

## Bridgmanite across the lower mantle

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1585-2022 Check for updates

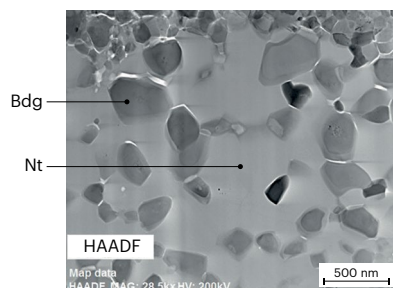
**Earth's most abundant mineral – bridgmanite – lies hidden in the lower mantle, but Li Zhang is hopeful that advances in analytical techniques may reveal the inner workings of our world.**

Extending from 670 km depth to the core–mantle boundary at 2900 km, the lower mantle comprises more than half of our planet by volume. The composition of this enigmatic region is dominated by bridgmanite ((Mg,Fe)(Fe,Al,Si)O<sub>3</sub>) – a magnesium silicate in the perovskite structure of ABX<sub>3</sub>, where A and B are cations and X an anion – likely making it the most abundant mineral on Earth<sup>1–3</sup>. Despite its dominance on Earth, it was only named in 2014 after it was isolated and identified in a meteorite<sup>4</sup>.

The transition of ringwoodite – a high pressure magnesium silicate – to bridgmanite marks the bottom of the mantle transition zone and the start of the lower mantle. Deeper into Earth's mantle, models of the lower mantle have been built on the assumption that bridgmanite remains unchanged down to the lowermost portion of the mantle known as the D'' layer, at some 2,700 km to 2,900 km depth.

However, the lower mantle might not be as homogenous as previously thought. Seismic data suggest the existence of two broad regions with lowered shear-wave speeds beneath the African and Pacific<sup>5,6</sup>, interpreted as a major chemical and/or phase transition in the middle of the lower mantle. The edges of these regions coincide with the reconstructed locations of large igneous province eruption sites, which may suggest deep-rooted plumes upwelling from the core mantle boundary<sup>7</sup>. Geochemical evidence indicates that primitive reservoirs of volatile components, including H<sub>2</sub>O, may be preserved in the deep mantle<sup>8</sup> and could impact the physical and chemical properties of the region.

The presence of H<sub>2</sub>O determines the stability of major silica phases that coexist alongside bridgmanite in subducted oceanic crust (Fig. 1). Under water-rich conditions, alumina-rich niccolite-type silica stabilizes while CaCl<sub>2</sub>-type silica is more stable in dry systems<sup>9</sup>. The



**Fig. 1 | The presence of H<sub>2</sub>O determines the stability of major silica phases and affects the chemical composition of coexisting bridgmanite.** Coexistence of bridgmanite (Bdg) and NiAs-type silica (Nt) in experimental simulations of water-rich subduction at conditions corresponding to about 2,000 km. Figure adapted with permission from ref. <sup>9</sup>, AGU.

different phase assemblages obtained from hydrated and dry basaltic compositions provide a plausible explanation for the heterogeneities observed in the deep lower mantle<sup>6</sup>.

Further, the chemical composition of bridgmanite itself changes in the presence of water (as well as with increasing pressure–temperature). The Fe<sup>3+</sup> concentration of bridgmanite is coupled to Al<sup>3+</sup> content<sup>10</sup> so, as Al<sup>3+</sup> preferentially partitions into coexisting hydrous phases<sup>9,11</sup>, Al<sup>3+</sup>-depletion in the presence of water may also reduce the concentration of Fe<sup>3+</sup>. Then, how Fe<sup>3+</sup> enters into the structure of bridgmanite is further complicated by the pressure-induced spin-pairing of iron's electrons. The effect of spin transition on the physical properties of bridgmanite remains controversial due to the lack of consistent data on Fe<sup>3+</sup> concentration and its site occupancies under the lower mantle conditions.

To constrain the mineralogy and chemical composition of the lower mantle, we need accurate knowledge of sound velocities of bridgmanite under relevant high pressure and temperature. The Fe<sup>3+</sup>/Fe<sup>2+</sup> ratio appears to affect the elastic properties of bridgmanite<sup>3,12</sup>. However, over the pressure range of the deep lower mantle, the data of Fe<sup>3+</sup>/total Fe ratios in bridgmanite are very scattered<sup>13,14</sup> and in need of further clarification as it remains unclear how much Fe<sup>3+</sup> exists in the lower mantle.

With multigrain diffraction methods allowing separation of individual grains in a multiphase assemblage<sup>15</sup>, in combination with chemical analysis on samples recovered from the extreme high pressure and temperature conditions, we are now able to obtain detailed information on composition and crystal chemistry of individual minerals under relevant high pressure and temperature conditions. The advancement of the analytical techniques further allows us to study the effects of H<sub>2</sub>O on the phase assemblages because H<sub>2</sub>O, even in extremely small amounts, can dramatically affect the element partitioning in the system<sup>9,11</sup>. Knowledge of the mineralogy and chemical composition of realistic lower mantle multicomponent systems, dry or wet, can place constraints on the geochemical and geophysical models of the region and provide key information on the structure and dynamics of the deep Earth.

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Published online: 05 December 2022

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## Competing interests

The author declares no competing interests.