ART. XXIII.—*Contributions from the Sheffield Laboratory of Yale College.* No. XXVII.—*On the Minerals found at the Tilly Foster Iron Mines, N. Y.;* by E. S. BREIDENBAUGH, M.A.

THE Tilly Foster mines in Putnam Co., N. Y., near Brewster's station, on the Harlem R. R., have for a number of years been furnishing a considerable quantity of magnetic iron ore. In the spring of 1872, Prof. O. D. Allen, of the Sheffield Scientific School, in examining some of this ore at the steel works in Bridgeport, Conn., found traces which indicated that at the mine there might occur a variety of interesting minerals. On subsequently visiting the locality, Prof. Allen found specimens of a number of mineral species; and of the most interesting of these, during the past winter I have made analyses.

During the fall I paid a brief visit to the locality, finding, in the main, specimens of the same species as those found by Prof. Allen.

Formerly the mines had been worked by means of shafts, but for the past year ore has been taken principally from near the surface, and it is far less rich in minerals than that previously mined. Nearly all the specimens procured were found in a large pile of rubbish, which has been accumulating since the opening of the mine.

Except where the contrary is stated, the ordinary methods of analysis have been employed. The silica was always re-fused with carbonate of soda to ensure purity. Special care was taken to effect a complete separation of lime and magnesia from iron and alumina.

Mica.—The variety of mica most common at this locality is of a dull pearly lustre, and of a dark brownish-gray color by reflected light, but gray with a honey-yellow tinge by transmitted light. It is in thin folia, transparent and quite tough, with slight elasticity; H. = 3. The plates are compact, irregular, and show a somewhat wavy structure. It occurs lining the wall rocks. Small particles of magnetite and pyrite distributed through the plates render it quite impure. Mr. C. S. Hastings, of this School, examined this mineral for the determination of the optical characters. But on account of the wavy character of the best specimens he could only approximate to the axial divergence, finding it to be from 4°–8°. Analyses gave the following results:

	I.	II.	III.	IV.	Mean.	Oxygen.
SiO_2	40·10	40·06	----	---	40·08	21.70
Al_2O_3	14·21	14·21	----	----	14·21	7·04
Fe_2O_3	11·51	11·51	----	----	11·51	3·35
MgO	21·86	22·19	----	----	22·03	8·47
Na_2O	----	----	·39	·05	·22	
K_2O	----	----	9·73	9·74	9·73	1·63
H_2O	----	----	1·69	1·69	1·69	1·39
Fl	----	----	----	----	*tr.*	
					99·47	

Giving as the oxygen ratio for Ṙ, R̶, S̈i, 1·11 : 1 : 2·1; which is approximately that of biotite, 1 : 1 : 2.

Chlorite.—A chloritic mineral is found very abundantly, usually in the fissures and cavities of the rock; it is of a bright grass-green to pea-green color by reflected light; by transmitted light, lighter green; and in thin plates almost colorless. It has a pearly luster and is quite transparent. Thin plates are flexible, but not elastic. H. = 2·5. Crystals are often quite perfect, being frequently grouped in rosettes and accompanied by crystals of chondrodite. Some of the specimens show a slight opalescence. Between the plates are found small particles of magnetite. The surface plates and edges generally show evidences of decomposition, which fact will be referred to under the white serpentine.

Mr. Hastings found the axial divergence to be 12°–14°.

Analyses gave the following results:

	I.	II.	III.	Mean.	Oxygen.
SiO_2	32·30	32·36	----	32·33	17·22
Al_2O_3	14·57	14·55	----	14·56	6·78
FeO	5·29	5·29	----	5·29	1·17
MgO	33·70	33·78	----	33·74	13·5
CaO	1·04	1·04	----	1·04	·29
K_2O	----	----	·87	·87	·14
Na_2O	----	----	·54	·54	·13
H_2O	12·01	12·04	----	12·02	10·68
				100·39	

Making for the oxygen ratio of

$\dot{R}$, $\bar{\bar{R}}$, $\ddot{Si}$, $\dot{H}$, 5·00 : 2·85 : 6·07 : 3·92, or for $\dot{R}\bar{\bar{R}}$, $\ddot{Si}$, $\dot{H}$, 4 : 3·09 : 2.

