MAJOR ELEMENT COMPOSITION OF CLAY MINERALS IN THE MURCHISON (C2) CARBONACEOUS CHONDRITE MATRIX

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Abstract: A large number of point analyses using EPMA made it possible to determine unique composition of clay minerals in the matrix of the Murchison (C2) carbonaceous chondrite. The matrix is composed mainly of serpentine, $3(FeO_{0.3}MgO_{0.7})\cdot 2SiO_2\cdot 2H_2O$, which is intimately associated with an abundant FeO-NiO-S phase.

1. Introduction

Little is known about elemental compositions of the individual minerals which make up the matrix of C chondrites. Such information is essential to the description of these minerals and is of value to elucidate the history of formation of meteorites in the solar nebula.

Here, the authors have used an electron probe microanalyzer (EPMA) to analyze the poorly characterized clay minerals in the matrix of the Murchison (C2) meteorite for major elements. The results are shown in this paper.

2. Experiments

The major difficulty in analyzing clay minerals in the matrix of meteorites is that they are extremely fine-grained, almost always less than 1 μm under the electron microscope, and that they are intimately associated with other minerals, such as fine-grained opaque minerals, carbonates and olivine. And there is another difficulty of obtaining the average of this extremely heterogeneous material. To avoid these problems, the following procedure was adopted.

A polished thin section of the meteorite was examined under the petrographic

microscope to select areas which were relatively free of inclusions greater than 3 μm and showed color and texture comparatively typical of the matrix. The matrix of the Murchison meteorite consists of fine-grained black clasts, up to 100 μm in diameter, in abundant interstitial light brown matrix (FUCHS *et al.*, 1973; KERRIDGE, 1976). The areas selected for analysis included both the categories.

Analysis was performed using a JXA-5A electron probe microanalyzer operated at 15 kV and 0.02 μA on ZrO_2. A 2 μm diameter beam was used to determine the abundances of 12 elements. Counts for all the elements were integrated over a 60 second time interval. After dead time correction and subtraction of background, the data were corrected for matrix effects following the procedure of BENCE and ALBEE (1968). "Water" content, which actually includes other light elements and epoxy resin in the pore space, was estimated by the method of YUSA and TSUZUKI (1976). All constituents were given as oxides, and the remainder after subtraction of the "water" content was normalized to 100%.

3. Results

Table 1 shows the mean corrected data, normalized to 100%, in terms of weight percent of oxides, and also their standard deviations and maximum and minimum values. The following conclusions were derived from a critical survey of these data.

Table 1. Microprobe analysis of the matrix of the Murchison meteorite (water free base wt% oxides)

	Average value	Standard deviation	Min. value	Max. value
SiO_2	27.30	8.26	8.24	41.96
TiO_2	0.08	0.02	0.05	0.12
Al_2O_3	3.16	0.55	1.93	4.81
Cr_2O_3	0.31	0.12	0.11	0.44
FeO	46.67	12.08	29.28	77.20
MnO	0.21	0.04	0.13	0.32
MgO	13.86	3.99	5.26	23.03
NiO	1.91	0.84	0.92	6.36
CaO	0.64	1.04	0.11	3.33
Na_2O	0.44	0.34	0.05	1.35
K_2O	0.04	0.01	0.02	0.07
SO_3	5.38	6.86	0.77	28.05

3.1. Relatively small amount of TiO_2, Cr_2O_3, MnO and K_2O are contained, and their standard deviations are small. These data show good agreement with those

of the Orgueil meteorite (KERRIDGE, 1976) and others (MCSWEEN and RICHARDSON, 1977; BUNCH *et al.*, 1979).

Large deviations were observed in Na_2O values on a point-by-point and area-by-area scale. This may be attributed to heterogeneous distribution of minerals, but a small amount of Na_2O impedes further discussion.

