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VOID STRUCTURES IN OLIVINE GRAINS IN THERMALLY METAMORPHOSED ANTARCTIC CARBONACEOUS CHONDRITE B-7904

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Abstract: The Antarctic carbonaceous chondrite Belgica-7904 suffered thermal metamorphism. The main constituent phyllosilicates of this meteorite are serpentine and/or saponite, which display transformation from serpentine to olivine or from saponite to enstatite in various degrees (J. AKAI: Geochim. Cosmochim. Acta, **52**, 1593, 1988; Proc. NIPR Symp. Antarct. Meteorites, **3**, 55, 1990). Detailed Transmission Electron Microscopy (TEM) observation of this meteorite reveals characteristic void structures, which are found mainly in olivine grains. The voids or bubble-like structures are very frequently found in some grains. The shapes of the voids are varied. Some are irregular and some are crystallographically controlled. Five possible mechanisms for their origin are: 1) thermal metamorphism, 2) irradiation by high energy particles in the solar nebula, 3) shock effects, 4) sample preparation artifacts and 5) alteration process. Among five or more possible mechanisms, the voids mostly likely formed during thermal metamorphism or as a result of irradiation damages by high energy particles in the early solar system.

1. Introduction

Unique carbonaceous chondrites, Belgica (B)-7904 and Yamato (Y)-86720, Y-86162 and Y-793321, have been found in Antarctica. They have unique petrographic features and oxygen isotopic natures (KALLEMEYN, 1988; TOMEOKA *et al.*, 1989a, b; ZOLENSKY *et al.*, 1989; MAYEDA and CLAYTON, 1990; TOMEOKA, 1990; IKEDA, 1991; IKEDA, 1992; IKEDA *et al.*, 1992). The oxygen isotopic nature, mineralogy and chemistry of B-7904, Y-86720 and Y-82162 have characteristics of both CI and CM groups or intermediate features between the two. Furthermore, these three and Y-793321 carbonaceous chondrites experienced characteristic thermal metamorphism (AKAI, 1984, 1988, 1990) which has not been found from non-Antarctic carbonaceous chondrites except for equilibrated carbonaceous chondrites. Intermediate transitional structures in the transformation from serpentine to olivine was a characteristic of these meteorites (AKAI, 1988, 1990). Their maximum heating temperatures and the extent of thermal metamorphism were estimated using T-T-T diagrams that were experimentally obtained (AKAI, 1992a). The relative degrees of thermal metamorphism were estimated to be in the following order:

$$\text{B-7904} \geqq \text{Y-86720} > \text{Y-82162} > \text{Y-793321}.$$

HIROI *et al.* (1993) recently found similarity of reflectance spectra between C, G, B, F asteroids and thermally metamorphosed carbonaceous chondrites. Their results suggest that thermally metamorphosed carbonaceous chondrites are never exceptional types but played an important role in the process of early or later solar system formation.

Recently I found void structures in olivine grains in B-7904 during additional detailed Transmission Electron Microscopy (TEM) observations (AKAI, 1992b). This structure may also be related to the formation process of these "unusual" meteorites. The objective of this paper is to describe the void structures and to discuss their origin.

2. Specimens and Experimental Methods

Antarctic carbonaceous chondrite, B-7904, was used. The petrography and mineralogy of the specimen have already been reported (AKAI, 1988; ZOLENSKY *et al.*, 1989; KIMURA and IKEDA, 1992). Specimens used are all ion-thinned samples. They were prepared from the matrix in thin sections which were made from the samples supplied from NIPR (Sample numbers are as follows: Y-793321,853, Y-82162,92, Y-86720,84, B-7904,962). Specimens were examined by Transmission Electron Microscopy (TEM) and Analytical Electron Microscopy (AEM). Experimental procedures are the same as those in AKAI (1990, 1992).

3. Results and Discussion

Figure 1 is an EM image of the matrix texture of B-7904. This photograph shows the presence of heterogeneous aggregate of various mineral grains in the matrix. Void structures are widely found in olivines in this Antarctic carbonaceous chondrite B-7904.

