A Note on Glaucophane.

By

B. Kotō, Ph. D.

Professor of Geology, Science College, Imperial University.

With Plate XII.

It is proposed in this paper to give a brief description of that interesting mineral—glaucophane, which the writer has collected during his excursions in two summer-vacations; hence exclusively confined to its occurrence in Japan.

In the island of Shikoku, we see the crystalline schist-system extensively developed, especially in the central mountain-chains which trend from S.W.-N.E. Among the schists a very characteric rock is found, which calls for our special attention, on account of its beautiful colour varying in tinge from a greyish-blue to a purplish-blue. It was formerly known among us as a cyanite-schist; but this is, however, not the case as will become perfectly clear from the discussion to which we shall refer hereafter. The typical specimens were brought from Mount Ōtakisan near the city of Tokushima, and from the copper mine at Besshi; the rock itself being not confined to the above-mentioned localities, but being widely distributed in the region of the crystalline schists. The glaucophane-bearing schist contains, besides other ingredients, a long rectangular, olive-green epidote, yellowish-green crystals of garnet, quartz, some felspars, rutile, also specular iron, and the last, but not the least important one is piemontite or manganese epidote. The glaucophane, when observed macroscopically,

is of an indigo-blue colour, and shows flat prismatic forms; all arranged parallel to each other, and also parallel to one prevailing horizontal direction in regard to the rock itself. Thus a thin slide of the rock in any one direction shows only the same side of glaucophane contained in it.

I. Basal Section.

Any one of the vicinal basal sections in a thin slide presents usually an approximate hexagonal outline, being bounded by four long, and two short sides. (*fig. II.*) These sides are the traces of ∞P (110), and $\infty P \breve{\infty}$ (010); those of the orthopinacoid never happened to be observed in any slide. The prismatic angle is about 124°, similar to that of a hornblende. The cleavage-traces upon ∞P (110) are distinct and well developed, but all are widely separated. (*fig. II. & fig. V.*) Only in a few cases the cleavage-direction parallel to the clinopinacoid ($\infty P \breve{\infty}$) is seen, although less clear. (*fig. V.*) On rotating the section cut nearly at $\perp$ to the vertical axis, over the polarizer, the crystals are seen to change from a light brown to a light bluish purple; and extinguish the light in the direction of both diagonals. We often observed the crystals attaching by the right prismatic face of the one with that of the left of another individual, or even one individual penetrates the other. (*fig. II.*) In the third case then, three or more crystals, are packed together by the prismatic faces so as to form a definite aggregate. Again, we have still another instance in which the glaucophane shows an intergrowth of two individuals, placed in such a manner that the orthopinacoid ($\infty P \breve{\infty}$) is the contact plane. On account of their minute size, here the character of interference ring could not be made out. Whether all these cases stated above are the outcomes from a mere intergrowth of crystal-individuals, or in some way connected with the twining formation, I am at present not able to say, as these are not capable of a rigid proof.

II. Clinopinacoidal Section.

As the glaucophane-individuals are all more or less arranged parallel with the orthopinacoid, to the plane of a schistose structure of the rock, slides taken in the longitudinal direction of the schist present quite a different aspect; here the crystals show all a light green with a slight tinge of blue. The sections are slender, and terminate in sharp points at both ends with unsymmetrical sides, thus indicating the probable presence of one of orthodomes. The surface of the section taken parallel to the clinopinacoid shows usually a striated appearance, while only a few stripes, if ever present, have been observed on the orthopinacoid. This is, indeed, a very characteristic feature. The direction of extinction :— $c : C = 11° - 12°$; these figures* seem to be somewhat large in comparison with those already well known to us.

III. Orthopinacoidal Section.

The section in this direction presents a broad tabular form without any distinct termination at both ends, being often resolved more or less into radiating fibres, so this particular feature gives a clue as to the direction in which a section is taken.

