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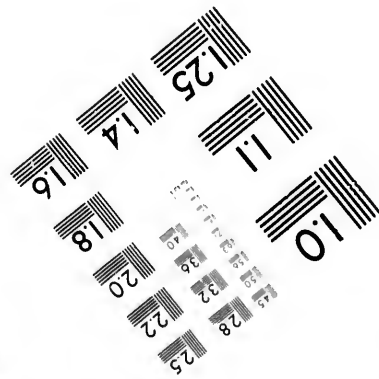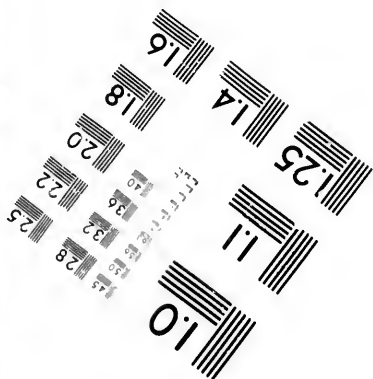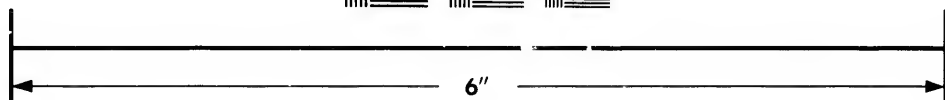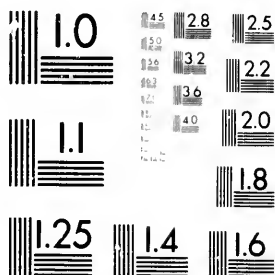
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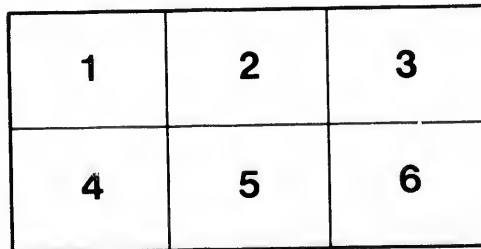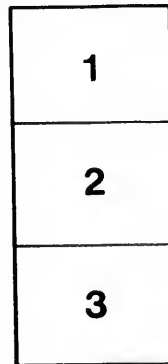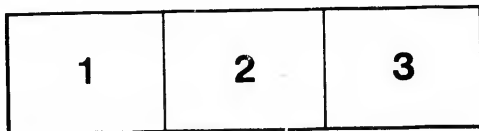The copy filmed here has been reproduced thanks to the generosity of:

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ON A NEW ALKALI HORNBLENDE AND A TITANIFEROUS ANDRADITE FROM THE NEPHELINE-SYENITE OF DUNGANNON, HASTINGS COUNTY, ONTARIO.

By Frank D. Adams and B. J. Harrington,
McGill College, Montreal.

ON A NEW ALKALI HORNBLENDE AND A TITANIFEROUS ANDRADITE FROM THE NEPHELINE-SYENITE OF DUNGANNON, HASTINGS COUNTY, ONTARIO.

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Mc Gill College, Montreal.

Art. XXII.—*On a new Alkali Hornblende and a titaniferous Andradite from the Nepheline-Syenite of Dungannon, Hastings County, Ontario;* by Frank D. Adams and B. J. Harrington, McGill College, Montreal.

In a paper which appeared in the number of this Journal for July, 1894, the discovery of a large area of nepheline-syenite in the township of Dungannon, in the Province of Ontario, was announced and the geological relations and mineralogical characters of the mass briefly described.

One of the many peculiarities of this rock is the absence from it of the mineral pyroxene, which is usually the chief iron-magnesia constituent in rocks of this class, its place being taken by hornblende and mica, but even these minerals are present in comparatively small amount. Of the hornblende two varieties, occurring in different parts of the mass, were distinguished. The first, from near the York river, has a large axial angle with strong pleochroism in tints varying from pale yellow to deep green, and although containing a considerable amount of soda, probably approaches common green hornblende in composition. The second variety, which occurs in a series of exposures about two miles to the east of the village of Bancroft, is quite different in character, having a small axial angle with high extinction and a much stronger pleochroism in the bluish tints suggestive of arfvedsonite.

