Abstract

The study of shock metamorphism of extraterrestrial planetary materials via meteorite samples has become a vital part of high-pressure research in the last few decades and has contributed to several discoveries of high-pressure phases that are otherwise rare or practically non-existent. Furthermore, natural impact events create extreme juxtapositions of pressure, temperature, and time which are still not possible to recreate in laboratory simulations. In this thesis, I investigated the heavily shocked Katol and Kamargaon L6 chondrites.

The analysis of the Kamargaon meteorite revealed the first natural occurrence of dissociated olivine by incongruent melting in an ordinary chondrite. The dissociation of olivine into bridgmanite and magnesiowüstite is one of the most crucial reactions in the lower mantle that vastly affects the physical and chemical properties of the Earth's interior. This dissociation assemblage can occur either by a solid-state transformation or by incongruent melting and both mechanisms of dissociation reaction have only been reported in a few Martian meteorites (DaG 735, NWA 2737, and Tissint). Recently, Bindi et al., (2020, Science Advance) reported the dissociation of Fe-rich olivine to hiroseite (Fe-rich bridgmanite) and ferropericlase by the solid-state transformation in the Suizhou L6 chondrite. However, no such dissociated assemblage by incongruent melting is reported in any meteorite from asteroids. Therefore, the occurrence of such textures in the Kamargaon L6 chondrite and their spatio-temporal relation with other textures may provide important clues to discern the shock history, P-T-t path, and the dynamic events experienced by its parent body.

Furthermore, I carefully examined the shock-melt vein (SMV) of the Kamargaon chondrite in detail to understand the dissociation and melting textures

displayed by the silicate phases present and their formation mechanisms which provide further clues to estimate the shock conditions in the chondrite parent body. Here, I found the first occurrence of vesicular olivine and pyroxene in an ordinary chondrite. I also investigated the occurrence of high-pressure minerals, and back transformation textures in an SMV of the Kamargaon L6 chondrite and calculated the shock-pulse duration required to produce the mineral assemblage. Based on these calculations, I further calculated the impact velocity and parent body size of the Kamargaon L6 chondrite. Kamargaon meteorite displays the first occurrence of vesicular olivine and pyroxene in an ordinary chondrite which opens up a new window to the understanding of the dynamic effects of impact events on their parent bodies. Vesicle formation in terrestrial lava flows is a common phenomenon but is rarely seen in meteorites mainly owing to the sheer contrast in the physical environmental inputs that contribute to the vesicle formation on the Earth. The textural evidence indicates multiple impacts origin of the sample. Therefore, the occurrence of such textures in Kamargaon chondrite and their spatio-temporal relation with other textures provide important clues to discern the shock conditions, P-T-t path, and the dynamic events experienced by its parent body.

I describe the first natural occurrence of Fe-bearing aluminous bridgmanite, in shock-induced melt veins of the Katol L6 chondrite. Bridgmanite, the most abundant mineral of the Earth's lower mantle, has been reported in a few shocked meteorites, however, the composition of these occurrences deviates from the compositional values that have been predicted for terrestrial bridgmanite. The Katol bridgmanite contains significant amounts of ferric iron and shows a strong preference for ferric iron as compared to coexisting majorite which agrees well with previous experimental studies. Moreover, I present a detailed analysis of the composition, texture, and growth kinetics of ringwoodites found in and around shock-melt veins in the Katol L6 chondrite.

Through our textural and compositional analysis, I show that the solid-state polymorphic transformation of parent olivine resulted in the formation of ringwoodite via homogeneous intracrystalline interface-controlled nucleation and growth. Furthermore, I employ temperature-time history and growth rate analysis to constrain the high-pressure pulse duration and infer the superheating of shock-induced melt in the chondrite. Our results suggest that the shock-induced chondritic melt in the sample was superheated to at least 2700 K and that the temperature of the melt strongly controls the growth rate and grain size of ringwoodite. Our findings have important implications for understanding the thermal history and evolution of planetary interiors. I demonstrate that high temperatures around thermal perturbations may enhance the growth rate of polymorphic phase transformations, which in turn controls the grain size and rheological properties of planetary interiors.