Various tinges of colour are discernible even in the same individual; the central part is lighter in tinge and more purple in its hue, while the periphery is intensely coloured, and a shade of green predominates. This zonal arrangement has also been observed by Stelzner† in the Swiss glaucophane, and G. H. Williams‡ assigned the cause to the new formation of arfvedsonite from glaucophane.

* $c : C = 3° - 4°$ as is observed by Luedecke in the specimen from Syra in Greece: Zeitschrift d. deutch. geol. Ges. 1876, XXVIII, p. 249. Vide also Tschermak's Mineralogische u. petrographische Mittheilungen, 1879, II, p. 71.

† Neues Jahrbuch für Mineralogie etc., 1883, I Band, p. 209.

‡ ibid. 1882, II Band, p. 202.

Such an assumption is, as it seems to me, precarious ; for, the writer has observed the same phenomenon in the pargasite from Pargas, Finnland, especially on the periphery, where the Finnish mineral shows a slight inclination to transformation. Even in the central intact part such green spots are by no means rare.

The orthopinacoid of our glaucophane extinguishes the light, of course, parallel to c, and also at $\perp$ to it; but the shade sweeps over the section in an undulating manner as we rotate the table. Owing to this fact, the direction of extinction might easily be mistaken for an oblique one with a small angle.

Taken as a whole, the crystal-individuals of our glaucophane possess a broad columnar form whose basal section presents an elongated rhombic outline, truncated at the acute corners by traces of the clinopinacoid; (*fig. II.*) and are terminated at both ends by an orthodome or hemi-pyramid. The axial colour: C = greenish blue; B = lavender blue ; A = bluish brown. $C > B > A$.

This mineral has been isolated from other constituents of the schist by the Thoulet solution, and the analytical result obtained by Mr. Yoshida,* is as follows :—

$Si\ O_2$	56, 71
$Al_2\ O_3$	15, 14
$Fe_2\ O_3$	9, 78
$Fe\ O$	4, 31
$Ca\ O$	4, 80
$Mg\ O$	4, 33
$Na_2\ O$	4, 83
$K_2\ O$	0, 25
	100, 15

Sp. Gr. = 2, 9912

* I gladly take this opportunity of returning my hearty thanks to him for the chemical analysis of this mineral.

The mineral, glaucophane is of comparatively rare occurrence. The typical one is found in Syra, in Greece, and in a few localities in the Western Alps. Quite recently, one more locality is found in the island of Groix in France, the descriptions of the latter occurrence were given by Barrois * and v. Lasaulx, but their works are unfortunately not accessible to me.

But this mineral is found in abundance in the *Japanese Islands*, and indeed, the glaucophane-bearing schist makes up a normal member amongst the crystalline schist-system, just occupying the upper horizon of chlorite-schist. Being of a beautiful colour, the rock can at once be recognized in hand specimens, and on this very account, it may be advantageously used in a classification of the crystalline schist-system of our country.

Secondary Glaucophane.

There yet remains to be described, a purple-green, more or less fibrous, mineral whose definite chemical relations, and also the crystallographic forms of which are of a somewhat doubtful nature. Before entering into the details, it is here to be remarked that the writer has been obliged to speak at some length of the rocks, and the augite contained in them, in order to give a clearer view of the formation of the secondary (paramorphosed) glaucophane.

According to the kind of rocks in which the glaucophane makes its appearance, descriptions are brought under the three headings.

I. Schalstein.†

(Slaty diabase-tuff.)

This rock plays an important rôle in the paleozoic group in Japan. There are two kinds of it, one being of a dark-red, the other of a green

* Cited by Rosenbusch in his 'Physiographie,' I Band, 2te Auflage, p. 471.

† Prof. Bonny is of opinion that some "schalsteins" are compact basalts that have undergone mechanical crushing. 'Quart. Journ. Geol. Soc.' Vol. XLII., 1886, Anniversary address, p. 60.

colour, and they are called respectively "brown or green slate." Both varieties come together in the same geological horizon, insensibly merging into one another. They decidedly belong to the paleozoic age, and are overlaid by the *sub*-carboniferous (?) limestone* which is extensively developed in Japan† and China.‡ The writer has often observed in fields, even, interstratification of the diabase-tuff with the subcarboniferous limestone.