A number of additional thin sections have been prepared and in the present paper the results of a further investigation of the optical properties and chemical composition of this second variety of hornblende are presented.

Hornblende—The mineral occurs in hypidiomorphic grains, which show the usual hornblende cleavages; it is optically negative, a being the acute bisectrix, but the double refraction is weak.

It possesses, as has been mentioned, a strong pleochroism as follows:

a = yellowish green. b and c = deep bluish green.

The absorption is $c = b > a$. b and c, if not quite equal in absorption, are nearly so, hence sections cut at right angles to the acute bisectrix show but little pleochroism and are nearly isotropic. c lies nearest the vertical axis, but whether toward the acute angle β or on the opposite side cannot be determined as the mineral does not possess a good crystalline form; it makes with the vertical axis a large angle the extinction amounting to 30°.   The plane of the optic axes is the clinopina-

coid, and there is a strong dispersion—red greater than violet. What drew especial attention to this hornblende in the first instance was the fact that it appeared to be nearly uniaxial. When a section, cut at right angles to the acute bisectrix, is examined between crossed nicols in convergent light, a black cross is seen somewhat thickened toward the intersection of the arms. This cross, on revolving the stage, divides into two hyperbolas, but these separate from one another but very little, and appear to separate less than they really do, on account of the fact that the low double refraction and deep color of these sections causes the hyperbolas to be ill-defined, while the whole field is very dark. The dispersion, however, makes itself evident in the varying colors on the sides of the hyperbolas. When, however, a gypsum plate giving a red of the first order is inserted above the objective the hyperbolas become a little better defined, although still not sufficiently definite to allow the axial angle to be accurately measured. The axial angle is found to be over 30°, possibly as much as 45°, which, however, is still very small for hornblende, being about one-half the usual value. Our thanks are due to Professor Rosenbusch for his assistance in working out these optical relations.

On examining a large series of thin sections of nepheline-syenites representing most of the important occurrences hitherto discovered, only two rocks were found which contain a hornblende at all similar to that above described. The first of these is the nepheline-syenite from the Corporation Quarry at Montreal, in which hornblende with the same small axial angle, low double refraction, intense color and pleochroism, large extinction angle and high specific gravity, occurs intergrown with the augite. The second is the hornblende described by Hackman under the name of arfvedsonite and which occurs intergrown with aegerine in the nepheline-syenite from Umptek in the Kola peninsula.* This mineral, however, differs from typical arfvedsonite in having an extinction of about 40° as well as in several other important respects. It possesses moreover a very small axial angle, although this fact is not noted by Hackman, while in true arfvedsonite the axial angle is very large. This Kola hornblende is much lighter in color than the hornblende from either of the above mentioned Canadian localities.

In order to determine the chemical composition of this somewhat remarkable variety of hornblende from the Dungannon rock, it was decided to separate a portion for analysis. A considerable quantity of the rock was accordingly reduced to

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* "Petrographische Beschreibung des Nephelinsyenites vom Umptek," von Victor Hackman. Kuopio, 1894, p. 14.

powder and passed through a sieve of 43 meshes to the inch—
the rock being rather coarse in grain—and after having been
freed from dust was treated with Thoulet's solution, having
a specific gravity of 3·13, in a large separating funnel.   In this
way an almost complete separation of the colored constituents
was effected.   These latter, which sank in Thoulet's solution,
were subjected to the action of a bar magnet and then treated
with dilute hydrochloric acid, and various impurities thus
removed.   The purified powder was then treated first with
Klein's solution, having a specific gravity of 3·22, and then
with methylene iodide, having a specific gravity of 3·323.   In
both fluids practically everything sank, only a few composite
grains floating.   A microscopic examination showed the pow-
der now to consist of grains of hornblende and of garnet with
some composite grains consisting partly of nepheline.   Fur-
ther separation became difficult since, as was subsequently
ascertained, the hornblende had a specific gravity of 3·433,
and the specific gravity of the garnet was 3·739, while many
composite grains consisting of garnet and nepheline had a
specific gravity practically identical with that of the horn-
blende.   As the electro-magnet was found to be useless, both
minerals being readily attracted by it, Retger's silver nitrate
method was employed.*   The silver nitrate was fused in a
properly arranged test tube, and after the introduction of the
powder, potassium nitrate in powder was gradually added to the
fused mass until the garnet fell, the whole being frequently
stirred and maintained at a temperature of from 200° to 240°
C.   On allowing the mass to solidify, a portion of the powder
was found to have collected at the top of the mass, while the
rest was at the bottom, the intervening part being quite free
from mineral grains.   The solid mass was then cut in two and
the salts dissolved by treatment with water.   After three suc-
cessive separations the hornblende was obtained quite free
from grains of garnet—the only impurities present being some
composite grains consisting of garnet and nepheline.   This
powder was then placed under a lens and all the composite
grains picked out by means of a fine needle.   In this way a
quantity of pure hornblende sufficient for purposes of analysis
was obtained, while the garnet was obtained directly in a state
of purity without the necessity of a final separation by hand.

