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Stress trajectories in descending lithospheric slabs and the consequent water cycle

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Analysis of stress within a subducting slab indicates that fluid released by dehydration reactions along the top surface of the slab should be channelled inward, into the slab along maximum principal compressive stress trajectories. Within the transition zone, that fluid should be dissolved in wadsleyite and ringwoodite, as well as taken into any stable hydrous assemblage. H_2O dissolved in ringwoodite and/or stored in stable hydrous minerals will then continue to descend with the slab down to the bottom of the transition zone. At the bottom of the transition zone, ringwoodite reacts to form lower mantle phases that, in contrast, can only absorb very small amounts of H_2O. The breakdown of ringwoodite amounts therefore to a dehydration reaction occurring at the bottom of the transition zone. A conservative estimate, assuming that the water is only held in ringwoodite, indicates that more than 28 l of water is liberated for each cubic metre of H_2O-saturated slab going into the lower mantle. That water then migrates upward, with its path again inward into the slab. Water can rise within the slab until it encounters dry ringwoodite and until a stable hydrous assemblage forms to take it in. H_2O will then move again downward, to be liberated again at the bottom of the transition zone. Gradually, as more H_2O enters the slab system at the trench, the 'hydration front' rises up the slab until the latter becomes saturated with water along its whole length. In a 'mature' slab, the water budget involves (1) the excess water subducted at trenches that does not emerge in island arc magmatism, (2) the water that emerges in serpentine mud volcanoes near trenches, (3) water that somehow escapes the guiding stress trajectories and leaks in the surrounding mantle, and (4) H_2O transported away from the inclined lithospheric slab by lithospheric megaliths travelling along the base of the transition zone.