3.2. Interesting conclusions are derived from the relationships FeO-SiO_2, NiO-

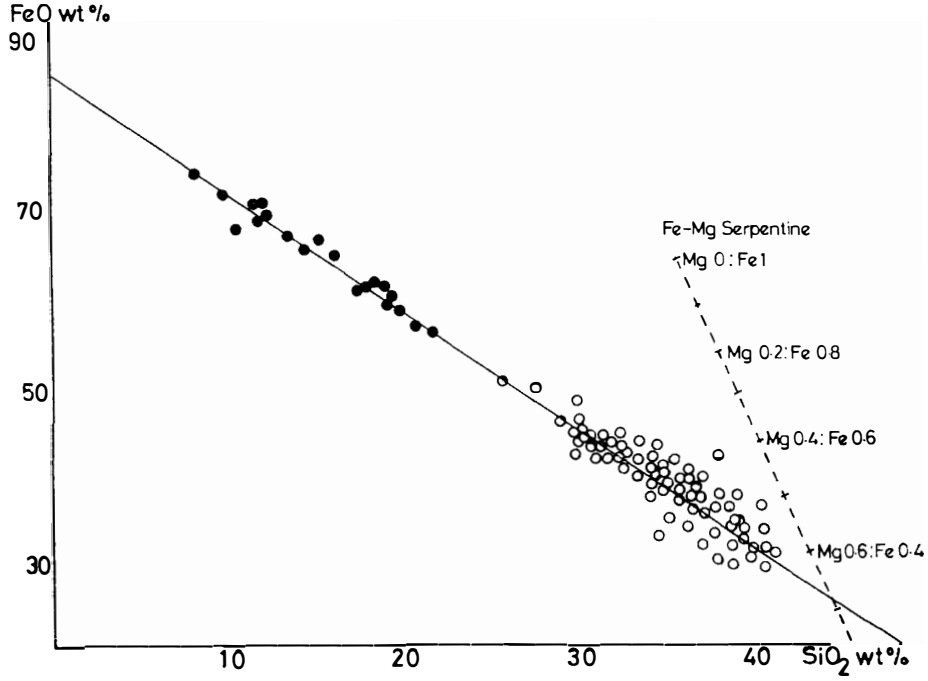

Fig. 1a.

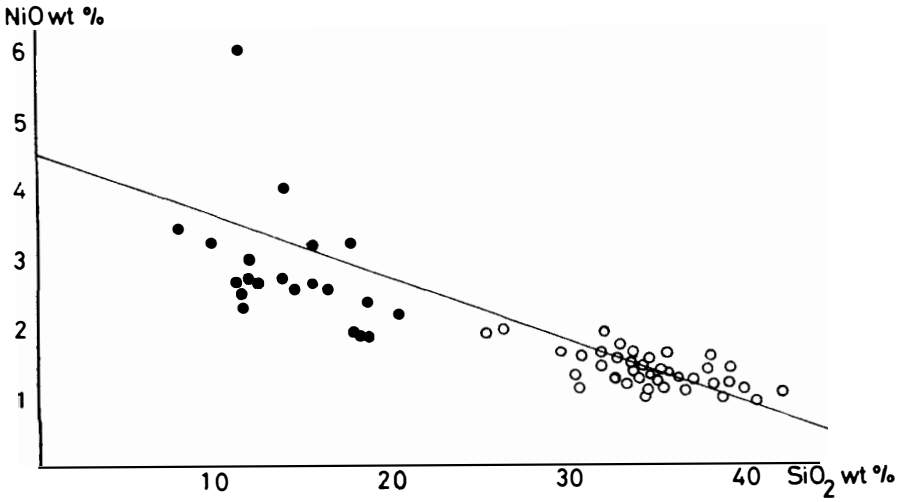

Fig. 1b.

