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Autor(en): **Zwaan, P.C.**

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Orthopyroxenes from the Embilipitya area in Sri Lanka*

by *P. C. Zwaan*[1]

Abstract

Colourless to deep brown orthopyroxenes from Sri Lanka are described. The colourless samples have exceptionally low refractive indices of 1.650 and densities of 3.194, while their composition lies very close to the magnesium endmember of the enstatite-ferrosilite series. All examined orthopyroxenes have a narrow absorption band at 506 nm which was found to be characteristic and therefore of diagnostic value. The intensity of this band increases with the depth of the brownish colour, hence with the Fe-content.

Keywords: Orthopyroxenes, inclusions, Sri Lanka.

Introduction

From investigations in recent years it became known that the Embilipitya area of Sri Lanka is very interesting from the mineralogical point of view. The small village Embilipitya is situated about 75 km from Ratnapura ("City of Gems") in a south-eastern direction (Fig. 1). The island is almost completely underlain by Precambrian rocks, which, on the base of lithology, structure and age, can be divided into three groups, that is the Highland group, the Southwest group and the Vijayan complex. The Embilipitya area is just situated in the Highland group, which contains rocks of the metamorphic granulite facies. The orthopyroxenes to describe here, however, are found in residual deposits only, like some other minerals as cordierite, kornerupine and scheelite. This residual type of deposit is abundant in the area. As different minerals of gem quality, like almandine garnet and spinel, besides the above mentioned minerals, occur in these deposits, some mining is done by native people in a primitive way, digging in small pits with a depth of about one or two meters. At several visits to the area in the past years, the author collected a large quantity of different minerals and selected the orthopyroxenes for this special paper because his thesis was dealing with the determination of pyroxenes by X-ray powder diagrams (ZWAAN, 1955). This investigation was carried out under the supervision of Prof. Dr. E. Niggli, at the time professor of mineralogy at Leiden University, The Netherlands.

The present study was done by using 17 rough specimens and four cut stones with different colours. The physical properties were measured by gemmological methods. The specific gravities were determined using a hydrostatic balance with ethylene dibromide as an immersion liquid, the temperature of which also taken into consideration. The accuracy obtained, by working in this way, is ±0.003.

A Rayner refractometer, provided with a synthetic Yttrium Aluminium Garnet as a prism, was used for the measurement of the refractive indices. The lowest and highest values observed at a specimen, do not automatically correspond with n_x and n_z respectively, due to the orientation of the "window" of the rough samples or the table facet of the cut stones. The

* Dedicated to Professor Ernst Niggli on the occasion of his 70th birthday.

[1] National Museum of Geology and Mineralogy, 2312 HS Leiden, The Netherlands.