Both minerals were found to be quite fresh and bright and
quite unacted upon by the fused salts.

The hornblende[†] was then analyzed by Dr. Harrington with
the following results:

* "Ueber Schwere Flussigkeiten zur Trennung von Mineralien." Neues
Jahrbuch für Mineralogie, etc., 1889, ii, p. 190.

† We would suggest Hastingsite as a varietal name for this hornblende, con-
necting it with the region where it occurs.

Silica	34·184
Titanium dioxide	1·527
Alumina	11·517
Ferric oxide	12·621
Ferrous oxide	21·979
Manganous oxide	·629
Lime	9·867
Magnesia	1·353
Potash	2·286
Soda	3·290
Water*	·348
	99·601
Specific gravity	3·433

The atomic and quantivalent ratios deducible from the above analysis are as follows:

	Atomic.	Quantivalent.	
Si	$570 \times 4 = 2289$	2356	2356
Ti	$19 \times 4 = 76$		
Al	$226 \times 3 = 678$	1152	
Fe^{III}	$158 \times 3 = 474$		
Fe^{II}	$305 \times 2 = 610$		2354
Mn	$9 \times 2 = 18$		
Ca	$176 \times 2 = 352$	1202	
Mg	$34 \times 2 = 68$		
K	48	48	
Na	106	106	

The ratio of $(R_2O + RO) : R_2O_3 : SiO_2$ is 601 : 192 : 589, or approximately $3 : 1 : 3$, and obviously the mineral is a true orthosilicate agreeing fairly with the formula $(\overset{I}{R}_2\overset{II}{R})_3 \overset{III}{R}_2 Si_3 O_{12}$, or, more fully, $(Fe, Mn, Ca, Mg, K_2, Na_2)_3 (Fe, Al)_2 (Si, Ti)_3 O_{12}$ —a constitution analogous to that of garnet.

So far as we are aware no other hornblende containing so small a proportion of silica has been analyzed; but the small percentage of silica is explained by the large proportions of ferrous and ferric oxides. This is made plain by the following formulæ and the corresponding percentages of silica deduced from them:

Formula.	P. C. of SiO_2.
$3FeO, Fe_2O_3, 3SiO_2$	32·19
$3CaO, Fe_2O_3, 3SiO_2$	35·43
$3FeO, Al_2O_3, 3SiO_2$	36·14
$3Na_2O, Al_2O_3, 3SiO_2$	38·38
$3CaO, Al_2O_3, 3SiO_2$	40·00

* Loss after igniting for about fifteen minutes. On further ignition the powder gained in weight owing to oxidation of the ferrous oxide.

The Dungannon hornblende is interesting in connection with the views of Scharizer, who suggested in 1884[*] that many of the aluminous hornblendes might be regarded as molecular compounds of the metasilicate actinolite, $Ca(Mg,Fe)_3 Si_4 O_{12}$, and the orthosilicate $(\overset{i}{R_2}\overset{ii}{R})_3 \overset{iii}{R_2} Si_3 O_{12}$, for which he employed the name syntagmatite, originally given by Breithaupt to a black hornblende from Vesuvius. The hornblende from the Island of Jan Mayen, analyzed by Scharizer,[†] and that from Bohemia, analyzed by Schmidt,[‡] agree closely with the so-called "syntagmatite molecule." The Stenzelberg mineral, analyzed by Rammelsberg,[§] also approximates to it; but these three and the Dungannon hornblende are the only ones yet examined, so far as we are aware, that give at all closely the syntagmatite ratios. The following table gives the analyses of these four minerals and the molecular ratios deducible from them:

