related antibody) can produce similar results in people. These clinical trials are being planned, and the results are eagerly awaited. In the meantime, antiretrovirals remain the best and only option for the long-term treatment of HIV infection. ■

Sharon R. Lewin *is at The Peter Doherty Institute for Infection and Immunity, University of Melbourne and Royal Melbourne Hospital, Melbourne, Victoria 3000, Australia.*
e-mail: sharon.lewin@unimelb.edu.au

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EARTH SCIENCE

Water takes a deep dive into the Mariana Trench

A tectonic plate descending into the Mariana Trench carries sea water deep into Earth's interior. It seems that much more water enters Earth at this location than was thought — with implications for the global water budget. **See Letter p.389**

DONNA J. SHILLINGTON

The subduction zones at which the tectonic plates beneath the sea thrust into the deep Earth act as gigantic conveyer belts, carrying water, fluids and volatile compounds into our planet. Water in Earth's interior is released back into the oceans and atmosphere by volcanoes. These inputs and outputs constitute a global deep-Earth water cycle, but quantifying the total water input from oceanic plates has proved difficult. On page 389, Cai *et al.*[1] report that the Pacific plate, which subducts in the Mariana Trench, contains much more water than was previously supposed — a finding that has major ramifications for Earth's water budgets.

Water is as crucial to the workings of Earth's interior as it is to Earth's surface processes: among other things, it triggers magma generation beneath volcanoes, lubricates deep fault zones, and fundamentally alters the strength and behaviour of Earth's mantle. Sea water seeps into the oceanic lithosphere through fractures and pores, and reacts with minerals in the crust and mantle to form hydrous minerals (such as serpentine) that store water in their crystal structures.

Water infiltration occurs at a couple of key stages of an oceanic plate's life cycle. The first is at mid-ocean ridges, when water circulates through hot, newly formed oceanic plates[2]. But at fast-spreading ridges (which are the primary 'diet' of the subduction zones that ring the Pacific Ocean), circulation and hydration are mainly restricted to the plate's upper crust. The accumulation of sediments subsequently seals off most of the oceanic plate from the ocean, but seamounts (underwater mountains) and fracture zones provide pathways for further water input and output, so that circulation continues away from the mid-ocean ridge[3]. The final infiltration occurs at the 'outer rise' of a subduction zone, where the oceanic plate bends before entering the trench. Here, extensional faults form in response to bending, and are thought to enable pervasive, deeply penetrating hydration of the crust and upper mantle[4–6].

The evidence for water entering subduction zones is clear, but several knowledge gaps have hindered attempts to quantify the total volume of water going down these hatches, even at individual subduction zones. One unknown is the depth to which water penetrates the oceanic plate. Most constraints on estimates come from controlled-source seismic data, which are produced by measuring seismic waves generated by artificial sources using dense arrays of recording instruments. These data provide excellent constraints on hydration of the crust and shallow mantle, but, with one notable exception[7], do not constrain the full depth of hydration. It is clearly not possible to tally the total volume of subducted water without knowing the full hydration depth.

Another important challenge is to untangle all the factors that alter the speed at which seismic waves travel through different parts of the plate; measurements of such seismic waves are one of the primary means of estimating the amount of water in the subducting oceanic plate. Most estimates assume that any reduction in wave speed results from the replacement of olivine (the main mineral found in the mantle) by serpentine. However, in the crust and shallow mantle, water-filled cracks can also contribute to velocity reductions[8]. To complicate things further, seismic-wave speeds in the upper oceanic mantle are anisotropic — they depend on the direction of propagation. This is because olivine crystals align in the direction in which the sea floor spreads when new oceanic plates are created at mid-ocean ridges. Further anisotropy can result from fractures formed at the outer rise.

Cai *et al.* tackle all of these issues by presenting constraints on the hydration of the approximately 150-million-year-old Pacific plate as it subducts at the Mariana Trench. The authors analysed seismic waves from distant earthquakes, recorded by an array of seismometers on the sea floor. This allowed them to model seismic-wave speeds to much greater depths (albeit at lower resolution) than is possible using controlled-source seismic data.

The researchers find that, impressively, the full hydration depth of the lithosphere extends to approximately 30 kilometres below the sea floor (Fig. 1). They were also able to examine velocity reductions in deep regions at which the pressure would be sufficiently high to close all cracks, thus allowing them to eliminate the possible contribution of such cracks to velocities in these regions. Finally, because the authors recorded waves travelling in all directions across their array, they were able

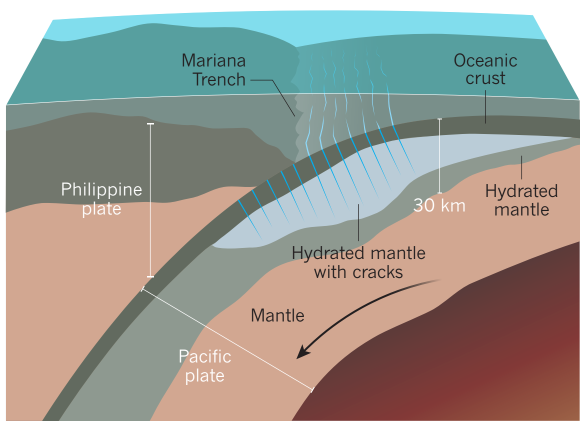

Figure 1 | Hydration of the Pacific tectonic plate at the Mariana subduction zone. At the Mariana Trench in the Pacific Ocean, the Pacific plate slips (subducts) beneath the adjacent Philippine plate, transporting sea water into the deep Earth. The water seeps through cracks and pores in the plate, and reacts with minerals in the crust and mantle to form hydrated regions consisting of minerals that store water in their crystal structures. Cai *et al.*[1] have used seismic measurements to show that water penetrates to depths of about 30 kilometres below the ocean floor. (Approximated from Fig. 2d of ref. 1.)

to account for the contribution of anisotropy to wave speed.

