THE APPLICATION OF X-RAY ANALYSIS TO THE STUDY OF METEORITES

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SUMMARY

It has been found that of the predominating components of the meteorite of Kaba (Hungary), iron-poor olivine (Mg : Fe = 3 : 1) is in excess as related to pyroxenes. Of the latter, clinoenstatite is the more enriched component. An important part is played further by highly oxidized iron, in the form of magnetite, carrying beside most of the total iron content also part of the nickel content. α-iron and sulphide were not observed in the X-ray pattern; however, as a further oxidic component, a Mg-Al spinel could be demonstrated.

Introduction

The processes used for determining the composition of meteorites do, especially in case of stony meteorites, not always express the true composition of the meteorite. The amount of material available for study being mostly very small, the possibilities of optically determining the mineralogical composition are much restricted indeed. Even if e. g. in the class of crystalline chondrites it is possible to define the well-developed constituents, with the smaller-sized components of cracked consistency having a great number of inclusions, and especially with the finely distributed ground mass, one is reduced to conjectures. Thus our knowledge concerning the predominant crystalline phases and their quantity relations, and especially concerning the role of the more special meteoritic constituents is in a number of cases by far not satisfactory. The problem was raised in one of the later papers by H. B. Wiik (6), in connection with considerations regarding the classification of the chondrites after Urey and Craig and the eventual further subdivision of the main divisions *H* and *L* as introduced by Urey and Craig. Wiik directs attention to the sources of error consisting in the application of routine chemical analysis methods and in the insufficient knowledge of the mineralogical composition, which are able to render all attempts at norm computation of this kind completely illusory. One of the bases of the latest classification is total iron content, and the state of ionization of iron, respectively. Wiik points out that this principle of valuation contains a contradiction inasmuch as in one and the same meteorite it reckons with all three states of oxidation of iron (metallic, ferrous, ferric), and he thinks that where the analysis yields minute amounts of metallic iron, or none at all, most of iron has to be in the ferric state. The problem is of special importance as regards the mineralogical composition of carbonaceous chondrites.

The considerations and experiences above outlined have prompted the author to add — in connection with a concrete case — new detail investigations to the usual line of meteorite research.

X-Ray investigation of the carbonaceous chondrite from Kaba (Hungary)

There is at present under way a reinvestigation of the carbonaceous meteorite fallen in 1857 in the environment of the village Kaba. In the course of this work, to complete chemical analysis, thin section and ore microscopic procedures, X-ray analysis of the material was also carried out. This has yielded on the one hand, a more precise establishment of the predominant components of the meteorite, and on the other, the presence of a crystalline phase hitherto unknown in meteorites. The results do, in general, serve as data of reference for that peculiar group of meteorites, carbonaceous chondrites.

The Kaba carbonaceous meteorite is a typical chondrite of brown-black ground material. For the purposes of X-ray analysis a finely pulverized sample of 1 gram weight was available. The grain size of the powder was 0,01 to 0,001 mm, so that there was no need of further pulverizing. The sample being magnetically susceptible in its entirety, the separation and concentration respectively of components was done by the aid of a heavy liquid (methylene jodide, $D = 3,3$) and a sample separated for investigation from both fractions by a mediumstrength permanent magnet (without touching the powder). Further investigated were the insoluble residue of dissolution in hydrochloric acid previous to chemical analysis (9) as well as the white to greyish-white crystalline filling of the cavities occurring in the meteorite.

The Debye-Scherrer patterns were registered by the aid of a Fe tube ($\lambda_a = 1,9359$ kX), with a radian chamber, and with an exposure of 6 hours at 40 kV, 8 mA. The evaluation of the films was done with an accuracy of 0,1 mm. The line intensities were estimated. Corrections were carried out on the hand of computed values of a simultaneously taken X-ray-gram of a halite sample ($a_0 = 5,6282$ kX).

1. The X-ray analysis results of the fraction separated by methylene jodide and extracted by permanent magnet are listed in Table 1.

On the hand of reflexion values and observed intensities it may be stated that this fraction mostly consists of magnetite, accompanied by olivine and a small amount of pyroxene.