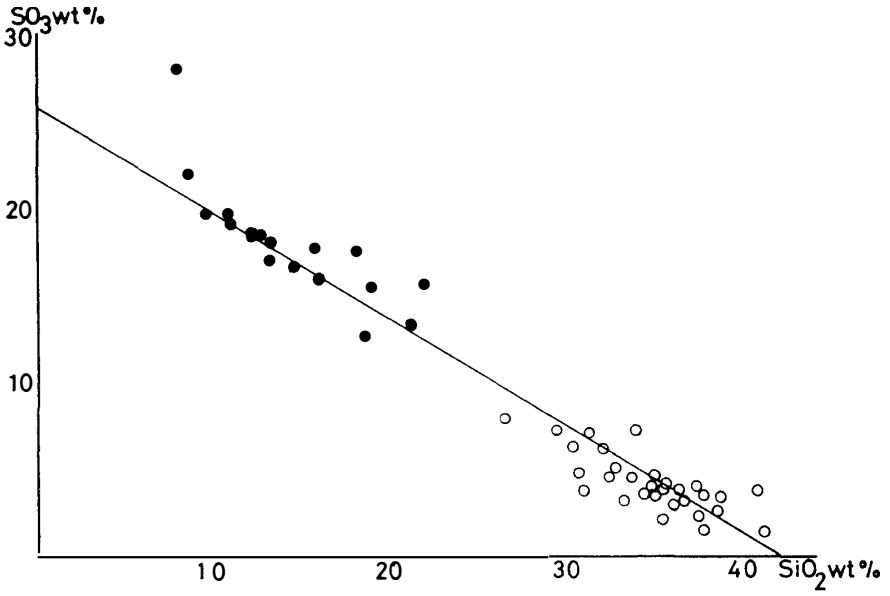

Fig. 1c.

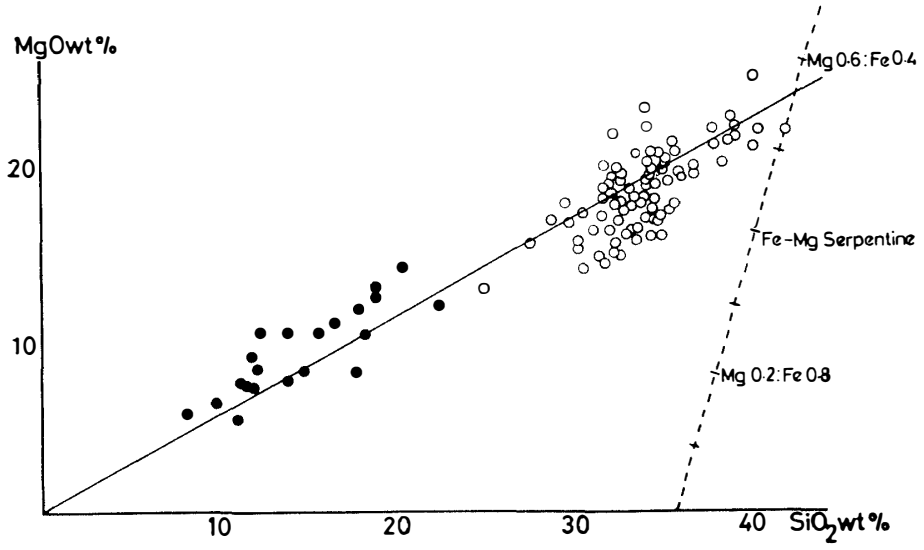

Fig. 1d.

Fig. 1. Relationships between amounts of oxides in the matrix of the Murchison meteorite. The amounts of oxides are in weight percent 100%-normalized on water-free base. (a) FeO-SiO_2, (b) NiO-SiO_2, (c) SO_3-SiO_2, and (d) MgO-SiO_2. ●, black clasts in the matrix; ○, interstitial light brown matrix. The dashed lines in (a) and (d) represent the ideal composition of serpentine, $3(FeO, MgO) \cdot 2SiO_2 \cdot 2H_2O$.

SiO_2, SO_3-SiO_2 and MgO-SiO_2 (Figs. 1a–1d). These relations obviously show a negative or positive linear correlation (r^2=0.78–0.98). The variation ranges of FeO and SiO_2 are too large to be attributed to any elemental substitution in a single

phase. This is only interpreted as mixing of two phases. Because MgO values have a positive correlation with SiO_2 values, they may be present in a same phase. X-ray diffraction analysis indicates that a 7 Å mineral is the most common silicate phase in the matrix of the Murchison meteorite (FUCHS *et al.*, 1973). More detailed mineralogical examination including that with an analytical electron microscope, the result of which will be given elsewhere, revealed that the 7 Å mineral is serpentine. Figs. 1a and 1d, in which ideal chemical composition of serpentine, $3(FeO, MgO)\cdot 2SiO_2\cdot 2H_2O$, is shown by dashed lines, indicate that the serpentine in the Murchison matrix has an approximate composition of $3(FeO_{0.3}MgO_{0.7})\cdot 2SiO_2\cdot 2H_2O$. The other phase in the matrix may consist of FeO 85%, NiO 5%, and S 10%.