	Jan Mayen.	Molec. R.		Bohemia.	Mol. R.		Stenzelberg.	Mol. R.		Dungannon.	Mol. R.	
SiO_2	39·167	653	653	39·66	661 }	672	39·62	660 }	662	34·184	570 }	589
TiO_2	....	....		0·89	11		0·19	2		1·527	19	
Al_2O_3	14·370	140 }	218	14·83	145 }	222	14·92	146 }	210	11·517	113 }	192
Fe_2O_3	12·423	78		12·37	77		10·28	64		12·621	79	
FeO	5·856	81		1·97	27		7·67	106		21·979	305	
MnO	1·505	21		.. ..	--		0·24	3		0·629	9	
MgO	10·521	263		14·25	356		11·32	283		1·353	34	
CaO	11·183	200 }	648	12·74	227 }	663	12·65	226 }	685	9·867	176 }	620
K_2O	2·013	21		1·25	13		2·18	23		2·286	24	
Na_2O	2·478	40		2·47	40		1·12	18		3·290	53	
H_2O	·396	22		....	--		0·48	26		0·348	19	
	99·912			100·43			100·67			99·601		

In all four analyses the ratios for $(R_2O + RO) : R_2O_3 : SiO_2$ (including TiO_2 when present) are practically $3 : 1 : 3$, or, to give the exact figures (excluding water):

	$(R_2O + RO)$:	R_2O_3	:	SiO_2
Jan Mayen	2·87	:	1 :	2·99
Bohemia	2·99	:	1 :	3·02
Stenzelberg	3·14	:	1 :	3·15
Dungannon	3·12	:	1 :	3·07

The ratio $(R_2O + CaO) : (Mg, Mn, Fe)O$ is, as observed by Scharizer in the case of the Jan Mayen and Bohemian hornblendes, approximately $3 : 4$, thus:

[*] N. Jahrb. f. Min., 1884, ii, p. 143.
[†] loc. cit.
[‡] Min. Mitth., iv, 23, 1831.
[§] Pogg. Ann., 1858, ciii, 454.

	Including Water.		Excluding Water.	
	(R₂O+CaO)	: (Mg, Mn, Fe)O.	(R₂O+CaO)	: (Mg, Mn, Fe)O.
Jan Mayen	3	: 3·87	3	: 4·17
Bohemia	3	: 4·10	3	: 4·10
Stenzelberg	3	: 4·02	3	: 4·38
Dungannon	3	: 3·84	3	: 4·11

Scharizer adopts the foregoing ratios (3 : 1 : 3 and 3 : 4) as those of syntagmatite in calculating the composition of horn-blendes intermediate between $(R_2\overset{\text{I}}{R})_3 \overset{\text{II}}{R_2} \overset{\text{III}}{Si_3O_{12}}$, and actinolite. He assumes in the first place that all the alumina and ferric oxide belong to the syntagmatite molecule (Σ). The sum of the Al_2O_3 and Fe_2O_3 molecules (from the molecular ratio) mul-tipled by *three*, gives $(SiO_2)\Sigma$ on the one hand and $(R_2O+RO)\Sigma$ on the other. The sum of $(R_2O+RO)\Sigma$ divided in the proportion of 3 : 4 gives $(R_2O+CaO)\Sigma$ and $MgO+FeO)\Sigma$. Subtracting $(MgO+FeO)\Sigma$ from the sum of the correspondin molecules deduced from the analysis gives $(MgO+FeO)_A$—that is the number of molecules of magnesia and ferrous oxide belonging to the actinolite molecule (A)—and $(MgO+FeO)_A$ divided by three (see actinolite formula) gives the lime mole-cules of the actinolite $(CaO)_A$. This value subtracted from the total number of lime molecules gives $(CaO)\Sigma$, and $(CaO)\Sigma$ subtracted from $(R_2O+CaO)\Sigma$ gives the alkali molecules (in some cases inc'ding H_2O). Finally $(MgO+CaO)_A$ gives $(SiO_2)_A$. These statements will be made clearer by the follow-ing example, one of those selected by Scharizer.

