ART. XV. — *Igneous Rocks from Eastern Siberia*; by
HENRY S. WASHINGTON.

THE rocks which form the subject of the present paper were collected near East Cape in Siberia, during the summer of 1900, by Mr. A. G. Maddren, who, through the kind offices of Dr. L. B. Bishop of New Haven, generously sent them to me for investigation. It is a pleasure to record my thanks to both these gentlemen for the interesting material thus made available for study, and which has added another to the growing list of localities of foyaite and related alkalic rocks.

East Cape.

Foyaite.—The most interesting rock of the suite is one—the only one—from a locality given as “South of Whalen or Itschan, East Cape.” As the locality is little known, it may be of interest to quote from a letter received from Mr. Maddren.

“The region in the vicinity of East Cape is a rugged one. Mountainous ridges of crystalline rocks come out to the seashore and form bold, rugged cliffs five to eight hundred feet in height. Between these ridges are low swampy stretches of tundra, with pebble beaches. The tops of the ridges are almost barren of vegetation, and the surface is overstrewn with frost-broken blocks of the country rock of all sizes and shapes.”

The rock is quite coarse in grain, composed very largely of an alkalic feldspar, with less nephelite of a slightly brownish color. Scattered through these are small (up to 5^{mm}), stout prisms of hornblende, the arrangement of which suggests a schistose structure. Minute specks of purple fluorite are also visible with a lens.

Under the microscope the feldspar is seen to be distinctly tabular, in stout individuals, generally twinned according to the Carlsbad law. They show little, if any, microperthitic development, or the *moirée* appearance so characteristic of soda-rich orthoclase, and it may be inferred that the feldspar is nearly pure orthoclase. The nephelite occurs in stout individuals, xenomorphic toward the feldspar tables.

Interstitial between these feldspars and nephelite areas, but varying much in relative amount in different parts of the sections, is a finely granular, colorless substance, of low refractive index, the irregular grains, between crossed nicols, being either isotropic or showing yellow or orange colors of the second order, and optically positive. This mineral cannot be cancri-

nite, as was thought at first, since this is optically negative, and the small amount of CO_2 shown by the analysis corresponds to only 0.8 per cent of this mineral. As the analysis also shows an excess of alumina, the granular material must be regarded as hydronephelite, especially as the appearance of the aggregate agrees with the description by Diller of the hydronephelite of Litchfield, Maine.*

The hornblende, which is seen only rarely in the sections, is of a dark olive-green, with very intense pleochroism. There is also present, in less amount, a highly pleochroic, yellowish-green biotite, in stout ragged individuals, which resembles that of the Maine Litchfieldite described by Bayley.†

The small grains of fluorite are seen here and there in the sections, the purple color being often intense and again very faint. They are usually xenomorphic toward crystal faces of the feldspars, almost never as inclusions in the latter. Small zircons are fairly abundant, for such an accessory constituent, and a few titanites were seen. One of these last includes a minute, colorless, isotropic, well-shaped octahedron, of high refractive index, the nature of which could not be ascertained.

	I.	II.	III.	Ia.
SiO_2	55.38	53.56	55.87	.923
Al_2O_3	23.74	24.43	21.82	.233
Fe_2O_3	0.63	2.19	2.34	.004
FeO	1.26	1.22	1.10	.018
MgO	0.81	0.31	0.48	.020
CaO	0.67	1.24	3.07	.012
Na_2O	5.29	6.48	4.81	.085
K_2O	10.05	9.50	10.49	.107
$\text{H}_2\text{O } 110^\circ +$	1.12	0.93	0.34	
$\text{H}_2\text{O } 110^\circ -$	0.38	----	----	
CO_2	0.05	----	----	
TiO_2	trace	----	----	
ZrO_2	0.06	----	----	
P_2O_5	0.06	----	----	
SO_3	0.07	----	----	
Cl	trace	----	----	
MnO	trace	0.10	trace	
BaO	----	----	----	
	99.57	99.96	100.32	

I. Foyaite, East Cape, Siberia. H. S. Washington anal.

II. Nephelite-syenite. Beemerville, N. J. L. G. Eakins anal.
J. P. Iddings, Bull. 150, U. S. G. S., p. 211, 1898.

III. Leucite-phonolite. Lake Bracciano, Italy. H. S. Washington anal. Jour. Geol., vol. v, p. 49, 1897.

Ia. Molecular ratios of I.

