Mineralogy of Y-981971 LL Chondrite and Brecciation Processes of the LL Parent Body.

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Introduction:

Because of the recent public interest in the returned dusts from the Itokawa by the Hayabusa Mission, we have a renewed interest in the LL chondrites, in order to better understand the geological processes on an asteroidal body. We performed mineralogical study on the Y-981971 LL chondrite and compared it with partly melted LL chondrites [1] to show that shock partial melting and recrystallization during breccia formation is extensive on the LL chondrite parent body. We will also compare zoning profiles of pyroxenes in totally melted LL chondrites including Y-790964 [2] with those in the Itokawa dusts [e.g. 3].

In some LL chondrites found in the Yamato Collection, we found the first evidence of a product of partial melting of the chondritic primitive solar system materials with albite and diopside assemblage in Y-74160 [1]. This material was produced by a shock partial melting, but we also found such material in the silicate inclusions in the IAB [4] and IIE iron meteorites [5]. Up to this study, eucrites have been thought to be the product of a partial melt product of the primitive solar system material, but we found the above material and stated that this is the first andesitic material with albite and diopside in the solar system other than the Earth.

We will perform mineralogical studies of the Y-981971 LL chondrite, which was described as LL6 breccia in the NIPR data base [6], to better understand surface materials of the Itokawa asteroid. We will look for the diopside-albite assemblage (andesitic material) together with olivine and orthopyroxene (Opx). When Y-793214 was displayed at the Chiba Museum of Sci. and Industry, together with the returned Hayabusa capsule, I had a chance to see a PTS of Y-793214. In this study, we will examine some LL chondrites with melted and metamorphosed materials, to show that the parent body of the Itokawa asteroid or a part of it is fairly processed materials, not in line with the primitive solar system materials.

Samples and Methods:

Three PTSs (polished thin sections) of LL chondrites Y-981971,51-1, Y-793214,92-1 (LL5), Y-790782,91-2, prepared at the NIPR [6] were observed by a petrographic microscope. Y-981971,51-1 was analyzed with a JEOL 8900 EPMA at AORI (Atomosph. Ocean Res. Inst.). Areal analyses of a region 30X40 microns of a granulitic clast were also obtained at AORI. 7 points were analyzed along the X and Y directions.

Results:

Y-981971,51-1 shows brecciation textures with many crystalline clasts (Fig. 1), which contain silicates with sub-rounded boundaries and a few opaque minerals filling interstices of silicate crystals (Fig.2). It is difficult to find remnants of chondrules, except for one part with metamorphosed barred olivine crystals (Fig. 3). Former matrices between the bars now show crystalline textures.

In a part of crystalline granulitic clasts, we found a sizable grain of albite in mafic silicates. In order to find the diopside-albite assemblage, we selected an area 30X40 microns above the irregular opaque grain in Fig. 2. Modal abundances of minerals obtained by the Arial analyses of JEOL 8900 EPMA along seven lines of the above area with 7 points along a line showed: Olivine 52.6%, Augite 40.0, Opx 5.3, albite 2.6, excluding a few low sum analyses of grain boundaries etc. The presence of augite and albite suggests the andesitic material. The Mg# (=MgX100/(Mg+Fe) mol %) of olivine is 68.4. Chemical composition of Aug is uniform ($Ca_{45.0}Mg_{44.5}Fe_{10.5}$), and Opx has composition $Ca_{2.7}Mg_{71.0}Fe_{26.3}$. The plagioclase in the clast has alkali-rich composition $Ab_{87.5}An_{10.8}Or_{19.4}$.

Y-793214,92-1 (1.4X0.8 cm in size) does not show a breccia texture, but the entire PTS retains a LL6-like texture. A part of the PTS, where an opaque vein with metallic luster runs 3.8 mm long and 0.3 mm width shows the granulitic texture similar to that of the crystalline granulitic clasts (Fig. 2) in Y-981971,51-1. Fine-grained silicate crystals distribute around large rounded grains of mafic silicates up to 0.6 mm.

Y-790782,91-2 (0.9X0.8 mm in size) consists of dark fine-grained mafic silicates and resembles devitrified glass. There is no metallic vein in this PTS, but metal spherules up to 7 mm in diameter distribute through out the PTS indicating total melting. The texture is different from Y-790964 [2].

