ART. XXXVI.—*On some Phonolitic Rocks from the Black Hills*; by L. V. PIRSSON.

FOR our knowledge of the geology of the Black Hills and of the occurrence and distribution of the igneous rocks of the region we are chiefly indebted to Newton.* Crosby† has also shown that the greater part of the younger eruptives are to be considered as occurring in the form of laccolites. Our information in regard to the petrographical character of these rocks is due to Caswell,‡ who studied the suite of specimens gathered by Newton. This was one of the earlier contributions to American petrology, and when we consider the amount of knowledge available on the subject at that time, it was an excellent and careful piece of work.

Reading between the lines of Caswell's report however and possessed of the facts which the great advance in petrographical knowledge during the past fifteen years has furnished we can see that many of the rocks studied by Caswell were of great interest, unusual in character and that they possessed relations not then brought out.

This was shown by an examination of several specimens from the region which have come into the writer's hands from various sources to be mentioned later and it was therefore decided to study them more in detail with the results given in the present article.

Phonolite.

This rock is definitely mentioned by Caswell, as occurring at Black Butte and he gives a figure and description of it.§ From the facts stated by him it would seem to be present also in other localities. Thus the rock from Bear Lodge, or as it is now commonly called, the "Devil's Tower," an isolated butte near the Little Missouri Buttes on the northwest border of the region and described by Newton|| as having a remarkable columnar structure is said to gelatinize readily in acid. It is described as sanidine trachyte.

A specimen of this rock has come into possession of the writer through the kindness of Mr. Geo. Leavenworth of New Haven, who visited the locality in 1889. Both in macroscopic appearance and in thin section it agrees quite well with the description given by Caswell but differs in some important characters. It may also be reasonably inferred that the rock

* Geol. of Black Hills of Dakota, U. S. Geog. and Geol. Surv. Rocky Mts., Washington, 1889.

† Proc. Bost. Soc. Nat. Hist., vol. xxiii, p. 511, 1888.

‡ Geol. Black Hills, as above, Chap. vii, p. 471, Micro. Petrog.

§ Op. cit., p. 503. Plate I. fig. 3.

|| Op. cit., p. 201.

would vary some in different parts of the mass. For Caswell's description the reader is referred to the original memoir as it would be too long to quote here.

The specimen collected by Mr. Leavenworth shows a dense felsitic looking groundmass of a dark gray color with somewhat greasy luster, very thickly dotted with white or pale gray feldspar phenocrysts which attain a size of 1^{cm} in diameter. Sometimes they are columnar on the *a* axis and sometimes short and stout in their habit. They are so thickly crowded as to form a very considerable proportion of the rock mass. Between them lie occasional small black prisms of augite.

In thin section the microscope discloses the following minerals: *feldspar*, *pyroxene*, *titanite*, *apatite* in the first generation and *feldspar*, *nephelite*, *egirine* and *sodalite* (?) in the second. The large feldspar phenocrysts sometimes show a zonal structure which is indeed plainly visible on the hand specimen where any process of alteration has taken place, as on a weathered rock surface—the center and certain zones being more affected than the outer mantle and remaining parts. Generally they are very fresh, showing only an occasional trace of decomposition along a cleavage crack. Between crossed nicols they sometimes reveal the zonal structure but never any appearance of micropertthite from intergrown albite lamellæ and never any twinning save that according to the Carlsbad law.

Since the chemical analysis of the rock—given later—had shown such an excess of soda over potash it was inferred that this feldspar might be anorthoclase and an analysis of it was therefore made.

To obtain material clear glassy fragments of the phenocrysts were first picked by hand, crushed fine enough to pass through a 100 mesh (to the inch) sieve and then washed free from dust and separated by the potassium mercuric iodide solution. They floated readily at 2.614 which would separate any albite (none sank however) and fell at 2.557 which would support any zeolites or decomposed matter. A considerable portion fell at 2.59 and the average specific gravity was between 2.58 and 2.59. Seen under the microscope the material consists of clear homogeneous grains. The analysis gave:

		Ratio.	
SiO ₂	66.44	1.1073	6
Al ₂ O ₃	19.12	.1854	1.005
Fe ₂ O ₃	0.56	----	
CaO	tr.	----	
Na ₂ O	7.91	.1274	} .1815
K ₂ O	5.10	.0541	
H ₂ O (ign.)	0.57	----	
Total	99.70		.984

Neglecting the small amount of water and ferric oxide—the latter due to minute amounts of limonite infiltrated into cleavage cracks—the ratios are those of a normal feldspar in which $\text{Or} : \text{Ab} :: 1 : 2\frac{1}{2}$.

