ART. XXXV.—*On Pseudomorphs of Garnet from Lake Superior and Salida, Colorado;* by S. L. PENFIELD and F. L. SPERRY.

1. *Garnets from Lake Superior.*

THE decomposed garnets from the Lake Superior region form quite common specimens in the mineralogical collections of this country. A description and microscopical examination of these garnet crystals have been made by Mr. Raphael Pumpelly.* According to Mr. Pumpelly, "these pseudomorphs of garnets occur in abundance in a bed of chloritic schist just overlying the great magnetite bed of the Spurr-Michigamme iron range." He calls the decomposition product, and also the material in which the crystals are imbedded, chlorite. But he gives no analyses to indicate its relations to the garnet.

Our examination of these pseudomorph garnets was made on crystals from a suite in the mineralogical collection of Professor Geo. J. Brush, to whom we take great pleasure in expressing our thanks for the material kindly placed at our disposal. The crystals are invariably dodecahedral. Many of them show interesting distorted forms. We first took the specific gravity of twenty of the best crystals, which were found to vary between 4·11 and 3·22. As would be expected, a close examination proved the heaviest crystals to be nearly pure garnet, while the lightest ones were almost wholly the decomposition product. This wide variation in specific gravity not only indicates the unequal extent to which the decomposition has gone on, but also guided us in selecting material for analysis.

In order to study the decomposition of the garnet, an analysis of the pure garnet was made. The material was taken from partially decomposed imbedded crystals. The heavier garnet was obtained, nearly pure, by means of the cadmium-borotungstate solution. An examination with the microscope revealed some of the green decomposition-product still adhering to and penetrating the garnet. The heavy powder, thus separated, was boiled with sulphuric and hydrochloric acids to decompose the chlorite and then with caustic potash to dissolve any separated silica. The garnet obtained had a light pink color and appeared to be very pure on examination with the microscope. The analysis is given below under I. It will be seen that it is essentially an iron alumina garnet, having this formula—$Fe_3Al_2Si_3O_{12}$, part of the iron being replaced by Ca, Mg and Mn. The ratio of $SiO_2 : Al_2O_3 : RO$ is 3 : ·96 : 2·87; required, 3 : 1 : 3.

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* This Journal, III, x, 17.

The analysis of the decomposition product was made from a selected fragmentary crystal having a specific gravity of 3·281. It was part of a large dodecahedron. Along the fracture it showed numerous little octahedrons of magnetite and a foliated structure of the chloritic material. A microscopical examination revealed the presence of a very little unaltered garnet. A mechanical analysis showed that there were 3·23 per cent of unaltered garnet and 3·28 per cent of magnetite in this decomposed product. The magnetite was carefully extracted with a strong magnet, and the garnet was obtained by a process similar to that mentioned above in the preparation of the pure garnet. The analysis is given below under II after deducting 3·23 per cent of garnet. A second decomposed crystal having a specific gravity of 3·22 was also analyzed. The material was obtained by powdering the crystal and sifting through a sixty-mesh sieve. The material was then suspended in water. The garnet was allowed to settle out and the light chlorite scales decanted off and collected in a platinum dish. The material was obtained in a nearly pure state. The analysis is given under III after deducting ·46 per cent of garnet.

Analyses of garnet and decomposition product from Lake Superior.

	I.	II.	III.
	Garnet.	Decomposition products.	
SiO_2 =	38·03 per cent.	27·45 per cent.	29·08 per cent.
Al_2O_3 =	20·83	19·53	19·94
Fe_2O_3 =	----	6·26	3·91
FeO =	36·15	29·42	30·48
MnO =	2·14	----	·20
MgO =	·97	6·04	5·56
CaO =	2·73	----	·25
Na_2O =	----	·42	·29
K_2O =	----	2·64	3·66
H_2O =	----	7·50	6·53
	100·85	99·26	99·90

No. II had specific gravity of 3·21, calculating it free from garnet and magnetite.

On comparing the above analyses, it will be seen that the following changes have taken place in the garnet: a slight oxidation of the iron, a decrease of nearly 10 per cent in silica, an almost total disappearance of manganese and calcium, and an increase in magnesium, alkalies and water. With the exception of the silica and water the change has not been very great. As regards the nature of the decomposition product, it is not an ordinary magnesium chlorite, such as ripidolite or penninite, but is essentially a ferrous chlorite, closely related to prochlorite, or more nearly to Sandberger's aphrosiderite. We find by calculating the ratios of analyses II and III that the elements are united in the following proportions:

	SiO_2	: R_2O_3	: RO	: H_2O
II =	4	: 1·97	: 5·11	: 3·49
III =	4	: 1·80	: 5·06	: 3·00 or nearly
	4	: 2·	: 5·	: 3·