* J. S. Diller, this Journal, vol. xxxi, p. 266, 1886.

† W. S. Bayley, Bull. Geol. Soc. Amer., vol. iii, p. 236, 1892.

As the analysis showed an excess of alumina amounting to three per cent, it was thought possible that corundum might be present. The rock powder was accordingly digested with hydrofluoric acid and the residue examined. None of this mineral was found, however, the only substances unattacked being fluorite (whose identity was thus surely established), zircon, and a little of the hornblende.

An analysis of this rock yielded the results given in I, in the other columns being given analyses of rocks of similar chemical composition from other localities.

It is seen that this foyaite differs decidedly from nearly all others in the ratio of $K_2O : Na_2O$, this being close to unity, while in most of these rocks the soda predominates over potash to a very considerable extent, i. e. over 1.5 : 1. Indeed, the Beemerville rock, whose analysis is given above, is almost the only one of this group which approaches the Siberian in this respect.

The close similarity of the Italian leucite-phonolite, which differs only in slightly higher ferric oxide and lime, is very interesting, as another example to be added to the rapidly increasing list of rocks which, with similar chemical composition, differ radically mineralogically. The difference here is of course to be connected with the difference in geological occurrence; the Siberian and New Jersey rocks being intrusive, while the Italian is a surface flow. This tendency of leucite to form in extrusive rocks, while it is absent in intrusives of the same chemical composition, is a well known fact, but the present case is so well marked, and the similarity in chemical composition so great, that it seems worth while calling attention to it.

As to the mineral composition, if the attempt be made to calculate hydronephelite using the extra alumina as a basis, we get 24.1 per cent of this, 4.7 of albite and only 4.5 of nephelinite. This result does not correspond with the appearance in thin section, which calls for much more nephelinite. I have, therefore, calculated the rock as free from hydronephelite, which is an alteration product, the excess of alumina remaining uncombined. As has been pointed out elsewhere, this is a marked feature of other rocks belonging to the foyaite group*. The result is given in Ia below, the composition of the Bracciano leucite-phonolite being given in IIIa.

The albite molecule in Ia is higher than the appearance of the orthoclase would indicate, as has been said above. It must be noted, however, that the hydronephelite present would reduce the amount of this considerably, as already seen.

* H. S. Washington, Jour. Geol., vol. ix, p. 609, 1901.

Ia.		IIIa.	
Orthoclase.....	55.5	Orthoclase.....	47.4
Albite.....	12.5	Anorthite.....	9.0
Nephelite.....	20.3	Leucite.....	12.7
Extra alumina.....	3.0	Nephelite.....	18.0
Hornblende.....	5.2	Aegirite.....	6.9
Biotite.....	3.4	Augite.....	6.0
Zircon.....	0.1		
<hr/>		<hr/>	
100.0		100.0	

The calculation of IIIa is somewhat arbitrary, and is based on the assumption that all the soda, above that required for aegirite, goes into the nephelite molecule. Presumably some of it is in the feldspar, as albite, which would increase the actual amount of leucite. Judging from the sections this is very probably the case, but the relative quantities in each are quite unknown, so the simplest assumption is made above. The anorthite undoubtedly exists in the fine-grained ground-mass, as its occurrence with orthoclase is a prominent feature of the Italian volcanic rocks. It is, however, difficult to detect it, and the augite may be somewhat more calciferous than the usual run of Italian augites, i. e. richer in the diopside molecule. Its amount as calculated is also increased by the assumption, made as usual, that all the Fe_2O_3 is in acmite.

In both cases the quantities of dark minerals calculated correspond well with the appearance in thin section.

From a general point of view this occurrence of foyaite is of interest, since heretofore these rocks have been observed in Siberia, and indeed in Asia outside of India, only at the Ilmen Mountains (Miask) in the extreme western part, this occurrence being long known. Recently another locality has been described by Morozewitch,* at Marinpol, Gov. Ekaterinoslav, in southern Russia, which may possibly, indeed probably, belong to the same general petrographical province.

