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THE CHEMICAL RELATIONSHIP BETWEEN HOWARDITES AND THE SILICATE FRACTION OF MESOSIDERITES

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Analyses of eleven major elements in five howardite samples and in the silicate fraction of seven mesosiderites are presented in a recalculated form and compared. The mesosiderite silicate fractions show distinct differences in chemical composition from the howardites, but the average Ca/Al determined for mesosiderites (1.05), which differs from most values previously published, is close to that typical of howardites (1.08). The inverse Ca/Mg relationship in the howardites is present also in the mesosiderites, the trend being displaced relative to that of the howardites but parallel to it. The chemical differences confirm that mesosiderites are not mixtures of howardite and metal. The Ca/Al and Ca/Mg relationships suggest that the two meteorite groups were subject to similar genetic controls, and may therefore have had a common parent body. Such a body is required by the cooling rate of the metal of mesosiderites to have been larger than any known asteroid.

INTRODUCTION

Although only 20 mesosiderites are known, they are of unusual interest because of the resemblance of their silicates to those of the howardites and have recently been studied extensively (*e.g.*, Powell 1969 and 1971). The existence of discrepancies and gaps in the published chemical data prompted us to analyze the silicate portion of seven mesosiderites and to compare critically their compositions with five new analyses of howardites.

The similarity in the oxygen isotope ratios of achondrites and mesosiderites (Taylor *et al.* 1965) supports the idea that they are genetically linked (Prior 1918). Comparison with oxygen isotope data on lunar materials (Taylor and Epstein 1970) disproved the lunar origin suggested for these meteorites by Duke and Silver (1967), but did not invalidate the possibility that they were formed on a similar body that may formerly have existed elsewhere in the solar system. Furthermore, the extremely slow cooling rates of the metal of mesosiderites require that body to be larger than Ceres, the largest known asteroid (Powell 1969). The joint problems of whether achondrites and mesosiderites had, in fact, a common parent body, and of the nature of such a body, can be solved only by careful comparison of the data on these meteorite classes. The present study which uses only analyses from one laboratory reduced to a common

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basis for comparison, may contribute to the solution of these problems. This paper reports some preliminary observations on important lithophile elements - Ca, Al, Mg, Fe, Si, and P - present in howardites and mesosiderites.

SAMPLE PREPARATION AND ANALYSIS, AND ANALYTICAL DATA

Representative silicate fractions, obtained by removing as much metal as

TABLE I

RECALCULATED ANALYTICAL DATA ON HOWARDITES AND MESOSIDERITES

	HOWARDITES					MESOSIDERITES						
	Malvern+ (UCT)	Malvern+ (BLM)	Binda	Kapoeta	Molteno	Mincy	Patwar	Esther-ville	Mt Padbury	Vaca Muerta	Emery	Łowicz
SiO_2	49.92	49.45	50.86	50.70	50.21	53.20	51.38	51.50	54.37	50.36	53.22	53.76
TiO_2	0.51	0.53	0.24	0.39	0.45	0.30	0.23	0.31	0.29	0.30	0.39	0.37
Al_2O_3	10.16	10.78	7.18	8.28	9.11	7.49	8.05	9.68	8.21	9.94	12.24	11.35
Cr_2O_3	0.58	0.57	0.76	0.79	0.69	1.65	0.68	0.90	1.06	1.26	0.84	0.82
FeO^*	17.76	17.95	16.77	16.29	17.07	8.70	14.64	11.98	9.81	13.56	7.86	7.94
MnO	0.54	0.53	0.53	0.53	0.53	0.60	0.57	0.50	0.62	0.49	0.54	0.57
MgO	11.93	11.16	17.89	16.10	14.25	20.48	16.44	16.98	18.59	14.03	12.84	14.86
CaO	8.19	8.59	5.59	6.58	7.32	5.93	6.61	7.28	6.38	7.82	9.39	8.55
Na_2O	0.31	0.32	0.15	0.29	0.30	0.25	0.24	0.31	0.19	0.27	0.38	0.34
K_2O	0.04	0.04	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.02	0.02
P_2O_5	0.06	0.07	0.03	0.05	0.05	1.39	1.15	0.56	0.49	1.96	2.28	1.42
TOTAL	100.00	99.99	100.01	100.01	100.00	100.00	99.99	100.00	100.01	100.00	100.00	100.00
Ca/Al	1.09	1.08	1.05	1.07	1.09	1.07	1.11	1.02	1.05	1.06	1.04	1.02