Abundant void structures are characteristic of olivine crystals in B-7904. In many cases, the shapes of the voids are crystallographically controlled. The voids are usually found in olivine grains but in exceptional cases enstatite grains have small amounts of voids. Figure 2 shows a typical void structure in olivine grains in B-7904. Figure 3 shows an (020) lattice image of olivine in B-7904. This photograph shows that the shapes of the voids are crystallographically controlled. Figure 4 shows another type of void structure in B-7904. This EM image indicates that the void density is very high. Both relatively regular and irregular roundish types of voids are found. Voids in olivine and enstatite in Y-86720 and Y-82162 are not always definite. They will be reported later. Void structures are widely found in the B-7904, Y-86720 and Y-82162 Antarctic carbonaceous chondrites.

There are many possible causes which can form voids. The possible mechanisms to form the void structure are the following:

1) Thermal metamorphism, 2) irradiation by high energy particles in the solar nebula, 3) shock effects, 4) sample preparation artifacts and 5) alteration process.

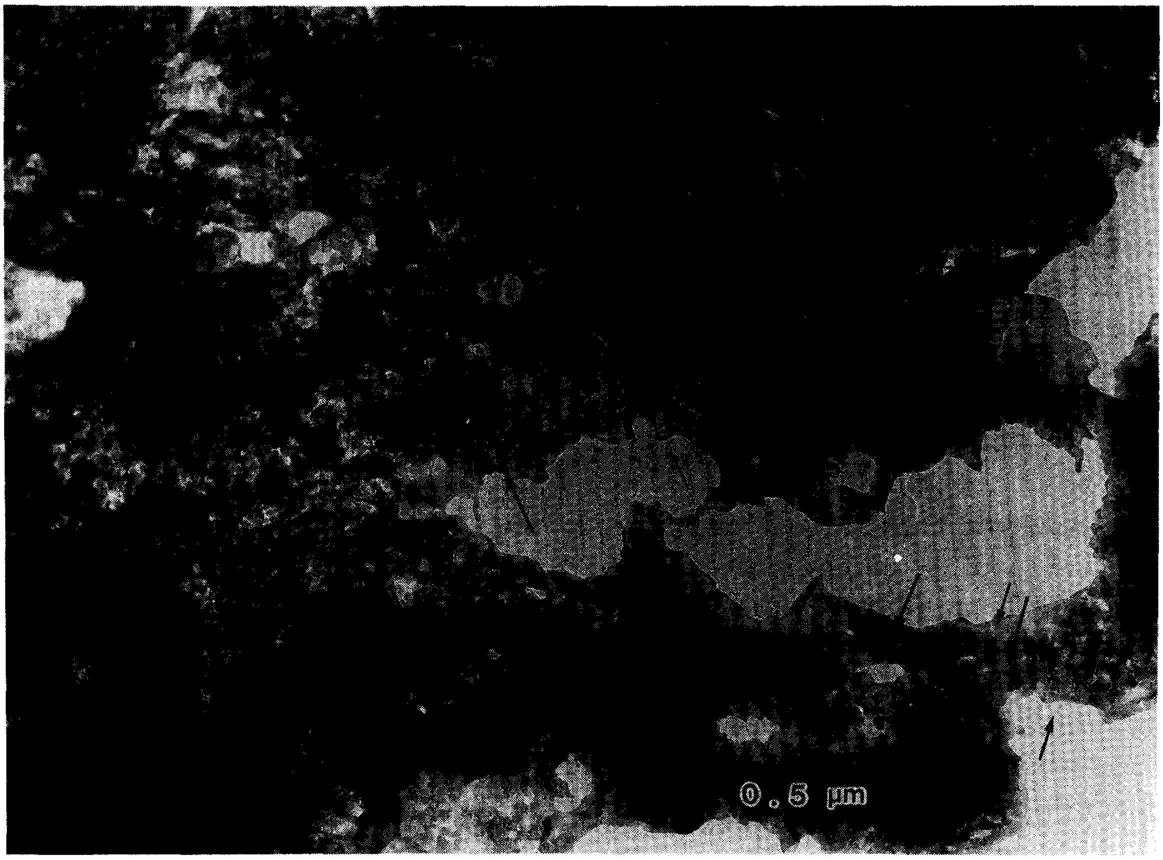

Fig. 1. Low magnification EM image of ion thinned specimen of matrix in B-7904. Heterogeneously aggregated minerals are found. Some voids or bubbles are indicated by arrows.