Discussion:

In-situ observation and sample return from asteroid Itokawa by Hayabusa Mission, are revealing data which cannot be obtained either from ground-based observations or meteorite studies to unravel the origin of the solar system [7]. Nakamura and colleagues [3] show that almost all of the olivine and pyroxene grains are quite uniform in composition, and the entire collection falls almost entirely within the LL compositional field. The chemical composition of a pyroxene crystal (Fig. 2 C) [3] are zoned from $Ca_7Mg_{73}Fe_{20}$ to $Ca_{47}Mg_{44}Fe_9$. We recognized that this zoning profile is similar to that found in pyroxene crystals grown in totally molten LL chondrite, Y-790964 with vesicles [2] [8]. This zoning trend is different from that of the LL3 pyroxene (e.g.: Semarkona) [9]. This fact indicates that at least a part of the Itokawa asteroid body is melted by a shock event or other processes.

Our discovery of granulitic clasts with the diopside-albite assemblage indicates that there is an andesitic material in some parts of the parent body. During the initial stage of the Yamato Antarctic meteorite researches, we found some unique LL chondrite found in the Yamato Collection. We found the first evidence of the product of partial melting of the chondritic primitive solar system materials with albite and diopside assemblage. This material was produced by a shock partial melting, and some thermal events, but we also found such material in the silicate inclusions in the IAB [4] and IIE iron meteorites [5]. The amounts of these andesitic materials are larger than that of the LL chondrites, but the presence of the product of a partial melt in a chondrite parent body suggests that even the primitive solar system material, such as chondrites experienced strong thermal events.

The sampled material of Itokawa was thermally metamorphosed, as is the case for most ordinary chondrites. To be heated sufficiently, the samples must have originated inside a much larger asteroid. The granulitic texture in some lunar samples are widely believed to have formed deep in the lunar crust. The granulitic materials in the LL parent body may also have been formed in some depth of their parent body.

The microscopic textures of the LL chondrites, including Y-981971, Y-793214, Y-790782, and Y-790964 suggest extensive processes of melting and metamorphism even in a primitive parent body, comparable to some parts of lunar crust. It is important to recognize that such events took place in a region of the LL chondrite parent body, from where Itokawa and parent asteroids of the Antarctic meteorites were ejected. It is to be remembered that chondritic materials keep records of primitive solar system [7], but some parts are partly melted and heavily metamorphosed.

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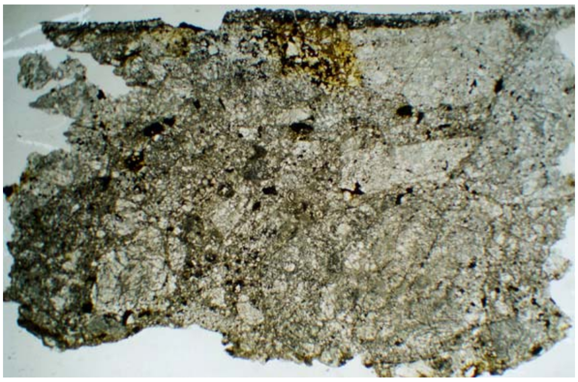

Fig. 1. The entire PTS view of Y-981971,51-1 LL chondrite of NIPR. Open light. Width is 1.2 cm.

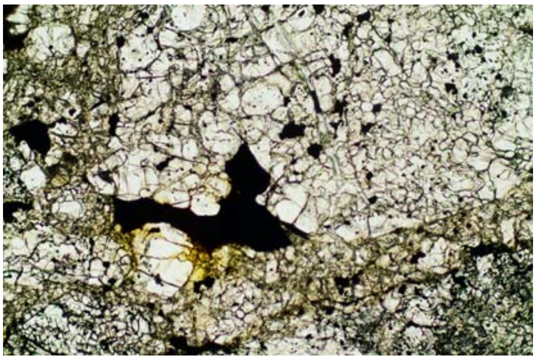

Fig. 2. Photomicrograph of a granulitic clast of Y-981971,51-1 Open, width 1.3 mm.

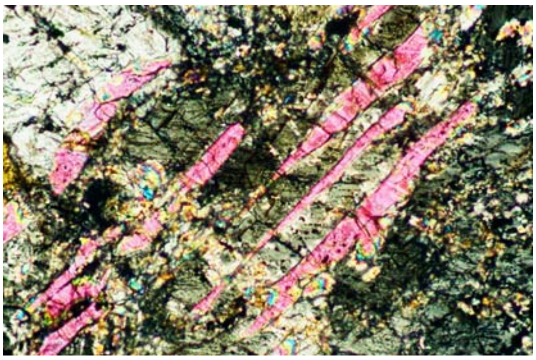

Fig. 3. Photomicrograph of barred olivines in Y-981971,51-1 PTS. Cross polar, width 1.3 mm.