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*On a Glaucophane-eclogite from the Val d'Aoste.*

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PLATE I.

[Read December 8th, 1885.]

THE number of localities at which glaucophane has been discovered is still comparatively small, so that it may be of interest to add another and to describe the microscopic structure of a rock in which this interesting variety of hornblende occurs.

The carriage road between Verrex and St. Vincent in the Val d' Aoste mounts along the left bank of the Dora Baltea, which, in one part, often called the defile of Mont Jovet, is scarped and craggy. The steepest part of the ascent is between the hamlets of Berrioz and Nus (?). I was walking up this, one day in July 1885, in company with my friend the Rev. E. Hill, F.G.S., when my eye fell upon a rock, which I at once recognised as a variety of eclogite, composed chiefly of small reddish garnets and dull-green hornblende. We secured specimens, though with considerable difficulty, for the rock was very tough; made a few observations and passed on. Next morning, as I was preparing to pack up my specimen, I noticed a peculiar violet-blue tint on its surface, which in certain positions became

very marked. Probably the glittering dispersion caused by the strong sunlight had been the reason of my overlooking the colour on the previous afternoon. I at once felt certain that the tint indicated the presence of glaucophane, and on my return to England lost no time in having slices prepared for microscopic examination, which showed that mineral to be present in no small quantity.

The rock has a slightly foliated structure and a rather rough fracture. The garnets (which project on slightly weathered surfaces) commonly vary from about the size of a hemp seed to that of a mustard seed, but are occasionally a little larger or smaller. Their outline is not very sharply defined, their colour a plum-red or brownish-red. The (dominant) hornblende constituent appears to be very slightly fibrous in texture, and to be an intimate mixture of a dull-green variety and one of a violet blue, inclining very slightly towards cobalt-blue; the prevalent colouring depending to some extent on the angle at which light is incident, and the blue tint being much more conspicuous on the freshly fractured surfaces. Besides this there is a fair amount of yellow-green epidote, more conspicuous on slightly weathered surfaces; and some scales of a silvery white mica. Examination with a lens shows also some tiny streaks of a minutely granular mineral, of a reddish brown colour, but paler than the garnet.

The following is a microscopic description of the rock, of which I have had six slides prepared from fragments taken from two different parts of the mass.

(1.) *Garnet*. Size commonly less than  $\cdot 1$  in. in diameter. The mineral is granular in outline, an external angle being seldom well-defined; much cracked, and showing occasional cleavage. Colour a pale wine-red. Minute microlithic enclosures not unfrequent; sometimes of glaucophane or hornblende, often of dark dust. It is, however, possible in certain cases that these are subsequent infiltrations.

(2.) *Hornblende*. On the whole the most abundant mineral, occurring in rather small, somewhat elongated crystals, in clustered groups, with a general uniformity of position, as if the mineral were a secondary formation developed under a pressure definite in direction. The crystals very often do not exhibit cleavage, and are not markedly dichroic. A distinct green in colour.

(3.) *Glaucophane*. The grains vary in external form, sometimes they are filmy and irregular in outline, sometimes the external faces are well defined. The former are interstitial with other minerals; the latter, though occasionally interrupted by a garnet, are often perfectly regular, as though developed

in a yielding matrix. Usually they are fairly free from inclusions, though sometimes they contain films of a chlorite or a more normal hornblende, or (more frequently) granules of a brown mineral to be described presently. The longitudinal sections of the glaucophane are often from .04 to .06 inch long, the transverse sections about .03 inch. The cleavage parallel to  $\infty P$  is often very well defined, but the mineral has sometimes a slightly fibrous structure in longitudinal sections. With transmitted light the colour varies from a beautiful tint of violet-blue in longitudinal sections to a pale violet in transverse sections. With polarised light the glaucophane, in longitudinal sections, with vibrations parallel to the  $c$  axis, gives a clear ultramarine blue, and, with perpendicular vibrations, a pale purplish or puce tint. In transverse sections, with vibrations parallel to the clinodiagonal plane it gives a pale, but slightly ruddy, sap-green, and, with vibrations perpendicular to it, a rich violet. It is difficult to estimate the amount of glaucophane in the rock, but it is rather less abundant than the hornblende and the garnet, and forms perhaps about one-sixth of the whole mass. From the fact that the glaucophane has not seldom a regular crystalline outline, as may be seen from the figures, and in other cases occupies cracks which traverse the garnet, I am of opinion that it is later in date than either that mineral or the normal hornblende, and probably than the compression which the rock has evidently undergone.

