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Abstract

Full Text

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LEAD AND ITS ISOTOPIC COMPOSITION IN IRON METEORITES

We have found ⁽¹⁾ that, contrary to previously established ideas, iron meteorites contain lead with different isotopic compositions. These studies were carried out on three samples of octahedrites. The present work is devoted to the study of all the principal groups of iron meteorites, namely: octahedrites of various structures, hexahedrites, and ataxites. In addition to the various groups of iron meteorites, it was essential to study mineral inclusions that differ in composition from the main iron-nickel mass. The most widespread of these is troilite, FeS. On the basis of general considerations concerning the distribution of lead between the metallic and sulfide phases, one should expect troilites to be enriched in lead. Such data were indeed obtained by Patterson ⁽²⁾ and by us ⁽¹⁾ on three meteorite samples.

In work ⁽³⁾ a description is given of the preliminary treatment of the samples, the methods for isolating lead and quantitatively determining it, and the mass-spectrometric analysis.

For all the meteorites studied, 2-3 parallel determinations were carried out both of the quantitative content and of the isotopic composition of lead. Contamination by reagent lead, according to blank experiments, amounted to $0.6-0.8 \cdot 10^{-8}$ g of lead per 1 g of meteorite; in the analysis of ataxites this value increased somewhat, since a larger amount of nitric acid was required to dissolve the ataxites. The total correction for ordinary lead was 10-30%, and for ataxites 50%.

Mass-spectrometric measurements were performed on amounts of lead from $2 \cdot 10^{-6}$ to $15 \cdot 10^{-6}$ g. Because of the greater error affecting the measurement of mass 204, the results for isotopic composition are presented not only in the form of the ratios to Pb^{204} usually given, but also in the form of the ratios 206/204, 206/207, 206/208, of which only one depends on the accuracy of the measurement of Pb^{204} .

The results of analyses of the metallic phase of 12 meteorites and of 5 troilites are presented in Table 1. In order to eliminate possible contamination by terrestrial lead captured by the surface zone of the meteorite, in analyzing the metallic phase, zones located 20-50 mm away from the fusion crust were studied. An

exception is the Toubil meteorite, the investigated parts of which were 3–4 mm from the fusion crust.

The analytical results presented in Table 1 confirmed the data obtained by us earlier that not all iron meteorites contain lead of primordial composition. Most of the meteorites investigated contain lead whose isotopic composition corresponds to ordinary terrestrial lead. No intermediate isotopic composition of lead was found. Four meteorites—Burgavli, Toluca, Bischtobe, and Arus—have the same isotopic composition of lead, similar to that first reported by Patterson ⁽²⁾ and later obtained by us ⁽¹⁾ in the Canyon Dia-

Table 1

Meteorite	Lead concentration, 10^{-7} g/g	206/204	207/204	208/204	206/204	206/207	206/208
1. Bur-gavlioc-ta-hedrite	2,4	9,34	10,53	30,28	9,34	0,887	0,308
1. Bur-gavl-itroilite	76,7	9,79	10,68	30,27	9,79	0,917	0,323
2. Tolucamedium-structured octa-hedrite	1,6	9,87	10,70	30,36	9,87	0,914	0,325
3. Arisoc-ta-hedrite	1,7	10,14	10,97	30,18	10,14	0,925	0,336
3. Aristroilite	23,0	10,01	10,85	30,78	10,01	0,923	0,325
4. Bilibinocoarse-structured octa-hedrite	1,8	9,80	10,74	30,08	9,80	0,913	0,326

Meteorite	Lead	206/204	207/204	208/204	206/204	206/207	206/208
	concentration, 10 ⁻⁷ g/g						
4. Bilib- inotroilite (?)	75,0	17,72	15,47	38,40	17,72	1,145	0,461
5. Avgustinovkamedium- to fine- structured octa- hedrite	1,9	16,80	15,20	37,30	16,80	1,105	0,450
6. Toubilmedium- structured octa- hedrite	2,0	17,49	15,56	37,62	17,49	1,124	0,465
7. Santa Catha- rina II- Iatax- ite No. 2179	4,0	17,99	15,67	38,51	17,99	1,148	0,467
7. Santa Catha- rina II- INo. 2180a) sur- face zone	2,4	≥ 16,42	≥ 14,44	≥ 35,04	≥ 16,42	1,137	0,469

Meteorite	Lead concentration, 10^{-7} g/g	206/204	207/204	208/204	206/204	206/207	206/208
7. Santa Catharina II- (No. 2180b) central zone	0,5						
8. Boguslavka-hexahedrite	0,2	17,39	16,11	37,33	17,39	1,107	0,466
9. Greck-hexahedrite	0,4	17,99	15,84	38,23	17,99	1,136	0,471
9. Greck-troilite	20,0	18,07	15,87	38,23	18,07	1,138	0,473
10. Chebankolcoarse-structured octahedrite	0,3	17,68	15,76	38,49	17,68	1,122	0,459
11. Chingeataxite	0,3	16,89	15,27	35,38	16,89	1,105	0,478
12. Sikhote-AlinNo. 2052	0,3	17,89	15,84	38,19	17,89	1,129	0,469
12. Sikhote-Alinoctahedrite, very coarse-structured, No. 1633	0,3	17,55	15,60	37,97	17,55	1,125	0,462

Meteorite	Lead concentration, 10^{-7} g/g						
	g/g	206/204	207/204	208/204	206/204	206/207	206/208
12. Sikhote-Alintroilite No. 2052*	10,0	17,60	15,76	37,83	17,60	1,116	0,465

* The sample of troilite No. 2052 (1) was obtained from the Committee on Meteorites of the Academy of Sciences of the USSR; the sample cited in the present work was separated by the authors from the same piece of meteorite in which the analysis of the metallic phase was carried out.

lead. The meteorites of this group are octahedrites of different structure. The lead content in them is $1-2 \cdot 10^{-7}$ g/g.

