Some data on the iron-rich hypersthenes.

By N. F. M. Henry, M.A., B.Sc.
Department of Mineralogy and Petrology, Cambridge.

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THE first iron-rich hypersthene reported was from Vittinki in Finland and was described by M. Saxén[1] in 1925. In 1932 N. Sundius[2] showed that the so-called 'iron-anthophyllite' from Tunaberg in Sweden was really a very iron-rich hypersthene. He suggested that two other 'iron-anthophyllites' occurring similarly in the eulysites of Sweden at Bygdsiljum[3] and at Mansjö[4] might also prove to be really iron-rich hypersthenes.

Here chemical and optical data are given for the Mansjö mineral which fits well into the series and proves to be slightly richer in iron than the Tunaberg one. Data are also given for hypersthenes from Loch Duich and from Glen Buchat in Aberdeenshire, while, thanks to the kindness of Professor P. Eskola, it has been possible to obtain a sample of the Vittinki mineral and to complete the data of M. Saxén.

The analyses (table I) show the high percentages of iron in these hypersthenes, while in the Loch Duich mineral the high percentage of MnO replacing FeO is noteworthy.

The Glen Buchat mineral occurs as brown crystals up to 4 mm. long in a biotitic norite, believed to be contaminated, from the Strathdon district of Aberdeenshire. The other four minerals discussed are all from eulysite rocks at four different localities. The Vittinki mineral contains a large number of inclusions of magnetite with small amounts of the accompanying green amphibole and of

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[1] M. Saxén, Om mangan-järnmalmfyndigheten i Vittinki. Fennia, Helsingfors, 1925, vol. 45, no. 11, p. 18.

[2] N. Sundius, Über den sogenannten Eisenanthophyllit der Eulysite. Årsbok, Sveriges Geol. Undersökning, 1932, vol. 26, no. 2 [M.A. 6–118].

[3] A. Högbom, Eulysit från Västerbotten. Geol. För. Förh. Stockholm, 1924, vol. 46, p. 711.

[4] H. von Eckermann. The rocks and contact minerals of the Mansjö Mountain. Geol. För. Förh. Stockholm, 1922, vol. 44, p. 267 [M.A. 1–396].

Table 1.

	A.	B.	C.	D.	E.
SiO_2	50·06	47·40	47·68	47·46	46·36
TiO_2	0·32	0·05	0·00	0·03	0·16
Al_2O_3	1·84	1·47	0·69	0·14	0·29
Fe_2O_3	2·06	0·46	1·34	0·34	0·20
FeO	29·39	35·39	37·37	42·23	44·93
MnO	0·19	6·29	2·50	3·88	1·16
MgO	13·63	7·02	6·91	5·05	5·09
CaO	1·43	0·88	2·48	1·05	1·64
$H_2O(+110°)$ ...	0·69	0·09	0·55	0·07	0·03
$H_2O(-110°)$ ...	0·17	0·63			0·07
Total	99·78	99·68	99·52	100·25	99·93

A. Hypersthene from contaminated norite, from Craig Wood, Glen Buchat, Aberdeenshire. Analyst, N. F. M. Henry.

B. Hypersthene in a hypersthene-grunerite-garnet rock, from Druideag Lodge, Loch Duich, Ross-shire. Collected by Prof. C. E. Tilley. Analyst, N. F. M. Henry.

C. Hypersthene from eulysite, from Vittinki, Finland. See M. Saxén (loc. cit). Analyst, N. Sahlbom.

D. Hypersthene from eulysite, from Tunaberg, Sweden. See N. Sundius (loc. cit.). Analyst, R. Mauzelius.

E. Hypersthene from eulysite, from Mansjö Mountain, Sweden. Analyst, N. F. M. Henry.

Table 2.

	A. Glen Buchat.	B. Loch Duich.	C. Vittinki.	D. Tunaberg.	E. Mansjö.
2V ...	51°	68°	70°	81°	83°
α ...	1·715	1·738	1·740	1·750	1·751
β ...	1·728	1·749	1·751	1·760	1·760
γ ...	1·731	1·755	1·757	1·768	1·769
$\gamma-\beta$ ...	0·003	0·006	0·006	0·008	0·009
$\gamma-\alpha$ ...	0·016	0·017	0·017	0·018	0·018
Pleochroism in thin section	Very weak α reddish, β and γ greenish	Very weak α pinkish, β and γ greenish	None	Very weak α yellowish β greenish-yellow γ weak green	Quite marked α reddish-fawn β light fawn γ greenish-grey
Dispersion	Not noticeable	Strong $v>r$	Strong $v>r$	Very strong $v>r$	Very strong $v>r$
Sp. gr.	3·60	3·75	3·77	3·83	3·84

Each Mineral can be picked up with a weak hand magnet.