(4.) *Epidote*, rather irregularly distributed in small grains, often rectilinear in outline. This mineral calls for no special remark.

(5.) *Mica*. This mineral is not abundant, and is rather irregularly distributed in the slides; with transmitted light it has a slight tinge of green; I consider it to be one of the hydrous micas, and if not exactly a secondary product at any rate in an altered condition. Small colourless belonites are sometimes included in it.

(6.) *Impure Sphene* (?). This mineral occurs in granules, occasionally assuming an outline which suggests a monoclinic crystal. Their diameter does not generally exceed .005 inch. They occur in rather streaky elongated clusters, which seem to cut through the other constituents of the rock, and have been formed, I think, at any rate in part, in minute cracks developed by subsequent pressure. This mineral varies from moderately translucent to opaque, being in the former case a resin-brown. I cannot precisely identify it by microscopic examination alone, and it would be no easy task to isolate a sufficient quantity for chemical analysis, so I must leave this constituent undetermined, merely stating that I conjecture it to be a titaniferous mineral, and to contain iron. I have occasionally met with it before, and think I have seen it named zircon in some purchased

slides, but doubt this identification. Rutile is said to occur in glaucophane-rock from the Val Tournanche.

In one of the specimens, the glaucophane, and I think some of the hornblende, is bordered by a dull green microlithic mineral which appears to be nearly related to chlorite; this I have no hesitation in considering a decomposition product, so that I deem a further description needless for my present purpose.

*Petrological Relations.* This glaucophane-eclogite is associated with a set of schists generally rather fine-grained; these by the Swiss geologists are referred to the great series of bedded schists which form the highest group in the truly metamorphic rocks of the Alps. They are, in the main, the "*Schistes lustrées*" of some authors; the *grauekalkhaltiger schiefer* and *grüner schiefer* of the Swiss Geological Survey map, with which schistose serpentines are not seldom associated. The commonest rocks of the group are quartz-mica schists, often calcareous, and sometimes passing into beds of crystalline limestone or dolomite, but in certain districts, as on the southern slopes of the Pennine and in the Graian Alps, green schists are important members of the group, occurring, I think, rather in the lower part. Some of the green rock I believe to be only serpentines\* crushed and rendered schistose by subsequent pressure, but others are chloritic and hornblendic schists, apparently of sedimentary origin. The series in this part of the Dora Baltea valley has a general south-west to north-east strike and a variable dip (not generally high) on the northern side; much evidence, however, of subsequent disturbance is afforded by corrugations and slickensided fractures. Below the glaucophane-eclogite† we have a calc-mica schist with some quartz, apparently interbedded with a green hornblende-epidote schist; above it a very fissile green schist, probably similar to that below in mineral composition, followed by a rock which is very possibly a crushed serpentine, and then a green schist, consisting chiefly of green hornblende and colourless mica with a little quartz and a few garnets. The eclogite varies a little in the coarseness of its constituents. It exhibits, as I have said, a slight foliation, and appeared to be interbedded with the schists above and below; but the former character is of little value in a region such as the Alps, and the evidence was not sufficient to determine the latter point. The rocks, on the day of my visit, were almost "whitewashed" with a thick coating of dust, and the time at my disposal did not allow me to endeavour to trace the eclogite up or down the craggy

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\* The word is used in its strict sense.

† Unfortunately I omitted to record the thickness of the exposure, but it is certainly several feet at least.

hillside, for this might have occupied some hours, and I could do no more without altering the plan of my journey.\*

*Comparison with other Specimens of Glaucophane.*—I discovered a glaucophane rock on the sea shore at Pegli, a little west of Genoa, in the year 1878, and gave some account of it the following year.† As, however, it was rather cursorily noticed, for the paper was mainly on serpentines and the rocks associated with them, I will venture to give a rather fuller description.‡ The rock microscopically is a dull green "greenstone," rather minutely crystalline, with a rough fracture, tough, heavy, and evidently rich in a hornblendic constituent. It appears in the field to become in parts more coarsely crystalline, when it resembles "some of the gabbros on the Cornish coast, except that the pyroxenic constituent is less metallic and the 'saussurite' less abundant" (unfortunately I did not bring away a specimen of this variety of the rock). Microscopic examination shows that secondary mineral changes have taken place to a great extent. The felspathic constituent has been almost wholly obliterated, being replaced by a minutely granular, dusky looking mineral, associated with flakes of actinolite. A clear mineral in larger grains occurs occasionally, which may in some cases be feldspar, but perhaps is more likely to be some hydrous silicate, or possibly now and then secondary quartz. The pyroxenic constituent has been converted into hornblendic minerals, as is commonly the case in gabbros; but here and there the close cleavage of the original diallage can still be discerned, and where this is most marked the mineral is dusty-looking, almost opaque, without definite characters. This is often bordered or traversed irregularly by glaucophane, and occasionally by ordinary pale-green actinolite. The glaucophane is abundant, and it appears to be a secondary constituent of the rock; most of it is more or less fibrous or "actinolitic" in structure, as is usual in the gabbros where the hornblende has resulted from the alteration of an original pyroxenic constituent—but (as may also be seen in such rocks)