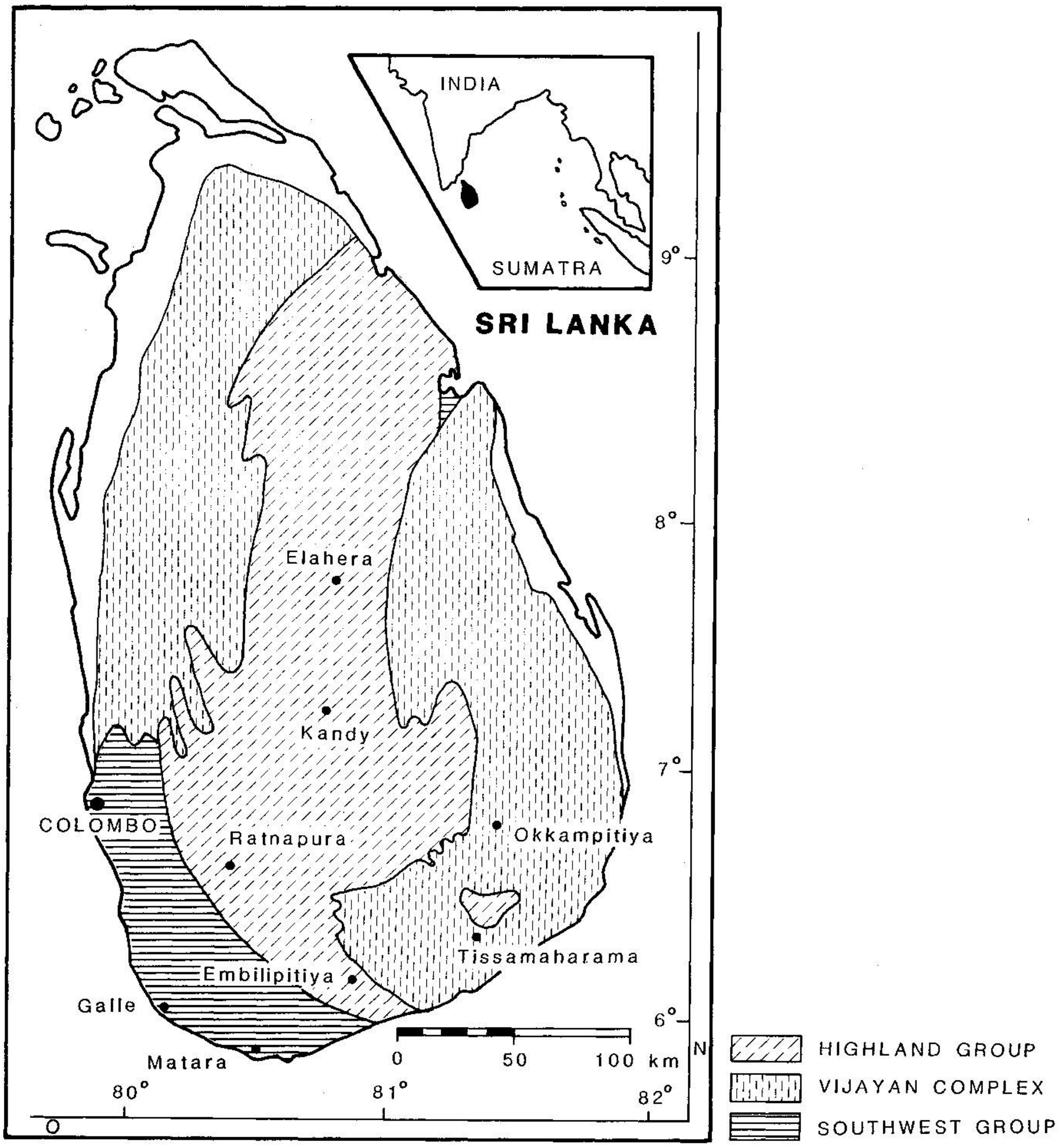

Fig. 1 Geological sketchmap of Sri Lanka.

absorption spectra were observed with a Zeiss handspectroscope provided with a built-in wavelength scale.

X-ray powder photographs were taken, using Fe-radiation and a camera with a diameter of 114.6 mm.

Electron microprobe analyses were performed at the electron microprobe laboratory of the "Instituut voor Aardwetenschappen, Vrije Universiteit, Amsterdam", with financial and personal support by Z.W.O.-W.A.C.O.M. (research group for analytical chemistry of minerals and rocks subsidized by the Netherlands Organization for the Advancement of Pure Research).

Physical properties

The specimen are crystals, or parts of crystals, with a long prismatic habit. They are corroded, due to chemical erosion, showing etch figures on crystal faces (see Fig. 2). These crystals can be rather large. In the collection of the National Museum of Geology and Mineralogy, the largest specimen is a cut colourless stone of 10.67 carats, the size of which is $20.7 \times 12.6 \times 4.1$ mm (RGM 152034)*. The colour of the crystals may vary from completely colourless through light yellowish brown to deep brown, corresponding with increasing Fe-content.

* Registration number Museum.