Attempts made to measure the cleavage angle of $c(001) \wedge b(010)$ were not successful as the cleavages were too imperfect to reflect light well and measurements could not be made within 1° with accuracy. The cleavage parallel to $b(010)$ is much better than that parallel to $c(001)$. Such cleavage plates resting on $c(001)$ between crossed nicols extinguish parallel to the edge of $c(001)$ on $b(010)$ or so nearly that no appreciable deviation could be seen with the Bertrand ocular or in monochromatic light; resting on $b(010)$ they have a positive extinction angle of about 9° and in convergent light show the obtuse bisectrix c about perpendicular to the field. The feldspar is therefore a soda-orthoclase.

From these results it would seem that soda-orthoclase or anorthoclase is probably a more common constituent of phonolitic and trachytic rocks than might be supposed from their petrographic description. The concealment of the triclinic character, produced very probably by sub-microscopic or even intimate molecular twinning according to the albite law, would naturally lead to confusion with sanidine while examination of cleavage plates of such material, giving only a slightly increased angle in the positive sense on $b(010)$ and a somewhat higher specific gravity, would scarcely yield sufficient data for reliable conclusions and it is evident that only chemical analysis combined with these can safely establish the precise nature of the mineral.*

Pyroxene.—This is ægirine-augite with characteristic color, pleochroism and extinction. Dispersion of the optic axes is marked. It is zonally built, the ægirine molecule increasing toward the periphery which is finally surrounded by a deep green ægirine mantle. This was evidently growing during the final stage of consolidation as the minerals of the groundmass are idiomorphic against it or else actually imbedded in it. *Titanite* occurs in characteristic lozenge shaped cuts which are almost invariably twinned. The *groundmass* is made up mostly of small lath-like feldspars with Carlsbad twinning arranged in trachytic structure and scattered amidst them are shreds and rods of ægirine and very small idiomorphic nephelites. These latter are very clear and colorless and often bounded by the ægirine shreds as is common in phonolites. They are easily told by their hexagonal basal cuts, dark between crossed nicols and short rectangular prismatic ones with

* Conf. also, article by Wolff and Tarr, Bull. Mus. Comp. Zool. Cambridge, vol. xvi, 1893, pp. 230–231).

parallel extinction and by their very low single and double refraction. There appear also small hexagonal sections of a mineral which is full of dusty inclusions and always isotropic. It is supposed to be of the sodalite group which is also indicated by the chlorine shown in the analysis. Patches of a zeolite in radial structure sometimes occur.

The powdered rock gelatinized readily with hydrochloric acid and no effervescence of CO_2 could be seen. A chemical analysis of it yielded the following results.

Sp. G. 2.582.	SiO_2	61.08
	TiO_2	0.18
	Al_2O_3	18.71
	Fe_2O_3	1.91
	FeO	0.63
	MnO	trace
	CaO	1.58
	BaO	0.05
	MgO	0.08
	Na_2O	8.68
	K_2O	4.63
	H_2O (ign.)	2.21
	Cl	0.12
	SO_3	trace
	Total	99.86
	O = Cl	0.03
		99.83

To be noted is the very small amount of bivalent metallic oxides present and the great excess of soda over potash.

A phonolite occurring in El Paso County, Colorado, has been described by Cross.* It is the only one thus far in North America which has been investigated.† The analysis of it is almost identical with that just given and shows the same excess of soda over potash. So also do the acmite trachytes from the Crazy Mts. described by Wolff and Tarr.‡ In this respect these rocks are noteworthy among American occurrences and

* Proc. Colorado Sci. Soc., 1887, p. 167.

† Recently A. Osann (Geol. Surv. Texas, Ann. Rep. 1892, p. 130) has briefly mentioned phonolites as occurring in the Trans Pecos district, Texas. This makes the third American locality. E. Goldsmith has described so-called phonolites from several localities in eastern Pennsylvania, but since he states that these rocks contain plagioclase, hypersthene and quartz and does not mention nephelite it is not likely that the majority of petrographers will agree with his determinations. His chief reason for calling them phonolites seems to be due to the fact that the rocks split into thin plates and ring when struck with the hammer. He calls them *gabbro phonolites*! and seems to have been unaware of the previous work of Cross and Caswell. (Proc. Acad. Nat. Sci. Philadelphia. 1893, p. 176.)

