2</sub> O.....                | 2.76  | .....  | 1.93  | 1.19   | 1.09   | 3.55   | 2.96   | 1.10    | 0.89   |
| CO <sub>2</sub> .....                | 1.82  | .....  | ..... | none.  | 0.25   | .....  | .....  | .....   | .....  |
|                                      | 99.58 | 100.27 | 99.80 | 98.19‡ | 98.52‡ | 97.14‡ | 98.30‡ | 100.43‡ | 100.53 |
| Sp. gr.....                          | 2.22  | .....  | ..... | .....  | .....  | .....  | .....  | 2.838   | 2.546  |

\* The Monchiquites or Analcite Group of Igneous Rocks, *Journal of Geology*, vol. iv, p. 679.

† Fortieth Parallel Survey Reports, vol. ii, p. 238.

‡ Additional components are given under the references which bring up the totals.

*Localities and Authorities.*

I. Rock from Leucite hills; R. W. Woodward, analyst. Fortieth Parallel Survey, vol. i; table opposite page 604, vol. ii, page 237. Duplicate determinations of the alkalies afforded  $\text{Na}_2\text{O}$ , 1.57;  $\text{K}_2\text{O}$ , 10.63.

II. Rock from Leucite hills; Pawel, analyst, for F. Zirkel. Sitzungsberichte der Sächsischen Gesellschaft der Wissenschaften, Mathematische-Physikalische Classe, 1877, page 239.

III. Leucite-tinguaite, Magnet cove, Arkansas, R. N. Brackett, analyst, for J. F. Williams. Annual Report Arkansas Geological Survey, 1890, page 287. Dense rock.

IV. Leucite-tinguaite, Magnet cove, Arkansas; J. F. Williams, analyst. Idem. Rock with phenocrysts; contains also rare earths, 0.48;  $\text{SrO}$ , 0.09;  $\text{MnO}$ , 0.44;  $\text{Li}_2\text{O}$ , trace;  $\text{Cl}$ , 0.53;  $\text{SO}_3$ , 0.52.

V. Leucite-tinguaite, Bearpaw mountains, Montana; H. N. Stokes, analyst, for Weed and Pirsson. American Journal of Science, September, 1896, page 196. Contains also  $\text{TiO}_2$ , 0.20;  $\text{Fl}$ , 0.27;  $\text{Cl}$ , 0.70;  $\text{SO}_3$ , 0.67;  $\text{P}_2\text{O}_5$ , 0.06;  $\text{SrO}$ , 0.07;  $\text{BaO}$ , 0.09;  $\text{Li}_2\text{O}$ , trace.

VI. Leucitite, Bearpaw mountains, Montana; H. N. Stokes, analyst, for Weed and Pirsson. American Journal of Science, August, 1896, page 147. Contains also  $\text{TiO}_2$ , 0.83;  $\text{Fl}$ , trace;  $\text{Cl}$ , 0.04;  $\text{SO}_3$ , trace;  $\text{P}_2\text{O}_5$ , 0.80;  $\text{CuO}$ , strong trace;  $\text{NiO}$ , 0.04;  $\text{CoO}$ , strong trace;  $\text{MnO}$ , 0.22;  $\text{BaO}$ , 0.50;  $\text{SrO}$ , 0.16.

VII. Leucite-absarokite, Ishawooa canyon, Wyoming; J. E. Whitfield, analyst, for J. P. Iddings. Journal of Geology, vol. iii, 1895, page 938. Contains also  $\text{TiO}_2$ , 0.88;  $\text{MnO}$ , 0.13;  $\text{P}_2\text{O}_5$ , 0.59;  $\text{Cl}$ , 0.18.

VIII. Leucitophyr, Lower California, v. Chrustschoff. Tschermak's Mineralogische und Petrographische Mittheilungen, vol. vi, 1884, page 160. Contains also  $\text{TiO}_2$ , 0.15;  $\text{P}_2\text{O}_5$ , 0.19.

IX. Leucite rock, Montalto, Italy, Antonio Verri. Bolletino della Societa Geologica Italia, vol. vii, 1888, page 49. The analysis is taken from the Neues Jahrbuch., 1891, vol. i, page 271.

An examination of numbers I and II at once shows marked peculiarities. The range in silica is high for basaltic leucite rocks, of which VI and VII illustrate the usual values, although somewhat low. The alumina is low, the lime fairly high, and the magnesia remarkably high, exceeding the lime. The alkalies are high, and the great richness in potash as compared with soda is worthy of comment. It is clear from the analysis that a very exceptional rock would result from this magma. Number IX is the nearest parallel to it in general composition. The other analyses illustrate the ranges of the leucite rocks that have been thus far discovered in the west.

The rocks of the Leucite hills, it seems to the writer, are best described as leucite-phonolites which shade into leucitites or related rocks, by which name they have been usually called, as the result of Zirkel's earlier observations, and before the presence of sanidine was known. Zirkel himself merely places them with the leucitites in his recently published and invaluable *Lehrbuch der Petrographie*. The forthcoming paper of Dr Cross, elsewhere referred to, will doubtless settle their systematic relations by means of additional analyses.