The foyaite of Miask differ from that of East Cape in being in general richer in soda and poorer in potash, resembling in this respect the normal types. Analyses of them are given in the Guide to the Excursions of the VIIth International Congress (No. V, A. Karpinsky, p. 22, 1897), but as the analyses differ much among themselves, and are apparently not very reliable, it seems scarcely worth while to quote them.

The Marinpol nephelite-syenites are still higher in soda, one of them giving a ratio of $\text{K}_2\text{O} : \text{Na}_2\text{O} = 1 : 2\frac{1}{2}$, though it is not stated in the reference whether this is molecular or not, nor is the analysis given. It may be mentioned that to this pre-

* J. A. Morozewitch, Ref. in Neues Jahrb. Centralblatt, 1901, p. 727.

dominantly albite-nephelite rock Morozewitch gives the name of "marinopolite."

Iskagan Bay.

All the other Siberian rocks which were sent me by Mr. Maddren come from "the head of Iskagan Bay," a small inlet in lat. $64^{\circ} 30' N.$ and long. $172^{\circ} 40' W.$, about 230 km southwest of East Cape. The locality is shown on the accompanying map, copied from that of Alaska of the U. S. C. and G. Survey, for the drawing of which I am indebted to Mr. H. H. Robinson.

The character of the locality resembles the other, for Mr. Maddren says of it: "The Iskagan region is a very rugged and mountainous one, the shores of the bay rising up abruptly to snow-covered peaks." The specimens were collected from the talus slopes.

With one exception these rocks represent lava flows, or at least fine-grained porphyritic forms. It is, of course, impossible to say anything of their age, in the total absence of geological data, but from the partial devitrification of some of them and their general appearance, it is probable that they are not very recent.

Comendite.—The most interesting of these specimens is dense and compact, with a tendency to platy parting under the hammer, of a general flesh tint, sprinkled with dull greenish specks.

In thin section the rock is seen to be holocrystalline, composed almost entirely of irregular quartzes and orthoclase grains, the latter showing a tendency to automorphic development as stout prisms. A micropegmatitic intergrowth of the two is quite common. The feldspar is uniformly clouded with a brownish ferritic dust which gives rise to the megascopic color. Scattered through the mass are irregular shreds of a dark green aegirite-augite, with magnetite grains here and there. Neither zircon nor apatite was seen.

The crystallization of the $\text{NaFeSi}_2\text{O}_6$ molecule as acmite rather than riebeckite, in such siliceous rocks, is of comparatively rare occurrence, as noted by Pirsson in describing the apparently analogous aegirite-granite-porphry of the Judith Mountains, Montana.*

	I.	II.	III.	IV.	V.	VI.
SiO_2	75.44	76.49	74.76	74.35	69.91	68.95
Al_2O_3	11.98	11.89	11.60	8.73	13.76	14.00
Fe_2O_3	0.88	1.16	3.50	5.84	2.17	2.12
FeO	1.02	1.56	0.19	1.00	1.23	3.56
MgO	0.10	trace	0.18	0.07	0.46	0.07
CaO	0.33	0.14	0.07	0.45	1.39	0.23
Na_2O	4.06	4.03	4.35	4.51	4.45	5.45
K_2O	5.01	5.00	4.92	3.96	6.33	5.29
$\text{H}_2\text{O} +$	0.68	0.38	0.64	0.25	0.12	0.05
$\text{H}_2\text{O} -$	0.13	0.12	----	----	none	----
CO_2	none	----	----	----	none	----
TiO_2	trace	trace	trace	----	0.16	0.35
P_2O_5	----	----	trace	----	0.11	----
MnO	trace	trace	trace	0.22	trace	0.55
	<hr/> 99.63	<hr/> 100.77	<hr/> 100.21	<hr/> 99.38	<hr/> 100.09	<hr/> 100.62

