THE ADVANCED PHOTON SOURCE

Investigating the Interiors of “Super-Earths”

$MgSiO_3$ perovskite, also known as bridgmanite, is thought to be the most abundant mineral in the Earth’s lower mantle. At the high pressures and temperatures of the lowermost mantle, about 150 km below the Earth’s surface, bridgmanite undergoes a phase transition, or a rearrangement of its structure, into a phase known as post-perovskite (pPv). Although pPv is most likely the final silicate phase in the Earth’s interior, other “post-post-perovskite” phases may exist in the interiors of much larger rocky planets (“super-Earths” up to ~10 Earth masses in size) recently discovered outside our solar system. Laboratory experiments to replicate the interior conditions of these giant planets (up to ~4000 GPa , ~10,000 K) are extremely challenging and generally beyond the reach of even state-of-the-art experimental techniques for static compression, so experiments using analogs of bridgmanite that might display similar phase transitions but at lower pressures and temperatures must be used.

One of these suitable analogs is neighborite, or $NaMgF_3$. Scientists used the APS to probe the structural changes of neighborite i*n situ* at extreme conditions. $NaMgF_3$ adopts the perovskite (Pv) structure at ambient pressure and undergoes a pressure-induced phase transition to a pPV form at only 19 gigapascals (GPa) at room temperature, compared to ~125 GPa and 2000 K for bridgmanite. Determining what phase transitions neighborite undergoes as pressure and temperature increase could provide insight into bridgmanite’s post-post-perovskite phases.T

The researchers placed neighborite into a diamond anvil cell and collected x-ray diffraction (XRD) data *in situ* at high pressure and temperature at the GeoSoilEnviroCARS 13-ID-D beamline at the APS. At room temperature and 13 GPa, the XRD patterns matched those of neighborite’s Pv structure identified in previous studies. Upon further compression to 40 GPa, the diffraction pattern changed, indicating a pressure-induced phase transition. They were able to index this pattern to a pPv structure identified in a previous study.

When the pressure was held at ~90 GPa and the temperature at ~2590 K, an NaF peak appeared in the diffraction results, suggesting that the compound had at least partially dissociated. This diffraction pattern remained stable at ~134 GPa, but changed again at ~162 GPa at ~1830 K, with indexing suggesting that this sample contained a mixture of NaF and MgF2. Figure 1 shows the proposed phase diagram in $NaMgF_3$.

The results show that neighborite undergoes multiple pressure-induced phase transitions and decomposes into a mixture of binary fluorides. These results using neighborite as an analog could aid in understanding the possible phase transitions and their effects in the interiors of super-Earths.

— Christen Brownlee

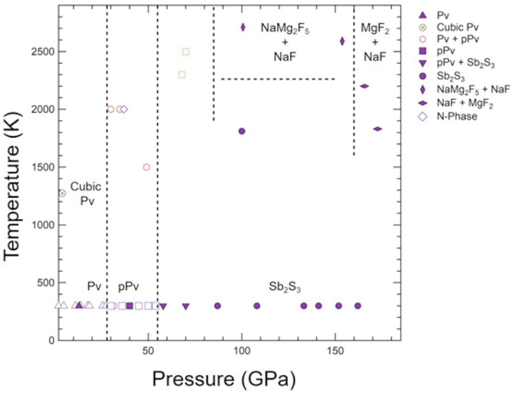

Fig 1. Summary of constraints on the high-pressure-temperature phase diagram of $NaMgF_3$. Solid symbols (triangles: perovskite, star: post-perovskite, circles: Sb_2S_3, inverted triangle: pPv + Sb_2S_3, vertical diamonds: $NaMg_2F_5$ + NaF and horizontal diamonds: NaF + MgF_2) represent present experimental data. Open symbols red, blue, and green show experimental literature data for respective phases. Brown open circle indicates high-temperature cubic phase. Dashed black lines are schematic phase boundaries. From R. Dutta et al., Proc. Natl. Acad. Sci. U.S.A. **116** (39), 19324 (2019). ©2019 National Academy of Sciences

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