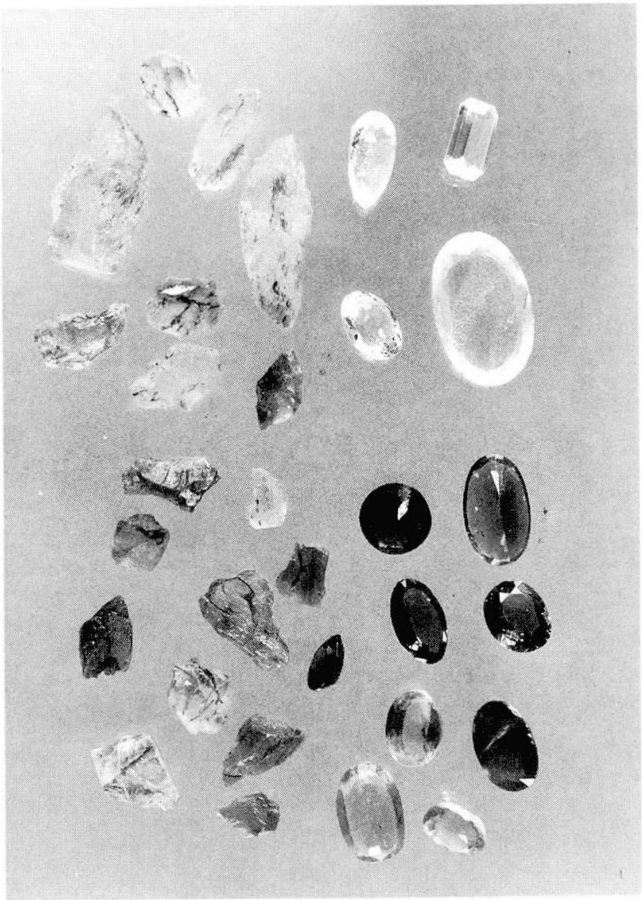

Fig. 2 Rough and cut orthopyroxenes from Embilipitya (×1.2).

Fig. 3 Quartz crystals included in colourless enstatite RGM 152003 (×30), polarized light.

The density is distinctly related to the colour of the specimens and, as could be expected, to the chemical composition. The deeper brown the specimen the higher the density. There is a linear function between the density and the chemical composition, although it cannot be derived exactly from the data in table 1. This is due to the fact that the results with small specimens are less reliable. For comparison, two extreme density values from (ZWAAN, 1986) are also given in table 1. From the density a rough idea of the Mg-content of the orthopyroxene can be derived.

The refractive indices vary in relation to the Fe-content and consequently to the colour. The lowest values were found with the most Mg-rich colourless specimens and the highest refractive indices could be measured at the deep brown stones with a relatively high Fe-content. Colourless RGM 152034 has 1.650 and 1.660 with a double refraction of 0.010, while deep brown RGM 151876 gave values of 1.674 and 1.684 respectively. All other refractive indices measured are between these data (see table 1). The tinted orthopyroxenes, in particular those with a deep brown colour, have a distinct to strong pleochroism in tones of brownish yellow and reddish brown.

The absorption spectrum is very characteristic and for that reason a valuable testing factor for these orthopyroxenes. Most of the specimens have a very strong narrow band at 506 nm, due to ferrous iron, while a distinct absorption line at 544 nm can only be seen in tinted to brown specimens with a Mg-content of less than 90%. The first mentioned 506 nm band is difficult to observe in colourless samples with more than 98,5% En (enstatite).

Inclusions

Although many specimens are relatively clean, the most typical inclusions found in others, are well-developed crystals with a rather low double refraction. Their identity was checked by X-ray powder photographs and found to be quartz (Fig. 3). The same result was

Tab. 1 Properties of various orthopyroxenes from Embilipitya, Sri Lanka.