A crystalline magnetite sample from Tyrol has served as a basis of comparison. On comparison it is seen that the X-ray pattern of the meteorite has yielded all the magnetite lines. The intensities do also agree well, considering that the magnetite concentration in the meteorite is smaller than in the reference material.

Because of the intense occurrence of K_β-radiation at some points, we have also carried out the indexing of magnetite; this procedure has much aided the determining of the other two components and the appropriate evaluation of the observed lines, respectively. In a number of cases, e. g. in those of the lines N^os^ 7, 12, 15, 19, 22, the relatively great intensity and partly diffuse character of the lines may be explained by the fact that here the olivine and pyroxene lines have almost or entirely coincided with β-reflections of magnetite.

By the aid of the line series we have determined the lattice constants of both magnetite samples. That of the Tyrolian sample used for reference is $a_0 = 8,3734$, as related to that of the magnetite from the meteorite:

$$a_0 = 8,3791 \text{ kX}.$$

Table 1

Serial	„Heavy" magnetic fraction, Kaba		Magnetite Tirol			Olivine (orig. unknown)			Clinoenstatite Kentucky	
	I	d_{hkl}	I	d_{hkl}	hkl	I	d_{hkl}	hkl	I	d_{hkl}
1	10	5,123	—	—	—	50	5,10	002	—	—
2	10	4,809	16	4,800	111	—	—	—	—	—
3	10	4,314	—	—	—	—	—	—	—	—
4	20	3,875	—	—	—	70	3,89	102	—	—
5	12	3,706	—	—	—	40	3,72	110	—	—
6	26	3,497	—	—	—	60	3,49	111	10	3,50
7	20	3,261	16	3,261	220 β	—	—	—	20	3,29
8	12	3,158	—	—	—	—	—	—	100	3,16
9	20	3,047	—	—	—	50	3,01	201	—	—
10	40	2,955	30	2,955	220	—	—	—	40	2,96
11	26	2,859	—	—	—	—	—	—	100	2,87
12	50	2,814	40	2,784	311 β	80	2,77	013	10	2,80
13	100	2,519	100	2,521	311	90	2,52	210	80	2,53
14	26	2,460	11	2,416	222	90	2,46	211	80	2,46
15	30	2,305	24	2,310	400 β	40	2,35	020	—	—
16	30	2,268	—	—	—	80	2,27	122	—	—
17	10	2,167	—	—	—	50	2,17	220	—	—
18	50	2,093	32	2,092	400	—	—	—	80	2,09
19	16 (d)	2,011	20	2,010	322,(332β)	30	2,03	221	40	2,01
20	10	1,941	10	1,925	422 β	20	1,96 ?	—	40	1,98 ?
21	10	1,886	16	1,887		20	1,88	150	—	—
22	30 (d)	1,787	26	1,780	333 β	10	1,80	142, 151	40	1,79
23	30 (d)	1,753	—	—	—	100	1,75	240	40	1,77
24	20	1,711	20	1,694	422	—	—	—	20	1,73
25	10	1,676	—	—	—	30	1,67	241	10	1,68
26	20	1,635	20	1,637	510, 431	30	1,64	232	10	1,64
27	70	1,613	64	1,615	333, 511	30	1,62	152	80	1,61
28	10	1,578	—	—	—	30	1,57	030	10	1,59
29	16	1,511	—	—	—	60	1,50	400	100	1,52
30	80	1,484	80	1,484	440	60	1,48	206	100	1,49
31	10	1,410	10	1,416	530, 433	—	—	—	—	—
32	10	1,395	—	—	—	50	1,40	—	—	—
33	20	1,376	—	—	—	—	—	—	100	1,38
34	16	1,355	—	—	—	50	1,35	—	40	1,36
35	24	1,328	10	1,328	620	—	—	—	—	—
36	16	1,315	—	—	—	20	1,30	—	—	—
37	30	1,279	20	1,280	533	—	—	—	60	1,29
38	20	1,265	16	1,268	—	10	1,25	—	80	1,27
39	16	1,212	10	1,213	444	—	—	—	40	1,21
40	25	1,122	—	—	—	—	—	—	—	—
41	50	1,092	—	—	—	—	—	—	—	—

We will yet come back to the interpretation of the deviation between the two lattice constants.

