

II.—*Some Results of a Microscopical Study of the Belgian Plutonic Rocks.* By A. RÉNARD, S.J.

(Read before the ROYAL MICROSCOPICAL SOCIETY, April 5, 1876.)

PLATE CXXXVII.

THIS paper is a very brief and comprehensive statement of a few of the results obtained by applying the microscope to the study of some Belgian rocks; they are developed more at length in the *Mémoire* which I made together with the Prof. de la Vallée Poussin.*

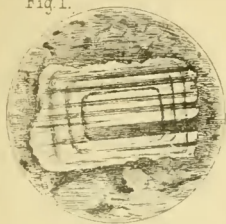
The most important of the Belgian plutonic rocks is the quartziferous diorite, found at Lessines and Quenast in the Silurian layers of Brabant. Delesse, who has made a chemical study of it, considered the base of that rock as a *residue* from crystallization, i. e. as a silicate whose variable elements are silicic acid, and all the bases which are found in the various minerals porphyrically developed in this rock. This eminent lithologist extended therefore to the rock in question his opinion concerning the constitution of the base of porphyries in general. But the microscope enables us to see that in the rock of Lessines and Quenast the base is composed of grains of quartz and feldspar forming a micro-granitoid agglomeration. As for the oligoclase which, together with quartz and more or less altered hornblende, makes up the essential elements of this rock, it presents a structure already observed in the plagioclases of trachytes and andesites. This structure is remarked in lines which are parallel to the outlines of the crystals. With ordinary light, these lines are of a feeble brownish colour; their

EXPLANATION OF PLATE CXXXVII.

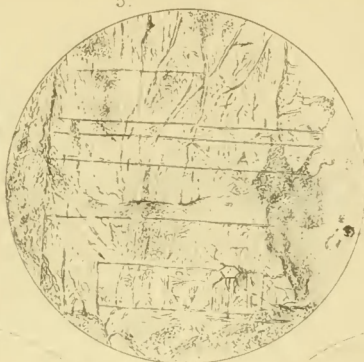
- FIG. 1.—Oligoclase in the diorite of Quenast, showing a concentric structure. Polarized light. $\times 40$.
 „ 2.—Epidote and calcspar, Quenast, $\times 40$.
 „ 3.—Liquid cavities containing crystals of Na Cl enclosed in quartz, Quenast. The prismatic crystals are tourmaline. $\times 450$.
 „ 4.—Crystal of labrador fractured and bent by *fluidal structure* in gabbro, Hozémont, $\times 40$.
 „ 5.—Diallage in gabbro, Hozémont, showing the cleavages of that mineral, $\times 25$.
 „ 6.—Diallage surrounded by fibrous hornblende, $\times 40$.
 „ 7 and 8.—Ilmenite, covered in some parts by its characteristic white coating, in gabbro of Hozémont, $\times 25$.
 „ 9.—Fragments of crystals of plagioclase and quartz, surrounded by Sericite in the elastic Porphyroid of Pitet. Polarized light. $\times 120$.

* “Mém. sur les Caractères Minéralogiques et Stratigraphiques des Roches dites Plutoniques de la Belgique et de l’Ardenne Française,” par Ch. de la Vallée Poussin et A. Rénard, S.J., t. xl. des ‘Mém. Couronnés de l’Académie de Belgique.’ This work, which is now in the Press, will soon appear.

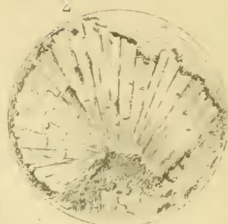
Fig 1.



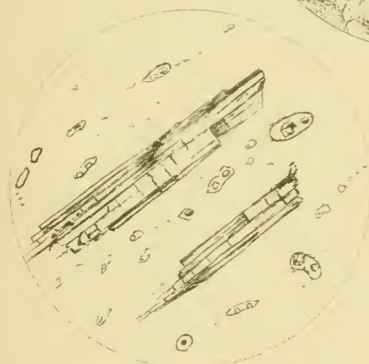
5.



2.



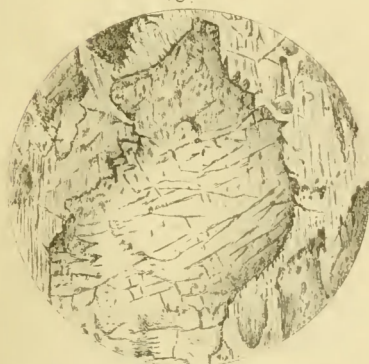
3.