HORNBLENDE FROM EDENVILLE, ANALYZED BY RAMMELSBERG.

Original analysis.	Molec. R. deduced from analysis.	Syntag-matite.	Actinolite.	Calculated composition.	Original analysis calc. to 100.
SiO₂.... 51·67	861	222	609	51·97	52·66
Al₂O₃ .. 5·75	56	56 } 74	. . .	5·99	5·86
Fe₂O₃ .. 2·86	18	18	. . .	3·00	2·91
MgO ... 23·37	584	127	457	24·35	23·82
CaO ... 12·42	222	70	152	12·96	12·66
Na₂O... 0·75	12	12 } 222	. .	0·78	0·78
K₂O.... 0·84	9	9	. . .	0·88	9·86
H₂O.... 0·46	25	4	. . .	0·07	0·47
98·12				100·00	100·00

Here $(SiO_2)\Sigma = 3(56+18) = 222$

$(R_2O+RO)\Sigma = 3(56+18) = 222$

$(R_2O+CaO)\Sigma = 3\dfrac{(R_2O+RO)}{7}\Sigma = \dfrac{222\times3}{7} = 95$

$(MgO)\Sigma = 4\dfrac{(R_2O+RO)}{7}\Sigma = \dfrac{222\times4}{7} = 127$

$(MgO)_A = 584-(MgO)\Sigma = 584-127 = 457$

$(CaO)_A = \dfrac{(MgO)_A}{3} = \dfrac{457}{3} = 152$

$(CaO)\Sigma = 222-(CaO)_A = 222-152 = 70$

$(Na_2O+K_2O+H_2O)\Sigma = (R_2O+CaO)\Sigma - (CaO)\Sigma = 95-70 = 25$

But $(Na_2O+K_2O)\Sigma = 12+9 = 21$

$$\therefore (H_2O)\Sigma = 4$$

Finally $(SiO_2)_A = (MgO+CaO)_A = 457+152 = 609$

Having thus deduced the molecular ratios of the syntagmatite and actinolite, the numbers for each constituent are multiplied by the corresponding molecular weights, in order to obtain the theoretical relative weights of the constituents of the mixed hornblende.

Syntagmatite.		Actinolite.	
222×60	$= 13320$	$609\times60 =$	36540
$56\times102\cdot6 =$	5745	....	....
$18\times160 =$	2880	....	....
$127\times\ 40 =$	5080	$457\times40 =$	18280
$70\times\ 56 =$	3920	$152\times56 =$	8512
$12\times\ 62 =$	744	....	....
$9\times\ 94 =$	846	....	....
$4\times\ 18 =$	72	....	....
	32607		63332

Then,

$$(32607+63332):(13320+36540)::100: x$$

and $x = 51\cdot97 =$ p. c. of SiO_2 in the mixed hornblende. And in like manner the percentages of the other constituents are calculated.

But $32607:63332$ practically as $1:2$, and therefore the formula of the Edenville hornblende might be regarded as

$$\overset{II}{R_3}\overset{III}{R_2}Si_3O_{12}+2(Mg_3CaSi_4O_{12})$$

or as Scharizer gives it

$$10(\overset{II}{R_3}\overset{III}{R_2}Si_3O_{12})+20(Mg_2CaSi_4O_{12})$$
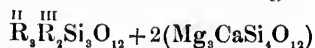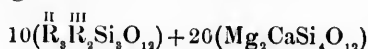
The analyses selected by Scharizer agree remarkably well with his theory, but there are aluminous hornblendes whose constitution cannot be readily explained in this way and which at the same time cannot be referred to the pargasite orthosilicate.*