A further study of the X-ray pattern has yielded the demonstration of olivine. Although a number of its lines almost coincide with those of magnetite (13, 14, 19, 21, 22, 26, 27, 30), and in consequence of the greater concentration of magnetite there has been a shift of intensities, and although some of the rest of the lines of olivine coincide with those of clinoenstatite or both magnetite and clinoenstatite, or appear in the form of closely adjacent lines, there is a number of lines being specific of olivine. Of course, the intensities of these are smaller because of the smaller olivine concentration of the meteorite. The indices of olivine were computed according to the new orientation and the dimensions of the unit cell determined from lattice plane distances belonging solely to olivine. The lattice constants computed for olivine are :

$$a_0 = 6{,}006 \qquad b_0 = 4{,}761 \qquad c_0 = 10{,}2605$$

As a third mineral component one of the members of the pyroxene group could be demonstrated. There occur here also a number of line coincidences ; however, the presence of clinoenstatite was reliably established by considering additive intensities as well as specific clinoenstatite lines and their relative intensities. The values were compared with those of a Cumberland Falls (Kentucky) clinoenstatite.

Two of the lines of the pattern could not be identified ; these are considered to derive either of β-radiation or of another meteorite component. The lines of α-iron are entirely absent, so that this mineral has not even reached a demonstrable concentration by the procedures of enrichment employed.

2. Of the further results of the X-ray pattern series we will now present those concerning the non-magnetic fraction of the "light fraction" obtained on separation with methylene jodide. Here a total of 46 lines was evaluated, the results being listed in Table 2.

The results shown in Table 2. establish the predominance of olivine. Another main component is clinoenstatite. The definite presence of magnetite in this sample is rather remarkable. Most of the lines are established to be those of olivine by the good agreement of intensities as well as by the d_{hkl} values. As following from the nature of the powder sample, there occur likewise a number of line coincidences ; however, in such cases the additive intensities offer a good possibility of orientation. The presence of olivine is proved by lines 1, 3, 5, 6, 7, 10, 19, 20, 25, 33, 36, 38, 39, 43. Some of the important reflections coincide, as earlier, with one or both of the two other main components (13, 15, 16, 22, 25, 27, 31).

In the small- and medium-angle range the indexing of olivine was carried out, too : the index belonging to the line № 43 was also established.

On the hand of reflection values belonging to olivine the following lattice constants were determined :

$$a_0 = 6{,}008 \qquad b_0 = 4{,}756 \qquad c_0 = 10{,}2501$$

Another important group of lines indicates, in this case too, the presence of clinoenstatite. However, this silicatic constituent is much less intensely concentrated than olivine : the independent appearance of the characteristic lines N^{os} 9, 12, 34, 35, although with intensities smaller than those of the reference substance, prove the presence of clinoenstatite.