Possibility 4 can be eliminated because the voids are observed only in these thermally metamorphosed carbonaceous chondrites although the same ion-etching procedure was applied for every sample. In connection with possibility 3, KIMURA and IKEDA (1992) insisted on the basis of their chemical and textural observations that B-7904 had experienced shock events. However, possibility 3 is here considered to be small because the void structures are different from those produced by shock effects and because no other evidence of shock is found in the electron microscopic observations in this study. This possibility may still remain. Possibility 5 should also be very small because the textures are different from the alteration textures and no alteration products are present in adjacent positions to the minerals which include voids.

A possible cause of this texture may be related to heating events because these meteorites suffered thermal metamorphism to some extent. The void structures are not found in all the mineral grains but in olivine grains; this fact may not be consistent with the supposed irradiation, shock effects, artifacts and alteration process.

However, the texture is also very similar to the fine structure and textures found in metal specimens irradiated by high energy particles (*e.g.*, OHNUKI *et al.*,

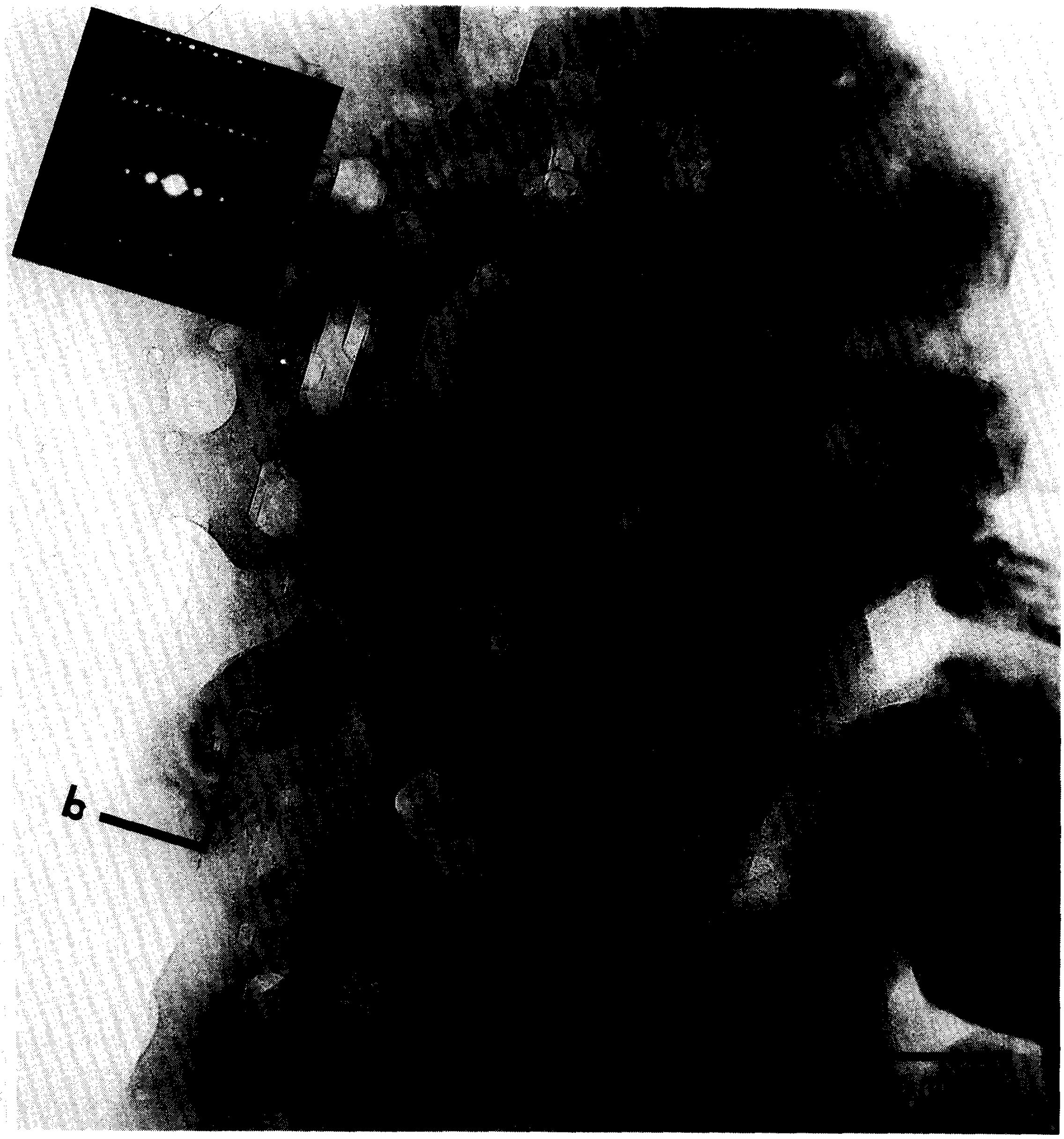

Fig. 2. An EM image of typical void structure in olivine in B-7904. Many voids are crystallographically controlled in shape.