Cai *et al*. report that more than four times as much water is entering the Mariana subduction zone than was previously estimated[9]. Old, cold subducting plates such as that entering the Mariana Trench are particularly effective conveyors of water into the deep Earth because hydrous minerals in such plates are stable to greater depths than in younger, hotter plates. If extrapolated globally to other places where old, cold plates subduct, the authors' result implies that the amount of water entering Earth's interior greatly exceeds current estimates[10] of the amount being emitted by volcanoes, and thus requires a rethink of the global water budget.

Several questions still need to be answered to better constrain estimates of the inputs to Earth's deep-water cycle and evaluate the implications of the new results. First, how variable is the water content in the oceanic plate at a range of depths and scale lengths along subduction zones? Many studies have reported changes in extensional faulting and in crustal and upper-mantle hydration along subduction zones, and several competing factors have been proposed to contribute to these changes[7,11,12]. Characterizing this variability throughout the hydrated part of the plate and understanding its causes will be essential for us to tally water inputs and compare them with outputs. It would also be useful to determine whether hydration occurs in focused zones near faults, as has been observed in a different tectonic setting[13], or is distributed more evenly, because this might control whether mineral-bound water is released by dehydration or is carried to greater depths[14].

Finally, because a substantial volume of water is probably stored in the crust and upper mantle (the regions that are most accessible to seawater infiltration), the thorny issue of whether changes to seismic waves reflect the presence of water-filled cracks or of hydrous minerals still needs to be directly addressed in these areas. A comprehensive understanding of inputs to Earth's interior will require a multi-pronged approach, including multi-scale marine geophysical studies, drilling of the faults that are thought to be conduits for water into the oceanic lithosphere, and numerical and laboratory studies. But for now, Cai and colleagues' results have taken us a big step closer to understanding the total water input at subduction zones. ■

Donna J. Shillington *is at the Lamont–Doherty Earth Observatory, Columbia University, Palisades, New York 10964, USA.*
e-mail: djs@ldeo.columbia.edu

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ORGANIC CHEMISTRY

From hydrocarbons to precious chemicals

Operationally simple chemistry enables aliphatic carbon–carbon bonds — the 'girders' in the framework of many organic molecules — to be prepared from widely available hydrocarbons known as alkenes. SEE LETTER P.379

JAMES P. MORKEN

Many valued reagents and catalysts used in the preparation of organic compounds are highly reactive and are therefore incompatible with exposure to the open atmosphere — in some cases, dangerously so. The instrumentation required to carry out reactions with these compounds, such as high-vacuum apparatus and gloveboxes (isolation chambers), is costly and demands special training. Chemical processes that do not have such requirements are therefore more likely to make a big impact on how chemists synthesize molecules, be it for the development of new materials, pharmaceuticals or agrochemicals. The reactions reported by Fu and co-workers[1] on page 379 are a case in point. Not only are they simple to carry out, but they also deliver a variety of useful products that are otherwise much more difficult to make.

Parallels are often drawn between the fields of organic synthesis and architecture[2]: aliphatic carbon–carbon (C–C) bonds are the architect's 'girders' on which many structurally complex molecules are built. Installing these girders is challenging, and necessitates the use of highly reactive reagents. To add to the challenge, the orientation in which new C–C bonds are installed — the stereochemistry of

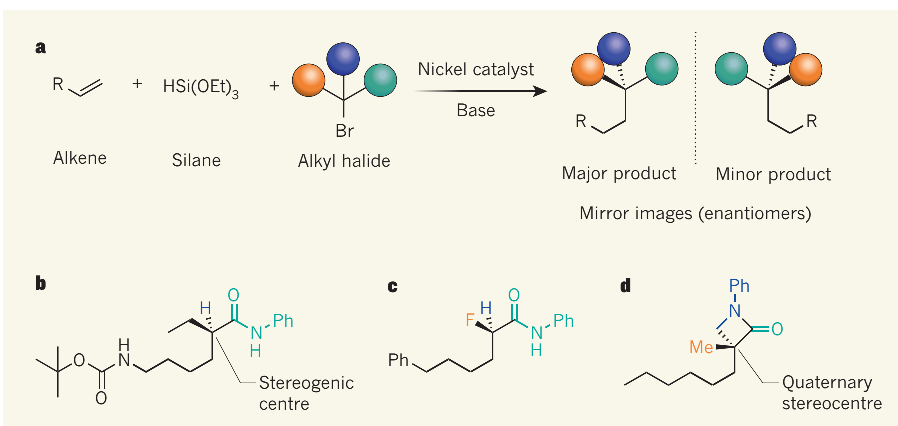

Figure 1 | Operationally simple reactions for making aliphatic carbon–carbon bonds. a, Fu and colleagues[1] report chemistry in which an alkene, a silane and an alkyl halide react in the presence of a nickel catalyst and a base to form potentially useful products. The reactions can be carried out without excluding air or moisture, which makes them straightforward in practice. Moreover, the reactions are enantioselective: they produce one isomer of the reaction product to the near exclusion of the product's mirror-image isomer. R and the coloured spheres represent a variety of organic groups or atoms; Si, silicon; Et, ethyl group; Br, bromine. **b**–**d**, The authors prepared a variety of products, including **b**, compounds in which a stereogenic centre (a carbon atom that has three other groups attached by carbon atoms) is next to a carbonyl group (C=O); **c**, compounds that contain fluorine atoms; and **d**, compounds that contain quaternary stereocentres (carbon atoms attached to four different groups by carbon atoms). Ph, phenyl group; Me, methyl group.