Table 2

Serial	„Light" non-magnetic fraction, Kaba		Olivine (orig. unknown)			Clinoenstatite Kentucky		Magnetite, Tirol		
	I	d_{hkl}	I	d_{hkl}	hkl	I	d_{hkl}	I	d_{hkl}	hkl
1	20	5,104	50	5,10	002	—	—	—	—	—
2	10	4,829	—	—	—	—	—	16	4,800	111
3	20	4,298	20	4,29	011	—	—	—	—	—
4	10	4,106	—	—	—	—	—	—	—	—
5	40	3,880	70	3,89	102	—	—	—	—	—
6	20	3,706	40	3,72	110	—	—	—	—	—
7	30	3,497	60	3,49	111	10	3,50	—	—	—
8	10	3,279	—	—	—	20	3,29	16	3,261	220 β
9	20	3,158	—	—	—	100	3,16	—	—	—
10	10	3,052	50	3,01	200	—	—	—	—	—
11	40	2,970	—	—	—	40	2,96	30	2,955	220
12	16	2,858	—	—	—	100	2,87	—	—	—
13	50	2,775	80	2,77	013	(10	2,80)	40	2,784	311 β
14	10	2,711	—	—	—	10	2,72	—	—	—
15	100	2,527	90	2,52	210	80	2,53	100	2,521	311
16	60	2,462	90	2,46	211	80	2,46	—	—	—
17	10	2,374	40	2,35	020	—	—	—	—	—
18	(10	2,334)	—	—	—	—	—	24	2,310	400 β
19	30	2,268	80	2,27	212	—	—	—	—	—
20	20	2,157	50	2,17	022	—	—	—	—	—
21	20	2,090	—	—	—	80	2,09	32	2,092	400
22	16	2,023	30	2,03	122	40	2,01	20	2,010	322 (332 β)
23	10 (d)	1,935	—	—	—	(40	1,98)	10	1,925	422 β
24	10	1,791	10	1,80	115	40	1,79	26	1,780	333 β
25	50 (d)	1,753	100	1,75	024	(40	1,77)	—	—	—
26	10	1,709	—	—	—	(20	1,73)	20	1,715	422
27	20	1,676	30	1,67	124	10	1,68	—	—	—
28	30	1,633	30	1,64	223	10	1,64	20	1,637	510, 431
29	40	1,611	(30	1,62)	—	80	1,61	64	1,615	333
30	10	1,571	30	1,57	030	(10	1,59)	—	—	—
31	50	1,479	60	1,48	—	100 100	1,52 1,49	80	1,484	440
32	10	1,410	—	—	—	—	—	10	1,416	530, 433
33	20	1,395	50	1,40	—	—	—	—	—	—
34	10	1,377	—	—	—	80	1,38	—	—	—
35	10	1,359	—	—	—	40	1,36	—	—	—
36	20	1,348	50	1,35	—	—	—	—	—	—
37	10	1,327	—	—	—	—	—	10	1,328	620
38	20	1,315	40	1,32	—	—	—	—	—	—
39	10	1,294	20	1,30	—	60	1,29	—	—	—
40	10	1,278	—	—	—	—	—	20	1,280	533
41	20	1,263	—	—	—	80	1,27	16	1,268	—
42	10	1,213	—	—	—	40	1,21	—	—	—
43	10	1,183	10	1,19	040	—	—	—	—	—
44	10	1,174	—	—	—	—	—	—	—	—
45	10	1,166	—	—	—	—	—	—	—	—
46	10	1,148	—	—	—	—	—	—	—	—

Table3

Serial	Acid-insoluble fraction, Kaba		Clinoestatite Kentucky		Enstatite, Bamle	
	I	d_{hkl}	I	d_{hkl}	I	d_{hkl}
1	20	4,364	—	—	40	4,38
2	10	3,836	—	—	20	4,00
3	10	3,465	10	3,50	60	3,55
4	20	3,294	20	3,29	—	—
5	40	3,171	100	3,16	100	3,16
6	50	2,993	(40	2,96)	80	2,91
7	100	2,887	100	2,87	—	—
8	10	2,785	10	2,80	60	2,78
9	10	2,697	10	2,72	60	2,69
10	50	2,532	80	2,53	80	2,53
11	40	2,445	80	2,46	—	—
12	10	2,352	—	—	40	2,38
13	20	2,220	—	—	40	2,23
14	40 (d)	2,122	80	2,09	60	2,11
15	30	2,024	40	2,01	40	2,05
16	20	1,978	40	1,98	40	2,01
17	10	1,931	—	—	60	1,95
18	26	1,780	40	1,79	60	1,78
19	30	1,607	80	1,61	40	1,61
20	10	1,566	10	1,59	—	—
21	30	1,529	100	1,52	50	1,52
22	20	1,487	100	1,49	80	1,49
23	20	1,467	—	—	60	1,47
24	10 (d)	1,438	—	—	20	1,45
25	30	1,378	100	1,38	60	1,39
26	16	1,358	40	1,36	40	1,36
27	20	1,291	60	1,29	60	1,30
28	30 (d)	1,265	80	1,27	60	1,27
29	20 (d)	1,217	40	1,21	40	1,21