+ Analyses of the two Malvern samples appear in Simpson (1977); all other data are new.

possible by repeated magnetic separation, were analyzed using an X-ray fluorescence method (Willis *et al.* 1971; 1972). Determinations of Ni and S enabled recalculation of the analyses of the nearly-pure silicate fractions on a metal-free, troilite-free, and volatile-free basis. Details of separation and analytical procedures and of calculation methods will be given elsewhere (Simpson and Ahrens, in prep). Table I contains the recalculated analytical data.

THE Ca/Al RATIO

McCarthy and Ahrens (1971) noted that the Ca/Al weight ratio typical of most chondrites, howardites, and eucrites (1.08) was greater than the average value for mesosiderites (0.88) derived mainly from the data of Powell (1971). The significance of this apparent difference was discussed by Mason and Jarosewich (1973). They tabulated Ca/Al ratios for 17 mesosiderites and attributed the considerable variation present partly, but not entirely, to analytical error and sampling difficulties arising from the control exercised on the Ca/Al ratio by the amount of plagioclase in the sample. They pointed out also that the silicates in the two meteorite groups are essentially identical, although the proportions in which they occur are different. This mineralogical similarity is evident from microprobe studies of the mineral chemistry of mesosiderites (Powell 1971), and of howardites (*e.g.*, Dymek *et al.* 1976; Desnoyers and Jérome 1977; Simpson 1977), and constitutes strong support for the conclusion reached by Mason and Jarosewich (1973) that "while the howardites and mesosiderites may not have a common source, the silicate material in the mesosiderites has had a parallel evolution to that in the howardites."

In view of this, a re-examination of the seeming disparity in the Ca/Al ratios of howardites and mesosiderites has become essential and is included in our study. Table II compares our new data with values of Ca/Al calculated from

TABLE II

A comparison of Ca/Al (weight) ratios from

(a) recent literature and (b) this work.

	(a)	(b)
Emery	0.92[1], 0.95[2], 1.00[2]	1.04
Estherville	0.90[3], 1.046[4], 1.12[5]	1.02
Łowicz	0.84[3], 0.88[2]	1.02
Mincy	0.97[2]	1.07
Mt. Padbury	0.74[6]	1.05
Patwar	0.84[7], 1.58[2]	1.11
Vaca Muerta	0.96[3], 1.26[2]	1.06
		Ave. 1.05

1 – Mason and Jarosewich (1973); 2 – Begemann et al. (1976);
3 – Powell (1971); 4 – Jérome (1970); 5 – Nelen and Mason (1972);
6 – Wiik (1969); 7 – Jarosewich and Mason (1969)

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analyses of mesosiderites published in recent years. The uniformity of the new data is noteworthy. The average calculated from our values is 1.05, which approximates to the figure for the stony meteorites. This suggests that the genetic factors controlling the Ca/Al ratio are common to both mesosiderites and howardites within the limitations imposed by sampling, and enhances the feasibility of at least parallel evolutionary processes in mesosiderites and howardites.

THE Ca-Mg RELATIONSHIP

The inverse relationship between Ca and Mg, first noted in the achondrites by Ahrens and von Michaelis (1969), is plotted for the new data in Fig. 1. The five howardites define a clear trend on this plot, while five of the mesosiderites lie on a line that is approximately parallel to this trend but is displaced towards higher values of Mg and Ca. The remaining mesosiderites, Patwar and Vaca Muerta, occupy an intermediate position and may lie on yet another parallel trend line close to that of the howardites. The non-coincidence of these trends may result from the different proportions of plagioclase and pyroxene present in the two types of meteorite (Mason and Jarosewich 1973). The intermediate trend defined by Patwar and Vaca Muerta suggests the possibility of a gradational relationship between the silicate materials of howardites and mesosiderites.