Garnet.—In the hand specimens the garnet is seen to possess a deep reddish-brown color. In the thin sections it is a paler brown although still deeply colored. It is not found in all parts of the mass and where it does occur is usually present only in small amount. It possesses the usual high index of refraction and is quite isotropic, occurring usually in irregular shaped grains but in some few cases showing distinct crystalline form. It frequently holds a few large inclusions which usually consist of calcite in single individuals, although the garnet is perfectly fresh and the calcite shows no distinct evidence of a secondary origin. It moreover sometimes holds inclusions of the hornblende above described, of pyrite, iron ore and even of nepheline. A garnet resembling this occurs in small amount associated with a similar hornblende, as above mentioned, in the nepheline-syenite of the Corporation Quarry at Montreal, and it also contains as inclusions most of the other constituents of the rock. The same is also true of the melanite in the nepheline-syenite of Alnö.†

Before analysis the garnet was purified by several separations with fused silver nitrate and on careful examination with the microscope the grains appeared to be entirely free from foreign matter. With the pycnometer their specific gravity at 16° C. was found to be 3·739. Chemical analysis gave the following results :

Silica	36·604
Titanium dioxide	1·078
Alumina	9·771
Ferric oxide	15·996
Ferrous oxide	3·852
Manganous oxide	1·301
Lime	29·306
Magnesia	1·384
Loss on ignition	·285
	99·577

The atomic and quantivalent ratios deduced from the above analysis are as follows :

* See Scharizer's paper, loc. cit., p. 156.
† "Ueber das Nephelinsyenitgebiet auf der Insel Alnö," von A. G. Högbom. Geol. Fören. i. Stockholm Förh., 1895, p. 144.

$$
\begin{array}{llll}
& \text{Atomic.} & & \text{Quantivalent.} \\
\text{Si} \dots\dots\dots & 610 \times 4 = 2440 & \left.\vphantom{\begin{array}{c}1\\1\end{array}}\right\} & 2492 \quad 2492 \\
\text{Ti} \dots\dots\dots & 13 \times 4 = 52 & \\
\text{Al} \dots\dots\dots & 192 \times 3 = 576 & \left.\vphantom{\begin{array}{c}1\\1\end{array}}\right\} & 1176 \\
\text{Fe}^{\text{III}} \dots\dots\dots & 200 \times 3 = 600 & \\
\text{Fe}^{\text{II}} \dots\dots\dots & 53 \times 2 = 106 & \\
\text{Mn} \dots\dots\dots & 18 \times 2 = 36 & \\
\text{Ca} \dots\dots\dots & 523 \times 2 = 1046 & 1290 \\
\text{Mg} \dots\dots\dots & 35 \times 2 = 70 & \\
\text{H} \dots\dots\dots & 32 32 &
\end{array}
$$

The ratio for $\dot{R}O : R_2O_3 : (SiTi)O_2$ is $629 : 196 : 623$, or, calculating the titanium as Ti_2O_3, $629 : 203 : 610 = 3 : 1 : 3$. The analysis therefore accords well with the ordinary garnet formula $3RO, R_2O_3, 3SiO_2$ or $\overset{\text{II}}{R}_3\overset{\text{III}}{R}_2Si_3O_{12}$, and the mineral may be regarded as a titaniferous andradite, with a considerable proportion of the ferric oxide replaced by alumina. In composition it resembles somewhat the brown garnet from the Island of Stokö, analyzed by Lindström.*

By way of comparison the analysis of the Stokö garnet and also one of a garnet from the nepheline-syenite of the Island of Alnö† are included in the following table.

	Stokö.	Molec. R.		Alnö.	Molec. R.		Dungannon.	Molec. R.	
SiO₂	26·63	610	610	31·15	519	603	36·604	610	623
TiO₂	....	---	---	6·73	84		1·078	13	
Al₂O₃ ...	9·97	98	182	3·14	31	180	9·771	96	196
Fe₂O₃ ...	13·45	84		23·83	180		15·996	100	
FeO	2·28	32		----	---		3·852	53	
MnO	·63	9		·58	8		1·301	18	
CaO.....	35·90	641	698	33·44	597	616	29·306	523	645
MgO	·28	7		----	---		1·384	35	
Na₂O....	---	---		·68	11		----	---	
Ign.	·16	9					·285	16	
	99·30			99·55			99·577		

* Zeitschr. fur Kryst. u. Min., xvi, 160, 1890.
† Sahlbom, in the paper by Högbom already cited.

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