As regards the repeated appearance of magnetite, it has to be stressed again that the pulverized meteorite substance is magnetically susceptible in its entirety, a fact that can be explained beside the high concentration of magnetite by its fine distribution and occurrence in the silicates in the form of inclusions. This is why it is present also in the fraction lighter than methylene jodide. The circumstance that it is contained even by the non-magnetic fraction in demonstrable quantities is due to the presence of a nickeliferous variety of smaller susceptibility. The certain presence and relatively high concentration of magnetite is indicated by the four independent magnetite lines (2, 26, 37, 40), as well as the two β-reflections determined in the smaller angle range. To further the solution of the magnetite problem, of importance with carbonaceous chondrites, a computation of lattice constants was carried out this time, too, (on the hand of the mentioned lines) with the result

$$a_0 = 8{,}378 \pm 0{,}003 \text{ kX}$$

3. A further X-ray pattern was taken of the residue of dissolution by hydrochloric acid in connection with chemical analysis.

This sample suffered, because of the hydrochloric acid treatment, a concentration of hydrocarbons causing a wide amorphous ring and a general foggedness of the entire film area. Consequently, the reflections of the acid-insoluble components have appeared only in the middle angle range and only 29 lines could be determined with certainty. The results of evaluation are shown in Table 3.

On the hand of the reflections observed, the insoluble residue is dominated by Mg-rich pyroxenes, above all by the monoclinic enstatite which appeared also in the previous samples. The d_{hkl} values and intensities of the lines show a good agreement. Beacuse of the hydrocarbon content the concentration is, here too, smaller than in the reference substance, resulting in an omission of weaker and a weakening of stronger lines. The lines 1, 2, 12, 13, 17, 23 and 24 agree with the d_{hkl} values of rhombic enstatite. It is remarkable that in the fraction separated by acid treatment neither pentlandite, determined under the microscope, nor any other acid-insoluble component was concentrated above the level of demonstrability. Consequently, there is a predominance of Mg-rich enstatite varieties in the insoluble residue, as was already indicated by the results of chemical analysis (9).

4. In some parts of the stone meteorite white spots are visible, being, as a matter of fact, cavity fillings of stretching or ramifying shape. The inside of the spots of locally 1 to 2 cm length and 2 to 3 mm width is filled by a granular fibrous crystalline aggregate of higher refractive index. The powder diagram prepared of this material has yielded an unexpected result. The data of the pattern are listed in Table 4.

It may be established on the hand of the results that the crystalline aggregate mostly consists of spinel ($MgAl_2O_4$), accompanied by pyroxenes, in the first place by clinoenstatite, and by smaller amounts of rhombic enstatite.

The appearance of magnesium aluminate spinel in the capacity of a meteorite constituent has made necessary comparative studies for the sake of more exactly determining the values. As a reference substance a quite light, greyish-white translucent crystalline spinel from Ceylon was chosen, which, on the hand of its chemical composition may be regarded to be a $MgAl_2O_4$ free of isomorphous admixtures. For the sake of comparison also the indices belonging to the individual lattice plane distances were determined. As the pyroxenes of lower symmetry possess in the small angle range a number of closely-spaced reflections, there occur, as seen in the table, a number of coincidences and the spinel lines emerge only in the medium and great angle ranges (18, 22, 25, 34, 37, 39). However, the two first lines of the series are also independent reflections of spinel. The agreement of spinel reflections and intensities is, however, most strikingly demonstrated by the comparison of the powder diagrams of the two substances (Fig. 1).

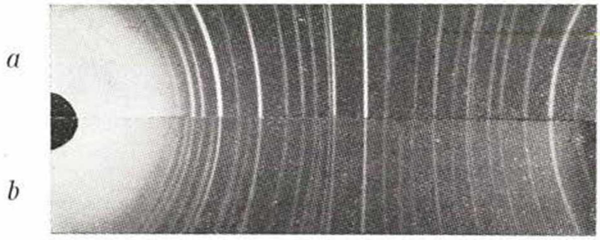

Fig. 1. Powder diagrams of the crystalline cavity fillings of the Kaba meteorite and of a spinel crystal from Ceylon. *a* — spinel, Ceylon; *b* — meteorite, Kaba (Hungary)