It is slaty in its outer appearance, but less fissil than common roofing slates, and is so named "slate" by geologists of the geological survey of Japan. This diabase-tuff becomes not unfrequently massive and at the same time porous, being filled with calcite; thus it has then, all the appearances of melaphyre.

The lamellar-granular ('flaserige') rock-mass encloses the round, bent augite, and produces a structure similar to that seen on a large scale in the "augen-Gneiss." The typical specimen comes from Ananai, in Tosa province, near the Kunimi-yama.

The *augite* which the writer supposes to be diallage, but without being able to give a decisive proof, presents quite a fresh vitreous aspect, although traversed by irregular transversal fissures in various imaginable directions. The augite shows neither the tendency of a parting in the orthopinacoidal direction, nor that characteristic interposition very common in the gabbro-diallage. In short, it is just like augite in younger eruptive rocks; the mineral is olive-green or brown in colour.

The augite is weakly pleochroic on the clinopinacoid, while on the orthopinacoid pleochroism is scarcely discernible. The extinction-direction varies from 23° — 31° with the trace of cleavage parallel to c. The writer does not wish to lay much stress on the angular

* Cf. C. Gottsche, 'Science,' Vol. I, p. 166.

† E. Naumann, 'Ueber den Bau und die Entstehung der japanischen Inseln.'

‡ v. Richthofen, 'China.'

measurement, as it is impossible to find a good orientated section.

Paramorphosis of the diallage is abrupt, and usually begins from peripheries or from transversal fissures. The glaucophane is a small columnar or very fine fibrous; in the latter case it may, perhaps, be proper to call it *crocidolite*, although it is not capable of a rigid proof, on account of the minuteness of its size. The direction of fibres coincides, as a rule, with that of the general mass of the rock without regard to the position of diallage. The compact glaucophane again resolves at its terminations into a fibrous crocidolitic mass which, then, becomes grass-green in colour, and insensibly merges in the general rock-mass. The colour of glaucophane and its derivative—crocidolite, is deep green when the longest side is parallel to the short diagonal of the lower nicol; at right angles to it, it is lavender-blue.

The glaucophanized portion and the intact diallage are orientated in the same direction, and extinguish the light in the direction of c', when viewed from the orthopinacoid. On the clinopinacoid, however, the extinctions do not occur simultaneously, but show great deviations; and as the glaucophane-prisms are usually minute in size and the extinction-angles are so small, it appears as if were in the direction of the axis c'.

II. Amphibolite.

Amphibolites form a member in the archæan complex; their external appearances are various, on one side they approach to an ash-grey clay slate; on the other to a compact chlorite-schist; thirdly they have a close resemblance to an ordinary serpentine. So multifarious are their outward aspects that the writer has been struck with the simplicity of the mineralogical composition, when viewed under the microscope.

The microscope reveals to us no other ingredients than diallage and its derivatives–glaucaphane, and a hardly definable chloritic

matter. Only a few quantities of felspar, and a yellowish-green, highly pleochroic epidote, are sporadically discernible.

(a.) A typical rock of the appearance of a compact chlorite-schist is found in Nakakubo, in Kanra Gōri,* Kōzuke.

Here the pyroxene presents many characteristic features quite distinct from those already mentioned. The most striking aspect of the pyroxene is its light yellowish-brown colour, very common in augites of Basalts, but less so in andesites and trachytes. It is, as usual, traversed by various transversal cracks, from which the process of 'glaucophanization' has been commenced as well as from peripheries. The paramorphosed glaucophane is compact so as to lead observers to think that there is an intergrowth with a pyroxene. In other respects it presents nothing very special, except its intensely blue colour. The glaucophane, in turn, passes into a somewhat finely striated, deep green substance, and its transformation is very gradual; the only difference between them is in the colour of both minerals. *(Fig. III.)* The above-mentioned, deep yellowish-green mineral might be classed near arfvedsonite, judging by its external habitus and colour after comparing it with a specimen from a locality unknown to me, in Greenland. This, as well as the glaucophane, resolves into a confused aggregate of a yellowish, fibrous mass and the latter may fitly be called crocidolite.

