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PREFACE

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Preface for article collection "Thermal, dynamical, and chemical processes in our early Solar System"

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Preface

Meteorites from asteroids, the Moon and Mars, as well as lunar and terrestrial impactites contain detailed records of the formation and early evolution of our Solar System and high energy dynamic processes on the celestial bodies. Primitive chondrites consist of various assemblages and provide a record of the physicochemical conditions and processes in the protoplanetary disk. Microstructures and shock-induced high-pressure phases found in meteorites, lunar samples, and terrestrial impact craters provide critical constraints to the history, dynamics, and kinetics of shock events. This SPEPS volume contains research topics related to mineral phase and micro-texture analysis, chemical and isotope compositions, and P-T-t path of terrestrial and extraterrestrial samples.

Hypervelocity impacts have been a major geologic process in the Solar System and its impact history is recorded in the meteorite shock effects. This volume contains five articles related to shock metamorphism and high-pressure minerals. Miyahara et al. (2021) provide a comprehensive review of the high-pressure minerals that occur in shocked meteorites and terrestrial impactites. Starting with the discovery of coesite and stishovite at meteor crater, they review the synthesis of high-pressure phases and the discoveries and naming of natural high-pressure minerals in meteorites and terrestrial samples. They note the recent acceleration of new mineral discoveries brought about by the development of new tools and describe the many new minerals discovered, including elgoresyite (Bindi et al., 2021a).

Stagno et al. (2021) present a study on the compression of icosahedrite, a natural quasicrystalline material found in the Khatyrka meteorite. Stagno et al. compressed synthetic icosahedrite up to 76 GPa in a diamond anvil cell to measure its compressibility and determine its stability at high pressure. They confirmed the pressure stability of this material and obtained compression data and EoS parameters consistent with other previous compression studies.

Ohtani et al. (2022) report shock experimental results on BCC iron to explore the formation of Neumann band twining in iron meteorites. This paper presents results from three shock experiments on pure body-centered cubic (BCC) iron with starting temperatures of 300, 670, and 1100 K. They also used the iSALE impact software to model the pressure and temperature distributions in each sample. They find that Neumann bands form at pressures from 1.5–2 to 13 GPa in 300 and 670 K samples. At higher pressures, the microstructures are dominated by flow banding and at 1100 K, Neumann bands are either not formed or not preserved.

Kubo et al. (2022) report experimental research into back transformation of high-pressure minerals at elevated temperature and pressure. The preservation of metastable high-pressure minerals in shocked meteorites and in diamond inclusions requires P-T paths that avoid conditions of back transformation. They used in situ high-pressure experiments to measure back transformation rates for ringwoodite, bridgmanite, and lingunite from 0.5 to 7.5 GPa. Their results provide important constraints on the preservation conditions for these minerals and show that the preservation of bridgmanite is very difficult in shocked meteorites.

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Hu and Sharp (2022) use shock temperatures and release paths to constrain conditions of formation, preservation, and extinction of high-pressure minerals in shocked meteorites. They calculate shock temperatures for chondritic and basaltic compositions and release paths from those conditions and for shock melt. With P-T constraints, they discuss the conditions required to form high-pressure minerals and likely P-T-t paths experienced during quench and release. They discuss high-pressure minerals in a variety of samples and conclude that high-pressure minerals associated with S6 shock melt require rapid thermal quench from moderate S4 shock conditions.

This volume contains four articles about petrology and chemistry of enstatite and carbonaceous chondrites. Hammouda et al. (2022) analyzed rare-earth element (REE) abundances in oldhamites (CaS) from EH and EL chondrites. In EH3, CI-normalized REE patterns are convex downward with strong positive Eu and Yb anomalies, whereas EH5 display flat patterns with enrichments reaching about 80 times CI abundances. The patterns reflect the condensation process in EH3, whereas those in EH5 chondrites suggest thermal metamorphic process. All the oldhamites from EL3-6 chondrites display a single kind of patterns with a negative Eu anomaly suggesting that these have experienced magmatic events.