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\* I hope the next visitor will endeavour to work this out. As it may prove, if it can be done, a rather long task, he had better sleep at St. Vincent, where the hotels are much better than at Verrex: if the roads are dusty he had better take a brush with him. He cannot miss the locality, it is on his left hand as he descends the high road.

† *Geol. Mag.* Dec. II. Vol. VI. p. 363.

‡ Mr. G. H. Williams (N. J. 1882, Bd. II. p. 201) notices a rock which he believes to be from this locality (of this I am doubtful), and intimates that I should have called it an *amphibolite*. As in 1879 it was not even certain that amphibolite denoted an igneous rock (I am not aware that there is harmony in its use now), and as I was satisfied the rock was of igneous origin, and had once been a gabbro, I preferred to call it (as I shall continue to do) a glaucophane-gabbro.

we occasionally find a grain (having usually its external outline rather ill-defined) where the characteristic cleavage of hornblende is very well marked; colour with transmitted light shades of violet blue inclining to ultramarine, with polarised light as described above, but perhaps a little less vivid. The slide contains a few granules of an iron oxide, but parts of some of the diallage crystals are replaced by an almost opaque mineral resembling a decomposed ilmenite. Glaucophane also occurs in a singular fragmental rock in the same neighbourhood, as to the origin of which I have not been able to come to any satisfactory conclusion.

Glaucophane seems to occur rather frequently in the central part of the Pennine Alps, for it is recorded as discovered at another locality, Champ de Praz, in the Val d' Aoste, also at Brozzo (near Ivrea) and in the Val Locarno (Stelzner, *Neu. Jahr.* 1883, Bd. I. p. 211). Strüver gives an analysis of the mineral from Brozzo, to which he gives the name *Gastaldite* (which, however, is now replaced by the older name glaucophane) (*N. J.* 1876, p. 664).\* Glaucophane has also been found in the Val Tournanche near the Matterhorn (Cossa and Strüver, *N. J.* 1880, Bd. I. p. 162), and in pebbles at Germagnano (Williams, *N. J.* 1882, Bd. II. p. 201). On the north side of the Alps it is recorded from near Zermatt (Bodewig, *Pogg. Ann.* CLVIII. 1876, p. 224), and as an erratic in Switzerland (Stelzner, *N. J.* 1883, Bd. I. p. 208). Besides the original locality, the Island of Syra (Lüdecke *Zeitsch. deutsch. geol. Ges.* XXVIII. p. 248), it has been found by Dr. C. Barrois at the Isle de Groix (Morbihan), Brittany (*Ann. Soc. Geol. Nord.* XI. p. 45).

The composition is exceptional, the amount of  $Al_2O_3$  being extraordinarily large, as will be seen from the analysis subjoined (Strüver). (The highest percentage in a list of 52 analyses of hornblende, given by Dana in his *System of Mineralogy* (pp. 238, 239), is 17·59; the specimen came from Bilin in Bohemia.)

$SiO_2$	=	58·55
$Al_2O_3$	=	21·40
FeO	=	9·04
MgO	=	3·92
CaO	=	2·03
$Na_2O$	=	4·77
$K_2O$	=	trace.

99·71

\* See also *Atti R. Accad. Lincei*, Ser. 2, Vol. II. p. 333. Here it is said that the specimens from the Val d' Aoste "furono estratti dagli affioramenti dei depositi cupriferi di Champ de Praz e S. Marcello." I cannot find on my maps the former place, but, as the latter is between Chatillon and Aosta, conclude the above localities are different from that which I have described. In this memoir the optical properties are described.

