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High-pressure microstructure and stability of water-bearing minerals

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Hydrous and nominally anhydrous minerals have long been central to geoscience research. They're theorized as pathways for surface water to enter the Earth's interior via subducting slabs. Recent high pressure-temperature experiments show that some hydrous minerals in hydrated subducting slabs can transport water to the core-mantle boundary. Water released from mineral dehydration significantly impacts multiple mantle propertie including mantle viscosity, crucial for mantle flow. It also influences phase equilibria, which determine deep mineral constituents. Moreover, this water release is linked to magma generation (fundamental for volcanism) and seismic events in the Earth's interior, with broad implications for surface geology and human safety. Notably, major mantle minerals have limited water solubility. Thus, if high-pressure hydrous minerals can endure the extreme mantle heat, deep-Earth water reservoirs and fluxes could be highly significant, potentially transforming our view of the deep-seated water cycle. Hydrous aluminosilicates, vital for deep-water transport, are key in subducting sediments. Yet, how they withstand the high temperatures in the mantle transition zone, an area of extreme P-T conditions, remains unresolved. In this talk, we report the crystal structures and chemical compositions of typical hydrous aluminosilicates. These single crystals, synthesized at 15.5-22.0 GPa and 1400-1800°C, show widespread structural disorders. Specifically, Al and Si atoms occupy previously unoccupied tetrahedral and octahedral sites (normally vacant in ordered structures). High temperatures trigger these disorders, leading to variable local crystal structures and more hydrogen incorporation into the crystal lattice. This finding highlights that the order-to-disorder transition is crucial for the high thermal stability of hydrous aluminosilicates. Consequently, it can strongly affect the deep-mantle water cycle, opening new research directions for a better understanding of deep interior processes and Earth's Habitability.