Table 4

Serial	White inclus. Kaba		Spinel, Ceylon			Clinoenstatite Kentucky		Enstatite Bamle	
	I	d_{hkl}	I	d_{hkl}	hkl	I	d_{hkl}	I	d_{hkl}
1	16	5,184	10	5,20	111 β	—	—	—	—
2	20	4,643	30	4,67	111	—	—	—	—
3	30	3,288	—	—	—	20	3,29	50	3,30
4	40	3,171	—	(3,143	220 β)	100	3,17	100	3,16
5	50	2,970	—	—	—	40	2,96	50	2,95
6	60	2,855	60	2,859	220	100	2,87	70	2,86
7	10	2,785	—	—	—	10	2,80	—	—
8	60	2,681	—	—	—	10	2,72	50	2,70
			50	2,627	311 β ?				
9	50	2,516	—	—	—	80	2,53	60	2,53
10	100	2,430	100	2,435	311	80	2,46	60	2,47
11	—	—	10	2,333	222	—	—	—	—
12	30	2,286	—	—	—	—	—	—	—
13	40	2,225	30	2,230	400 β	—	—	—	—
14	50	2,123	—	—	—	80	2,09	60	2,11
15	80	2,019	80	2,020	400	80	2,01	20	2,05
16	30	1,969	—	—	—	40	1,98	20 40	1,97 1,96
17	20	1,823	10	1,814	422 β	—	—	—	—
18	40	1,715	40	1,707	511 β	—	—	20 20	1,73 1,70
19	30	1,652	40	1,651	422	—	—	—	—
20	30	1,603	—	—	—	80	1,61	50	1,604
21	40	1,577	40	1,576	440 β	10	1,59	—	—
22	80	1,565	80	1,558	511	—	—	—	—
23	20	1,525	—	—	—	100	1,52	40	1,519
24	30	1,506	—	—	—	100 100	1,49 1,47	30	1,485
25	100	1,429	100	1,430	440	—	—	—	—
26	20	1,409	—	—	—	10	1,39	40 80	1,418 1,390
27	30	1,365	10	1,366	531	40	1,36	20	1,360
28	—	—	10	1,289	—	—	—	—	—
29	—	—	16	1,278	620	—	—	—	—
30	—	—	10	1,250	—	—	—	—	—
31	—	—	26	1,235	533	—	—	—	—
32	10	1,220	10	1,219	622	40	1,21	40	1,227
33	10	1,192	10	1,192	642 β	10	1,19	30	1,186
34	20	1,167	30	1,168	444	—	—	—	—
35	10	1,161	10	1,162	731 β	10	1,16	10	1,162
36	10	1,148	—	—	—	10	1,14	10	1,150
37	20	1,132	30	1,134	711	—	—	—	—
38	10	1,114	10	1,116	800 β	—	—	—	—
39	40	1,085	30	1,082	642	—	—	—	—
40	—	—	40	1,051	731	—	—	—	—

The lattice constants of the two structures also exhibit a remarkably good coincidence. The lattice constant of the Ceylon spinel is $a_0 = 8{,}086 \pm 0{,}003$ kX. The cell dimension of the spinel component found in the meteorite (as computed exclusively by the lines of the above listed serials) is

$$a_0 = 8{,}084 \pm 0{,}003 \text{ kX}.$$

The rest of the lines is doubtlessly due to enstatite reflections. Although the d_{hkl} values and intensities prove the presence of clinoenstatite in the first place, some lines may be interpreted as indicating that of rhombic enstatite.

Conclusions

On the hand of X-ray analysis results in the first place the unusual enrichment of magnetite may be stated. Its lines are observed in all of the fractions separated from the base substance by heavy liquid and magnetic procedures. Of course, greatest intensities occur with the "heavy magnetic" fraction. However, in the "heavy non-magnetic" fraction magnetite is also observed. It can be similarly demonstrated in the "light" magnetic and non-magnetic fractions of which the treatment has been omitted from this paper.

This experience sheds some light upon part of the difficulties encountered in the classification of carbonaceous chondrites according to Urey and Craig (3) and Wiik (6). It is seen that a significant part of the relatively high "total iron" content occurs in oxidic rather than silicatic bond, mostly in the form of the trivalent cation. Thus α-iron is also almost entirely lacking because of the high-grade oxidation and magnetitization respectively. Similarly, the sulphide component is also subordinate as related to the rest of the stony meteorites. In this way the problem as to what mineral contains the chemically demonstrated nickel (1,3—1,5%) of this peculiar meteorite group has arisen. Is it present as an isomorphous admixture in some of the silicates (as e. g. in olivine), or is it held by some other component? The approach to this problem is made possible in the first place by the X-ray analysis results above described.

