Allanite in Korea

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1. Allanite at P'ano-ri, P'allyung-ni, An'ak-ŭp and Naep'yŏng-ni, Unhong-myŏn, An'ak County, Hwanghae-do[1)]

Allanite is found at a point some 19 km north of the Hwanghae branch of the main tracks between Seoul and Sinŭju. The general geology around the spot where allanite is found is mostly composed of granitic gneiss of pre-Cambrian age and two-mica granite of the Cretaceous period, the latter probably cuts the former and includes not only the main mass but also many intrusions of aplite, pegmatite and even quartz veins. The general strike of these dikes coincides with the schistosity of the granitic gneiss (Fig 1).

Allanite occurs as one of the accessory minerals in dikes of pegmatite and aplite, accompanied by paragenetic minerals such as garnet, hornblende, diopside, zircon, sphene, rutile, ilmenite and various sulphides. General rules, directly related to the origin of the allanite obtained from field observations of the modes of occurrence of this mineral are as follows:

1. No allanite is found in quartz veins which are associated with pegmatite dikes or aplite, but in the latter (dikes) themselves;
2. Dikes of pegmatite or aplite which are associated with allanite are usually found in a granitic gneiss district only, and little allanite is found in dikes which are intruded into the two-mica granite district;
3. The portion which includes some allanite of pegmatite or aplite dikes in the two-mica granite district is limited to xenoliths of the granitic gneiss cited above. The fine-grained crystalline allanite which encircles these xenoliths occurs with paragenetic biotite;
4. Allanite is found only in dikes of pegmatite or aplite in granitic gneiss, and little allanite is found in two-mica granite dikes, which are distributed through both these rocks;
5. Allanite is more numerous and occurs in larger crystals in granitic gneiss which surrounds the dikes rather than in the dikes of pegmatite or aplite them-

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selves. In such cases, the allanite usually accompanies large crystals of biotite, one paragenetic mineral;

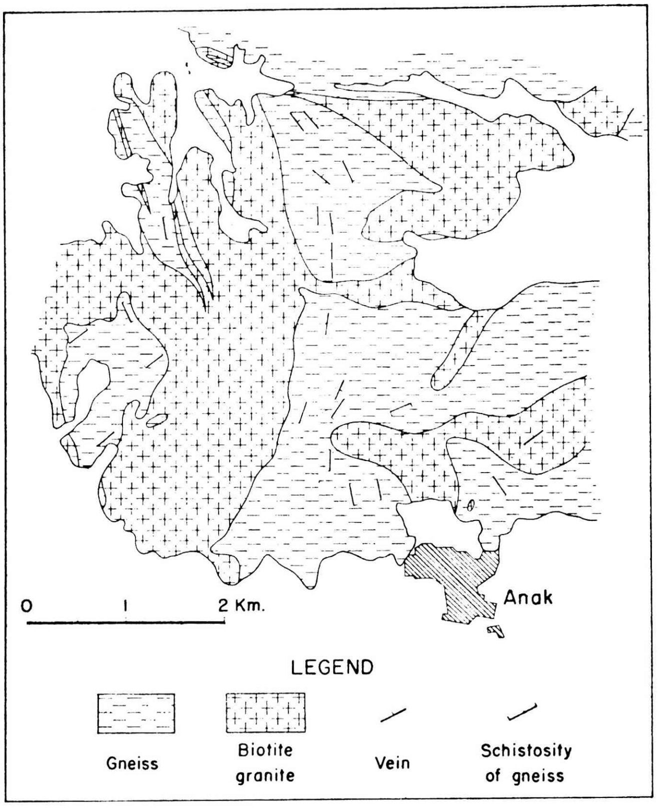

Fig. 1

6. There are three types of combinations of allanite and paragenetic minerals: a) allanite accompanied by biotite, garnet and some sulphide minerals, such as pyrite, chalcopyrite, pyrrhotite, etc.; this type is most common and contains small crystals of allanite particularly embedded with swarms of garnet and biotite; b) a combination of allanite with zircon alone, containing neither garnet nor sulphides; c) a combination of allanite with epidote, grossularite, hornblende, zircon, etc., as contact minerals in the zone between aplite dikes and granitic gneiss, the former of which give contact metamorphism to the latter; in this case, the allanite occurs intimately mixed with zircon;

7. Dikes which contain some allanite in this district are mostly fine-grained, rather compact in nature and differ from common pegmatite dikes. The plagioclases, which form the principal constituents of the pegmatite contain An 12–30 and microcline, which is rather uniformly distributed in ordinary dikes, is scarcely

found. In addition, the nature of these plagioclases tends to be basic. Moreover, considerable traces of hydrothermal metasomatism are seen in the dike, but no traces at all of pneumatolytic metasomatism occur in the same dike.