(b.) On the southern side of the Tsuyetate pass, in the village of Kitagawa, Tosa province, there occurs an ash-grey, earthy slate which under a simple macroscopical consideration, gives scarcely any indication as to nature of the mineral contained in it.

Under the microscope thin slides show nothing more than glaucophane, and its derivatives of an extremely fine fibrous structure, together with some remnants of the original diallage. We may follow,

* Kōri or Gōri is nearly synonymous with a township or 'Kreis' in Germany.

step by step, every stage of transformation from diallage to glaucophane, and furthermore to a fibrous asbestiform substance. (*Fig. III.*) Compact glaucophane is comparatively rare, and if it is present then, shows a columnar form terminated at both ends by radiating tufts of the glaucophane-asbestus.

Both the glaucophane, and glaucophane-asbestus extinguish the light at the same time, and the ray vibrating parallel to c is of a light blue; at $\perp$ to it light lavender-blue. Sometimes the asbestus-fibres assume a light yellow colour or become even colourless; this mass alone makes up nearly the whole rock.

Sometime ago, a stone-ax (10 *cm.* × 2 by $^1/_2$ *cm.* in size) was brought from the village Nomiya near Sapporo, Yesso (Hokkaidō); this is supposed to have been used by Ainos, the aborigines of that island. A slide made from this possesses exactly the same feature as that of Kitagawa, and therein we find a few diallage-remnants, one portion of each of them has been already changed into glaucophane, showing, if proved on the extinction-direction, a considerable deviation in their angular measurement.

It elucidates most typically the various stages of fibrillation from the intact diallage to an infinitely small crocidolitic fibres. A resolved part displays a corymbose ramification, proceeding from both ends of diallage-individual, and afterwards it makes undulating curves, indicating the effect of pressure upon the rock. (*fig. I.*) Farther researches of glaucophane-rocks from other localities might bring forth many not uninteresting facts, considered especially from the ethnological point of view.

(c.) The amphibolite of a serpentinous aspect is most typically developed near Izushi in Kodama Gōri, Musashi province. By a macroscopical consideration it looks just like an ordinary blue serpentine, for which, indeed, it has often been taken; and in which here

and there a brown diallage (2-4 *cm.*) is sporadically distributed.

The rock has precisely the same structure possessed by the "schillerspath" or "bastite" of the Harz Mountains, and following the suggestion given by Geo. H. Williams,* the writer here uses the term "poicilitic" for that structure. The diallage is provided with that peculiar, finely striated appearance, which is well-known to be the result of pressure.† In a large number of cases crystals are bent, thereby presenting an appearance as in the case of mica-lamellæ.

The outlines of the diallage are very irregular, being traversed by various cracks in all possible directions; consequently the original crystallographic form is nowhere visible.

The process of 'glaucophanization' seems to have commenced from the above-mentioned fissures and peripheries of individuals, precisely in the same manner as that of olivine in becoming a serpentine. One portion of crystals is, however, resolved into somewhat larger columnar individuals of glaucophane which have the same optical orientation as the mother-mineral. Transformation proceeds molecule after molecule in so gradual a manner, that when the section of diallage is at ⊥ with the shorter diagonal of the polarizer, both the glaucophane, and the original mineral are of a light brown, and we can scarcely discern the boundary of the two. If the section is at right angles to the former position, then the difference of colour becomes at once quite distinct, one being a lavender-blue, the other a brown. (*Fig. I.*)

The glaucophane thus produced resolves itself again into the glaucophane-asbestus which in turn, passes into a confused aggregate of minute fibres, assuming at the same time a grass-green colour.

Prof. Bonny‡ has ably described a gabbro from Pegli near

* Ameri. Journ. of Science, vol. xxxi, January, 1886, p. 30.

† Vide. O. Mügge, Neues Jahrbuch für Min. etc., 1883, I., p. 84.

