ART. XXIII.—*A New Occurrence of Pseudo-Leucite*;* by
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THROUGH the kindness of Dr. A. E. Barlow of the Canadian Geological Survey there came into the possession of the writer two rock specimens whose characters are herewith described. Mr. R. G. McConnell of this Survey collected the material during the summer of 1904 and has sent this note regarding the field relations:

"The leucite rock described in the following paper occurs in the Ogilvie range on the upper part of Spotted Fawn creek, a tributary of Twelve-mile river, Yukon Territory. It occurs in a long dyke-like area about a mile wide where crossed. It is bordered on the north by a reddish granitoid rock, probably a syenite, and on the south by altered sedimentaries, mostly quartzites and slates of Upper Palæozoic age. It has suffered considerable deformation, the leucite crystals in places being crushed into lines.

"The leucite rock is probably intrusive rather than effusive in character, although the examination was too hurried to obtain definite information on this point. It appeared to be older than the syenite and younger than the sedimentaries."

The work was carried on in the geological laboratory of Columbia University, New York, and the writer would express his acknowledgments to Professor Kemp and Dr. Berkey for advice and assistance.

Specimen A is of a medium gray color and perfectly fresh. The ground-mass is very fine-grained and the constituent minerals cannot be distinguished with the naked eye. The principal phenocryst occurs in well developed icositetrahedrons usually less than 1^{cm} in diameter. Fig. 1 is a photograph of two of these phenocrysts showing their crystal form. In color they resemble the ground-mass of the rock so as not to be distinguished from it. They, however, are readily separated from the matrix. The crystal habit is that of the mineral leucite, though in the microscopical examination given later on no trace of an isometric mineral was found. A few sanidines tabular in form and generally less than 5^{mm} in diameter are also seen to play the part of phenocrysts.

Specimen B is quite similar to the one just described with the exception that it has not as many of the icositetrahedral crystals. Instead are seen grayish white, rounded areas 5^{mm} in diameter with apparently no crystal form. Both specimens show a striking resemblance to the pseudo-leucite tinguaita

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from the Bearpaw mountains in Montana, described by Weed and Pirsson.*

Thin sections from specimens A and B when examined under the microscope showed the rock to be made up of the following minerals: orthoclase, pseudo-leucite, nephelite, scapolite and biotite. The first three minerals play the part of phenocrysts; orthoclase and nephelite also appear in the ground-mass and consequently occur in two generations.

Orthoclase:—The ground-mass consists largely of orthoclase laths, showing flow structures. They exhibit a tendency to flow around the pseudo-leucite. Wavy extinction is always observed with crossed nicols. These laths average about $\cdot 1^{\text{mm}}$

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FIG. 1. Pseudo-leucite crystals from Spotted Fawn Creek, Yukon Territory, Can. The crystal form (icositetrahedron) is that of the mineral leucite. Diameter of large pseudo-crystal is 1^{cm} . The crystals have been very slightly flattened by pressure.

in length, while the phenocrysts, which often show the common Carlsbad twins, average 5^{mm} in diameter.

Pseudo-leucite:—These extremely interesting and puzzling pseudomorphs consist of the following minerals: orthoclase, scapolite, nephelite, biotite and a very little plagioclase. The *orthoclase* is most abundant and occurs under two conditions: first, in allotriomorphic grains, less than $\cdot 1^{\text{mm}}$ in diameter, generally concentrated in the more central portions of the pseudo-crystals; second, in lath-shaped individuals often concentrated on the outer borders and oriented in such a way that their longer axes lie normal to the crystal faces of the pseudo-leucite (see fig. 2). It is a striking fact that this border arrangement appears to be a characteristic of the pseudo-leucites from Brazil, Magnet Cove, Arkansas, and the Bearpaw Mountains, Montana. Williams in his description of pseudo-leucites from Magnet Cove has referred to this arrangement of the orthoclase as a "palisade" structure.† The allotriomorphic

* On some Phonolitic Rocks from Montana, this Journal, vol. i, p. 394, 1895, see also vol. ii, Aug. and Sept. 1896, p. 194.