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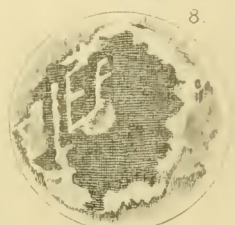
9.



7.



8.



angles are not perfectly sharp; and, what is very remarkable, the lines which lie perpendicular to the polysynthetic lamellæ run clear through, without any break at the point where they intersect the striæ (Fig. 1).

In this diorit the microscope has enabled us to prove the presence of orthoklas, a result to which we have been led by the phenomena of polarized light, just as is observed in the twin crystals of Carlsbad. We need not stop to describe the microscopic details of the hornblende, which is generally much altered and often surrounded by an opaque zone in a state of decomposition, which has also obliterated the cleavages. This mineral often contains apatite, and this we consider to have been formed simultaneously with the hornblende; it is also intimately associated with chlorite, ilmenite, magnetic iron, biotite, epidote (Fig. 2), calcspar, and quartz; minerals which we believe to have been formed for the most part by the decomposition of the hornblende. Notwithstanding its state of decomposition, the sections of this mineral are still dichroic. We have also found in this rock uralite, augite, and diallage; and by means of the microscope we have proved the presence of crystals of apatite and ilmenite. These two minerals, which play an important part in the Belgian plutonic rocks, are always of microscopical dimensions, and had not been remarked in that country before we examined them under the microscope.

The microscopic study of the quartz of this rock is of the greatest interest, since it allows us to determine to a certain point the conditions in which this diorit was formed. Mineralogists have long been engaged in the study of the numerous minerals contained in quartz, and of the liquids enclosed in the cavities of this mineral; but it is especially Sorby, who by opening the way to a new method in petrography, has shown the geological importance of these phenomena. Following his example, and relying on the facts revealed by the microscope in the cavities of the quartz of this rock, we will endeavour to determine the temperature and the pressure at the moment of the crystallization of this rock.

The sections of the quartz of Quenast are rich in liquid cavities, but many of them, besides the bubble and the liquid, contain little cubic crystals (Fig. 3). An ellipsoidal cavity has enabled us to measure with great precision by means of the micrometer the dimensions of the cavity, those of the bubble and of the cubic crystal.

Major axis of the cavity	0,mm00964
Minor axis of the cavity	0,00660
Side of the cube	0,00214
Diameter of the bubble	0,00187

Of all the rocks subjected to microscopic examination, that of Quenast is perhaps, after the syenite of Laurvig, the one which

presents the greatest number of cavities with these little cubic crystals, whose faces are sometimes covered with parallel striations answering to the cleavage $p (\infty 0 \infty)$. It would be easy to prove that these cavities were formed and filled with the substances now found in them at the very moment of the crystallization of the quartz. By raising the temperature to about 100° C. we did not succeed in expanding the liquid; so that it is not liquid carbonic acid, but rather a saturated aqueous solution, as Sorby showed. The little cubic crystals gave rise naturally to the idea that the cavities are filled with a supersaturated solution of sodium chloride; their form and the parallel striæ which cover their faces call at once to mind the crystals of this same salt.

Following the example of Zirkel, Vogelsang, and Behrens, we investigated the nature of these microscopic crystals by spectral analysis. We carefully removed from the grains of quartz extracted from the diorite all the feldspar which could possibly remain attached to them. They were hardly put in the Bunsen flame when they slightly decrepitated, the cavities broke open, and the ray D appeared; this experiment repeated several times always gave us the same result. However, in order to be more assured of the exactness of our research, we wished to confirm it by an entirely different method. Some fragments of quartz reduced to a fine powder were put in a test tube of distilled water; when the grains of quartz had subsided we poured in a few drops of silver nitrate, the water became slightly milky, and presented the opalescent tint which characterizes the silver chloride.

Thus we think we can affirm that our experiments demonstrate that these cubes are crystals of sodium chloride, and the liquid in the cavities is a saturated aqueous solution of this salt. This result is not astonishing, if we reflect upon the analogy existing between the plutonic and volcanic rocks. The latter almost always, as is well known, show traces of this salt, and often are impregnated with it. We will now endeavour to find the temperature at which this water was enclosed, and therefore that of the rock at the very moment of its crystallization. We take as the ground of our calculation the experiments made on the solubility of sodium chloride in water. It has been observed that the solubility of this salt increases directly as the temperature. The cubic crystals contained in the cavity having been deposited by the liquid while it was cooling.