Groth* gives the ratio of aphrosiderite as

SiO_2	: R_2O_3	: Ro	: H_2O
4	: 2	: 6	: 5

But analyses from different localities vary to quite a large extent, and Sandberger's analysis shows less water than is required by Groth's formula. A little admixture of ripidolite having a ratio of 4 : 2 :: 6·66 : 6† would materially alter the proportion of RO : H_2O in aphrosiderite, and a little admixture of free silica would account for the excess of SiO_2. It is not probable that the potash belongs to muscovite, which is mechanically mixed with the aphrosiderite. In the first place, a microscopical examination reveals no muscovite, and secondly, by calculating out 22 per cent of muscovite, the amount required by the potash in analysis II and 31 per cent in analysis III, the elements left would be too low in sesquioxides and very much too high in protoxides to be referred to any known species of chlorite.

The matrix.—The material in which the garnets are imbedded appears to be very homogeneous, when examined in thin sections under the microscope, appearing as a mass of minute, pleochroic green scales in which an occasional grain of magnetite is imbedded. An analysis shows that it is also a ferrous chlorite differing from the alteration product of the garnet and agreeing closely with thuringite. The analysis gave:

	I.	II.	Mean.	Mol. ratio.		
SiO_2	= 22·45 per cent.	22·26 per cent.	22·35 per cent.	= ·3725	= 3·	3
Al_2O_3	= 25·23	25·05	25·14	= ·244	= 1·98	2
FeO	= 34·34	34·43	34 39	= ·447		
MnO	= trace	----	----		= 5·15	5
MgO	= 6·31	6·51	6·41	= ·161		
H_2O	= 11·25	11·25	11·25	= ·625	= 5·04	5
	99·58	99·50	99·54			

The ratio SiO_2 : Al_2O_8 : RO : H_2O = 3 : 2 : 5 : 5 does not quite agree with Rammelsberg's ratio for thuringite, 3 : 2 : 4 : 4, but

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* Tabellarische Uebersicht der Mineralien. Zweite Auflage. 1882.

† Taken in this form for easier comparison.

the ratios are sufficiently close to justify us in referring the material to that species.

It should be stated that all these analyses were made in duplicate from carefully selected air-dried material, none of which lost more than 0·10 per cent at 100° C. Fe_2O_3 was determined in every case when present. Although these analyses do not indicate well-defined species, they show clearly what changes the garnet has undergone. The microscopical examination did not reveal anything not noticed by Mr. Pumpelly in his article already referred to.

2. *Decomposed garnets from Colorado.*

We have also examined the pseudomorph garnets from Salida, Chaffee Co., Colorado. The garnets were large dodecahedrons coated with chlorite. They differ from the Lake Superior garnets in that the decomposition forms only a coating, while the interior of the garnet crystal is quite homogeneous. One large crystal, 7^{cm} in diameter, is in the collection of Professor Geo. J. Brush. We are indebted to Mr. Whitman Cross of the U. S. Geological Survey for information concerning the correct locality in which these specimens occur, and to Mr. L. G. Eakins for the material which he kindly procured for us from a mineral dealer in Colorado. The material was obtained by scraping off the thin coating of chlorite, which was readily removed from the hard garnet. The analyses of this material are given below.

		Garnet. Specific gravity 4·163.	Decomposition product after deducting 1·04 per cent of garnet.
SiO_2	=	37·61 per cent.	28·20 per cent.
Al_2O_3	=	22·70	22·31
Fe_2O_3		----	----
FeO	=	33·83	19·11
MnO	=	1·12	----
MgO	=	3·61	17·68
CaO	=	1·44	·48
Na_2O		----	·72
K_2O		----	1·03
H_2O		----	10·90
		100·31	100·43

From the above analyses, it will be seen what changes have taken place here. It is essentially the same change that the Lake Superior garnet has undergone, with the exception that a greater quantity of magnesium has replaced the protoxide of iron. The ratios of the above analyses are:

	SiO_2 :	Al_2O_3 : :	RO :	H_2O
Garnet .... =	3 :	1·05 : :	2·88	
Decomp. product =	4 :	1·84 : :	6·25 :	5·08

The garnet ratios agree closely with the theoretical. The ratios of the alteration product agree closely with Groth's formula for aphrosiderite. It is higher in protoxides and water than the Lake Superior specimens, but it may be the same compound mixed with ripidolite, which would account for this increase. No microscopic section of this decomposed product was made. Some of the larger scales showed, in convergent light, the dark cross and interference figure of a uniaxial crystal. The color of the aphrosiderite is light green, much lighter than that from the Lake Superior locality.

The changes which have previously been noted in garnet differ from ours, in that they have been the alteration of pyrope (magnesia garnet) into ripidolite or serpentine-like magnesia silicates.

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