‡ Op. cit., p. 232.

to be paralleled with those occurring in various parts of Europe and especially in southern Norway. For phonolites they are rather high in silica; thus an analysis of "Nordmarkite" or quartz syenite from Aueröd as quoted by Brögger* has a composition very similar but a greater amount of the ferromagnesian oxides in forming meta-silicates has left a little more silica than was necessary to turn the alkalis and alumina into feldspar and this excess appears as a minute amount of interstitial quartz; while in the present case as the amount of bivalent metals is very small there has not been sufficient silica to turn all the alkalis and alumina into feldspar and nephelite has thus been forced to form.

Another rock very similar to this has been furnished the writer by Prof. C. E. Beecher, who collected it at Deadwood in the summer of 1890. In regard to its occurrence Prof. Beecher says "it occurs as a vertical dike about fifty feet wide cutting through the schists and Paleozoic series in the mountain just south of Deadwood. The specimen was collected in the little ravine above the cemetery near the base of the mountain and where the dike cuts the Potsdam sandstone." The rock has a dense felsitic looking groundmass in which lie reddish *feldspar* phenocrysts, very thin tabular on $b(010)$ and often 1^{cm} across. They are not very numerous. Phenocrysts of a glittering black *hornblende* occur freely sprinkled through the rock. They are generally quite small, and needle-like but are sometimes stouter and attain a length of several m.m.

In thin section are seen in addition *apatite*, *titanite*, *pyroxene*, *nephelite*, *calcite* and zeolitic material. The feldspar is mostly sanidine in Carlsbad twins. A smaller amount of a striated feldspar occurs. The *hornblende* is very idiomorphic, often twinned on $a(100)$ and has the following pleochroism: a light brownish yellow, b olive brown, c olive green, with absorption $c = b > a$. The angle $c \wedge a$ is about 12° and the double refraction is weak. A crystal extracted from the rock was found to have the forms $m(110)$, $a(100)$, $b(010)$ and $r(011)$ and to be twinned on $a(100)$. The prism $m(110)$ is largely developed, the pinacoids being very narrow. On the reflecting goniometer $m \wedge m (110 \wedge \bar{1}\bar{1}0)$ was measured and found $55^\circ 45'$. Before the blowpipe the mineral fuses easily to a black shining magnetic globule coloring the flame strongly and persistently yellow—thus indicating the soda-iron molecule to be largely present. From these facts it would seem to approach most nearly to *barkevikite*, differing somewhat in pleochroism. There is also a gray green augite present in the rock in much smaller amount, which is generally greatly decomposed—limonite and calcite having formed at its expense.

* Min. der Syen. peg. gänge. Zeit. für Kryst., vol. xvi, p. 57, 1889.

These minerals lie in a *groundmass* of trachytic structure consisting mainly of singly twinned feldspars between which lie patches of a colorless mineral of very low single and double refraction which is assumed to be nephelite. Also shreds and fibers of ægirine and the hornblende just mentioned are present. The rock is considerably altered and for that reason no analysis is given. It effervesces considerably in acid and gelatinizes readily.

A rock from this region has been supplied to European dealers by the specimen dealers in Deadwood. The exact locality is unknown—the labels reading simply “Black Hills,” but it is probably from the northern part of the region. It is sold under the name of “Tinguaite.” The hand-specimen shows a splintery fracture and is of bright green color with a grayish cast and the rock strongly resembles some of the varieties of the acmite trachyte from the Crazy Mts. already mentioned. The grain is dense and an occasional long columnar augite is the only phenocryst to be seen.

In thin section it is seen to consist chiefly of a singly twinned feldspar arranged in trachytic structure with an occasional patch of nephelite. It is everywhere penetrated by a fine interminable mesh of ægirine rods and needles which sink to trichites in dimensions. While the feldspars are arranged in flow structure these ægirine needles are scattered without orientation, pass through and through the smallest feldspars and penetrate to some distance the larger ones. They particularly abound in the interspaces and with low powers give the section a peculiar mossy appearance. To them is due the green color of the rock. They are evidently a final product of consolidation, forming after the moving mass which had developed some augite phenocrysts and to a considerable extent the microlites of feldspar of its groundmass, had come to rest. The augite phenocrysts are of ægirine-augite with a deep green mantle of ægirine. The rock appears quite fresh. It gelatinizes in acid. As the locality is unknown, no analysis is given.

From Caswell's report and from what has been shown in the foregoing it is evident that in the Black Hills region there is an extremely interesting series of high alkali-rocks, a fuller knowledge of whose mode of occurrence and petrographical and chemical relations would aid materially in solving for the region that most interesting problem in petrology which Judd has so aptly characterized in the term “petrographical provinces.”

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