Kimura et al. (2021) studied an EL3 fragment in Almahata Sitta polymict breccia. This fragment shows a typical type 3 chondritic texture with EL chondritic minerals. However, the mineral abundances and compositions are different from the other EL3s. The major pyroxene is orthoenstatite, and the silica phase is quartz. Troilite is enriched in Cr and Mn. These observations indicate that this fragment experienced a high-temperature event under subsolidus conditions by shock event. It is probable that some other E3 chondrites also experienced similar heating events on their parent bodies.

Lin (2022) showed that unusual minerals in enstatite chondrites, such as Si-bearing metal and phosphide, record the nebular processes and the thermal metamorphism in asteroidal bodies under extremely reducing environments. EH3s and EL3s show distinct mineral compositions, which reflect their different oxygen and probably sulfur fugacities during condensation. Most sulfides condensed from the nebula, with a fraction of troilite via sulfurization of metallic Fe–Ni. Minor exotic components, Ca-, Al-rich inclusions and FeO-rich silicate clasts, are suggestive of migration of dust in the protoplanetary disk. The highly reducing conditions might be established via repeating evaporation and condensation of water ice and organic matter across the snow line along the protoplanetary disk. Both the authors in this volume, Lin and Kimura, once studied enstatite chondrites with Ahmed El Goresy at Heidelberg, Germany.

Krot et al. (2021) investigated metasomatism of the Allende Ca-, Al-rich inclusions. The alteration affected primary minerals, and many secondary minerals formed, such as nepheline and ferroan olivine. Oxygen isotopic compositions of secondary minerals plot along mass-dependent fractionation line with $\Delta^{17}O$ of $\sim -3 \pm 2‰$. Allende CAIs experienced an open-system in situ metasomatic alteration at relatively high temperatures (200–250 °C) in the presence of CO_2- and H_2O-bearing fluid followed by thermal metamorphism at $\sim$ 500 °C on the CV chondrite parent asteroid. The alteration occurred after nearly complete decay of ^{26}Al, > 3 Ma after crystallization of CAIs.

This volume contains two articles related to the topic on early earth and planetary formation. Borgeat and Tackley (2022) have examined the influence of Hadean to Eoarchean impacts on subduction and plate tectonics, and mantle mixing using three- and two-dimensional numerical models. The simulations provided the following important conclusions. Impacts can have a huge effect on global tectonics, inducing subduction and resulting in a higher surface mobility, greater crustal production, and greater recycling of crust. Subduction is a direct consequence of impacts and after the impact flux terminates, subduction stops, and the system returns to being stagnant lid. Thus, impacts do not influence the long-term tectonic mode: they cannot permanently start plate tectonics.

McDonough and Yoshizaki (2021) present compositional models for the terrestrial planets showing that their core mass fractions, and uncompressed densities correlate with their heliocentric distance. They presented a simple model related to the magnetic field strength in the protoplanetary disk, i.e., the distribution of iron in terms of increasing oxidation state, aerodynamics, and a decreasing magnetic field strength outward from the Sun lead to decreasing core size of the terrestrial planets with radial distance. This distribution may be applicable also to exoplanetary systems.

This SPEPS volume is dedicated to late Prof. A. El Goresy who accomplished outstanding achievements in meteoritics and high-pressure mineral physics and made excellent contributions to better understanding of cosmochemical processes in the early solar system. His research focused on minerals and mineral assemblages from terrestrial impactites to extraterrestrial samples covering a wide range of solar system evolution, which is the topic of this SPEPS. Prof. El Goresy passed away on October 3, 2019, at the age of 85.

Because of his many contributions to high-pressure mineralogy and understanding of shock processes in meteorites, Prof. El Goresy has been honored in the naming of a new high-pressure mineral "elgoresyite" (Bindi et al. 2021a). Elgoresyite was identified in close association with ringwoodite in a thin shock vein within the Suizhou L6 chondrite. Elgoresyite $(Mg, Fe)_5Si_2O_9$, which is isostructural with Fe_7O_9, is monoclinic *C2/m*. Bindi et al. (2021b) proposed that a similar series of $(Mg, Fe)O + SiO_2$ structures may be important in the mantles of planets with (Mg + Fe)/Si higher than that of Earth.

This issue celebrates the breath and impact of Prof. El Goresy's research, the training and collaboration with international scientists including many early career researchers, and his inspirational influence on the community in meteoritics and planetary science.

Acknowledgements
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