

OXYGEN ISOTOPIC STUDIES OF CARBONACEOUS CHONDRITE BELGICA-7904; Toshiko K. Mayeda¹, Robert N. Clayton^{1,2,3}, ¹Enrico Fermi Institute, ²Department of Chemistry, ³Department of the Geophysical Sciences, University of Chicago, Chicago, IL 60637; and Yukio Ikeda⁴, ⁴Department of Earth Sciences, Ibaraki University, Mito, Japan.

Several Antarctic carbonaceous chondrites have been found to have chemical, mineralogical, and isotopic properties which extend beyond the range of those known for non-Antarctic members of the CI1 and CM2 classes. These meteorites provide the opportunity to increase our understanding of the processes of formation of meteorites of these important classes. A characteristic feature of all C1 and C2 chondrites is their abundant phyllosilicate matrices, although the detailed properties of matrix materials may differ from one meteorite to another. There is widespread agreement that the phyllosilicates were produced by reaction of anhydrous silicates with liquid water within a parent body. The properties of C1 and C2 chondrites should then depend on a combination of processes: (a) formation of anhydrous precursors, (b) aqueous alteration, (c) subsequent alteration, brecciation, and metamorphism.

Before study of the Antarctic meteorites, a simple classification into CI1 and CM2 was possible, based on (a) trace-element abundances (factor of two depletion in CM2), (b) chondrules (abundant in CM2, absent in CI1), (c) oxygen isotopic composition. Several of the Antarctic meteorites fail to fit into this scheme, such as B-7904, Y-82162, Y-86720. These meteorites have oxygen isotopic compositions enriched in heavy isotopes well beyond the range previously found in C1 or C2 chondrites. They have also been found to contain a second generation of olivine, evidently formed by thermal dehydration of phyllosilicates (Akai, 1988; Tomeoka et al., 1989a and b; Tomeoka, 1989).

Oxygen isotopic compositions have been measured of various components of B-7904, in order to determine the nature of the precursor silicates and the effects of aqueous alteration and metamorphism. The data on B-7904 can be compared directly with analogous data from Murchison, a representative CM2 chondrite.

Olivine fragments. Samples B1 and B2 are single olivine grains about 1 mm in diameter. Their isotopic compositions fall in the range of unaltered chondrules from carbonaceous chondrites. These samples are probably chondrule fragments and represent the unaltered precursor of the phyllosilicates.

Chondrules. C1 and C2 are chondrules of 2 mm diameter; CC is a 1 mm chondrule. All are partially altered to phyllosilicates. The oxygen isotopic compositions fall along the previously observed mixing line found for many carbonaceous chondrites, connecting compositions of the anhydrous silicates to those of the matrix material.

Inclusions. D2 (2 mm) and D5 (3 mm) are two inclusions which appear to be altered chondrules. Their oxygen isotopic compositions indicate a higher proportion of phyllosilicates than in chondrules C1, C2, and CC (amounting to about 50% phyllosilicate).

Matrix. The matrix sample consisted of submillimeter hand-picked chips of chondrule-free material. Its oxygen isotopic composition is almost identical to the whole-rock value for Y-86720, a meteorite which lacks chondrules, but is otherwise very similar to B-7904 (Tomeoka, 1989).

Carbonate. Oxygen and carbon isotopic compositions were measured on CO₂ liberated from a 470 mg bulk meteorite sample by phosphoric acid. The yield corresponds to a calcite concentration of 1400 ppmw. The $\delta^{13}\text{C}$ value of +5.6‰ (PDB) is much lower than the range typical of C1 and C2 chondrites (+40 to +70‰). The oxygen isotopic composition is compared with Murchison calcite composition in Table 2.

Whole-rock. Isotopic analyses of three different whole-rock fragments gave identical results, indicating oxygen isotope homogeneity for samples of a few millimeters or larger. Isotopic material balance implies that the fraction of *unaltered* chondrule material in B-7904 is on the order of 10%, in contrast with Murchison, in which it is about 50%.