The corresponding ratios of ripidolite are 5 : 3 : 6 : 4 and 4 : 3 : 2 ; and hence the mineral is that species.

Associated with the above, in several specimens from this locality, is a hydrous mineral, composed of quite small foliated scales very compactly united; by reflected light it is of a dark bright green color, in the mass almost black; but by transmitted light, light pea-green. In thin plates it is translucent. The luster is pearly to resinous, and it is greasy to the feel. H.=1·5 to 2. Before the blowpipe it exfoliates, and at 4½ to 5 fuses to a grayish glass. On ignition it assumes a dirt-brown color. It is partially decomposed by hydrochloric acid. The mineral is easily crumbled into small fragments, but further reduction to a powder is accomplished with difficulty in an agate mortar. The result of an analysis was

		Oxygen.
SiO_2	37·33	21·00
Al_2O_3	7·58	3·53
FeO	9·62	2·13
MnO	*tr.*	
MgO	33·56	13·4
H_2O	11·63	9·91
	99·72	

The oxygen ratio for

$\dot{R}$, $\bar{\bar{R}}$, $\ddot{Si}$, $\dot{H}$, is 15 : 3 : 21 : 9, or for $\dot{R}$, $\bar{\bar{R}}$, $\ddot{Si}$, $\dot{H}$, 6 : 6·6 : 3.

It approaches the ratio of pyrosclerite, in which this ratio is 4 : 2 : 6 : 3 or 6 : 6 : 3. It seems to be perfectly homogeneous, and not the result of decomposition.

Serpentine.—Several varieties of serpentine are found at this locality differing much in color and structure; they usually occur in the fissures of the ore bed, either alone filling up the fissures, or in connection with chondrodite or chlorite.

In color the varieties vary from dark green to pure white. Variations in structure will be described in speaking of the several varieties. They all present a smooth, polished surface, and are generally greasy to the feel. Hardness varies from 2 to 4.

White Serpentine.—This variety is opaque white, soft (H.=2), possesses a dull pearly luster, and has a fibrous to columnar structure. Small grains are found disseminated through the ore, but it usually appears in the fissures, when it forms the matrix for rounded crystals of chondrodite and magnetite and crystals of chlorite. The chlorite and serpentine occur in all proportions not only united by contact, but in intimate admixture; and in the latter case, there is a gradual shading of color from bright green to pure white, and in texture from the foliation and transparency of the chlorite to the compactness and opacity of the serpentine. Results of analyses are—

	I.	II.	III.	Mean.	Oxygen.
SiO_2	42·27	42·30	- - - -	42·28	22·53
Al_2O_3	·85	·87	- - - -	·86	·40
FeO	2·58	2·56	- - - -	2·57	·69
MgO	40·29	40·30	- - - -	40·29	16·11
CaO	1·41	1·29	- - - -	1·35	·36
K_2O	- - - -	- - - -	*tr.*	*tr.*	- - - -
Na_2O	- - - -	- - - -	·48	·48	- - - -
H_2O	12·58	12·47	- - - -	12·52	11·13
				100·35	

The oxygen ratio for $\dot{R}$, $\ddot{S}i$, $\dot{H}$ is 17·26 : 22·53 : 11·13, or 3·1 : 4·03 : 2 ; that of serpentine being 3 : 4 : 2.

Green Serpentine.—This variety sometimes presents a quite peculiar appearance; light green and greenish white alternate in thin layers parallel to the walls of the fissure. Across the layers at a considerable inclination to them run traces of a fibrous structure; neither the layers nor fibers are separable. The layers assume a wavy appearance, depending probably on the character of the fissure. On thin edges this variety is translucent. Sometimes the color is quite dark green—again very light—with more or less distinct structure such as is described above. Analyses of this variety were made in this laboratory, by Mr. C. A. Burt, with the following results:

	I.	II.	Mean.	Oxygen.
SiO_2	41·29	41·57	41 43	22·08
FeO	2·13	2·07	2·10	·46
MgO	40·56	39·79	40·18	16·07
CaO	1·08	·82	·95	·27
H_2O	13·61	14·00	13·81	12·28
			98·47	

This likewise gives the ratio of serpentine.