† The Igneous Rocks of Arkansas—Annual Report Geol. Sur. Arkansas, vol. ii, 1890, p. 268.

grains of feldspar are almost always quite clear and fresh; the lath-shaped individuals around the borders, however, generally show incipient kaolinization and are in consequence cloudy when examined with one nicol. The *scapolite* is recognized by its low relief, high interference colors reaching the yellows and reds of the first order, cleavage cracks crossing at right angles, parallel extinction and the distinct uniaxial cross of negative character which is readily observed in basal sections. It occurs in clear allotriomorphic individuals, generally irregularly

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FIG. 2. Photo-micrograph of pseudo-leucite; crossed nicols; actual field 2.5mm. Near the border the lath-like orthoclase individuals lie with their longer axes more or less normal to the faces (icositetrahedral) of the crystal. In the central portions the small allotriomorphic orthoclases are seen.

distributed throughout the pseudo-leucite, but sometimes also gathered together in little groups $\cdot 4^{\text{mm}}$ in diameter. In some instances the individual scapolites reach a diameter of nearly 1^{mm} , but it generally occurs in grains much smaller than this. It was observed in one case to have the appearance of being formed directly from nephelite; and further, the grains of scapolite sometimes occupy areas whose boundaries are distinctly quadratic—a characteristic form of nephelite. It should be noted here that scapolite has not been described before as occurring in pseudo-leucite.

The remaining three minerals which are seen in the pseudo-crystals are *nephelite*, *biotite* and an acid *plagioclase* feldspar. The first of these occurs in allotriomorphic and quadratic sections, showing low relief and low interference colors. Basal

sections give a distinct uniaxial cross, negative in character. The mineral does not seem to be abundant, but a more careful examination with high powers shows it to be present in greater amount than would at first appear. Wavy extinction, as observed in the orthoclase, is likewise seen in the nephelite. The *biotite* occurs in grains always less than $\cdot 05^{\text{mm}}$ in diameter. It is a greenish brown variety, strongly pleochroic. The tiny plates tend to arrange themselves along lines; again they are segregated into patches 1^{mm} or so in diameter, or are irregularly distributed throughout the pseudo-crystals. A very few individuals of an acid *plagioclase* feldspar were noted.

It has been already stated that the pseudo-leucites in specimen B do not appear to possess a crystal form when examined macroscopically. Under the microscope, however, some crystal faces are observed. It is possible that the absence of distinct crystal form may be due to the action of the magma on the original leucite crystals. Apart from the form of the crystals the microscopic description given above applies equally well to the pseudo-leucites of both specimens.

Nephelite:—A few crystals with quadratic cross-section and low interference colors give uniaxial interference figures negative in character. They occur in the ground-mass with one exception; in this instance a crystal $1\cdot 2^{\text{mm}}$ in diameter plays the part of a phenocryst; the mineral gelatinized easily in HCl. Nephelite is not an abundant mineral in the rock.

Scapolite:—Besides occurring as a constituent mineral of the pseudo-leucite, scapolite also forms part of the ground-mass. It is readily recognized by those characters already enumerated above. In size the grains will average less than $\cdot 05^{\text{mm}}$ in diameter.

Biotite:—The orthoclase laths and biotite make up the principal minerals in the ground-mass. The biotite occurs in plates, generally less than $\cdot 1^{\text{mm}}$ in diameter, lying in the interstices of the feldspar laths. It is a greenish brown variety, strongly pleochroic and appears to be similar to that found in the pseudo-leucite crystals.

Though nephelite does not play a prominent part, the rock is nevertheless here classified as a *pseudo-leucite phonolite*. It is highly probable, however, that nephelite was once present in greater amount than it is now, since the scapolite appears to be secondary after it.

The pseudo-leucites studied in this paper resemble very closely those from Brazil; from Magnet Cove, Arkansas; from the Bearpaw Mountains, Montana; from Beemerville, N. J.; and from the Highwood Mts., Montana. O. A. Derby* described the porphyritic types of foyaitite from Brazil containing

* Quart. Jour. Geol. Society, May, 1891, p. 251.