The Tunaberg data, except the dispersion, are taken from N. Sundius (loc. cit.). For the Vittinki mineral M. Saxén gives γ 1·756 (approx.) and α 1·740; his figure for the specific gravity, 'over 4', is obviously a mistake. The refractive indices were measured by the ordinary immersion method in sodium-light and are ±0·002.

quartz. The Loch Duich mineral, which is green, is accompanied by grunerite and a garnet, but it often contains small platy inclusions of ilmenite which lie on the plane (100) and are elongated along the *b*-axis. According to N. Sundius the Tunaberg mineral, which is yellowish-green, is accompanied by manganfayalite and garnet with occasional grains of grunerite and of a green hornblende,

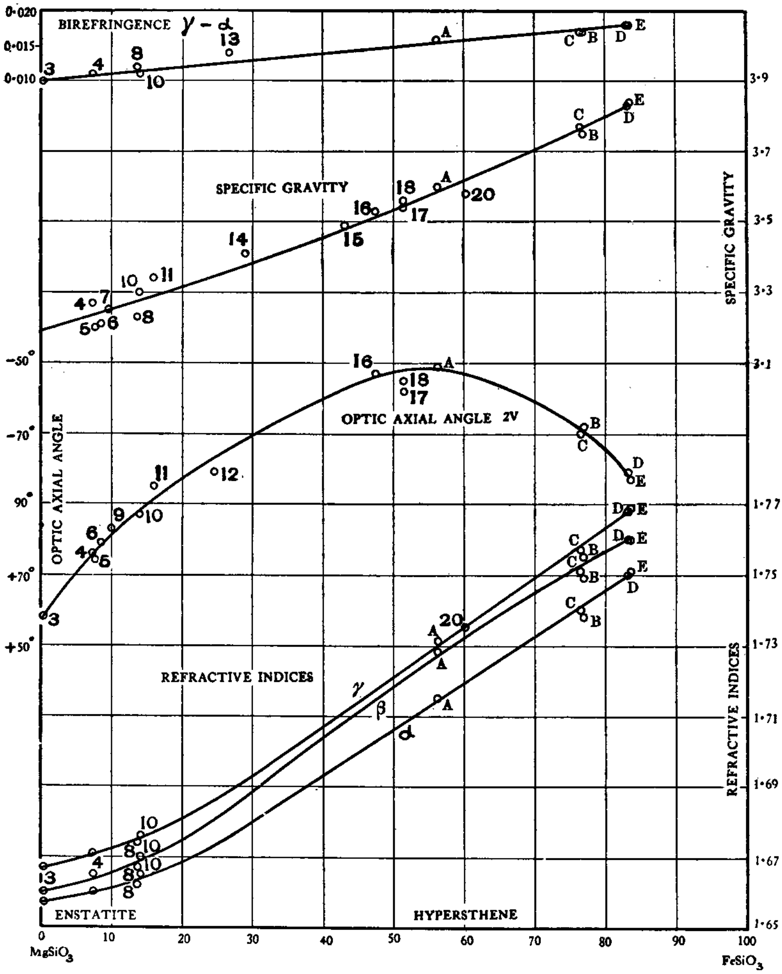

Fig. 1. Variation of optical properties and specific gravity with iron content (Fe + Mn atomic %) in the orthorhombic pyroxenes.

[Plotted points marked by letters are for data given in the present paper; those marked by numbers for data given in R. Walls's graph, this vol., p. 167.]

which occur with a little apatite as inclusions in the iron-rich hypersthene. The Mansjö mineral, which is also green, occurs as large crystals separated often by a mosaic of smaller ones. It contains numerous inclusions of quartz with occasionally a little apatite and green hornblende. In addition to the prismatic cleavage, these iron-rich hypersthenes show a good development of the vertical pinacoidal cleavages, but the (010) one is not so pronounced as the (100).

In the plotting of the results (fig. 1) all constituents are excluded except (Fe,Mn,Mg)SiO_3. The various curves were drawn for the present data in the iron half of the diagram, and for the magnesian half data were selected from the tables given by R. Walls,[1] which could be fitted on to reasonably smooth curves. The reference numbers of R. Walls have been retained, but the analyses used have been recalculated in terms of the percentage of (Fe + Mn) atoms out of the total (Fe + Mn + Mg) atoms. The addition of Ca does not improve the plotting in fig. 1 although it was added to the Mg by both R. Walls[1] and A. N. Winchell.[2] In the former case the improvement may have been due to the use of weight percentage, and in the latter case to the over-steepness of the refractive-index curves. The refractive-index lines of A. N. Winchell[2] and of N. L. Bowen and J. F. Schairer[3] are drawn straight to the values of the Bishopville meteorite, but A. N. Winchell later discarded the 2V value of this mineral in his ‘ Optical mineralogy ’. The unreliability of much of the data for enstatites makes the form of the curves at this end of the diagram very doubtful.