From the results of general field observations, the existence of gneiss is thought to be one of the principal reasons for finding crystal of allanite. That is, the allanite is believed to be a product of hybridization between the pre-existing gneiss and pegmatitic magmas. It is also thought that the allanite is found (a) in the contact zone between the gneiss and the dikes, (b) around the zenoliths of gneiss in the pegmatite and (c) in the fissures of the gneiss, into which the pegmatitic magmas, were injected.

It is inferred that allanite and biotite are contemporaneous products; Fe and Ca in the former were supplied principally from gneiss, while the rare elements were furnished by pegmatitic magmas.

Physical properties

Allanite has a hardness of 5–6 and is black. It has a resinous luster on a fresh surface and gives a bluish green streak. The specific gravities of the following two allanites were obtained by means of a pycnometer.

1. Allanite paragenetic with minerals such as biotite, garnet and sulphides;
2. Allanite paragenetic with minerals such as common hornblende, diopside, zircon, sphene, etc. Results obtained;

(1) G $\left(\frac{2^\circ}{4^\circ}\right)=4.076$

(2) G $\left(\frac{2^\circ}{4^\circ}\right)=3.915$

Only one crystal of allanite showing three plane faces of a(100), c(001) and δ(103) has been found at Naep'yŏng-ni, Ŭnhong-myŏn; most of the allanite is massive and rarely crystalline, and even though some plane crystal faces are sometimes found, they are usually uneven.

The interfacial angles of an allanite crystal obtained at Naep'yŏng-ni were measured. The results were as follows:

	Found results	*Dana's values*
$a \wedge c$	65° 00′	64° 59′
$c \wedge \delta$	22° 06′	22° 19′
$a \wedge \delta$	87° 26′	87° 18′

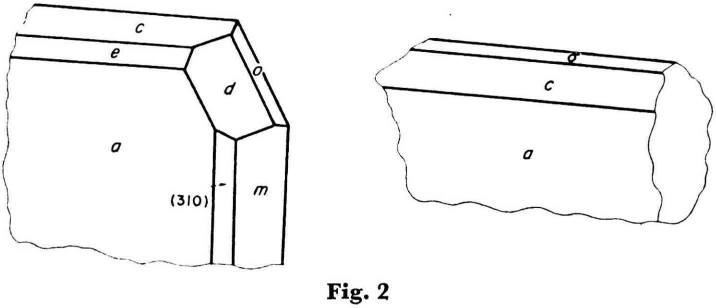

Fig. 2

According to KINOSAKI[2,3], the following crystal faces were found (Fig 2).

m(110), c(101), 1(201), o(011), d(111) and ?(310)

The results of microscopic tests on an allanite section cut parallel to the plane (001) are as follows: The plane of the optic axis is usually parallel to the (010) plane, and is optically negative, biaxial, $2V=55°-51.4°$ and $C \wedge X=57° 1'$; pleochroism is strong; color along the X axis is slightly brown, but sometimes colorless; Y is brown while Z is light brown; however, sometimes parts of both the Y and Z axes are deep brown. The deepness of the brown color also varies, that is, it is deep in the center and light on the periphery of the crystal.

This variation in color sometimes changes gradually from one place to another, but the color boundary is also sometimes clear. The index of refraction of the part with the deep-brown color is greater than that of the part with the light-brown color, but double refraction is less in the dark part than in the light. Such a phenomenon depends mostly upon the difference in chemical constituents between the center and periphery of a crystal of allanite, which is caused largely by the degree of decomposition of that mineral by weathering, according to Winchell, but we could not determine whether this is true or not. KINOSAKI described the results of his examinations of the refractive index of Korean allanite in this locality as follows:

$$Np=1.765,\ Nm=1.768 \text{ and } 1.774<Ng<1.779.$$

Chemical properties

Two kinds of allanite which were used in the specific gravity measurements by means of the pycnometer, were also chemically analysed.

The results of these tests are as follows:

Columns (3) and (4) in Table 1 contain results on Korean allanites reported by NAKAI[4] and MIZUMA[5], respectively, and are listed for comparison:

Samples (1) and (2) used for chemical analysis vary little in their constituents, although their modes of occurrence were quite different. The differences in the results of the chemical analysis of No. (3) show that it is higher in Fe_2O_3, $[Ce]_2O_3$ $+[Y]_2O_3$ and H_2O^{+} and is somewhat less in Ce_2O_3 as compared with (1) and (2), but the amounts of other constituents do not differ very greatly.