"segregations" which present the aspect of crystals or groups of crystals. These consist of orthoclase, nephelite, augite, hornblende and titanite, with the crystal form of leucite. The marginal layer, rarely absent, is composed of lancet-shaped orthoclase (with nephelite) disposed normally to the faces of the pseudo-crystals. The peculiar masses were studied by Graeff and Hussak;* the former regarded them as inclusions of pre-existent foyaite; the latter looked upon them as true pseudo-crystals representing a tendency to the formation of leucite under physical conditions unfavorable to the complete development of that mineral. Derby suggested "that perhaps crystals of leucite exceedingly rich in inclusions (phenocrysts from the surrounding magma) were actually formed; but that before the complete consolidation of the magma, some change of conditions brought about, through magmatic action, a pseudomorphosis of the leucite molecule into orthoclase and nephelite."

As will be shown below, the pseudo-leucites from Spotted Fawn Creek, Yukon Territory, have about the same chemical composition as those from Magnet Cove, Arkansas, described by J. F. Williams.† At the latter locality they are found in leucite-syenite dikes and leucite-tinguaite. The pseudo-crystals occur in icositetrahedrons 5^{mm} in diameter and consist of a network of allotriomorphically bounded, tabular crystals which are generally arranged in radial forms and which are often interspersed with small allotriomorphic eleolite crystals and idiomorphic pyroxenes. The orthoclase crystals often lie with their symmetry-planes at right angles to the edge of the section and hence forming a sort of palisade about the edge. In the slide of this material examined by the writer it was at once noted that the minerals composing the pseudo-leucite were coarser in grain than in the pseudo-crystals from the Yukon territory. Wavy extinction was also noted in the crystals from Magnet Cove. Williams' hypothesis regarding their formation is similar to that of Derby. He says "they began to form under conditions favorable to the formation of leucite and, as is frequently the case with true leucite crystals, they included all sorts of foreign particles, such as magnetite and aegirite. The conditions then changed and instead of becoming true leucites their substance was recrystallized and the leucite molecule was broken up into eleolite and orthoclase."

The pseudo-leucites described by Weed and Pirsson‡ from the Bearpaw Mountains, Montana, occur in icositetrahedrons

* Neues Jahrb. 1887, vol. ii, p. 255; and 1890, vol. i, p. 166.

† Annual Report Geol. Sur. Arkansas, 1890, vol. ii, "Igneous Rocks of Arkansas."

‡ This Journal, vol. i, p. 394, 1895, 4th series. See also vol. ii, 1896 (4), p. 194.

which average 1^{cm} in diameter. They consist of an allotriomorphic mosaic of orthoclase and nephelite. "In some cases the outer edge of the section is composed of orthoclase crystals with their longer axes perpendicular to the crystal faces of the original leucite." A thin section of the Bearpaw pseudo-leucite examined by the writer contains in its center an isotropic kernel, whose outline resembles the figure 8. Part of the feldspar surrounding the kernel radiates out from this material, giving a spherulitic structure to this part of the slide. It may be that the orthoclase and nephelite have been formed directly from the isometric kernel, or, in other words, this isometric substance might be regarded as a remnant of the *original leucite crystal*. Prof. Pirsson, however, has proved by chemical tests that the material is either sodalite or analcite and not any original unchanged leucite substance. The material examined by the writer was too small to permit the use of microchemical tests.

Prof. Wolff* studied a leucite-tinguaite from Beemerville, N. J., which contains pseudo-leucites similar to those described above. They are made up "of an aggregate of orthoclase, partly in irregular grains, more often in radiating prisms." Between the orthoclase a comparatively small amount of nephelite occurs. The centre of the pseudo-crystals contains an isotropic mineral determined as analcite. Near the same district Prof. Kemp† examined a basic dike consisting of biotite and pyroxene set in a ground-mass that is chiefly analcite. In portions some curious, spheroidal inclusions appear having a diameter up to 10^{mm}; they are made up chiefly of analcite and are always rounded and without crystal form. In the fresh material Prof. Kemp was able to show that the spheroids consisted partly of leucite. These pseudo-crystals have, however, evidently been formed by surface alteration and differ in this respect from the pseudo-leucite from Yukon territory and the other localities mentioned above.

Prof. Pirsson‡ described pseudo-leucites from the Highwood mountains, Montana, consisting of alkali feldspars, nephelite and small amounts of what is held to be analcite. They occur in a "granular intrusive rock consisting of dominant leucite with subordinate augite." These pseudo-crystals are similar to those already described.