The micrometric measurements of the cavity, of which we have just spoken, furnished the elements for our calculation. The volume of the water was found 0,0000002198687 mm., that of the salt 0,000000098003. We had then only to ascertain to what temperature we should raise the volume of water to make it dissolve this volume of salt. On calculation we obtained for our

result a temperature of 307° C.* By studying the rate of expansion of the liquid, Sorby concluded that the quartz in the trachyte of Ponza must have been formed at about 356° C., which may be looked upon as a very similar temperature. The number

* The volume of the liquid cavity (an ellipsoid of revolution) is $\frac{4}{3} \pi a b^2$.

$$a = 0,mm,00482$$

$$b = 0,mm,00330$$

$$b^2 = 0,00001089$$

$$a b^2 = 0,0000000524898$$

$$\frac{4}{3} \pi = 4,1887901$$

$$E = \frac{4}{3} \pi a b^2 = 0mmc,0000002198687$$

$$\text{Bubble formula, } \frac{4}{3} \pi r^3$$

$$r = 0,00093$$

$$L = \frac{4}{3} \pi r^3 = 0mmc,000000003429$$

$$\text{Volume of the cube, } c = 0mmc,0000000098003$$

For the relation of the weight to the volume, we have the following formula: Water, $P = V \times 1000$; for any given body, $P = V \times 1000 \times \text{specific gravity}$. In these formulæ, when V represents cubic metres, P denotes kilogrammes. Consequently if V denotes cubic millimètres, P represents thousandths of milligrammes. Hence

$$V = \frac{P}{1000 \times \text{specific weight}}$$

p denoting the weight of water contained in the cavity, ω the weight of the salt (without the cube), we have at the temperature of these micrometric determinations, and admitting that in the solution of salt there is neither augmentation nor diminution of the total volume,

$$\frac{p}{1000} + \frac{\omega}{1000 + 2,26} = E - (L + C) = 0,000000206644 \quad [a]$$

2,26 is the density of salt at 0°; at 20°, the temperature at which the micrometric measurements were made, this density is less than the zero-value by some thousandths. We have neglected this slight variation. A similar allowance must also be made for the water. According to Regnault ('Chimie,' t. i. p. 456, table), at 0°, 100 grammes of water contain, when saturated, 35,5 grammes of salt; at 120°, 100 grammes of water, when saturated, 40,5 grammes of salt.

Moreover, the solubility increases in proportion to the variation of temperature; this gives an increase of $\frac{5}{100}$ grammes of salt for a variation of 1°. Consequently, at 20°, 100 grammes of water contain 35,5 grammes of salt + $\frac{2}{20}$; that is, 36,33 grammes.

We have then the equation,

$$\frac{\omega}{p} = \frac{36,33}{100} \quad [b]$$

By representing the weight of the cube by q, and the temperature at which the cavity was formed by t,

$$\frac{\omega + q}{p} = \frac{35,5 + \frac{t}{24}}{100} \quad [c]$$

The

307° C. would be exact if the law of solubility of salt in water already referred to, was well established for high temperatures. Unfortunately experiments are wanted here. The law of solubility of sodic chloride remains constant to 120° C.; above this we are ignorant of its behaviour. Considering that superheated water becomes a powerful dissolvent of artificial glass in the experiments of MM. Daubrée and Sorby, we are led to believe that its action upon sodic chloride is greatly augmented at 200° or 300°. The doubt upon this fundamental point permits us to assign to our number 307° only an approximative value. Accepting this as such, we will continue our examination of the physical conditions under which the crystallization of this rock has taken place. This is an example of calculation which will hereafter doubtless give results on which we can confidently rely. Knowing the temperature at which the cavity was formed, we can determine the pressure necessary to prevent, at this temperature, the complete evaporation of the water. It suffices to apply the formula of M. Roche.*

The equation [a] gives $p + \frac{\omega}{2,26} = 0,000206644$

„ [b] „ $\omega = 0,3633 p$

„ [c] „ $t = 24 \left\{ \frac{100(\omega + q)}{p} - 35,5 \right\}$

$$p = 0,000178$$

$$\omega = 0,000064$$

$$q = 0,000022$$

$$\frac{\omega + q}{d} = 0,483.$$

Hence $t = 24(48,3 - 35,5) = 24 \times 12,8$
 $t = 307^{\circ}.$

* The theoretical formula of M. Roche is the same as that found by Clapeyron, August, De Vrede, Holtzmann. "This formula," says M. Regnault, "represents the elastic force of aqueous vapour for a great extent of temperature with remarkable accuracy; it, indeed, between 100° and 220°, gives a result for the elastic force too great, but the greatest error only amounts to 35 millimètres. It is applicable perfectly to the vapour of water, and also to the vapours of alcohol and ether." M. Roche's formula is as follows:

$$F = a \alpha^{\frac{x}{1+mx}}$$

In this formula x represents $t + 20^{\circ}$, t being the Centigrade temperature counted from the melting point of ice as zero, and according to Regnault's calculations:

$$m = 0,004884085$$

$$\log. \alpha = 0,0386182275$$

$$\log. \alpha = 1,9590414$$

We obtain for our result a pressure of 66291 mm., or 87 atmospheres.

