Editorial

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Deep Earth bound by water

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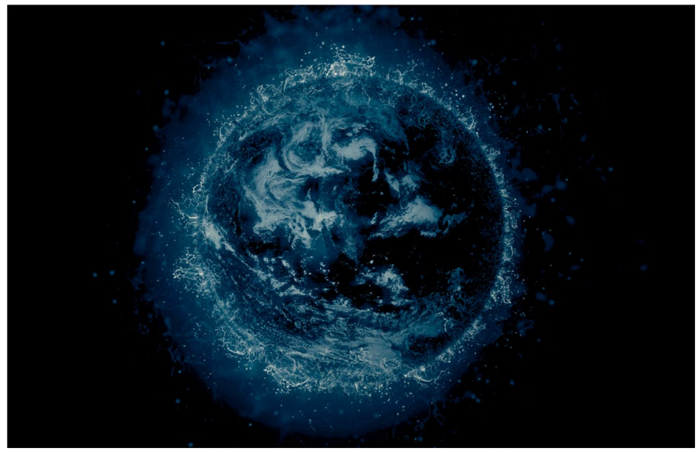
Research efforts from across the geosciences are uncovering how water deep within the Earth affects its fundamental workings.



Earth can be considered a water world. Day-to-day, people interact with the hydrological cycle, in which water continuously moves between surface reservoirs and the atmosphere. But inside Earth, there lies a deep water cycle that is largely hidden from, but still connected to, these surface processes. In this issue, accompanied by an online Collection of work from across the *Nature Portfolio*, we uncover this deep water cycle and how it underpins many Earth processes.

As emphasized in a Q&A with experts working to decipher the deep water cycle, at the high pressures and temperatures of Earth's interior, water exists not as free-flowing H_2O, but rather as mineral-incorporated and bound OH^- anions. In a Correspondence, Olivier Alard and colleagues further point out that water can be stored not only within the crystal lattices of minerals, but also in spaces between the mineral grains, potential repositories for volatile elements and water-derived species that remain poorly understood.

Constraining the nature of Earth's deep water reservoirs and fluxes is vital to our understanding of geological processes. From magma generation and fault zone lubrication to the fundamental properties of Earth's mantle[1], water plays a role. As interfaces between Earth's surface and interior, subduction zones facilitate the exchange of water between the surface and the deep. As the downgoing oceanic plate bends beneath the overriding plate, extensional faults allow pervasive infiltration of seawater and hydration of the crust and mantle. The extent to which this water is retained in the downgoing plate and transported into the mantle, or is released back into the surface environment via volcanism, depends in part on the metamorphic reactions that liberate some of the water.

Dehydration and the release of mineral-bound water from the downgoing plate during metamorphic reactions lowers the melting temperature of the overlying mantle, contributing to the generation and buoyant ascent of hydrous magmas[2]. These magmas can contribute to the formation of continental crust[3] and rise to form volcanic arcs, which are typically characterised by the potential for highly explosive volcanic eruptions[4,5], in part because of their water content. Further, fluid-rich areas in the descending plate generally host the highest rates of small earthquakes and less frequent large earthquakes[5] and mineral dehydration reactions may cause deep earthquakes at some 600 km depth[6]. Hence, deep water can be linked to both volcanic and seismic hazards.

Deeper still, and concealed in the mantle transition zone some 410 to 660 km beneath our feet, there could lie an oceans'-worth of water. The hydrated nature of this region, which separates the upper mantle from the lower mantle, was confirmed by the identification of the water-rich mineral ringwoodite in a diamond inclusion[7]. Building on this discovery, Gu and colleagues report lower mantle minerals and hydrous phases in a diamond from the 660 km boundary, suggesting that the hydrous conditions could extend across the transition zone, at least into the lower mantle.

Water that is retained in the descending slab may ultimately find a way into the very deepest regions of Earth's lower mantle, beyond 1,250 km (ref. [8]). We know very little about the distribution, movement, and quantity of this deepest water inventory. However, experiments suggest that at such great depths hydrogen ions can start to behave in a liquid-like way, moving freely within crystal structures[9]. The high electrical conductivity that this H^+ movement generates may allow for future electromagnetic mapping of water in the deepest mantle[10]. And, at the very heart of our planet, calculations on the behaviour and liquid-iron affinity of water at the time of core formation suggest that Earth's core could host a substantial portion of Earth's water[11].

Investigations into deep water have demonstrated that Earth is so much more that a blue dot seen from space, with a surface covered by oceans. Deep inside, both the mantle and the core may host their own oceans of mineral-bound water. Full appreciation of the Earth's deep water cycle – and the myriad of ways in which it influences the dynamics of Earth's interior – will require further unveiling of these vast, hidden volumes of water.

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