We must pay attention to the smaller amount of H_2O present in samples (1) and (2). It is rather common for 1.5%–2.0% water to be present in allanite crystals previously discovered in Manchuria, Korea and Japan, but these specimens contain much less water. This smaller amount of water in the crystals of allanite indicates that they are more resistant to weathering.

Allanite crystals are often covered with a weathered product on their surfaces, like a fairly thick skin that resembles limonite, which shows that they are, in general, easily weathered.[6] Accordingly, it is rather common that much water is added to the crystals secondarily, although they look fresh after stripping off the so-called weathered skin of the crystals. Allanite crystals obtained in this locality have a strong durability against weathering and have no limonite-like skin on their black faces at all, and their constituents do not change between the surface and the inside of the crystals. They might be called "Bucklandite", a name given by HERMANN for such strong allanites, which contain less water, as shown in the Table 2.

Table 1. Chemical Analyses of Allanite.

Constituent	(1)	(2)	(3)	(4)
SiO_2	32.99	33.00	31.23	30.60
Al_2O_3	14.68	17.04	15.67	21.96
Fe_2O_3	1.85	2.82	4.65	7.43
FeO	12.53	10.01	10.83	7.46
CaO	10.03	11.62	10.60	3.90
MgO	0.77	0.92	1.11	1.23
MnO	0.82	0.66	1.28	—
ThO_2	0.57	0.44	0.60	—
Ce_2O_3	12.06	10.61	6.78	12.54
$[Ce]_2O_3$	11.20	9.41	} 15.63	
$[Y]_2O_3$	0.47	0.91		
TiO_2	1.35	0.73	—	—
$H_2O^{+)}$	0.42	0.70	1.54	0.44
$H_2O^{-)}$	0.49	0.53	—	—
Total	100.23	99.40	99.92	85.56

An X-ray analysis of sample (1) was conducted using a spectroanalytic camera of the Siegbahn type, and the distribution of Lanthanide elements determined. The results of these examinations are given in Table 2.

Table 2. Chemical Analyses of Allanite.

No. of atoms	Element	$\alpha 1$	$\alpha 2$	$\beta 1$	$\beta 2$	$\beta 3$	$\beta 4$	$\gamma 1$	$\gamma 2$	$\gamma 3$	4
57	La	2659.7	2668.9	2453.3	2298.0	2405.3	2443.8	2137.2	—	—	—
58	Ce	2556.0	2565.1	2352.3	2204.0	2306.1	2345.2	2045.5	1956.1	1951.5	1895
59	Pr	2459.7	2467.6	2253.9	2114.8	2212.4	—	—	—	—	—
60	Nd	2365.3	2375.6	2162.2	2031.4	2122.2	—	1873.8	—	—	—
61	Il	—	—	—	—	—	—	—	—	—	—
62	Sm	2195.0	2205.4	1994.8	—	—	—	—	—	—	—
63	Eu	2116.3	—	—	—	—	—	—	—	—	—
64	Gd	2041.9	—	—	—	—	—	—	—	—	—

The results of X-ray spectroanalysis clearly show the existence of elements such as La, Ce, Pr, Nd, Sm, Eu and Gd; moreover, the order of abundance of these elements was determined as follows:

Ce, La, Nd, Pr, Sm, Gd and Eu

This order depends entirely upon the relative intensity of the La spectra in each element. The results concerning the amounts of elements with present coincides very closely with that given by Harkin's law.

1.86×10^{-11} g/g of radium was found to be present in this mineral by NAKAI[7], which is, expressed in percent, 1.86×10^{-9}%

Chemical composition

The molecular ratios of each constituent are calculated in order to determine the chemical composition of the allanite from the results of the chemical analyses mentioned above. In this case, a value of 144.69 was tentatively used for calculation from the weight ratio of the average atomic weight of cerium oxide, which can be separated in chemical analysis by anhydrous sulphide salts.

The element Yt is omitted in this calculation because the amount present is so small that it is too difficult to deal with.

The results of the molecular ratio calculations, with the valency of each constituent-element, are as follows:

Table 3. Molecular Ratio.

Constituents	Samples		
	(1)	(2)	(3)
1) $R^{II}O$ (CaO, MgO, MnO, FeO)	0.3840	0.3786	0.3853
2) $R_2^{III}O_3$ (Fe_2O_3, Al_2O_3, $[Ce]_2O_3$)	0.2285	0.2509	0.2498
3) $R^{VI}O_2$ (ThO_2)	0.0022	0.0019	0.0023
4) (SiO_2, TiO_2)	0.5662	0.5586	0.5200
5) H_2O	0.0233	0.0389	0.0856

Calculation can be carried out assuming a value of 6 for (SiO_2, TiO_2) in the residue (SiO_2) extracted from thorite, which is tentatively contained as (Th SiO_4) in the ThO_2 constituent. The results of calculation are given in Table 4.