1986, 1988, 1992; TAKAHASHI *et al.*, 1988). Thus, formation of the voids by irradiation is also a possibility. Possibility 2 cannot be eliminated completely.

The possibility of heating events which were experienced by B-7904 has been discussed by AKAI (1992a). Some of the observed void structures may be explained by heating events. The abundance and characteristics of such void structures are not unique but vary among the specimens with different degrees of thermal metamorphism. The degree of metamorphism in B-7904 is the strongest among the four carbonaceous chondrites. The void structure in B-7904 is the most abundant and has crystallographicaly well controlled shape. Y-86720 which experienced the second strongest heating, has small amount of void structures with ill crystallographically

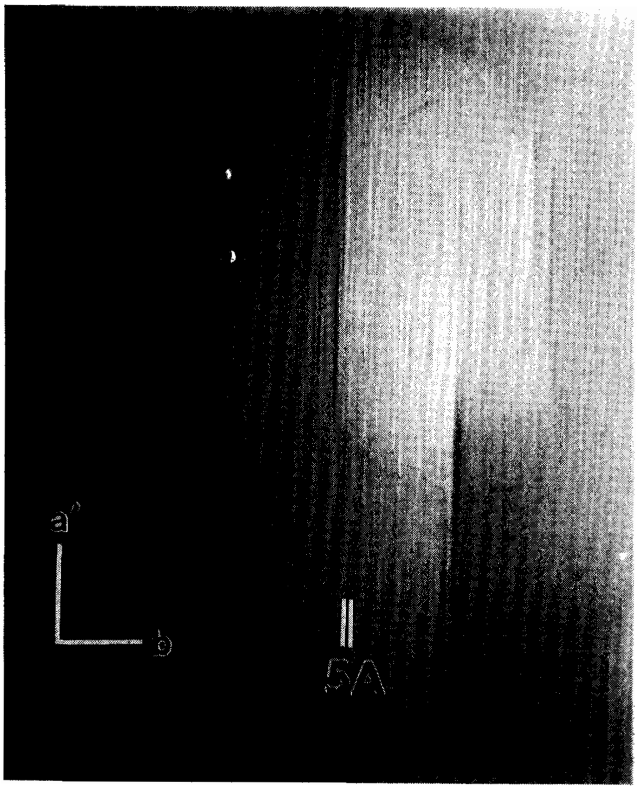

Fig. 3. An EM image of voids in B-7904. (020) lattice fringes of 5 A are found.

Fig. 4. EM image of matrix in B-7904, showing very frequent voids or bubbles.

controlled shape. Thus, the degrees correspond well to the character of the void structures. The transformation process of phyllosilicates has also been discussed using a schematic figure (AKAI, 1992a) in which a donor and acceptor region model is mentioned. The donor and acceptor region model implies material exchange between the decomposition region and neoformation region (BRINDLEY and HAYASHI, 1965). The donor region may correspond to a relatively vacant region because of supply of some materials. So, it is estimated that the donor and acceptor region structure model may be related to this void structures. Otherwise, olivine crystals which include void structures, were formed from porous phyllosilicate aggregates.

Natural irradiation damage by high energy particles (Possibility 2) may not be ignored in the early solar system. In this case, olivine grains with voids might have been formed in an isolated place because only olivine grains have voids.

Similar textures have not been found in artificially heated specimens of serpentine or saponite hitherto; however, heating durations of experiments are very short and may be different from the natural heating process. A combination of all the mechanisms described above may also be possible.

To ascertain these problems, more detailed examinations are necessary.

4. Summary

Characteristic void structures were found mainly in olivine grains in B-7904. Similar void structures were frequently found in the thermally metamorphosed carbonaceous chondrites. The shapes of the voids vary from irregular to crystallographically controlled. They may have formed during 1) thermal metamorphism, 2) irradiation by high energy particles in the solar nebula, 3) impact events, 4) sample preparation artifacts or 5) hydrous alteration. It is most likely that thermal metamorphism or irradiation was responsible.

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