‡ Geological Magazine, vol. VI., 1879, p. 363. 'Lingurian and Tuscanian Serpentine.'

Genoa, and found in the groundmass "rather fibrous or filmy patches, many of which show a peculiar blue colour." "On testing for dichroism," he came to the conclusion that "there can be no doubt it is glaucophane" and of a secondary origin. Prof. Bonny was, perhaps, the first who had spoken of a secondary glaucophane, and his very specimen from Italy, has a close resemblance to that of Musashi, as may be judged from his descriptions, as far as the groundmass is concerned.

A fresh portion of our diallage has been mechanically separated by the Thoulet solution, and a chemical analysis prosecuted by the writer in the laboratory of Prof. W. Knop in Leipzig, gave the following result:—

SiO_2	46, 40	
Al_2O_3	15, 59	
FeO, Fe_2O_3	12, 62	$FeO > Fe_2O_3$
MgO	7, 15	
CaO	13, 52	
Na_2O	2, 23	
K_2O	0, 93	
H_2O	1, 60	
	100, 04	

As it contains over 2 % of Na_2O, it approaches in its chemical composition to an alkaline augite, and to this very fact the formation of the secondary glaucophane may be attributable.

III. Melaphyre.

We have still another occurrence of glaucophane to be considered, and this is in the melaphyre-enclosure in a slate at Akaya, east of Ōmiya, Musashi province.

It is generally supposed that the occurrence of glaucophane in eruptive rocks is exceptionally rare. The mineral glaucophane, says Rosenbusch,* appears exclusively confined within the formation of crystalline schists, and phyllite. "Als Ausnahme† ist das Auftreten in einer Minette der Gegend von Wackenbach in Breuschthal zu erwähnen." Therefore, it may be of some interest to give a short description of it. The rock itself appears dark grey, and contains small amygdaloidal cavities filled with the carbonate of lime.

Under the microscope thin slides show a typical eruptive character, but the decomposition has so far advanced that the fresh porphyritic pyroxene is nowhere visible. The whole groundmass is made up of a trichitic substance exhibiting a skelet-like arrangement. *(Fig. IV.)* The glaucophane in this rock is surely of a secondary origin, as it contains still remnants of a brown pyroxene in the centre. The colour of this glaucophane is a light indigo-blue with a slight tinge of purple. Sometimes amygdaloidal spaces are filled with radiating needles of the same mineral. In all other respects it differs in no wise from those already described.

Before leaving the subject it may be well here to make some remarks on the difference between the primary, and secondary glaucophane; and furthermore, on a probable mode of procedure, by which the latter has been derived from the former.

As to the distinctions of both, the crystallographic forms are most apparent; the primary one is bounded by the prism together with the clinopinacoid, while in the other, the above pinacoid is lacking. Secondly, the primary mineral is considerably large in size of individuals. One more difference still exists, and this is in colour; the

* Mikroskopische Physiographie, I Band, 2te Auflage, p. 471.

† The writer may add one more exception of its occurrence in Europe. Lossen mentioned its presence in an acidic eruptive rock in the Devonian, near the basin of Elbingerede, in the Harz Mountain. Here unfortunately, the veteran-geologist does not give the exact description of it Zeitschrift d. deutch. geol. Ges. XXXIII, 1881, p. 175.

original glaucophane being bluish or purple, while the other is rather greenish.

The very first step of transformation is the production of stripes in the original, compact diallage, of which mineral alone the primitive rock seems to have been composed, and may then be termed pyroxenite. The cause of stripes or rather a lamellar structure may be sought in the action of pressure, under which the rock has been subjected in the the course of geological time. The action of pressure was so great as in many cases to have caused an actual crushing of massive diallage, and pulled it asunder in the direction of schistosity. *(Fig. I.)* This act of mechanical deformation of rocks, accompanied by the molecular rearrangement in mineral contained in them, has been so ably discussed by J. Lehmann,* Teall,† G. H. Williams,‡ and others that it is quite unnecessary to enter into details on the present occasion, and the writer expresses but his agreement with the view advocated by the above-named geologists.