Table 4

Constituents	Samples		
	(1)	(2)	(3)
$R^{II}O$	4.1	4.1	4.5
$R_2^{III}O_3$	2.4	2.6	2.9
(SiO_2, TiO_2)	6	6	6
H_2O	0.3	0.4	1.0

Accordingly, chemical formulae are as follows:

(1) 4.1 $R^{II}O$, 2.4 R_2^{III} O_3, 6(SiO_2, TiO_2), 0.3 H_2O;

(2) 4.1 $R^{II}O$, 2.9 R_2^{III} O_3, 6(SiO_2, TiO_2), 0.4 H_2O;

(3) 4.5 $R^{II}O$, 2.9 R_2^{III} O_3, 6(SiO_2, TiO_2), 1.0 H_2O.

Many discussions on the chemical composition of allanite have been made by mineralogists such as A. MICHEL-LEVY, R. HERMANN, N. KOCHSKAROFF, etc. N. ENGSTROM[8)] proposed the following two chemical formulae after detailed investigations on many chemical analyses of allanite made by many scholars; he concluded

(1) 2(2 $R^{II}O$. SiO_2), $3R_2^{III}O_3$, $4SiO_2$, H_2O;

(2) 2($R^{II}O$. SiO_2), $3R_2^{III}O_3$, $4SiO_2$, H_2O.

(1) corresponds to the chemical formula of fresh allanite, while (2) corresponds to the chemical formula of more or less decomposed allanite.

P. GROTH proposed the following for the chemical composition of allanite after he concluded that allanite should be a basic orthosilicate salt:

$$Ca_2\ (Al,\ O\ H)\ (Al,\ Ca,\ Fe)\ (SiO_4)_3$$

GROTH's molecular ratio for each constituent of allanite is in accord with (1) of N. ENGSTROM. However, the chemical formulae obtained from the chemical analyses of material from the above district are not strictly in agreement with any of the chemical formulae given by N. ENGSTROM on the point of too little $R_2^{III}O_3$ and H_2O in samples (1) and (2), and on the point of too much $R^{II}O$ in sample (3).

The following results on valency of all the basic elements can be obtained through calculation under the assumptions that samples (1) and (2) are hydrous crystals, and that all the H_2O is a basic constituent in sample (3):

(1) $2\times4.1+3\times2\times2.4=22.6$,

(2) $2\times4.1+3\times2\times2.7=24.4$,

(3) $2\times4.4+3\times2\times3-2=24.8$.

These results are in accord with a valency of 24 for SiO_4^{III}, the acidic ion, within certain limits when the allanite is considered an orthosilicate salt. Hence, this chemical formula of the allanite is thought to substantiate the existence of an equilibrium between positive and negative ions considering the valencies of the atoms contained in the orthosilicate.

F. MACHATSCHKI[9)] stated that the structural formula of allanite can be expressed as $X_2\ Y_3\ Z_3\ (O,\ OH)_{13}$, from the standpoint that all lattices in the crystal alternate with each other within those that bear a close resemblance in ionic radius in each crystal. In this formula X stands for the group Ca, Mn, Th, Ce and (Ce), Y for Fe^{II}, Fe^{III}, Al, Mg, and Ti and Z for Si.

The ratios of X, Y, Z, and (O, OH) which constitute the mineral can be obtained after calculating the molecular ratios as above. The results are as follows:

Although MACHATSCHKI thought that the constituent Mn should be distributed between X and Y, and part of the Al constituent in Z, here they are calculated for all the Mn constituents attributed to X and all the Al constituents to Y.

Table 5

Sample	(Ca, Mn, Th, Ce, [Ce]) X	(Fe^{II}, Fe^{III}, Al, Mg, Ti) Y	(Si) Z	(O, OH)
(1)	1.8	2.9	3	12.4
(2)	1.9	3.0	3	12.4
(3)	2.0	3.1	3	13.1

Accordingly, chemical structural formulae obtained from the chemical analyses of these three samples cited above are as follows:

(1) $X_{1.8}\,Y_{2.9}\,Z_3\,(O, OH)_{12.1}$
(2) $X_{1.9}\,Y_{3.0}\,Z_3\,(O, OH)_{12.4}$
(3) $X_{2.0}\,Y_{3.1}\,Z_3\,(O, OH)_{13.1}$

Compared with the chemical structural formula of MACHATSCHKI mentioned above, those of samples (1) and (2) contain a little less (O, OH).