The data for chondrules and matrix of B-7904 are shown in Fig. 1 for comparison with whole-rock data for a large number of C2 chondrites. The B-7904 data form part of the same overall trend, with the same anhydrous source material as other carbonaceous chondrites. The aqueous alteration processes must have been generally similar, but different in reaction conditions such as temperature, duration, and water/rock ratio in order to produce a more extreme isotopic composition in the matrix of B-7904 (and also Y-82162 and Y-86720) compared to typical C1 or C2 chondrites. The most likely

factor to produce such high $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$ values is water/rock ratio, with larger ratios producing larger δ -values (Clayton and Mayeda, 1984).

Thermal dehydration of phyllosilicates requires loss of water from the system, with a consequent change in isotopic composition of the residual silicates. If the isotopic fractionation in the dehydration process can be approximated by the equilibrium olivine-water fractionation at 500°C (Onuma et al., 1972), then the $\delta^{18}\text{O}$ of the residual olivine should be lower than that of the original phyllosilicate by about 1‰. This is a relatively small perturbation in comparison with the difference of about 11‰ in the opposite direction between Murchison matrix and B-7904 matrix.

Thermal metamorphic effects may be very important for the isotopic composition of a minor phase, such as calcite. Table 2 compares the calcite/matrix data for B-7904 with those from Murchison. The very high $\delta^{18}\text{O}$ -value of calcite in Murchison was taken to indicate a low temperature of formation, near 0°C (Clayton and Mayeda, 1984). In B-7904, the calcite-matrix fractionation has been reduced to only 2‰, presumably as a consequence of exchange during metamorphism. Furthermore, the $\delta^{13}\text{C}$ -value of B-7904 is nowhere near the range typical of C1 and C2 chondrites, and may also have undergone metamorphic exchange with the abundant ^{13}C -poor carbon compounds in the meteorite.

In summary, the oxygen isotope data suggest that B-7904 was formed from a precursor material similar to that of typical C2 chondrites, but that aqueous alteration occurred in an environment of higher water/rock ratio, and progressed to a considerably greater degree than in typical C2 meteorites. Thermal metamorphism had only a minor effect on the isotopic composition of the matrix and bulk meteorite, but had effects on the oxygen and carbon isotopic compositions of the minor carbonate phase.

Table 1
Oxygen Isotopic Compositions of Components
of B-7904

Sample	Description	$\delta^{18}\text{O}$ (‰)	$\delta^{17}\text{O}$ (‰)
B1	Olivine fragment	4.69	1.22
B2	Olivine fragment	3.97	1.70
C1	Chondrule	3.56	-1.77
C2	Chondrule	3.71	-2.71
CC	Chondrule	8.38	2.10
D2	Inclusion	10.34	4.44
D5	Inclusion	13.08	5.71
Mx	Matrix	23.27	12.08
R1	Whole-rock	20.85	10.80
R2	Whole-rock	21.28	11.01
R3	Whole-rock	20.92	10.92

Table 2
Carbonate and Matrix in B-7904 and Murchison

	B-7904			Murchison		
	$\delta^{18}\text{O}$	$\delta^{17}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{17}\text{O}$	$\delta^{13}\text{C}$
Matrix	23.3	12.1		12.6	4.7	
Carbonate	25.5	—	5.6	35.1	16.7	38.0

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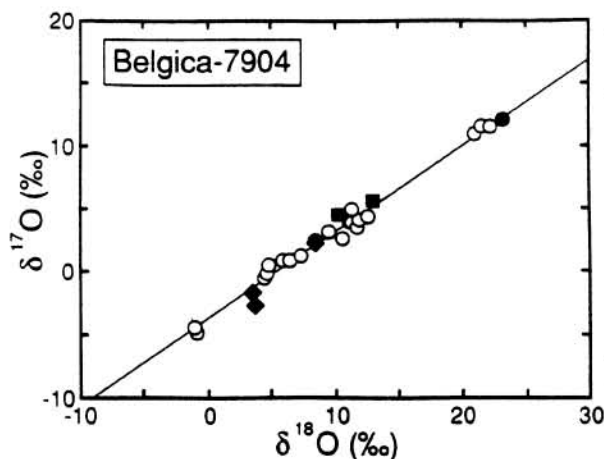


Fig. 1. Oxygen isotopic compositions of B-7904 components (filled symbols) compared to whole-rock compositions of several CM2 chondrites (open symbols). See Table 1 for data.