In order to study the chemical composition of the pseudo-leucites from the Yukon territory, and also to compare them

* Harv. Coll. Mus. Comp. Zool. Bull., vol. xxxviii, p. 273-277, 1902.

† This Journal, 3d series, vol. xlv, p. 298-305, 1895; also vol. xlvii, May 1894.

‡ Bull. 237, U. S. Geol. Surv. p. 83.

with other occurrences, two crystals were selected for analysis. The crystals, which were of a medium gray color with two or three white streaks running through them, broke away very readily from the ground-mass. This fact seems to indicate that the original leucite on breaking up into orthoclase, nephelite and plagioclase contracted so that it could be isolated easily from the ground-mass. It also goes to show that the breaking down of leucite probably occurred when the rock had entirely solidified, but was still at a temperature not far below its fusion point. Fig. 1 is a photograph of the two crystals analyzed; their actual diameters are about 1^{cm}.

A.	B.	C.
Spotted Fawn Creek, Yukon Territory.	Magnet Cove, Arkansas.	Mt. Vesuvius.
SiO ₂ 58.15	55.06	58.30
Al ₂ O ₃ 23.66		
Fe ₂ O ₃ 1.59	25.26	23.80
CaO 0.43	0.60	0.96
MgO 0.21	0.28	0.17
Na ₂ O 7.08	7.60	5.80
K ₂ O 8.49	10.34	10.94
H ₂ O— 0.10		
H ₂ O+ 1.25	1.78 (ignition)	
Cl ..... trace*		
100.96	100.92	99.97

* Present, but not determined.

A. Spotted Fawn Creek, Yukon territory, Canada; analyzed by C. W. Knight.

B. Magnet Cove, Arkansas, analyzed by J. F. Williams.

C. Mt. Vesuvius, analyzed by Ramelsberg.

For comparison two other analyses are given in the above table. The close resemblance which the pseudo-leucites from Magnet Cove bear to those from the Yukon territory is at once noted. From the high amounts of Na₂O which are shown by the above analyses it seems clear in each case that the original mineral was a *soda-leucite*. On the presumption that the scapolite in the pseudo-crystals from the Yukon territory is secondary after nephelite and that consequently the leucite broke down into feldspar and nephelite, we may find the proportions in which these minerals occurred by recasting the analysis. The biotite may be considered as inclusions (or as a secondary product from inclusions) in the original leucite. Since only a small per cent of biotite is present, the amount of K₂O required for this mineral is not great. To obtain, therefore, an idea of the relative amounts of orthoclase, nephelite

and anorthite all the K_2O may be calculated as present in the orthoclase; this gives: Orthoclase, 50.04%; nephelite, 32.38%; anorthite, 2.22%.

The small amount of lime is considered to belong to the plagioclase, which as previously stated occurs in very subordinate quantities. It is thus obvious that the scapolite is composed essentially of the marialite molecule (Na, Al, Si, O, Cl).

The pseudo-leucites from the various localities previously enumerated have generally three common characteristics: (a) the crystal form of the icositetrahedron, (b) the "palisade" structure about the border, (c) the similarity of the constituent minerals.

Though the only specimen containing scapolite is that from the Yukon territory, still it seems highly probable that the scapolite in this case is secondary after nephelite and that consequently the original leucite broke down into orthoclase (with a small amount of plagioclase) and nephelite. The general resemblances just enumerated would appear to indicate that all these pseudo-crystals were formed under somewhat the same conditions. Just what those conditions were must still be a point open for discussion. It is believed by the writer that the mineral originally crystallized out, in the intra-telluric period of the magma, as a *soda*-leucite, that after the entire magma had solidified the leucite changed over into orthoclase, nephelite and subordinate plagioclase, and that still later the nephelite (both in the pseudo-leucite and in the ground-mass of the rock) changed partly into scapolite.

Leucite, which under any circumstances is a very unstable compound, is evidently rendered much more so by the large replacement of K_2O by Na_2O . It would seem that the presence of the latter in such large amount was responsible for the change of the *soda*-leucite into orthoclase, nephelite and very subordinate plagioclase.

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