In general, it can be said that the amount of H_2O which coincides with chemical formula (1) of N. ENGSTROM agrees with the chemical structural formula of MACHATSCHKI, but samples (1) and (2), which have much less water, are a little lower in (O, OH) compared with MACHATSCHKI's formula.

2. Allanite at Talli-dong, Haksŏng-myŏn, Sŏngjin-gun, Hamgyŏng-pukto[10)]

Allanite occurs along the western railroad at a point some 1.5 km south of the Ssangnyŏng R. R. station which is about 6 km South of Sŏngjin, one of the principal railway stations of the Hamgyŏng Line.

The general geology of the district is mainly comprised of the Mach'ŏl-lyŏng system, which is mostly composed of alternate mica schist, dolomite and limestone.

The general strike is NW–WNW and the dip is rather steep, 45–60°, which varies considerably in places.

One large pegmatite dike which contains allanite runs N 55° W, almost parallel to that of the main strata of the district, but its dip is not ascertainable.

This pegmatite dike crops out obliquely near the top of the range of hills which runs east to west.

Elongation of the dike cannot be traced to either side of the hill; the dike is exposed clearly only at the top.

Many pegmatite blocks are found scattered on both sides of the hill, the north of which is steeep, while the other is rather gentle. The extent of the dike can be inferred to be some 300 m long and 100 m wide, after observing the distribution of these blocks. The dike consists principally of large crystals of quartz and kali-feldspar (orthoclase) with associated zircon, sphene and hedenbergite in addition to allanite. Many of the blocks, which include much allanite, are spread over the southern slope of the hill; among these some blocks are found which consist of two-thirds allanite. There are also found in fields on the same side many large and small pieces of allanite, which have been washed away from these blocks by weathering. This is thought to indicate the richness of the allanite crystals in the southern limb of the dike.

The allanite generally has a large platy form, and occasionally a single crystal weighs several kg, though it is not so rare. The surface of most of the allanite is covered with a limonite-like skin, produced by weathering, but the inside of the mineral, which looks fresh, is black with a resinous luster.

Physical properties

Almost no crystal face is found in the allanites occurring in dike outcrops on the southern side of the hill except for a tabular face, a(100), in a big allanite block, or in fragments from the big allanite block, or from other big blocks in the same locality. However, some crystal faces such as a(100), m(110), d(111), $n(\bar{1}11)$, c(001), $i(\bar{2}01)$, $r(\bar{1}01)$, $l(\bar{1}02)$ can be seen in small crystals of allanite which are not affected by weathering and which are usually associated paragenetically with sphene and zircon in the pegmatite blocks scattered over the southern slope of the hill (Fig. 3).

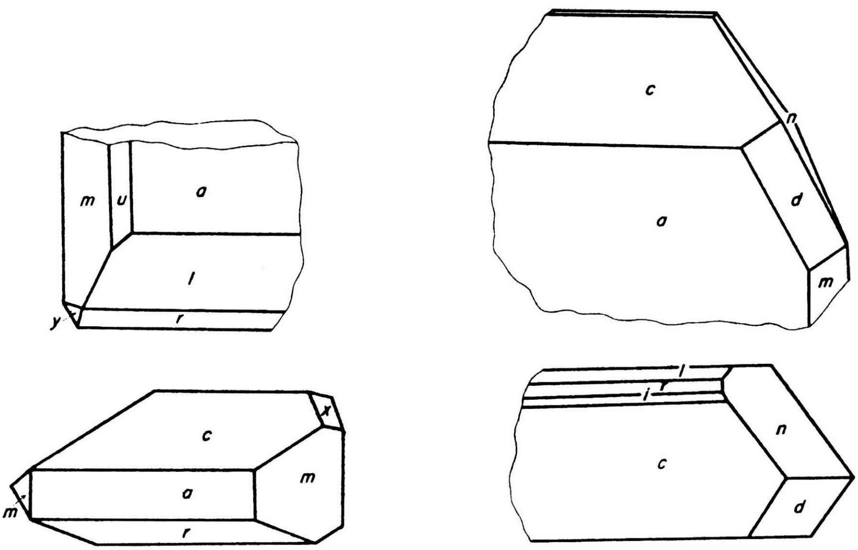

Fig. 3

KINOSAKI[11] described some additional crystal faces in these allanites, such as u(201), x(112) and y(211), besides those mentioned above.

In general, crystals are often tabular in a(100), and also are long and slender parallel to the b axis. The faces a(100), c(001) and m(110) are most common.

The microscope reveals that the structure of a crystal of allanite from this locality is rather homogeneous, and has some optical properties common to other allanite.