I. Comendite. Iskagan Bay, Siberia. H. S. Washington anal.

II. Paisanite. Magnolia, Mass. H. S. Washington anal. Jour. Geol., vol. vii, p. 113, 1899.

III. Comendite. San Pietro, Sardinia. M. Dittrich anal. Rosenbusch. Elemente, p. 237, 1898.

IV. Grorudite. Varingskollen, Norway. Särnström anal. Brögger, Eruptivgesteine Christianiagebietes, i, p. 48, 1894.

V. Aegirite-granite. Miask, Ural Mts. H. S. Washington anal.

VI. Arfvedsonite-grorudite. Frön, Norway. V. Schmelck anal. Brögger, op. cit., i, p. 139, 1894.

A chemical analysis of this Iskagan Bay rock is given in I above, with a few of the very many analyses which might have been chosen for comparison, in II, III and IV. It is

* L. V. Pirsson, Eighteenth Ann. Rep. U. S. G. S., Pt. III, p. 559, 1898.

remarkably close to the paisanite of Magnolia, Mass., but, as the dark mineral here is riebeckite and not aemite, the Siberian rock cannot be called by this name,—an instance of the undue importance attaching to comparatively trivial characters in the present system of classification.

It also resembles the comendite of Sardinia, differing from this notably only in the absolute and relative amounts of the iron oxides. In all three, it will be noted, the ratios (molecular) of the two alkalis are very close to unity. From the most siliceous of Brögger's gronudites (IV) it differs not only in this respect, for in the Norwegian rock the soda greatly preponderates over the potash, but also in the much higher ferric oxide and lower alumina of the latter.

It is true that comendite is placed by Rosenbusch among the effusive rocks,* as the equivalent of the hypabyssal paisanites, and that we have here no exact knowledge of the geological occurrence of the rock in question. Leaving this point aside, it would seem proper to call our rock a comendite, since the development of aegirite rather than paisanite is characteristic of this, and also because the Siberian specimen resembles a specimen of the Sardinian comendite kindly sent me by Signor Bertolio.

The mineral compositions of the Siberian and Sardinian comendites are given in Ia and IIIa below, and are seen to differ only in the relatively greater amount of aegirite as compared with augite in the latter. The two are not calculated to 100 per cent, and the difference from the totals of the analyses are accounted for by the H₂O, etc., of these.

	Ia.		IIIa.
Quartz	31.9	Quartz	31.6
Orthoclase	30.0	Orthoclase	28.9
Albite	33.0	Albite	32.0
Aemite	0.9	Aemite	4.2
Augite	2.1	Hyperstene	0.5
Magnetite	0.9	Magnetite and hematite }	2.5

Recently aegirite-granites from Miask have been described by Pirsson† and Johnsen,‡ and, as it was thought that a chemical comparison of these with the comendite of Iskagan Bay might be of interest, an analysis was made of the Miask granite. The material for this was very generously given me by Prof. Pirsson, from the specimen already described by him, and I take this opportunity to tender my hearty thanks for his

* Rosenbusch, *Elemente*, p. 268, 1901.

† L. V. Pirsson, this *Journal*, vol. ix, p. 199, 1901.

‡ A. Johnsen, *Neues Jahrb.*, 1901, II, p. 117.

kindness. The results are given in V above, with the analysis of a Norwegian grorudite in VI for comparison.

The Miask rock resembles that of Iskagan Bay, especially in the ratio of the alkalis, though these are here absolutely a little higher, as is to be expected, in view of the somewhat lower silica. Ferric oxide and lime are also present in somewhat greater amount, as is also alumina, but the two do not differ in any radical respect, except in the purely physical one of size of grain.

It is of interest to note that the relation of the Miask granite to the Frön grorudite is just about the same as was that between the Iskagan comendite and the Varingskollen grorudite, especially in the respective alkali ratios.

Quartz-porphry.—A rock which resembles the preceding is represented by a slightly worn beach pebble. It is very fine-grained and porphyritic, the groundmass composed of alkali-feldspar and quartz, with phenocrysts of the latter mineral visible. The general color is a light yellowish brown.

