Shock pressure estimation by high-pressure polymorphs and cathodoluminescence spectra of maskelynite in Yamato-790729 L6 chondrite and their significance for collisional condition

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Most asteroidal meteorites have experienced impact events that occurred on their parent-bodies because shock-induced features (e.g., melting textures, high-pressure polymorphs and vitrification) provide clear evidences for impact events. L6 type ordinary chondrite frequently has a vein-like shock-induced melting texture (a shock-melt vein or shock vein). Furthermore, they may contain high-pressure polymorphs and shock-induced glasses (e.g., maskelynite) that were transformed from the constituent minerals (e.g., olivine, pyroxene and plagioclase) due to high-pressure and –temperature conditions induced by impact events. Such high-pressure polymorphs and shock-induced glasses provide constraints on the asteroidal impact history. In this study, Yamato (Y)-790729, which is classified as heavily shocked L6 type ordinary chondrites, was investigated to estimate the shock-pressure, temperature and size of the parent body, based on high-pressure polymorph assemblage and cathodoluminescence (CL) spectroscopy of maskelynite. The shock pressure conditions estimated by these two methods were also compared each other to evaluate the validity of the methods.
Y-790729 is a typical L6 ordinary chondrite with remnants of chondritic textures, and has a shock-melt vein. The host-rock of Y-790729 consists mainly of olivine, low-Ca pyroxene, feldspar, metallic Fe-Ni, and iron-sulfide with minor phosphate and chromite. Undulatory extinction was recognized in some plagioclase and pyroxene grains under the optical microscope. A scanning electron microscope (SEM) , laser micro-Raman spectroscopy and transmission electron microscope (TEM) equipped with an X-ray energy dispersive spectrometer (EDS) were carried out for this meteorite to determine the chemical composition, observe the petrological features and identify the high-pressure phases. Another SEM with a CL spectrometer was also conducted to characterize the shock metamorphic effects of the feldspar and maskelynite.
A shock-melt vein with a width of < ~620 μm exists in Y-790729. TEM observations and micro-Raman spectroscopy of this meteorites demonstrated that ringwoodite, majorite, akimotoite, lingunite, tuite, and xieite occurred in and around the shock-melt vein. The ringwoodite is polycrystalline assemblages under the TEM observations, where the individual grain reaches from ~0.1 to ~1.3 μm across. According to the phase equilibrium diagrams of these high-pressure polymorphs, the shock pressure in the shock-melt vein is about 14-23 GPa.
Part of plagioclase grains in the host-rock occurred as maskelynite under the optical microscope and Raman spectroscopy. Sixteen different CL spectra from maskelynite portions of Y-790729 showed characteristic emission bands at ~330 and 380 nm. The obtained CL spectral data of maskelynite portions

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were deconvoluted into three emission components at 2.95, 3.26, and 3.88 eV. The intensity of emission component at 2.95 eV was selected as a calibrated barometer to estimate shock pressure, and the results indicate shock pressures of about 11-19 GPa. The difference in pressure between the shock-melt vein and host-rock might suggest heterogeneous shock conditions.
Assuming an average shock pressure of 18 GPa, the impact velocity of parent-body of Y-790729 is calculated to be ~1.90 km/s. The melting temperature of the shock vein could be about 2173 K at 18 GPa, according to previous data obtained from the KLB-1 peridotite and Allende meteorite. It is likely that the duration of high-pressure and -temperature conditions recorded in the shock-melt veins of Y-790729 is several seconds, implying that the parent-body size is ~ 10 km in diameter at least, based on the incoherent formation mechanism of ringwoodite in Y-790729.

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