Chemical properties

Distillation and drying is repeated for exactly one gram of fine powdered allanite: it is heated on a sand-dish for a while, then some hydrochloric acid is added and heating is repeated; after treatment with HCI once more, and heating, the fused material is resorbed with sodium carbonate into an infusible residue of the first distillation. To the residue, which is left after extraction of SiO_2, a fixed amount of ammonia chloride and ammonia are added for alkalization, then the material which was filtered from the above residue is dissolved in nitric acid and neutralized with ammonia. The sediments of thorium and rare-earth element oxalates are obtained from solution after pouring oxalic acid into the neutralized solution; all rare-earth elements can be abstracted from the solution of nitric acid by the following processes:

Thorium by means of the hydrogen peroxide process, cerium by means of the kalium-bromic acid process, and the rare-earth elements of the cerium and yttrium groups by means of the kalium sulphuric acid process. Manganese, calcium and magnesium are separated and measured by the most common processes of chemical analyses from the solution from which the compounds of the rare-earth elements were obtained after the complete removal of oxalic acid in the oxalates from which many rare-earth elements have been filtered. Bivalent iron and water in the allanite were separated and measured from another sample. The results of the chemical analyses are as follows: (The figures in both columns (2) and (3) in the table were tabulated by SAITO[12)] and MIZUMA[13)], respectively.)

Table 6. Chemical Analyses of Allanite from Talli-dong, Sŏngjin-gun, Hamgyŏng-pukto.

Constituents	(1)	(2)	(3)
SiO_2	30.48	28.26	28.30
Al_2O_3	16.16	16.32	16.34
FeO	11.82	10.88	10.74
Fe_2O_3	7.05	8.81	7.55
MgO	0.34	1.24	1.12
CaO	10.83	13.49	13.60
Ce_2O_3	9.81	12.84	12.52
$[Ce]_2O_3$	11.16	5.66	6.76
$[Y]_2O_3$	0.19		
ThO_2	0.25	1.29	—
MnO	0.31	0.81	1.46
TiO_2	0.40	—	—
$H_2O^{+)}$	1.59	1.05	1.60
$H_2O^{-)}$	0.11	0.89	—
Total	100.50	99.74	99.99

The results of Nos. (2) and (3) almost completely coincide with each other, but No. (1) is somewhat different, that is, the value of SiO_2, $[Ce]_2O_3$,$\cdot[Y]_2O_3$ of No. (1) is somewhat higher than those of Nos. (2) and (3); on the contrary, the value for CaO, Ce_2O_3 and ThO_2 in the same sample is somewhat smaller than the others. These differences may be caused not only by differences in the materials tested, but also in the dissimilarity in the methods and processes of chemical analyses. The amount of Fe_2O_3 in the results of all three tests is, in general, larger than that of most of the other results.

The rare-earth elements were extracted from a 10-gram sample by precipitation. The precipitated hydroxides were dissolved in dilute HCl and dried, then

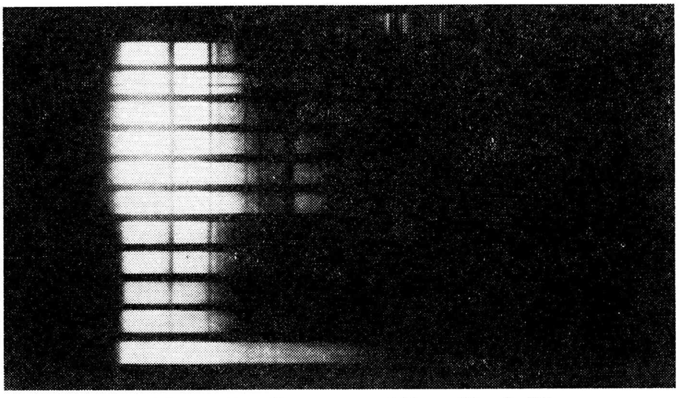

Fig. 4. Absorption Spectrum of Rare-Earth Elements.