RGM sample no.	colour	refractive indices	D	% En
152034*	colourless	1.650 - 1.660	3.194	--
202797	colourless	1.650 - 1.658	3.216	98.33
202799	colourless	1.650 - 1.658	3.222	98.64
202798	colourless	1.650 - 1.658	3.223	97.67
202803	colourless	1.650 - 1.658	3.230	99.37
202792	colourless	1.652 - 1.660	3.231	97.75
151875*	colourless	1.650 - 1.658	3.235	—
202801	colourless	1.652 - 1.660	3.236	97.56
152003*	colourless	1.650 - 1.660	3.238	—
202790	yellow brown	1.662 - 1.670	3.302	89.48
202795	yellow brown	1.661 - 1.669	3.340	90.00
202786	light brown	1.663 - 1.670	3.357	87.98
202789	deep brown	1.670 - 1.678	3.367	82.92
151876*	deep brown	1.674 - 1.684	3.390	—

* cut stone, analysis not available

reported by ZOYSA (1985). The presence of forsterite or another enstatite inclusion as suggested by HARDING et al. (1982), could not be found, but both liquid and two-phase inclusions are usually seen, in particular in the brown coloured specimens (Fig. 4).

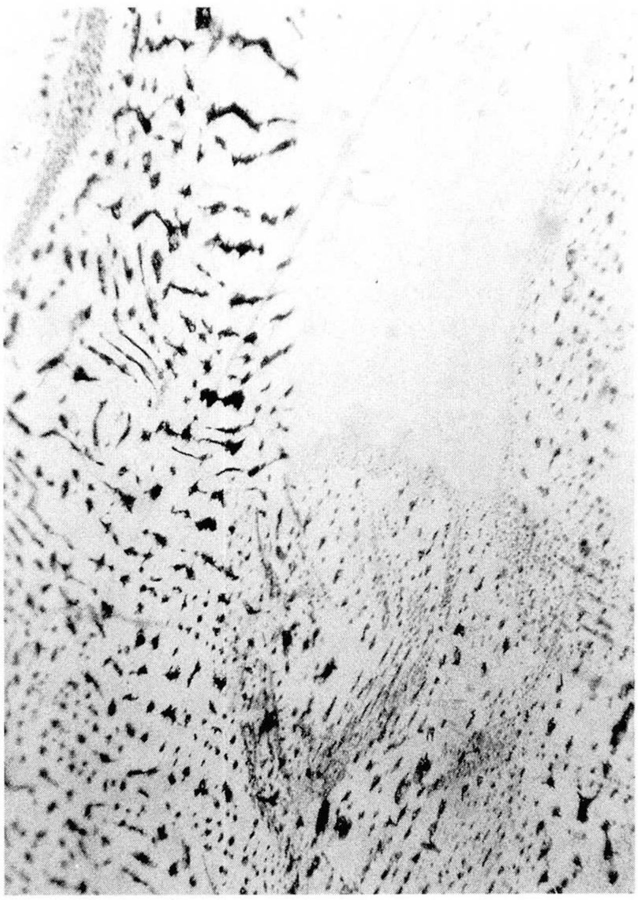

Fig. 4 Liquid feathers and two-phase inclusions in colourless enstatite RGM 152034 (×15).

Chemical composition

In order to obtain approximate data on the chemical composition of the examined specimens, use was made of a method, described by the author in his thesis (ZWAAN, 1955). This method was developed with the help of Prof. Dr. E. Niggli and is based on small differences in the X-ray powder patterns of the different orthopyroxenes. In particular it can be observed that the distance between the strong diffraction lines 1031 and 060 is decreasing with an increasing Fe-content. In Fig. 5 the relation between this distance Δ and the chemical composition is illustrated and it is also seen that all investigated orthopyroxenes have a very high Mg-content. The highest is 99.7% and the lowest 83.1% for specimens RGM 202803 and RGM 202789 respectively. All dots, except one, are situated close to the top line (Al = 0.050), which agrees with the data obtained from the chemical analyses in table 2.