Another very interesting rock on account of its microscopical constitution is that which was designated by Dumont as hypersthénite of Hozémont; having found that it contains diallage instead of hypersthène, this rock should be called Gabbro. Chemical analysis has demonstrated that here the feldspar is labrador feldspar. In certain cases the thin sections of this gabbro show us the crystals of labrador broken; the broken parts are slightly separated from one another; and, what is important for our interpretation, the surrounding minerals and the base present the aspect of a mass bent, as is seen in the rocks of true volcanic character which have a fluidal structure (Fig. 4). The diallage such as we have found here should not be confounded with hypersthène, on account of its want of dichroism and because we find frequently the cleavage corresponding to h^1 ($\infty P \infty$) associated with another cleavage perpendicular to the former. This second cleavage is indicated merely by irregular and interrupted striæ which correspond to the plan g^1 ($\infty P \infty$) (Fig. 5). This second cleavage, as is well known, is less easy than the other. Hence we never have the regular reticulated structure which should be found in augite. This diallage is frequently surrounded by little fibres of hornblende 0,3 mm. in length (Fig. 6). This fibrous hornblende is colourless, perfectly transparent, and dichroic. The minerals which constitute this rock are imbedded in a greenish substance, which under the Nicol prisms appears in some places monorefringent, and in others presents a sky-blue colour. Upon close examination this substance is found to be of a fibrous structure and offers an irregular network similar to that which is well known in the case of serpentine; although we have not met with olivine whose decomposition would have given the explanation of the presence of serpentine. Besides apatite we have also detected ilmenite, remarkable on account of its decomposition products, and which we will now briefly describe.

The sections of this titanic iron are surrounded and covered in some cases with coatings of an opaline substance perfectly homo-

$$\text{for } t = 307 \quad 1 + mx = 2,597095795$$

$$\frac{m}{1 + mx} = 129,91$$

$$\log. F = \log. a + \frac{x}{1 + mx} \log. a$$

$$\log. F = \bar{1},9590414 + 125,91 \times 0,38618275$$

$$= \bar{1},9590414 + 4,86241700$$

$$= 4,82145840$$

$$F = 66291m = 87 \text{ atmospheres.}$$

geneous, which seems a result of the decomposition of ilmenite. The first stage of this decomposition is represented by the appearance of whitish veins running through the mineral; a second stage exhibits it enclosed in the opaline substance; finally, the metamorphosis can be pushed so far that nothing more is visible except a few black specks (Figs. 7 and 8). Its chemical composition has not been determined, but we have ascertained that it is unalterable by the action of hydrochloric acid, and therefore it is not carbonate of iron, as has been taught by some. We are, however, persuaded that the opinion of Gumbel, who admits that it is not a decomposition product, cannot be sustained.

In the Cambrian and Silurian beds of Belgium and of the Ardennes we meet with feldspathic rocks having at the same time a schistoid and a porphyritic texture, and which appear to be regularly imbedded in quartzites, slates, and schists. Dumont interpreted this feldspathic rocks as so many dykes injected between the adjacent layers; other geologists have admitted that these schistoporphyrlic rocks were the result of a metamorphic action exerted at certain points. The stratigraphic study of these rocks in the Silurian of Brabant and their examination both with the naked eye and under the microscope have led us to admit for them an elastic origin. The microscopic characters on which we rely to demonstrate this fact are that the numerous feldspars in the thin sections are all without distinction broken or their angles blunted, and present at both extremities the appearance of fracture. In the same way the grains of quartz are not terminated by crystalline lines which have their regular form (Fig. 9). However, in other places in the same schisto-porphyrlic rocks we found indications that a part of the quartz has crystallized *in situ*. This latter mineral with sericite and triclinic feldspar constitute the essential elements of this rock. Hence we arrive at the same conclusion as Sorby, who considers some sericitschiefer of the neighbourhood of Wiesbaden as elastic, and we know besides that the rocks of which we are now speaking have the same identical schisto-porphyrlic structure and the same composition as those described by Sorby.