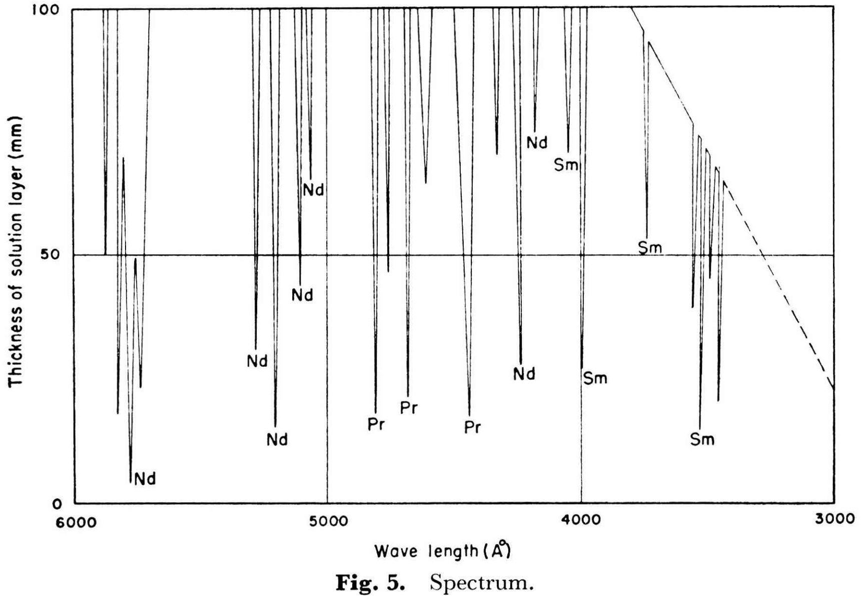

Fig. 5. Spectrum.

dissolved in 100 cc of water, placed in a Baley absorption pipe and examined through absorption spectrometry. The absorbed bands of Pr, Nd and Sm are clearly recognizable in the absorp-tionspectra photographs and absorption curves (Fig. 4 and 5).

Chemical composition

The molecular ratio of each constituent was calculated, determining chemical compositions from the above chemical analyses. The value of 144 for the average atomic weight of the cerium group of rare-earth elements in the An'ak allanite is also used here, because nothing else was tested for this group in this locality. The atomic weights of the yttrium group and ThO_2 are omitted from this calculation, because they occur in too small amounts.

The molecular ratios which were classified according to the atomic weights of each element are as follows:

Table 7

Constituents	Samples		
	(1)	(2)	(3)
1) $R^{II}O$ (CaO, MgO, MnO, FeO)	0.3706	0.4341	0.4404
2) $R_2^{III}O_3$ (Fe_2O_3, Al_2O_3, Ce_2O_3, $[Ce]_2O_3$)	0.2658	0.2661	0.2657
3) (SiO_2, TiO_2)	0.5125	0.4705	0.4712
4) H_2O	0.0883	0.0583	0.0889

All molecular ratios in the constituents $R^{II}O$, $B_2^{III}O_3$, (SiO_2, TiO_2) and H_2O, with a tentative value of 6 for (SiO_2, TiO_2) are as follows:

Table 8. Molecular Ratio.

Constituents	(1)	(2)	(3)
$R^{II}O$	4.3	5.5	5.6
$R_2^{III}O_3$	3.3	3.4	3.4
(SiO_2, TiO_2)	6	6	6
H_2O	1.0	0.7	1.1

Accordingly, the chemical composition for each sample is expressed as follows:

1) $4.3R^{II}O.\ 3.3R_2^{III}O_3.\ 6\ (SiO_2,\ TiO_2).\ H_2O$
2) $5.5R^{II}O.\ 3.4R_2^{III}O_3.\ 6\ (SiO_2,\ TiO_2).\ 0.7\ H_2O$
3) $5.6R^{II}O.\ 3.4R_2^{III}O_3.\ 6\ (SiO_2,\ TiO_2).\ 1.1\ H_2O$

These chemical formulae are a little different from those given by N. ENGSTROM: the ratios of $R^{II}O$ and $R_2^{III}O_3$ are larger and the SiO_2 constitutent is less; the values for CaO and Fe_2O_3 are larger, on the other hand, than those in the other allanites previously analyzed.

The values for the chemical structural formula X, Y, Z and (O, OH) which correspond to X_2, Y_3, Z_3 and (O, OH), as given by MACHTSCHKI, are as follows:

Table 9

Sample	X (Ca, Mn, Th, Ce) [Ce]	Y (Fe^{II}, $Fe,^{III}$ Al, Mg, Ti)	Z Si	(O, OH)
(1)	1.9	3.5	3	13.5
(2)	2.4	3.8	3	14.3
(3)	2.4	3.8	3	14.5

Accordingly, chemical structural formulae obtained from chemical analyses are as follows:

(1) X 1.9 Y 3.5 Z_3 (O, OH) 13.5,
(2) X 2.4 Y 3.8 Z_3 (O, OH) 14.3,
(3) X 2.4 Y 3.8 Z_3 (O, OH) 14.5

No. (1) approaches the formula given by MACHATSCHKI, but the values of X, Y and (O, OH) are large compared to that of Z in Nos. (2) and (3). This fact depends mostly upon the presence of a smaller amount of SiO_2, in this case, than in the other allanites already mentioned.