RGM 202796 is near the bottom line (Al = 0.010), its Al-content is the lowest found, as can also be seen in table 2. From these figures it may be concluded that the composition lies very close to the magnesium endmember of the enstatite-ferrosilite series. In fact it is the most Mg-rich natural enstatite we ever examined. It

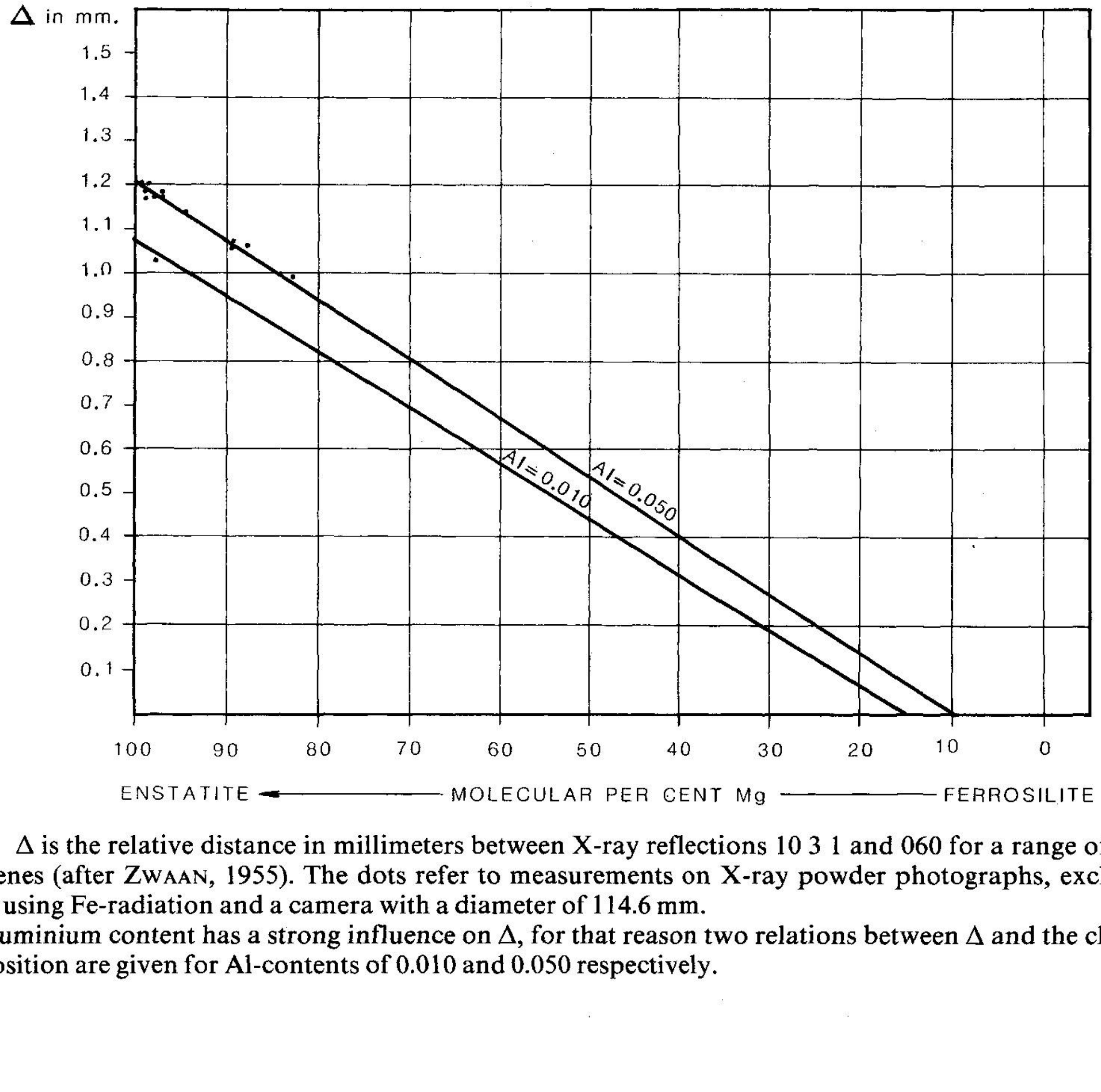

Fig. 5 Δ is the relative distance in millimeters between X-ray reflections 10 3 1 and 060 for a range of orthopyroxenes (after ZWAAN, 1955). The dots refer to measurements on X-ray powder photographs, exclusively taken, using Fe-radiation and a camera with a diameter of 114.6 mm.
The aluminium content has a strong influence on Δ, for that reason two relations between Δ and the chemical composition are given for Al-contents of 0.010 and 0.050 respectively.

is completely colourless as are all other specimens until about 90% En. The brown colour becomes deeper with increasing Fe-content.

The chemical composition of the different specimens was also calculated from electron microprobe analyses. Except for RGM 202791 and RGM 202798, average values of three analyses are given in table 2. The results are arranged in order of decreasing Mg-content.

From the data in table 2 can be seen that the elements Ti, Mn and Na are really trace elements, while Ca is playing an unimportant part, as can be seen at the percentage of Wo (wollastonite). It is remarkable that with increasing Fe-content, the Al-content is also increasing, while the Si-content is decreasing. This means that the concentration of Al is dependent on the concentration of Fe and also that Al is replacing Si in the crystal structure.