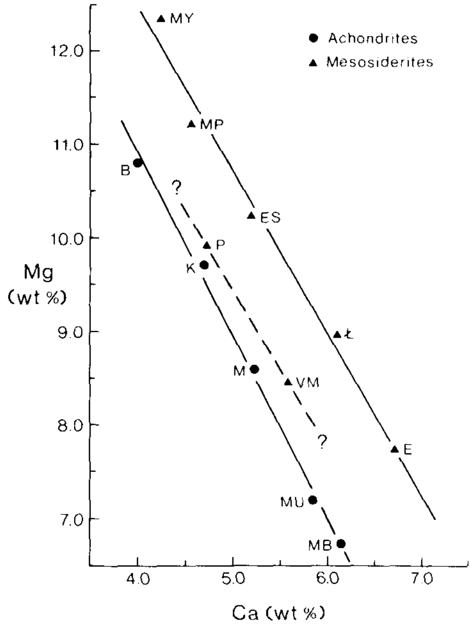

Figure 1. The inverse correlation of Mg and Ca in the recalculated data for howardites and mesosiderites presented in Table I. Abbreviations: MU - Malvern (UCT); MB - Malvern (BLM); B - Binda; K - Kapoeta; M - Molteno; MY - Mincy; P - Patwar; ES - Estherville; MP - Mt Padbury; VM - Vaca Muerta; Ł - Łowicz.

The range of variation of Ca and Mg appears to be similar within the two groups and is governed largely by the choice of meteorites for analysis. If, for instance, the Mg-rich howardite Frankfort (McCarthy *et al.* 1972) had been

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included in the study, the range of Ca and Mg values in the howardites would have exceeded that in the mesosiderites.

SiO_2, FeO AND P_2O_5

Ahrens and Dunchin (1971) observed that the range of concentration of SiO_2 in howardites and eucrites is very small, with the average at about 49% Distinctly higher values have been reported for the mesosiderites by Powell (1971), and our recalculated data confirm the generalization that the SiO_2 content of the silicate fraction of the mesosiderites exceeds that of the howardites and eucrites, but the difference calculated from our data is less than that indicated by the earlier study.

Table I contains analytical data recalculated to compensate for metal and troilite remaining in the samples after preparation. This recalculation brings out the important fact that the FeO content of the silicate fraction of mesosiderites (average 10.64%) is considerably lower than that of the howardites (average 17.17%), while MgO is slightly higher (average 16.32% *vs* average 14.27%). The implications of this observation for the origins of howardites and mesosiderites will be discussed in another paper (Simpson, in prep.).

Earlier observations that the silicate fractions of mesosiderites are strikingly enriched in P (Powell 1971; Mason and Jarosewich 1973) are confirmed by our analyses, in which P_2O_5 averages 1.32%. By comparison, average howardite contains only 0.05% P_2O_5 (this work) and average eucrite 0.10% P_2O_5 (McCarthy *et al.* 1972). Features of the extraterrestrial chemistry of P will be discussed elsewhere (Ahrens and Simpson, in prep.).

CONCLUSIONS

Although our comparative study of howardites and mesosiderites is not yet complete, some preliminary conclusions may be stated: 1) The silicate fractions of mesosiderites, though similar to howardites, are not chemically identical to them *e.g.*, in FeO and P_2O_5 content. Therefore mesosiderites cannot be regarded as mixtures of howardite and metal. 2) Although the absolute concentrations of elements present in howardites and mesosiderites may differ markedly, the ranges of compositions are broadly similar. 3) The similarities observed in the chemical and mineralogical composition of the two meteorite groups, and particularly in the interelement trends, suggest that their evolutionary processes were similar, and do not preclude the possibility of a common parent body larger than the asteroids.

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