The remaining 8 meteorites, as well as the Henbury meteorite ⁽¹⁾, form a second group, whose isotopic composition of lead corresponds to the abundance of lead isotopes in terrestrial material with an age within several hundred million years. This age was obtained on the assumption that the meteorites and the Earth belong to one system and that, at the moment of the Earth's formation, the lead entering into the material composing it had the same isotopic composition as that found in the meteorites of the first group. As is evident from Table 1, the isotopic compositions of the meteorites of this group differ somewhat among themselves. At present it is difficult to say whether these relatively small discrepancies are due to experimental errors or whether they reflect the true isotopic composition.

The second group of meteorites includes all the main varieties of iron meteorites: octahedrites, hexahedrites, and ataxites. We note that all the hexahedrites and ataxites investigated belong to the group of meteorites with the ordinary isotopic composition of lead. The concentration of lead in them corresponds to the lower limit of abundance ($2-4 \cdot 10^{-8}$ g/g). A similar lead content was obtained for the coarse-structured octahedrites Sikhote-Alin and Chebankol. For two medium-structured octahedrites, Avgustinovka and Toubil, the lead concentration proved to be an order of magnitude greater, i.e., $2 \cdot 10^{-7}$ g/g.

The low lead content obtained in a number of meteorites (on the order of 10^{-8} g/g) confirms the absence of contamination of meteorites containing lead on the order of 10^{-7} g/g by ordinary terrestrial lead.

In studying the lead content in different parts of meteorites of the first group, no appreciable nonuniformity in the distribution of lead was found.

The question of the lead content in the second group of meteorites proved to be

more complex. Thus, in the Santa Catarina meteorite (Table 1), we obtained different values for the lead concentration for two samples. The value of the lead concentration in sample No. 2179, equal to $4 \cdot 10^{-7}$ g/g, is possibly too high, since this sample had a strongly destroyed metallic phase and, in addition, contained significant amounts of troilite inclusions. Individual sample No. 2180 of the same meteorite, weighing 31 g, consisted of unaltered metal. Stepwise dissolution of this sample showed a lead content of $2 \cdot 10^{-7}$ g/g in the surface zone, and $< 0.5 \cdot 10^{-7}$ g/g in the central part.

Analyses of the surface and central zones of the Sikhote-Alin (sample No. 1) and Chinge⁽³⁾ meteorites revealed the same regularity, namely: enrichment of the surface zones with lead in comparison with the central zone. The lead content in the central parts of the Sikhote-Alin meteorite (samples Nos. 1633 and 2052⁽³⁾) proved to be the same and equal to $3 \cdot 10^{-8}$ g/g. It should be noted that sample No. 2052 was a cracked plate, whereas sample No. 1633 was a monolithic piece containing no visible mineral inclusions. The isotopic composition of the lead in these different individual samples proved to be identical. The opposite relation was obtained in the Toubil meteorite*: stepwise dissolution of the sample in this case showed a lower value for the lead content in the surface zone (by a factor of 3) compared with the central part.

The authors believe that the difference in lead content in different zones of meteorites and in different samples of one and the same meteorite may be explained, first, by contamination of the surface zones by terrestrial lead and, second, by nonuniform distribution of mineral inclusions enriched in lead. The solution of this question requires special study.

From the data presented in Table 1 it follows that no definite dependence is observed of the content and isotopic composition of lead on the type and structure of iron meteorites. As we have already indicated, the second group of meteorites with ordinary isotopic composition of lead includes all varieties of meteorites, whereas the first group includes only octahedrites. Since we investigated only two samples each of ataxites and hexahedrites, it is premature to assign all meteorites of these types to the second group.

For the greater part of the meteorites investigated, we had the opportunity to analyze troilite inclusions. Comparing the data on the study of the content and isotopic composition of lead in the sulfide and metallic phases of meteorites (Table 1), it should be noted that the lead content in troilites is 1-2 orders of magnitude greater than in the iron-nickel phase, while the isotopic composition remains the same. Such a regularity is entirely understandable if one assumes that differentiation into sulfide and metallic phases took place within the limits of one and the same parent body. An exception is the Bishtobe meteorite, where in the metallic phase lead shows the primordial isotopic composition, whereas the troilite contains lead with ordinary isotopic composition. This inclusion was removed from the fusion crust by 100 mm and could not have been contaminated by terrestrial lead while the meteorite was in the soil. The mineral composition of this inclusion was not precisely identified. It is possible that we are dealing not

with troilite, but with some other rare sulfide mineral containing significantly larger amounts of ura-

* Table 1 gives the average lead content in the entire sample.

and the theory. The insufficient amount of material did not allow us to study this interesting fact in detail.

The presence of two groups of iron meteorites differing in the isotopic composition of lead makes it possible to suggest their different origin. Two analogous groups are also observed in the case of stony meteorites. According to the data of Patterson ⁽²⁾ and our own ⁽⁴⁾, stony meteorites contain lead with the ordinary isotopic composition, whereas Reed et al. ⁽⁵⁾ found lead with primordial isotopic composition in enstatite and carbonaceous chondrites. Thus, at present, depending on the isotopic composition of lead, two analogous groups of stony and iron meteorites are distinguished. The most probable explanation may be the supposition that each group of meteorites originated from its own parent body.

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