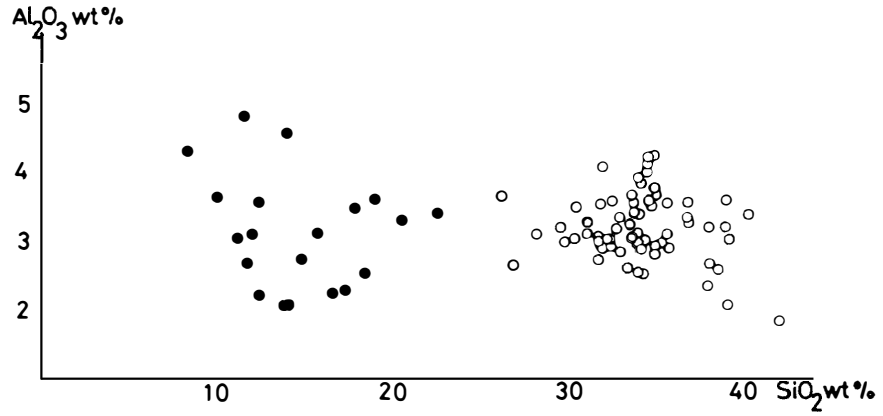

Fig. 2a.

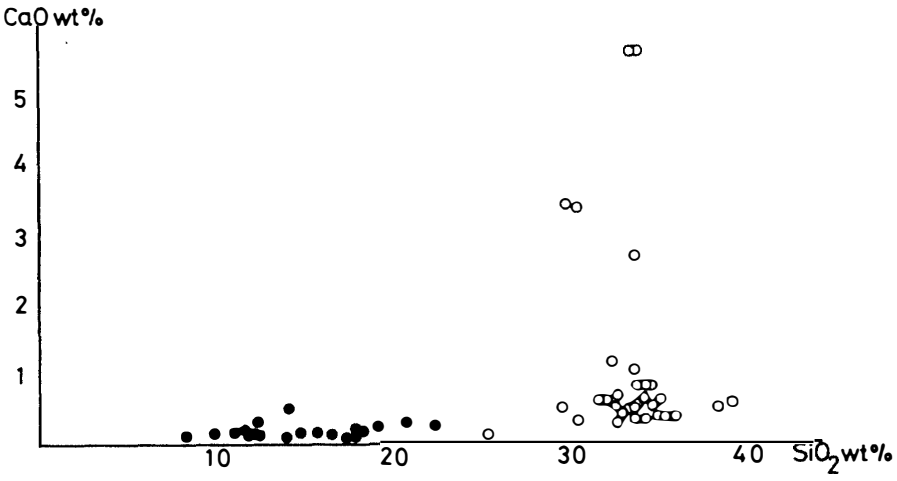

Fig. 2b.

Fig. 2. Relationships between (a) Al_2O_3-SiO_2 and (b) CaO-SiO_2. The amounts of oxides are in weight percent 100%-normalized on water-free base. ●, black clasts in the matrix: ○, interstitial light brown matrix.

3.3. The relationships Al_2O_3-SiO_2 and CaO-SiO_2 (Figs. 2a and 2b) are different from the above mentioned. Al_2O_3 has no correlation with SiO_2 and other oxides. Al_2O_3 may constitute a phase or phases independent of the silicate and nonsilicate phases mentioned in 3.2.

CaO shows a large variation on a point-by-point scale and no linear correlation is observed with other oxides. But an increase in SiO_2 is associated with an increase in the variation of CaO. Under the petrographic microscope, fine-grained carbonates are observed in the matrix. It may be possible that CaO is included in extremely fine-grained carbonates which are intimately associated with silicates.

4. Conclusions

A large number of point analyses (over 1000 points) using EPMA revealed that the matrix of the Murchison meteorite is composed mainly of mixtures of a silicate phase and a nonsilicate phase. The silicate phase is serpentine with a composition of $3(FeO_{0.3}MgO_{0.7})\cdot 2SiO_2\cdot 2H_2O$. If this serpentine has been formed under hydrothermal conditions, the highest temperature of formation is estimated at about 600 K based on the experimental data on synthesis of serpentine solid solution (JASMUND *et al.*, 1975). The nonsilicate phase has an approximate composition of FeO 85%, NiO 5% and S 10%. Because this FeO-NiO-S phase shows only one peak at 5.4 Å in the X-ray diffraction diagram, it cannot be identified.

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