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DISSOLUTION OF LIGHT ELEMENTS INTO IRON DURING THE EARLY EARTH'S EVOLUTION

The current Earth's core is considered to be several percent less dense than pure Fe, which is its main component. To account for this density deficit, light elements such as H, C, O, Si, and S are thought to be dissolved into Fe. The primitive atmosphere supplied a large amount of water vapor to the Earth's interior although its amount and the timing of the supply to the primitive Earth are still unknown. Hydrogen (H) is one of the promising candidates for the light elements, which can be incorporated into solid Fe and form Fe hydrides (FeH_x, x is H concentration) under high pressure and high temperature (*HP–HT*). However, because this lightest element cannot be directly detected by X-ray, it has been difficult to determine its site occupancy in the structure of Fe.

Neutrons are very powerful probes for observing light elements because the neutron scattering power is independent of atomic numbers, and they are complementary to X-rays, which are sensitive to heavy elements. We have directly observed dissolution of H into Fe using in situ neutron diffraction measurements. Our previous study (Iizuka-Oku et al. 2017) on the Fe–$MgSiO_3$–H_2O system, which simulates the ideal composition of the primitive materials, suggested that H had preferentially dissolved into solid Fe in the early stage of Earth's evolution. However, several light elements should exist in the current core. But those mutual interactions have been unclear. We, therefore, focused on sulfur (S) and investigated its effect on the hydrogenation of iron (Iizuka-Oku et al. 2021).

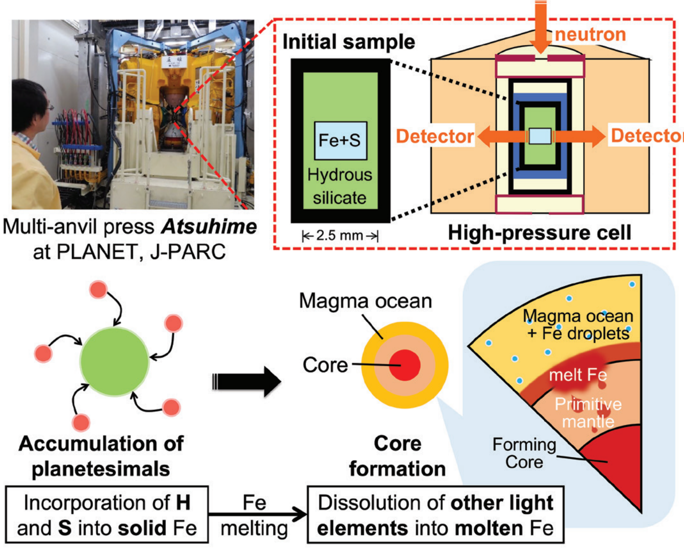

FIGURE 1 (UPPER LEFT) In-situ neutron diffraction experiments at PLANET beamline, J-PARC. (UPPER RIGHT) Cross section of high-pressure cell and path of pulsed neutron. Incident neutron beam passing though the cell irradiated the sample, diffracted neutron was detected with two detectors at 90 degrees. (LOWER) Scenario of the primitive Earth's formation. The amount of water and its origin as H source is a key factor for understanding dissolution process of light elements into the core.

In situ neutron diffraction experiments were conducted using a combination of pulsed spallation neutrons and the multi-anvil high-pressure apparatus *Atsuhime* installed at the PLANET beamline (Sano-Furukawa et al. 2014; Hattori et al. 2015) in J-PARC, Tokai (Japan) (FIG. 1 UPPER). As a starting material, an iron-enstatite ($MgSiO_3$) system with saturated water with/without S was prepared. A pellet of Fe powder was placed in the center of the capsule and surrounded by a powder mixture of quartz (SiO_2) and deuterated brucite $Mg(OD)_2$. Deuterated substitutes have conventionally been used for neutron studies to reduce the high background caused by incoherent scattering of H in diffraction patterns. The diffraction data obtained at 6–12 GPa up to ~1,200 K were refined to determine the D site occupancies in the structures of deuterated Fe and FeS. As the temperature increased at high-*P*, a series of reactions occurred: several phase transitions of Fe, dehydration of $Mg(OD)_2$, and the formation of FeS (*HP–HT* phase) and silicates. High-*P* phases of Fe were deuterated by redox reaction with water dehydrated from brucite, forming iron deuterides (FeD_x). The D concentration (x) in FeD_x increased with pressure and temperature. In contrast, FeS was hardly deuterated until the deuteration of Fe was completed. The D concentration in FeD_x of the initial sample without S was higher than that of the sample containing S, but did not exceed the miscibility gap ($x < 0.4$). This suggests that the deuteration/hydrogenation of Fe is suppressed by S (FeS). The present results for the samples containing brucite differed from those of previous study for hydrogenated FeS alloys in FeS–H_2 system (Shibazaki et al. 2011). This is probably because water derived from hydrous minerals affects the mechanism and reaction rate of Fe hydrogenation as well as the phase equilibrium between FeDx and FeS.

We revealed that both H and S are preferentially incorporated into solid Fe, which is stabilized as FeH_x and FeS before melting in the very early stages of Earth's evolution (the accretion of planetesimals). These two light elements substantially lowered the melting temperature of the Fe–FeS system and promoted the dissolution of the other light elements into molten FeH_x and/or FeS during the subsequent core–mantle formation process (FIG. 1 LOWER). Next, it will be necessary to clarify the behavior and interaction of multi light elements in molten Fe under much higher *P–T* conditions corresponding to the formation of the core of the Earth and other planets.