B. I. Mikheew and A. I. Kalinin (8) have carried out computations of the lattice constant of magnetite in stony meteorites. They state, on having compared the value $a_0 = 8{,}370$ kX obtained for the Modvinovka meteorite with a number of analyzed ferri-spinels, that the latter is close to the lattice constant of Tyrolian magnetite given by T. Gebhardt (2) ($a_0 = 8{,}367$ kX) and to that of artificial magnesioferrite ($a_0 = 8{,}360$). As the variation of the lattice constant in the spinel group depends on the radii of the bi- and trivalent cations and on their role in the structure, the two authors have proceeded to compute the function describing this correlation, and have obtained the result that the cation distribution in magnetite of the Modvinovka meteorite is, according to the lattice constant observed, $(\mathrm{Fe}^{\cdot\cdot}_{0,75}\ \mathrm{Fe}^{\cdot\cdot\cdot}_{0,17})\ \mathrm{Fe}^{\cdot\cdot\cdot}_{2}\ \mathrm{O}_4$. This signifies that the magnetite of the stony meteorites has an inverse structure to be explained by high-grade ionization. As in carbonaceous chondrites, we have to reckon, according to all indications, with an exceptionally high state of ionization, it should be expected that the abundance of the ferri-cation of smaller radius brings about a further decrease of the lattice constant. On the contrary, the lattice constant of the Kaba meteorite's magnetite was proved to be larger in both cases. Table 5 represents the values obtained, as compared to pertaining literature data.

Table 5

	Origin	Reference	a_0 kX
Magnoferrite	Artificial	**Clark, Ally, Badger**, 1931 (1)	8,366
Magnetite	Tyrol	**Gebhardt**, 1933 (2)	8,367
Magnetite	Modvinovka, meteorite	**Mikheew**, 1958 (8)	8,370
Magnetite	Kaba, meteorite	**Sztrókay**, 1958 (9)	8,378
Magnetite	Kaba, meteorite	**Sztrókay**, 1958 (9)	8,379
Trevorite (Ni-ferrite)	Artificial	**Palache-Berman-Frondel**, 1946	8,41

It is certain that in the present case the ferro-cation of the magnetite lattice is substituted neither by bivalent manganese ($a_0 = 8{,}474$) nor by zincum ($a_0 = 8{,}42$), not even partially. The increase of lattice dimensions may thus be only caused by nickel. The fact that the increase is not greater may be explained by assuming that, because of the intensely oxidized nature of the mineral, part of the the $R^{\cdot\cdot}$ positions is also filled in by ferri-cations, thus tempering the lattice dilatation due to the introduction of nickel. Thus we have to record the new result that a significant part of the nickel content of carbonaceous meteorites occurs in oxidic bond, more accurately in magnetite. Besides, this statement is also corroborated by microscopic investigations.

As to the lattice constants of olivine, predominant silicatic constituent, the following values were obtained by calculation on the hand of two X-ray patterns :

a_0	b_0	c_0
6,006	4,761	10,2605
6,008	4,756	10,2501

As known, the lattice constants of fayalite increase in proportion with the Fe content from forsterite towards fayalite. On the hand of the value obtained, as well as applying the method of calculation given by **Mikheew** and **Kalinin**, the Mg and Fe contents of the Kaba meteorite are approximately in a proportion 3 : 1, i. e. the formula of this olivine is approximately $(Mg_{75}, Fe_{25})_2SiO_4$.

As regards the pyroxenic constituents (monoclinic and rhombic enstatite), it may be stated that clinoenstatite is much more abundant than rhombic pyroxene, but that the role of both is subordinate as related to that of olivine.

The Mg-Al spinel, found in the randomly distributed cavity fillings, is a mineral phase hitherto unknown from meteorites. Its demonstration by X-ray analysis does not only increase the number of oxidic constituents of carbonaceous chondrites, but it gives another proof of the successful application of the X-ray method in meteorite research.

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