A third variety was analyzed, of which only a few specimens were found. It occurs as a group of nodules, formed of radiated fibers, and is of a light grayish color with a greenish tinge and a pearly luster. Fuses at 5. H.=3. Sp. gr.=2·4. Analysis gave—

		Oxygen.
SiO_2	39·38	21·00
Al_2O_3	1·56	·73
FeO	13·87	3·08
MnO	*tr.*	- - - -
MgO	32·25	12·9
K_2O }	·17	- - - -
Na_2O }	- - - -	- - - -
H_2O	11·90	10·59
	99·13	

Oxygen ratio for $\dot{R}$, $\ddot{S}i$, $\dot{H}$ is hence 3 : 3·9 : 2.

One other variety of this species deserves a passing mention; it is massive, of an olive-green color, with a porcelain-like luster on the smooth fractured surface. No analysis was made.

Amphiboles.—Several varieties of the amphibole group of bisilicates appear at this locality, and are quite abundant, occuring usually along the walls of the ore bed. Of two varieties I have made analyses.

Enstatite.—This occurs massive, having a slight fibrous appearance with a pearly to vitreous luster on a broken surface, and is of a light grayish-brown color, with a yellow tinge by transmitted light. In thin pieces it is translucent. It is quite free from impurities. There is no distinct cleavage. H.=5·5. Infusible. Sp. gr. 3·29. The results given by analyses are—

	I.	II.	III.	Mean.	Oxygen.
SiO_2	54·16	54·19	----	54·17	28·87
Al_2O_3	3·35	3·25	----	3·30	1·40
FeO	9·90	9·98	----	9·94	2·19
MnO	·24	·24	----	·24	----
MgO	32·22	31·77	----	31·99	12·5
CaO	1·01	·98	----	·99	·28
K_2O	----	----	·16	·16	----
Na_2O	----	----	·32	·32	----
Ignition	---------	----	·13	·13	----
				101·24	

Oxygen ratio for $\dot{R}$, $\ddot{Si}$, 16 : 29, approximately the $\dot{Mg}\,\ddot{Si}$ of enstatite; the composition shows it to be this mineral. If the Al_2O_3 be considered as replacing SiO_2, we have a ratio of 15 : 30·9.

Actinolite.—This variety of hornblende occurs in considerable abundance, and is generally crystalline, often only obscurely so. A few fine crystals were found. The crystallized specimens have commonly a bladed structure, H.=5·5. The color is dark green, the luster vitreous; and when free from impurities, the specimens are quite translucent—almost transparent. Small particles of magnetite and pyrrhotite are so widely disseminated through the specimens examined, even in fine crystals, that it was with great difficulty enough was obtained to make an analysis. The results obtained are—

	I.	II.	III.	Mean.	Oxygen.
SiO_2	57·39	57·50	----	57·44	29·61
Al_2O_3	1·13	1·14	----	1·13	·52
FeO	4·36	4·30	----	4·33	·85
MnO	·15	·16	----	·15	----
CaO	13·22	13·36	----	13·29	3·83
MgO	22·56	22·63	---	22·59	8·92
K_2O	----	----	*tr.*	----	----
Na_2O	----	----	*tr.*	----	----
H_2O	----	----	1·52	1·52	1·34
				100·45	

Al_2O_3 being considered as replacing SiO_2, the oxygen ratio for $\dot{R}$, $\ddot{S}i$ is 14·8 : 30·1.

Chondrodite.—Of the mineral species found at this locality by far the most interesting, with respect to both occurrence and chemical constitution, is the chondrodite, which occurs in very great abundance, small grains being widely and generally disseminated through the ore, forming what the miners term "the sand." But, approaching seams in the ore bed, the proportion of chondrodite increases, until, in the seams, fissures or cavities, chondrodite occurs crystalline with rounded crystals of magnetite and crystals of chlorite, imbedded in the white serpentine described above.

