On the Humite Series.

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[Read April 14th, 1896.]

THE humite series has formed one of the most interesting problems to mineralogists ever since Scacchi established the three types. I may, perhaps, recall that he found the crystals to be divisible into three classes, all capable of representation by reference to a common parametral plane and three zone-axes at right angles to one another. But the three classes differ in the following respects :—(1) Each has a peculiar set of faces, and, with the exception of the pinakoids and the actual or theoretical prisms, few of the forms coincide in different types. (2) Whilst all the faces on crystals of one class can be easily represented by quite simple indices, such as (111) (123) (103) by a judicious selection of one of its faces as parametral plane, the faces on crystals of the remaining two classes give for the same parameters very high and complicated indices. For the sake of simplicity of indices a different parametral plane has therefore to be assumed for each class. (3) Whilst in one class, that now specially denoted as humite, the faces are arranged about the axes so as to conform to the holohedral forms of the rhombic system, in the remaining two classes the faces are developed in sets of four tautozonal planes in the manner characteristic of the oblique system. This latter character so impressed Miller, whose material was limited, that he has described the mineral as oblique. Miller's crystals were undoubtedly of the kind now termed clinohumite. His determination, apparently simultaneous with Scacchi's work, is very accurate, and the commonest twin law of the class is given in a very precise manner.

The next important contribution to our knowledge was vom Rath's classical memoir published in 1871 (*Pogg. Ann. Erg. Bd.* V.). He confirmed Scacchi's results, and gave a very exhaustive description of the twins of the different classes, many of which had hitherto escaped notice. Referring the crystals to the same axes, he gave the following parameters, which have been but slightly modified since.

		a		b		c	$=$	$m\,\gamma$
Chondrodite	...	1·08028	:	1	:	3·14379	=	$5 \times$ ·62876
Humite...	...	1·08028	:	1	:	4·4013	=	$7 \times$ ·6288
Clinohumite	...	1·08028	:	1	:	5·65884	=	$9 \times$ ·62879

The faces present on crystals of the three varieties are now all capable of simple representation. Thus we have common prisms $\{110\}$, $\{120\}$, also a series of domes $i_1\{011\}$, $i_2\{012\}$, &c.

The faces of forms $e_1\{101\}$, $e_3\{103\}$, &c., which should form domes, are found in chondrodite and clinohumite to be frequently present in pairs of parallel faces only, or those inclined to one another are differently developed.

Again, we have zones common to all the varieties with forms $n_1\{111\}$, $n_3\{113\}$, &c., and $r_1\{121\}$, $r_3\{123\}$, $r_5\{125\}$, &c., which should constitute pyramids of eight faces. This is the case in humite. But in the other two varieties we have frequently only sets of four tautozonal faces, the characteristic form of the oblique system, and the pyramid, when eight faces with equal indices are present, is generally divisible into two sets of four tautozonal planes, owing to different development.

In 1876 M. DesCloizeaux showed that chondrodite and clinohumite both form polysynthetic twin-lamellæ parallel to (001), and that sections of such crystals parallel to the pinakoid b(010) do not, between crossed nicols, extinguish the light in the lamellæ simultaneously or parallel to the base. In chondrodite the direction of extinction makes an angle with (001) of nearly 30°, and is nearly parallel and perpendicular to the important normal e_5(105). In clinohumite the extinction of the lamellæ occurs in a direction inclined at $+11°$ to the vertical axis. This had already been established by Prof. E. S. Dana for chondrodite from Brewster, and was at a later date confirmed by him for clinohumite. At the same time M. DesCloizeaux showed that humite has no twin lamellæ parallel to (001), and that the extinction in sections parallel to (010) is parallel to the face (001). Hence humite is rhombic, whilst chondrodite and clinohumite have to be relegated to the oblique system. It has not, however, been found possible to find variations in the angles between the base and faces, such as $\pm e_3 \pm n_3$, which have like indices but lie on opposite sides of the axis ZZ'. Hence the angle between the axes of X and Z has to be regarded as 90°; and Prof. Dana says that careful examination of chondrodite crystals has convinced him that the angle XOZ cannot differ by 1′ from 90°,

In 1894 Prof. Penfield showed by a series of careful analyses that if the water be taken as hydroxyl (HO) replacing fluorine, the three varieties have the following composition :—

Chondrodite	... ...,	$Mg_3[Mg(F,OH)]_2(SiO_4)_2$
Humite	... ...	$Mg_5[Mg(F,OH)]_2(SiO_4)_3$
Clinohumite	... ...	$Mg_7[Mg(F,OH)]_2(SiO_4)_4$