3. Allanite at Sanhyŏl-li, Kŭnbung-myŏn, Kŭmhwa-gun, Kangwŏn-do[14)]

Allanite occurs on the weathered surfaces of nepheline-syenite with paragenetic lepidomelane. All are massive blocks smaller in size than a man's fist. None of them show any crystal form, and are covered on their surfaces with a skin of brown earthy material which is produced by weathering. However, their fractured surface has a glassy luster and is black in color.

General physical properties of this mineral are as follows:

Hardness=6, specific gravity=4.1, optically negative, 2V is not large; index of refraction is approximately 1.78; pleochroism is Z dark brown, Y light brown.

The results of chemical analysis are given in Table X.

The figures in columns (1) and (2) of this table are results obtained by SAITO and MIZUMA, respectively.

Formulae, in accordance with the chemical formula proposed by N. ENGSTROM and the chemical structural formula introduced by MACHATSCHKI after chemical analysis of No. (1), are as follows:

4.2 $R^{II}O$. 3.4 $R_2{}^{III}O_3$. 6 SiO_2. 1.1 H_2O,
X 2.0 Y 3.1 Z 2.9 (O, OH) 13.5.

Both formulae approximate those of either ENGSTROM or MACHATSCHKI.

Table 10

Constituents	(1)	(2)	Constituents	(1)	(2)
SiO_3	28.12	27.80	$[R_2]O_3$	12.84	11.91
Al_2O_3	14.01	14.84	ThO_2	1.02	—
Fe_2O_3	7.98	5.29	MnO	3.10	3.15
FeO	7.65	9.82	$H_2O^{+)}$	1.03	1.35
MgO	0.39	2.10	$H_2O^{-)}$	0.57	—
CaO	9.16	9.35			
CeO_2	14.21	13.79	Total	100.08	99.43

4. Allanite at Chuksal-li, Ijumg-myŏn Ansŏng-gun, Kyŏnggi-do; Kaegong-ni, Oedong-myŏn, Kyŏngju-gun, Kyŏngsang-pkuto; and P'altam, Puryŏng-myŏn, Puryŏng-gun, Hamgyŏng-pukto[15)]

The first collection and investigation of allanite from these localities in Korea was made by IIMORI, YOSHIMURA, and HARA in April, 1941. Allanite from all these localities occur as an accessory mineral in pegmatite.

Table 11

Sample	Chuksal-li	Kaegong-ni	P'altam
Length of crystal	5.0 mm	8.0 mm	15.0 mm
Specific gravity	3.4	3.87	3.34
Hardness	5.5 – 6.0	5.5	5.5–6.0
Weight used for chemical analysis	0.0380	0.0308	0.030
Chemical analyses:			
SiO_2	34.7	29.5	30
FeO	17.0	13.1	18
Al_2O_3	11.0	15.4	5
$(R)_2O_3+Th\ O_2$	21.0	21.3	21
MnO	3.4	0.5	2
CaO	12.4	12.9	17
TiO_2	—	3.3	1
MgO	—	1.0	3
Total	99.5	97.0	97

Allanite at Chuksal-li is found with fine-grained garnet and magnetite, while that at Kaegong-ni is embedded in aggregates of microcrystalline epidote with magnetite.

Allanite at P'altam occurs paragenetically with rutile and yellowish-colored quartz.

All allanites of these localities have a glassy luster with greenish-brown streaks, and are weakly radioactive. Other general physical properties such as specific gravity, hardness, crystalsize and the results of chemical analysis are given in Table 11.

5. Allanites at Kanji-dong, Haksŏl-li, Puktuil-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo[16]; Samno, Sech'ŏn-dong, Haksŏ-myŏn, Sŏngjin-gun, Hamgyŏng-pukto[17]; T'apko-ri, Kŭmsŏng-myŏn, Kŭmhwa-gun, Kangwŏn-do[18]; Poksap'yŏng, Ilgŏm-dong, Musan-myŏn, Hamgyŏng-pukto[19]

Allanite occurs not only as an accessory mineral in pegmatite at the localities listed above, but also is sometimes found as an accessory mineral in contact metamorphosed limestone, or in acidic and basic igneous rocks.

Allanite crystals are so large and abundant that they may be profitably worked in the former case (pegmatite), but not in the latter case, in contact metamorphism, because they are generally very small and few in number.

Some allanite is found in the limestone paragenetically with other minerals such as actinolite, epidote, hornblende, graphite, etc., at Kanji-dong and Samno, but also occurs in basic nickel-bearing dikes and in gneiss at T'apko-ri and Ch'angyŏl-tong, respectively.

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