

**Ar-Ar, I-Xe ages and shock textures of Northwest Africa 2139 LL6 chondrite:****Implications for shock history of LL chondrite parent body**

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**Introduction:** Since collisional records in meteorites reflect ancient asteroidal movement, we expect to describe asteroidal moving histories by revealing how and when collisional events occurred. Relations between shock features and pressure-temperature-time (P-T-t) path have been investigated from the 1960s [e.g., 1]. Shock chronology commonly adopted Ar-Ar technique because a high diffusion rate of Ar easily leads to lose radiogenic Ar during moderate shock heating [e.g., 2]. However, the number of studies combining detailed shock petrology and chronology is still limited [3-6]. Therefore, we need to conduct shock petrological-chronological studies on various types of meteorites. In this study, we reported both shock features and chronological data of the Northwest Africa (NWA) 2139 LL6 chondrite and discussed collisional histories of the ordinary chondrite parent body(ies).

**Sample and Methods:** NWA 2139 consists of two portions, visually light and dark parts. We prepared two thin sections from each portion for petrological observation by FE-SEM (JEOL JSM-7100F). Noble gases were analyzed using a noble gas mass spectrometer (modified-VG3600) [7]. For Ar-Ar and I-Xe analysis, aliquots from each portion were irradiated by neutron at the Institute for Integrated Radiation and Nuclear Science, Kyoto University. The Hb3gr hornblende and synthesized CaF<sub>2</sub> and K<sub>2</sub>SO<sub>4</sub> were simultaneously irradiated to monitor neutron flux and correct neutron-produced Ar interferences, respectively [8]. The Shallowater (aubrite) was also irradiated as an anchor of I-Xe age (4562.7±0.3 Ma) [9].

**Results:** Light portion is mainly composed of chemically homogeneous olivine, orthopyroxene, Fe-Ni metal, troilite and a small amount of albite. We cannot readily recognize chondrules and matrices indicating high-degree of thermal metamorphism. Constituent minerals such as albite, commonly show wavy extinction (not vitrified). Two types of shock veins were observed; one is thick (~400 µm) cataclastic vein containing fragments of mineral and matrices. The matrices display a fine-grained (~3 µm) granular texture accompanied by voids along grain boundaries. The fragments and surrounding minerals contain healed cracks. The other vein is thin (<10 µm) and composed of finer-grained or glassy matrices without voids. These thin veins sharply cut the other thick ones. Dark portion consists of fine-grained olivine-pyroxene fragments with scattered Fe-Ni metal and troilite, resulting from a brecciating process. Thin shock veins are texturally similar to the thin one in the light portion and cut the brecciated regions. Albite in dark parts also shows wavy extinction. We cannot find any high-pressure phases so far in this meteorite.

In Ar-Ar analysis, we cannot define “plateau ages” in neither light nor dark portions. In particular, Ar-Ar spectra from the dark portion are highly disturbed showing unrealistically old ages, which may be caused by recoil effect due to fine-grained (brecciated) texture. In the light portion, each Ar fraction indicates gas retention ages of 3.8-4.4 Ga. I-Xe analysis results in 4515.9±11.7 Ma and 4494.9±8.5 Ma for light and dark portions, respectively.

**Discussion:** Petrological observation revealed that the light portion in NWA 2139 experienced at least two shock events. The first and second shock events induced the thick and thin veins, respectively. The first shock may be intense and reset the I-Xe age at 4515.9±11.7 Ma. After the first shock, thermal modification by post-shock heating may have occurred, which resulted in healing cracks, annealing vein matrices and possibly devitrifying maskelynite. The Ar-Ar ages in high-temperature fractions (~4.4 Ga) may record this thermal event. The second shock occurred at 3.8 Ga or later inducing partial or no resetting of Ar-Ar ages. Brecciation may have happened between the thermal modification and the second shock event because both light and dark portions showed similar thin veins overwritten on brecciated texture and dark portion contains mineral fragments with healed cracks within less annealed matrices. This study indicates that the thermal modification after intense shock event may occur in the early stage of the LL chondrite parent body(ies) as pointed out by [6]. Since such thermal activity may erase shock features of hypervelocity impact, high-pressure phases could not survive even if they formed by the initial shock event at around 4.5 Ga. Since L chondrite which experienced a severe shock at ~0.5 Ga [3, 5, 10] commonly contains high-pressure phases indicating weak modification by post-shock heating, collisional conditions, such as impactor/target size ratios, should be different between early and late stage shock events on ordinary chondrite parent bodies.

**References:**

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