It can be seen, however, that the iron-rich hypersthenes fit perfectly into the series as a whole and that there is no indication of the ‘ mixture-gap ’ suggested as a possibility by N. Sundius (loc. cit.). The optic plane remains (100) throughout (taking $a > b$), but the optic axial angle passes through a minimum of approximately 51°. The form of the curves beyond the last fixed point must await the examination of more iron-rich hypersthenes, if these exist.

The text-book explanation that in the enstatite-hypersthene series the intensity of the pleochroism increases with increase in iron content obviously does not hold for the series as a whole, as some

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[1] R. Walls, A critical review of the data for a revision of the enstatite-hypersthene series. Min. Mag., 1935, vol. 24, p. 165.

[2] A. N. Winchell, Studies in the pyroxene group. Amer. Journ. Sci., 1923, ser. 5, vol. 6, p. 504 [M.A. 2–219].

[3] N. L. Bowen and J. F. Schairer, The system MgO–FeO–SiO_2. Amer. Journ. Sci., 1935, ser. 5, vol. 29, p. 189.

of these iron-rich members are very weakly pleochroic. The occurrence of very varying intensity of pleochroism in hypersthenes in close proximity to one another in the same rock-mass, which has often been noted, seems to need some explanation. But an attempt to offer such an explanation by comparing the remarks on the pleochroism with the analyses of hypersthenes has not been successful. It does not seem possible yet to ascribe strong pleochroism to high content of Fe_2O_3, MnO, or TiO_2. Perhaps more quantitative measurements of pleochroism might make some chemical explanation of its intensity possible.

In the case of the dispersion of minerals in this series considerable confusion exists. Text-books contradict one another and there is often doubt as to whether the acute or the obtuse optic axial angle is being referred to. W. Luczizky[1] gives a table showing that most of the hypersthenes examined are said to have dispersion $r > v$ (over a, the acute bisectrix), but some, chiefly in meteorites, are said to have $v > r$. Original papers on enstatites, such as H. L. Bowman[2] and K. Johansson,[3] give $v > r$ (over a, the obtuse bisectrix) for these minerals. In the case of the iron-rich hypersthenes examined here the dispersion is $v > r$ and increases with increase of iron to a very marked degree in the Mansjö and Tunaberg minerals. If the enstatites are $v < r$, the hypersthenes $r > v$, and the iron-rich hypersthenes $v > r$ (all over a), then there must be two points in the whole series, approximately at 2V 90° and 50° (negative), where there is no dispersion. In agreement with this suggestion the Glen Buchat mineral is found to have no discernible dispersion. But many of the older statements would have to be re-examined before this problem could be cleared up.

The high percentages of the $FeSiO_3$ molecule which are found in some of these hypersthenes make it desirable that this molecule should have a name. In recently describing a new natural occurrence of monoclinic $FeSiO_{34}$, Dr. N. L. Bowen[4] puts forward the name 'clinoferrosilite', adapting the name 'ferrosilite' suggested by H. S. Washington[5] for the normative molecule. It is suggested here that

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[1] W. Luczizky, Min. Petr. Mitt. (Tschermak), 1905, vol. 24, p. 140.

[2] H. L. Bowman, Min. Mag., 1900, vol. 12, p. 349.

[3] K. Johansson, Zeits. Kryst. Min., 1894, vol. 23, p. 152.

[4] N. L. Bowen, Ferrosilite as a natural mineral. Amer. Journ. Sci. (in the press).

[5] H. S. Washington, Prof. Paper U.S. Geol. Survey, 1903, no. 14. p. 90; Min. Petr. Mitt. (Tschermak), 1932, vol. 43, p. 63 [M.A. 5-222].

the name ‘orthoferrosilite‘ be used for the $FeSiO_3$ end-member of the orthorhombic pyroxene series, which would then be the enstatite-orthoferrosilite series. It is not intended that the name be used for the Tunaberg or Mansjö iron-rich hypersthenes, but that its possible use as a mineral name be left undecided until more is known about this end of the series. If the new name is adopted it would be possible to define any member of the series in terms of En_xOf_y.