ART. XXI.—*On some Minerals of the Chlorite Group*; by JOHN B. PEARSE.

THE diversities of color among the varieties of the mineral species are in many cases still unexplained. A case of this kind occurs in the so-called kämmererite, from Lancaster county, Pa., of which there are three kinds—one colored pure green, a second red and green, while the third is of a pure red. The following investigation was undertaken to determine, if possible, the cause of this variation; and as the results have proved interesting, they have been further discussed in their general relations.

The mineral is in distinct crystals. There is the strongest evidence that all belong to the trimetric system, closely resembling many specimens of chlorite and some crystals of clinocllore. They are usually hexagonal in form, rising from their base as a truncated pyramid, but the lateral surfaces are so striated as to be incapable of measurement. The pyramid is made up of a pile of crystalline plates, with their slightly projecting edges manifestly replaced, indicating a dome and an octahedron.

The three varieties are well defined, the color of the first being a pure green, sometimes a rich emerald-green, while that of the second varies considerably between these two tints, being sometimes of a pure white; and that of the third is red, with an occasional tinge of reddish-white. In the second, the colors are confined to the laminae, instead of mixing and giving a medium tinge. The third was also dichroic in the direction of the planes of its axes, being red in the direction of its shorter lateral axis, but of a violet-blue or hyacinth in that of the longer axis.

The hardness of the green and red is 2.75; the specific gravity of the green at 64° Fahr. 2.355, that of the red 2.383, which is perhaps a little too low, as it was impossible to free the crystals of a few minute bubbles of air. They consist of flexible micaceous plates, with a vitreous lustre, and white streak. Their blowpipe reactions show the presence of chrome, and silica, the absence of manganese in both, and the absence of fluorine in the green. Traces of the alkalis were shown in the red. Both the green and red are soluble in sulphuric acid with separation of silica, but are not acted on by chlorhydric acid. The purplish green not being obtained in sufficient quantity is not included in this description. This deficiency however proved unimportant, as the analysis showed its identity with the red.

Extreme care was taken in selecting the material for analysis. Fresh and perfect crystals were used for each analysis of the same variety, in order to certify undeniably the composition.

AM. JOUR. SCI.—SECOND SERIES, VOL. XXXVII, No. 110.—MARCH, 1864.

In no case was any crystal chosen the color of which was indistinct.

The following is an outline of the method of analysis adopted. After solution by means of carbonate of soda, and chlorhydric acid, the usual precautions being taken for an accurate estimation of the silica, the filtrate was rendered slightly alkaline with ammonia which precipitated the sesquioxys of iron, chrome and aluminum, with part of the nickel. This precipitate being dissolved was treated with acetate of soda, which separated the nickel oxyd from the sesquioxys; the latter was then dried, weighed, pulverized carefully with carbonate of soda, and then fused together with nitrate of potash for chrome. This metal was estimated with the precautions detailed by Genth.¹ The residue being again dissolved, the iron was separated from the aluminum by caustic potash with the addition of sulphid of potassium. Great care was taken that the sesquioxys of iron and aluminum were free from silica and perfectly washed. The nickel remaining in solution after the acetate separation was precipitated by sulphid of potassium. The filtrate from the ammonia precipitation, after the destruction of the ammonia by nitric acid, was treated by sulphid of potassium, as above, to separate the nickel from the lime and magnesia. The lime was precipitated as oxalate, and estimated as sulphate; the magnesia in the usual way. After the solution of the sulphid and the estimation of the oxyd of nickel, the oxyd was redissolved, and separated by ammonia from the impurities which cling to nickel so closely. The analyses, so described in outline, gave the following results—two determinations being generally made of each constituent of the green and reddish-green.

	Green.			Reddish-green.			Red.
	No. 1.	No. 2.	Average.	No. 1.	No. 2.	Average.	
SiO ₂ *	28·800	28·444	28·622	31·515	32·200	31·857	31·315
Al ₂ O ₃	18·375		18·375	13·746		13·746	12·840
Cr ₂ O ₃	1·935	2·000	1·967	2·154		2·154	2·985
Fe ₂ O ₃	3·362	3·606	3·734	2·307		2·307	2·457
Ni ₂ O	·370		·370	·231	·200	·215	·450
Ca ₂ O	1·590	1·803	1·446	1·273		1·273	·815
Mg ₂ O	31·766	32·483	32·125	34·871	34·929	34·901	35·020
H ₂ O	13·900	14·135	14·025	13·933	14·033	13·983	13·200
			100·664			100·436	99·082

* Si = 28·4, O = 16.

The joint weight of sesquioxys in the green was 25·68 and 24·89; that of their separate determinations 24·32, the latter confirming the former, after exclusion of silica. These analyses show that the red and reddish-green are identical, but that they differ from the green. Since there is one per cent more of oxyd

¹ Chem. News, vol. vi, p. 32.

of chrome, and one and a third per cent less of protoxyd of iron in the red than in the green, the first question as to the cause of the difference of color is unanswered by analysis. It is possibly due to molecular arrangement.

The following formulæ exhibit the number of each class of ingredients, the sesquioxys of chrome, iron, and aluminum being represented by Al_4O_3 and the protoxyds of magnesium, calcium, iron, and nickel, by Mg_2O , because aluminum and magnesium constitute by far the larger proportion of the bases.

Without attempting at present to reconcile these numbers to any theory of the silicates, it will prove interesting to discuss the reliable results of analysis attained by different chemists, with different specimens of this and other minerals referable to the chlorite group. In order to show their mutual relations more clearly, I subjoin a table of their atomic composition, reducing them all to the proportions arising from two atoms of alumina.

Proportion of atoms in chloritic minerals.