The glaucophane rock from Syra, in the British Museum Collection,\* is a fine-grained light-grey to brownish schist (not markedly fissile) with conspicuous crystals of glaucophane, roughly about  $\cdot 1'' \times \cdot 3''$ . Under the microscope the ground-mass mainly consists of a white mica inter-banded with small granular quartz—much resembling, in fact, one of the quartz schists which occur in the Alpine series rather low down in the upper group of schists, *i.e.* probably not very far away from the horizon of the glaucophane rock described in this paper; the external angles of the glaucophane crystals are generally well-defined, though sometimes imperfect. They do not, however, seem to have been subjected to pressure, though the ground-mass does. The crystals are dark in colour, and the characteristic violet hue is not always perceptible. Glaucophane occurs in another schistose rock from the same island, in which is much of a mineral resembling impure epidote. The specimen figured by MM. Fouqué and Lévy (*Roches Eruptives*, Plate I. Fig. 2) is less markedly foliated than the British Museum specimen. In the Isle de Groix† the glaucophane occurs in no great abundance with greenish mica, epidote, garnet, hornblende and but little quartz. The rock has all the characters of a schist. The glaucophane crystals are of no great size, but fairly abundant in a specimen from Canton Valais (exact locality uncertain), with quartz, actinolite (?), and are often scattered about in patches of a chloritic mineral. The largest and most characteristic glaucophane crystals are in a rock from the neighbourhood of Zermatt; here their structure suggests to me the possibility of the replacement of a diallage. Comparing my own specimens with the above, I may say that the glaucophane in them is as characteristic as in any, and the crystals are only surpassed in size by those from Syra and Zermatt. I may add that in the majority of the above specimens the glaucophane appears to me to be more probably a mineral formed late rather than early in the rock's history.

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\* I am indebted to the President and Mr. T. Davies for the opportunity of studying the slides, &c. mentioned in this paragraph.

† I have a specimen of this and of the Syra rock in my own collection, for which I am indebted to Prof. Judd.

## DESCRIPTION OF PLATE I.

Fig. 1.—Section of glaucophane-eclogite, exhibiting (1) glaucophane; (2) garnet, in a ground-mass chiefly composed of green hornblende (3); traversed by an irregular line (4) of the brown mineral (? impure sphene). In this section the principal crystal of glaucophane is cut parallel with the vertical axis.

Fig. 2.—Section of glaucophane-eclogite, exhibiting the same minerals, numbered 1, 2, 3, as before. The principal crystal of glaucophane is cut transversely to the vertical axis, and exhibits the characteristic outline and cleavage of a hornblende crystal. The sections are drawn with ordinary transmitted light, and the dichroism of the mineral is well indicated by the difference between the blue tint of the upper and the purple tint of the lower crystal. In each case, it may be noted, grains of the green hornblende are included in the glaucophane.

Magnified 27 diameters.

I have to thank Mr. Felix Oswald for kindly making the drawing.

T. G. B.



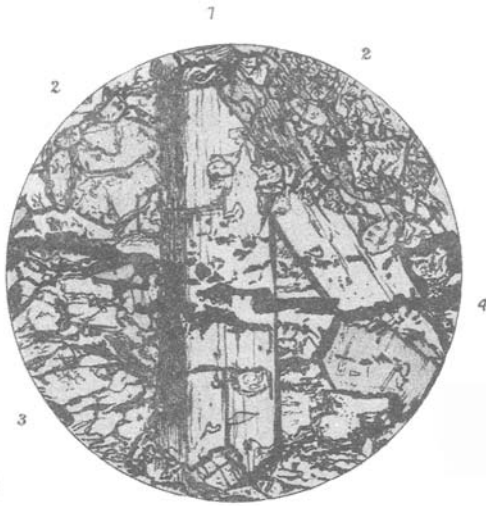


Fig. 1

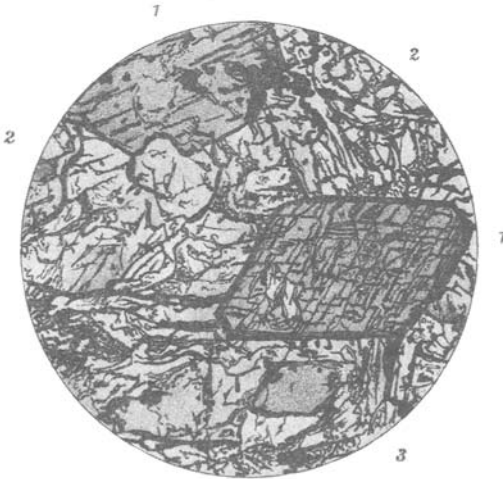


Fig. 2.

Mintern Bros. Chromo lith.

*Glaucophane-eclogite from the Val d'Aoste.*

[Copied from original colour plate.]