The microscope shows that it is composed very largely of a fine-grained, holocrystalline groundmass of alkali-feldspar and quartz in almost equal amounts, with very rare specks of magnetite. Phenocrysts of quartz and of a somewhat micropertthitic feldspar, often in Carlsbad twins, are scattered through this. The groundmass is highly micropegmatitic, and closely resembles on a smaller scale the granite-porphry of the Castle Mountains.*

It was not thought worth while to make a chemical analysis of this rock, but from the microscopical examination it is evident that it is considerably richer in silica than the preceding one, and that probably the potash and soda are present in about equal amounts (molecularly). It may, therefore, be held to belong to the same series as the comendite.

Rhyolite.—A magma of a distinctly less siliceous character is represented by a specimen of a very dense, dark gray rock, sprinkled with many small phenocrysts of white orthoclase and rare ones of quartz. In general appearance it much resembles the old rhyolites of Massachusetts and other eastern states.

Under the microscope it is seen to be far from fresh, composed very largely of alkalic feldspar in irregular grains and small phenocrysts, a few of which show twinning lamellae, with extinction angles which correspond to albite or an acid oligoclase. A few irregular quartz grains are scattered throughout, but the total amount of this mineral is very small. There are also shreds and specks of a black substance representing an original ferromagnesian mineral, but this can have been pres-

* L. V. Pirsson, Bull. 139, U. S. G. S., p. 86, 1896.

ent only to a limited extent. There may have been glass in the rock originally, but, if so, devitrification has obscured it.

As no analysis was made of this rock its exact relationships cannot be discussed. It is evident, however, that it is rather more siliceous than the trachytes proper, and probably occupies in this respect a position intermediate between them and the rhyolites. The character of the feldspars indicates that it is decidedly alkalic, and with potash and soda probably in about equal amount.

Obsidian.—Three of the specimens are of flow rocks, highly glassy in character, but much devitrified, and offering little of interest.

One of these is purplish gray, with small yellowish spots and chains of what megascopically look like spherulites, but which the microscope shows to be at present, in great part, irregular quartz grains. A few are still true spherulites, and it is probable that they were all so originally. The groundmass, which was formerly glassy, is now thoroughly devitrified to a cryptocrystalline aggregate, apparently of feldspar with subordinate quartz. Ferromagnesian minerals are practically absent.

Another is a glassy breccia, much decomposed, of a general reddish brown color. Irregular fragments of a feldspathic rock, sometimes itself glassy, and often carrying aegirite, are cemented by a ferritic glass, which shows well marked flow structure.

The third is a dense black rock, almost wholly composed of devitrified and dusty glass, with fragments of quartz and of alkali-feldspar.

Monzonite.—The last rock to be described differs so much in a chemical and mineralogical way from all the others that it is highly probable that it belongs to a distinct rock series, though it also comes from Iskagan Bay. It is also the only one which was almost certainly of intrusive character.

It is of medium grain and granitic texture, composed of very white feldspar, with a little quartz, and quite abundant stout prisms and anhedral of black hornblende, though the amount of this is very much less than that of the other minerals, probably constituting from 20 to 25 per cent. of the whole.

In thin section the feldspar is seen to predominate very largely over all the other constituents, and to belong to two species. One of these is a finely striated plagioclase in partly automorphic individuals, which Lévy's method shows to be a labradorite of the composition Ab, An . Along with this, but xenomorphically developed as interstitial masses, is an alkali-feldspar which, judging from the optical characters, is a predominantly potassic orthoclase. Some of this latter is cloudy

through incipient decomposition. Quartz occurs in anhedral, but its total amount is very small. It carries minute liquid inclusions.

The hornblende is olive-green, and shows the usual characters of this mineral in the dioritic rocks. It is occasionally epidotized, and some actinolite is also present, derived apparently from the normal hornblende. There are also a few grains of magnetite, which are occasionally, when embedded in orthoclase, surrounded by a zone of biotite. Some grains of titanite are also present.

Although no analysis was made of this rock, yet its systematic position is quite clear. It obviously belongs to the monzonites of Brögger, and indeed much resembles type specimens of this from Predazzo, being slightly finer in grain. The amount of quartz is also a little greater, and the Siberian rock may possibly belong to the banatites or quartz-monzonites.

Locust, N. J., December, 1901.