	SiO_2	Al_4O_3	Mg_2O	H_2O	Analyst.
1. Kämmererite, crystallized,	5	2	8	8	Hermann.
2. My green, "	5	2	9	8	Pearse.
3. Chlorite (average analysis)	6	2	10	8	Rammelsberg.
4. Kämmererite, fibrous,	6	2	10	8	Hermann.
5. Chonikrite, massive,	7	2	10	6	von Kobell.
6. Rhodophyllite, crystallized,	7	2	12	10	Genth.
7. My red, "	7	2	13	10	Pearse.
8. Kämmererite, "	8	2	14	10	Smith & Brush.
9. Pyrosclerite,	8	2	12	10	von Kobell.
10. Tabergite,	9	2	14	10	Svanberg.
11. Kämmererite, crystalline,	9	2	11	10	Hartwall, Garrett.
12. Pyrosclerite, impure,	9	2	14	6	Lychnell.

A study of the above series of minerals by formulæ, and by their general agreement in external characters, establishes their relations and connection. I might have extended the list to embrace epichlorite, metachlorite, ripidolite, delessite, etc., but the above are sufficient for the discussion.

Genth's analysis of rhodophyllite (6) gives nine or ten atoms of water, and twelve atoms of magnesia; my red, and reddish-green (7) give ten atoms of water and rather less than thirteen atoms magnesia. I therefore prefer the formula I have given for Genth's rhodophyllite, with which my red is identical. Smith & Brush's kämmererite differs from rhodophyllite by an atom of olivine. These two formulæ may be regarded as reliable, being derived from well executed analyses of crystallized specimens.

We may reject at once from the above list chonikrite (5), and pyrosclerite (12) as impure. The kämmererite of Hartwall and Garrett (11) not being quite pure, and differing but slightly from von Kobell's pyrosclerite (9) might be referred to the latter, as Dana has done. But as pyrosclerite (9) differs by only one atom of silica from rhodophyllite, the latter in crystals, and the former of doubtful purity, pyrosclerite may be regarded as a less pure rhodophyllite. Svanberg's tabergite differs from Smith and Brush's kämmererite by only an atom of silica, and because the latter was in crystals, it is the true mineral, and the former an impure exhibition of it. I therefore refer the formulæ of 9, 10, and 11, to 6, 7 and 8, or 6 and 8.

It is noticeable that Hermann's kämmererite (4) is identical with chlorite, as determined by Rammelsberg's discussion of the latter's composition, but the former being fibrous, its purity may be doubted, and its formula set aside. The formula of chlorite is accepted as correct.

Comparing my green crystals (2) with Hermann's kämmererite (1) it is seen that they are manifestly identical; but as mine were carefully selected, perfect, transparent crystals, I give the preference to my own formula. Comparing my green with chlorite, it is clearly distinct; and I have therefore named it *Grastite*, (Greek *γρᾱστις*, *grass*), from its green color.²

Our critical examination of the above series of minerals limits their number to four, viz. Nos. 2, 3, 6, (7) and 8, which are here presented as distinct varieties, together with the formulæ of olivine, augite, and serpentine, for the sake of further discussion.

Nos.	SiO ₂	Al ₂ O ₃	Mg ₂ O	H ₂ O	
2. Grastite,	5	2	9	8	Pearse and Hermann.
3. Chlorite,	6	2	10	8	Many analysts.
6. Rhodophyllite,	7	2	12	10	Genth and Pearse.
8. Kämmererite,	8	2	14	10	Smith & Brush.
Augite,	1		1		
Olivine,	1		2		
Serpentine,	2		3	2	

A comparative study of the above shows the following remarkable differences between these varieties of the chlorite group:

Grastite + augite = chlorite.

Grastite + serpentine = rhodophyllite.

Grastite + olivine + serpentine = kämmererite.

In other words, the differences of composition between members of the chlorite group are the simpler minerals associated with them in locality, or from which they have been heretofore assumed to be derived.

² My apology for a new name is that not one of those heretofore proposed for any member of this group is applicable.

If I may be allowed to hazard a conjecture as to the introduction of alumina to those simple minerals to build up the chlorite group, I suggest that it is due to the conjoined influence of adjacent decomposed feldspar, and a solution of magnesia. For decomposed feldspar, I take the most general composition of kaolin, and for solution of magnesia, brucite. Grastite and kämmererite may be supposed to be formed thus:

Grastite :	SiO ₂	Al ₂ O ₃	Mg ₂ O	H ₂ O
1 atom of kaolin,	3	2		3
2 " " olivine,	2		4	
5 " " brucite,			5	5
1 " " grastite,	5	2	9	8
Kämmererite :				
1 atom of kaolin,	3	2		3
3 " " olivine,	3		6	
1 " " serpentine,	2		4	2
5 " " brucite,			5	5
1 " " kämmererite,	8	2	14	10

A moment's consideration will show that these conjectures are not unfounded. Chlorite is found where talcose matter and feldspar are associated or near together, and is supposed to arise from augite. The others are found in or near serpentine with adjacent feldspar, and serpentine has been supposed to be derived from olivine. The locality in which grastite, rhodophyllite, and kämmererite are remarkably developed, viz. Lancaster county, Penn., abounds in brucite. In fact brucite either as such or altered into serpentine, is a common constituent of serpentine rock. Thus the marmolite of Hoboken, and of other localities, a pure serpentine, exhibits all the crystalline peculiarities of brucite. A similarly altered brucite from Siberia, in the collection of J. A. Clay, Esq., of Philadelphia, has the precise hexagonal forms of the fine crystals of brucite from Lancaster Co., Penn. We have therefore only hazarded a natural conclusion, that chloritic minerals are formed from their simpler mineral associates.

Philadelphia, Oct. 26th, 1863.