From the results in table 2 can be derived that most of the analyzed orthopyroxenes have a Mg-content above 90%. They are all colourless, while the more Fe-rich specimens are light yellowish brown to deep brown, with a maximal content of about 17% Fs (ferrosilite). These results agree very well with those obtained with the above mentioned X-ray method and indicate also the Mg-richness of these orthopyroxenes.

Concluding remarks

The orthopyroxene crystals and crystalfragments of Embilipitya have some exceptional properties, like very low refractive indices and specific gravities, mainly a complete lack of colour and a remarkable high Mg-content. In fact the purest natural enstatites, ever examined in the laboratory of the National Museum of Geology and Mineralogy in Leiden, occur in these deposits together with more Fe-

Tab. 2 Microprobe analyses of 17 orthopyroxenes from Embilipitya, Sri Lanka.

RGM:	202803	202799	202793	202785	202797	202802	202794
SiO_2	59.50	58.10	59.57	58.33	58.83	57.90	57,73
Al_2O_3	1.15	2.32	0.93	2.30	1.58	2.53	2.48
TiO_2	--	--	--	--	--	--	--
FeO	0.26	0.79	0.74	0.95	0.99	1.35	1.45
MnO	--	--	--	--	--	--	--
MgO	38.89	38.30	38.57	37.77	38.13	37.70	37.73
CaO	0.14	0.12	0.05	0.12	0.13	0.03	0.00
Na_2O	--	--	--	--	--	--	--
total	99.94	99.63	99.86	99.47	99.66	99.51	99.39
Numbers of ions on the basis of six oxygens							
Si	1.9900	1.9562	1.9767	1.9667	1.9800	1.9557	1.9536
Al	0.0457	0.0922	0.0726	0.0916	0.0627	0.1007	0.0988
Ti	--	--	--	--	--	--	--
Fe^{2+}	0.0073	0.0223	0.0277	0.0267	0.0279	0.0382	0.0411
Mn	--	--	--	--	--	--	--
Mg	1.9367	1.9227	1.8863	1.8984	1.9133	1.8985	1.9034
Ca	0.0050	0.0042	0.0019	0.0043	0.0047	0.0010	0.0000
Na	--	--	--	--	--	--	
total	3.9847	3.9976	3.9652	3.9877	3.9886	3.9941	3.9969
% En	99.37	98.64	98.47	98,39	98,33	97.98	97.89
% Fs	0.37	1.14	1.43	1.39	1.43	1.97	2.11
% Wo	0.26	0.22	0.10	0.22	0.24	0.05	0.00