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Iizuka-Oku R and 5 coauthors (2017) Hydrogenation of iron in the early stage of Earth's evolution. Nature Communications 8: 14096, doi: 10.1038/ncomms14096

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Original Articles

Fe–rich olivine from an andesite dike in Miocene Shitara volcanic rocks, central Japan: a revised relationship between Mg/Fe ratio and Raman spectrum in olivine – Masaki ENAMI, Aya NISHII, Takashi MOURI, Motohiro TSUBOI, Yui KOUKETSU

Sulfur, carbon and oxygen isotopic compositions of Newania carbonatites of India: implications for the mantle source characteristics – Anupam BANERJEE, M. SATISH–KUMAR, Ramananda CHAKRABARTI

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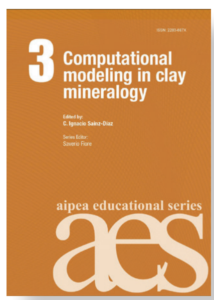
Reiner Dohrmann

Peter Ryan

The past one-and-a-half years living with the SARS-CoV-2 virus (COVID-19) and without having in-person meetings are now almost over. It has been a challenge. But, as an upside, we have improved our video conferencing techniques for meetings, particularly in offering ways by which our younger generation can have intensive discussions with scientists in our interdisciplinary clay world.

The AIPEA is striving to serve clay societies in these hard times by establishing an early career clay scientists (ECCS) network for scientists within 5 years of completion of their PhD. We also serve the National Clay Groups by offering them a free-of-charge website in English: good examples of which are the Israeli Society for Clay Research (https://israel.aipea.org/) and the Clay Science Society of Japan (CSSJ) (https://japan.aipea.org/). After a secret vote, members supported to legally register AIPEA as a non-profit society, and this process was finished in 2020, making AIPEA a registered society based in Spain.

Computational Mineralogy in Clays is the third volume in the AIPEA Educational Series (AES). This follows volume 1 (*Interstratified Clay Minerals*) and volume 2 (*Magnesian Clays*). The organization of the chapters in volume 3 follow the didactic approach of the 3rd AIPEA School for Young Scientists (ASYS) convened 15–16 July 2017 at the Andalusian Institute of Earth Sciences (CSIC-UGR, Granada, Spain). The book can be downloaded free of charge at https://aipea.org/publications/.



News on Conferences and Field Trips on Clay Minerals Around the World is Available at www.aipea.org.

Peter Komadel was an internationally distinguished clay scientist who passed away peacefully on 27 February 2021 in Bratislava (Slovakia) at the age of 65. Peter was widely recognized and greatly appreciated in the international clay research community because of his scientific contributions and friendly personality. He will forever be remembered as an outstanding scientist and researcher, but above all as a principled and kind man. Many people still remember when they met Peter for the first time. The AIPEA expresses its gratitude for Peter Komadel's warm cooperation and his clear views, particularly on international cooperation and the needs of young researchers.

The 64th Annual Meeting of the Clay Science Society of Japan (CSSJ) has been rescheduled for September 2021. The CSSJ did, however, hold elections for officers and announce award winners. Those elected included Toshihiro Kogure (President), Masaharu Nakagawa and Hiroyuki Chino (Vice Presidents), and Tsutomu Sato (Secretary). The Clay Science Society of Japan Award was given to K. Tamura; the Achievement Award to S. Wada; the Astec Co., Ltd. Young Researcher Award to H. Mukai; and the Best Technological Award to Hazama Ando Corporation. Best Paper Awards were given to J. Kemi et al. (*Clay Science* 23: 31-39) and M. Okawara et al. (*Clay Science* 23: 19-24). The Young Student Award went to K. Arakawa.

The Nordic Clay Meeting was held 8–10 February 2021 and was organized by the Latvian Clay Science Society. It was convened online and was attended by 40 delegates; the book of abstracts and program, and details on the plenary speakers and organizers, can be found on the conference website (https://www.latclay.lv/konferences/nordic-clay-meeting-2021/). This was the first known meeting of the Nordic group since 2001, and we hope that the 2021 conference inspires regular cooperation and exchange among Nordic scientists involved with clay mineral studies.

It is time to start making plans for the 17th International Clay Conference in Istanbul (Turkey) in July 2022! This meeting will have over 30 thematic sessions, plus field trips, workshops, and tours. We look forward to seeing you there.

Peter Ryan (Secretary)
Reiner Dohrmann (President)

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Ferriprehnite, $Ca_2Fe^{3+}(AlSi_3)O_{10}(OH)_2$, an Fe^{3+} analogue of prehnite, from Kouragahana, Shimane Peninsula, Japan – Mariko NAGASHIMA, Daisuke NISHIO–HAMANE, Shuichi ITO, Takahiro TANAKA

Quantitative and semi-quantitative analyses using a portable energy dispersive X–ray fluorescence spectrometer: Geochemical applications in fault rocks, lake sediments, and event deposits – Takahiro WATANABE, Chikako ISHII, Chika ISHIZAKA, Masakazu NIWA, Koji SHIMADA, Yuki SAWAI, Noriyoshi TSUCHIYA, Tetsuya MATSUNAKA, Shinya OCHIAI, Fumiko W. NARA

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Letters

Orthopyroxene–magnetite symplectite in olivine gabbros from the lower crustal Oman Ophiolite: Oman Drilling Project, Hole GT2A – Sayantani CHATTERJEE, Debaditya BANDYOPADHYAY, Eiichi TAKAZAWA, Katsuyoshi MICHIBAYASHI

Redistribution of magnetite during multi-stage serpentinization: Evidence from the Taishir Massif, Khantaishir ophiolite, western Mongolia – Otgonbayar DANDAR, Atsushi OKAMOTO, Masaoki UNO, Noriyoshi TSUCHIYA