New research shows how water is transferred into our planet's interior

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Fig. 1

The Earth's interior could contain more than three times the amount of water in all our oceans combined, existing within the structures of silicate materials that are stable at the prevailing conditions deep inside the Earth. New research from ETH Zürich has helped to elucidate exactly how deep water gets transported into the Earth's interior.

Water is fundamental for processes that occur at the Earth's surface, but also plays a critical role in many geological processes occurring deep inside of it that shape its evolution. Small amounts of water incorporated into the structure of minerals have a major effect on their stability, behaviour and phase equilibria. Global processes such as mantle convection, plate tectonics and naturally occurring catastrophic events such as earthquakes and volcanic eruptions are strongly influenced by the activity of this water.

Water is reintroduced into the Earth's interior by hydrated tectonic (oceanic) plates that return into the mantle in subduction zones, and released when hydrous minerals/phases are decomposed due to the high pressure and temperature of the Earth's interior. Much of this water returns to the surface by volcanism, but a large fraction of is retained in newly formed high pressure hydrous phases that are stable at much higher depths, opening the possibility for water to recirculate deeper into the mantle beyond 400 km depth. However, the exact amount of water stored in the solid Earth, and how (and how much) of this water is recycled back to the surface, remains obscure.

Carmen Sanchez-Valle, a former assistant professor of experimental geochemistry and mineral physics at the Swiss Federal Institute of Technology, Zurich, has worked with her team that includes graduate student Angelika Rosa to develop several novel analytical techniques to investigate this environment. "Through learning about the Earth's interior, we become more aware of what actually occurs on the surface," she explains. A group of dense hydrous silicate phases discovered in laboratory experiments in the mid-1960s, the so-called alphabet phases (phase A, E, D and superhydrous B), are plausible candidates for the transport of water at depth due to the large stability field. The physical and chemical properties of these materials, obtained through mineral physics studies, are fundamental to revealing the deep water cycle.

Fig. 2

A device called a diamond-anvil cell (Fig 1) is the primary tool used by researchers to replicate extreme conditions that exist at the Earth's interior, and explore how hydrous phases behave. By powerfully compressing micrometric-size samples between the flat surfaces of quarter-carat diamonds, the apparatus authentically simulates pressure conditions down to the Earth's core. To recreate the infernal temperatures present in these realms, heating elements or infrared lasers are introduced to the tests. "Crucially, the diamonds are transparent, which means that brilliant x-rays produced by synchrotron sources and laser analysis can be used to probe the physical and chemical state of samples while they are submitted to extreme pressure and temperature conditions," adds Sanchez-Valle. "These experimental simulations provide us with a virtual window into the deep Earth."

Fortunately, seismic waves can be simulated within the team's facilities. Using a unique laser spectroscopy called Brillouin scattering spectroscopy (Fig 2), the speed of seismic waves and elasticity of materials can be monitored under pressure, divulging their water-bearing qualities. The team also use the brilliant X-rays produced at synchrotron sources to monitor the development of textures in hydrous materials deformed at conditions that mimic those of subducting slabs penetrating in the lower mantle.

"Our combined studies on hydrous phases has allowed us for the first time to interpret seismic anomalies observed in deep subducted slabs," says Sanchez-Valle. "The work has shown that hydrous slabs penetrating below the transition zone in areas such as Tonga could contain at least 1.2% in weight of water bound to dense hydrous phase D. The dehydration of phase D at greater depths is a potential mechanism to activate very rare (and less damaging) deep focused earthquakes, and the water released into the lower mantle has important consequences for the geodynamical and geochemical evolution of the deep Earth."

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