RGM:	202796	202792	202798	202800	202801	202791(a)	202791(b/c)
SiO_2	59.37	58.40	58.65	58.13	58.07	58.30	57.55
Al_2O_3	0.63	2.18	2.40	2.65	2.40	2.40	2.20
TiO_2	--	--	--	--	--	--	--
FeO	1.47	1.50	1.42	1.55	1.69	1.78	4.80
MnO	--	--	--	--	--	--	--
MgO	38.43	37.57	37.60	37.37	37.47	37.20	35.10
CaO	0.06	0.04	0.14	0.05	0.04	0.06	0.10
Na_2O	--	--	--	--	--	0.03	0.04
total	99.96	99.69	100.21	99.75	99.67	99.77	99.79
Si	1.9960	1.9689	1.9667	1.9593	1.9608	1.9665	1.9679
Al	0.0251	0.0867	0.0947	0.1053	0.0954	0.0952	0.0883
Ti	--	--	--	--	--	--	--
Fe^{2+}	0.0414	0.0423	0.0399	0.0437	0.0477	0.0530	0.1374
Mn	--	--	--	--	--	--	--
Mg	1.9270	1.8885	1.8797	1.8779	1.8863	1.8706	1.7894
Ca	0.0020	0.0012	0.0050	0.0018	0.0014	0.0022	0.0037
Na	--	--	--	--	--	0.0020	0.0023
	3.9915	3.9876	3.9860	3.9880	3.9916	3.9895	3.9890
% En	97.80	97.75	97.67	97.63	97.56	97.27	92.69
% Fs	2.10	2.19	2.07	2.27	2.37	2.61	7.12
% Wo	0.10	0.06	0.26	0.09	0.07	0.12	0.19

RGM:	202795	202790	202786	202789
SiO_2	56,83	56.40	56.30	55.30
Al_2O_3	2.03	2.75	2.99	2.68
TiO_2	--	0.04	--	--
FeO	6.78	6.83	7:79	11.07
MnO	0.07	0.05	0.08	0.14
MgO	33.67	33.63	32.87	30.73
CaO	0.16	0.17	0.17	0.17
Na_2O	0.03	0.03	0.05	0.04
total	99.57	99.90	100.25	100.13
Si	1.9420	1.9469	1.9450	1.9432
Al	0.0817	0.1120	0.1214	0.1111
Ti	--	0.0010	--	--
Fe^{2+}	0.1930	0.1970	0.2250	0.3251
Mn	0.0021	0.0013	0.0023	0.0040
Mg	1.7921	1.7300	1.6928	1.6101
Ca	0.0060	0.0060	0.0062	0.0065
Na	0.0021	0.0020	0.0031	0.0025
	4.0190	3.9962	3.9958	4.0025
% En	90,00	89.48	87.98	82.92
% Fs	9.69	10.20	11.69	16.74
% Wo	0.30	0.32	0.32	0.34

rich orthopyroxenes, having light tinted to deep brown colours. All colourless specimens have a Mg-content higher than 90%, while the deep brown samples have an Fe-content of no more than 20%.

These orthopyroxenes can easily be identified by observing the absorption spectra in which a clearcut narrow band can be seen in tremendous strength at 506 nm, even in colourless specimens.

In a number of the specimens quartz crystals are included, but most common are liquid feathers and two-phase inclusions. A systematic examination of the fluid inclusions could certainly be of importance to get more information on the genesis of these orthopyroxenes.

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Mr. J. van der Linden prepared the X-ray powder photographs and provided the rough specimens with flat polished facets, for the measurement of the refractive indices.

Mr. B.F.M. Collet made the illustrations, while the photographs were taken by Mr. W.A.M. Devilé. I am grateful to all for their help.

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