When undecomposed the chondrodite is clear, translucent, in very thin edges transparent, and possesses a vitreous luster, particularly on fractured surfaces, which are always irregular. When decomposed, as is frequently the case, it becomes opaque, grayish white, loses its vitreous luster and is easily broken, passing even into a crumbling condition.

In color, it varies from dark-brown and cinnamon-red to a light grayish-brown or yellow. Although the intermediate shades of color are found, still several varieties are so easily distinguished by color that three may be noticed. H.=5·5–6·5.

Brown Chondrodite.—This is of an amber-brown color, having by transmitted light a red tinge; the powder is light gray, and it seldom shows marks of decomposition. Disseminated through the piece which was analyzed were some small but very perfect crystals of actinolite, showing under the microscope sharply defined angles. Sp. gr. 3·2.

Red Chondrodite.—The second variety is cinnamon-red by reflected light; transmitted light gives it a yellow tinge. The powder is reddish-gray. This is the prevailing color of the crystals and crystalline specimens which were examined.

Grayish-brown Chondrodite.—The third variety has a grayish-brown color, shading into a honey-yellow, which is the prevailing color of the grains disseminated through the ore. It was found impossible to separate from the magnetite enough for an analysis, but it was proved to be chondrodite by its pyrognostic characters. This variety may be merely an altered form of the red variety. Analysis of the brown variety gave—

	I.	II.	Mean.	Oxygen.
SiO_2	35·21	35·64	35·42	18·86
FeO	5·73	5·71	5·72	1·17
MgO	54·23	54·21	54·22	21·49
Fl	----	----	9·00	----
			104·36	
Equivalent of oxygen replaced by fluorine,			3·79	
			100·57	

Analysis of red variety gives—

	I.	II.	Mean.	Oxygen.
SiO_2	----	----	35·42	18·86
FeO	9·77	9·70	9·73	2·14
MgO	51·70	52·07	51·88	20·75
Fl	5·33	5·42	5·38	----
			102·41	
Oxygen replaced by fluorine,			2·26	
			100·15	

The brown variety gives 7·3 $\dot{M}g$ and $3\ddot{S}i$, in which part of the oxygen of magnesia is replaced by fluorine, or $MgFl_2 + 3\dot{M}g^2\ddot{S}i$.

The red variety gives 7·5 $\dot{M}g$ and $3\ddot{S}i$.

The fluorine on the above analyses was determined by the method of Wöhler, modified by Fresenius.* The silica and bases were determined according to the method given by Rammelsberg. A large number of experiments made on these methods confirmed their superiority to others suggested during the progress of this investigation.

Mr. C. A. Burt made an analysis of a dolomite found at this locality, obtaining—

	I.	II.	Mean.	Oxygen.
FeO	·91	·49	·70	·15
MnO	·13	·64	·39	·07
CaO	30·30	29·98	30·14	8·61
MgO	20·78	20·80	20·79	8·31
CO_2	46·97	47·05	47·01	10·02
	99·09	98·96	99·03	

This corresponds to $FeCo_3$ 1·13, $MnCo_3$ 0·63, $CaCo_3$ 53·82, $MgCo_3$ 43·66=99·24.

The ratio of $CaCo_3$ and $MgCo_3$ is 1 : 1 nearly.

Besides the minerals mentioned above, there occur at this locality *pyrite*, chalcopyrite, *pyrrhotite*, calcite, quartz (small crystals), a few specimens of fluorite and apatite. I found also two specimens of molybdenite.

I gladly take this opportunity of expressing the obligation which I am under to Prof. Allen for his kindness in furnishing me with material for my work and advice during the progress of it.

Sheffield Laboratory, New Haven, Ct., May, 1873.

* Fresenius's Quantitative Analysis, American edition, p. 404; Zeitschr. Analyt. Chem., v, 190. Pogg. Ann., liii (1841), pp. 130–9.