He also points out that the number of atoms of Mg in each gives exactly the multiple of $\gamma = \cdot 6288$ required for the parameter c. This being the rule he then indicates the possibility of an extension of the series $Mg_{2x-1}[Mg(F,OH)]_2(SiO_4)_x$ with parameters $a : b : (2x+1) \gamma$, and also that the lower term is probably $Mg[Mg(F,OH)]_2SiO_4$ with parameters

$$1\cdot08028 : 1 : 1\cdot88628.$$

In passing from one member to the next one in the above series the chemical change consists in the addition of a molecule of forsterite Mg_2SiO_4 or olivine $(Mg,Fe)_2SiO_4$, and the addition of 2γ to the parameter c.

Now Prof. Sjögren[1] (*Bulletin of the Geol. Inst. of Upsala* II.) has recently announced the discovery of prolectite with the parameters just given, *i.e.* with $c = 3\gamma$. The amount of material at his disposal has not enabled him to analyse the substance; but there is a strong presumption that its composition will accord with that suggested by the rule of the series.

Now the comparison with olivine, though frequently made, has not brought out the relation between it and the members of the above series with much precision. This is to some extent due to the recent adoption of the parameters of Kokscharow instead of those of Naumann and Miller. If we take the representation given in Miller's edition of *Phillips' Mineralogy*, 1852, we have parameters

$$a : b : c = 1\cdot0733 : 1 : 2 \times \cdot6297,$$

where a and b are almost identically those of the humite series, and the multiple of γ (namely 2) is the number of atoms of Mg. The parameters of forsterite differ very slightly from those of olivine.

To carry the inquiry to the lowest possible step, we must go to enstatite and hypersthene $(Mg,Fe)SiO_3$. Unfortunately the crystals of these substances so far available leave much to be desired. The divergence from the parameters $a : b : \gamma$ is much greater than those which exist in the preceding minerals. The prisms $\{110\}$, $\{120\}$ have angles differing greatly from those in the same forms of olivine and the humites, and the acute angle of $\{110\}$ occupies the position of the obtuse one in the humites. But if we consider the zone $[100, 001]$ —a pseudo-hexagonal

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zone in all the minerals—we find the ratio of $a : \gamma = 1\cdot0685 : \cdot62886$; a very close approximation to that required by the series. The divergence from the rule of the series is then thrown on the parameter b, which becomes $1\cdot1013$, when c is $\cdot62886$. The variation in the ratio $a : b$ is not surprising, seeing that there has been a change from an ortho- to a meta-silicate.

We may call attention to the remarkable fact that the twin-face in all the minerals, except clinohumite, is practically the same face, *i.e.* one making an angle of nearly $30°$ with $c(001)$, which meets the axes at distances a and γ, and has the indices (101), (102), (105), (107), in the different minerals.

In clinohumite the common law is twin-face $-e_3$ ($\bar{1}03$), *i.e.* a face at nearly $90°$ to (109).

The examination of prolectite is as yet too incomplete, owing to lack of material, for us to know whether it will correspond to or deviate from the common rules of twinning.

Again, as to habit, we have the curious fact that all the minerals have a marked inequality in the development of like faces, so as frequently to give the appearance of oblique crystals. The extinctions and the other optic phenomena have been very carefully determined by several observers of the greatest skill. We can, therefore, hardly expect that future investigations will relegate the whole series to the oblique system. At the same time such a result would harmonise with the close relation which exists between enstatite and pyroxene.

Another common feature is the great predominance of the forms lying in the zones [010], [1$\bar{1}$0] [2$\bar{1}$0] *i.e.* faces such as $e(101)$, $e_3(103)$ $n_1(111)$, $n_3(113)$, $r_3(123)$ $r_1(121)$, &c. In these zones the faces are never the same, for being represented by the same indices, they occupy different positions owing to c being a different multiple of γ. It may not be amiss to point out that the minerals closely approximate in density, hardness and fusibility. If V represents the molecular volume, M the weight of the atoms in the chemical molecule, and d the density, and hence $V = \dfrac{M}{d}$. Then we have—

For Olivine ...   ... $V_2 = 44 = 2 \times 22$
Chondrodite   ... $V_5 = 105\cdot6 = 5 \times 21\cdot1$
Humite ...   ... $V_7 = 150 = 7 \times 21\cdot4$
Clinohumite   ... $V_9 = 182\cdot1 = 9 \times 20\cdot2$
Enstatite   ... $V_1 = 32\cdot8 = \frac{3}{2} \times 21\cdot9$

The attempt to get topical axes, as suggested by Herr Muthmann, clearly gives no new relation.