In the weak, unprotected part, that is peripheries, and fissures of the mineral, paramorphosis readily begins to set forward in becoming glaucophane; the latter mineral seems, however, to be a chemical nature of unstable equilibrium, and represents only an ephemeral stage in the process of transformation; for, the secondary glaucophane soon assumes a fibrous structure, and becomes crocidolite. The writer observed a fact that might corroborate the above statement, and it is a matter of no small importance. For microscopic examination, a number of slides had been prepared of specimens from different localities, and glaucophane in these slides in the course of some weeks, totally lost its original blue colour, and turned into a light green substance.

* Ueber die Entstehung der altkrystallinischen Schiefergesteine, p. 190 et seq;

† Q. J. G. S., Vol. XLI, 1885, p. 139.

‡ Ameri. Journ. of science, Vol. XXVIII, 1884, p. 267.

Concerning the geographical distribution of the glaucophane-bearing rocks in Japan, a few words may still yet be said. As it is already stated, the rock containing the primary one is of a tolerably wide distribution; but the secondary glaucophane-rock is by far the most extensive.* E. Naumann† has already pointed out the importance of chlorite-schist among the crystalline schists, and it is a startling fact that nearly the half of what he called chlorite schist, turns out, on microscopic examination, to be the glaucophane-amphibolite. It is no wonder that such a rare rock as this, has been prodigiously developed in this part of the world.

Imperial University, Tōkyō, October, 1886.

* We have still to mention the other localities:—Yoshinobu village, Tosa-gōri, Tosa province; Yamakami and Hashikura, both in the Kanra-gōri in the Kōzuke province.

† loc. cit. p. 9.

EXPLANATION OF THE PLATE XII.

Fig. I. A striped diallage-fragment, showing the gradual transition of diallage into glaucophane, and then into crocidolite. Slide is taken from a stone-ax found in the village Nomiya, near Sapporo, Yesso.

Fig. II. Intergrowth and the penetration of one individual of glaucophane into the other upon the prismatic face.

Fig. III. Microscopic appearance of a slide of a slaty amphibolite from the Tsuyetate pass, Tosa, showing some remnants of diallage, secondary glaucophane and the derivative mineral of the latter.

Fig. IV. Secondary glaucophane with a diallage remnant, found in the trichitic groundmass of Melaphyre, found in Akaya, Musashi province.

Fig. V. Intergrowth of two individuals of glaucophane upon the clinopinacoid.

Fig. VI. A diallage-remnant in a slide of amphibolite from Izushi, Musashi province, showing the same orientation of diallage, and the paramorphosed glaucophane; but with different angles of extinction.

Fig. I

Fig. II

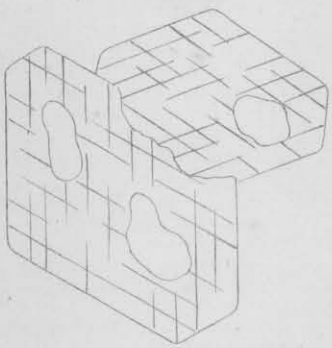


Fig. IV

Fig. VI

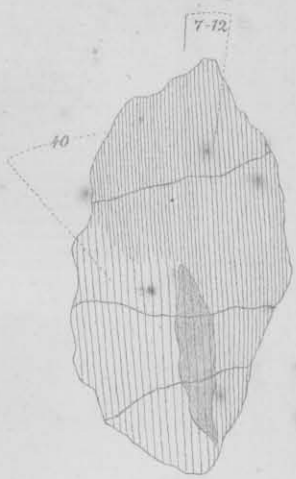
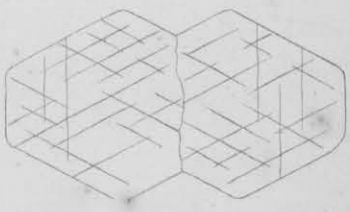


Fig. III

Fig. V



Hiwatchi del.