the inner core would be sufficient to activate such a mechanism[8]. Gleason and Mao's finding that the core is weak suggests that, indeed, stresses in the inner core suffice for iron deformation by dislocation creep and the alignment of iron crystals.

According to Gleason and Mao[1], the strength of iron at inner-core conditions permits the development of a preferred alignment of mineral grains at inner-core strain rates. This suggests that seismic anisotropy can be used as a proxy for understanding the dynamics and formation of the inner core. The study also highlights how physics-based deformation models can be used to overcome the problematic extrapolation of experimental data to deep-Earth conditions. ❐

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MARINE BIOGEOCHEMISTRY

The ups and downs of ocean oxygen

The daily vertical migration of small marine animals transfers organic carbon from the surface ocean to depth. An assessment of acoustic data reveals that the depth of migration is closely tied to subsurface oxygen levels throughout much of the global ocean.

Scott C. Doney and Deborah K. Steinberg

Across the world's oceans, many small marine animals feed near the surface during the night and move to, and reside in, deeper, darker waters during the day. Such vertical migrators include zooplankton from nearly all major invertebrate phyla, and micronekton (small, actively swimming organisms such as shrimp and small fish). This daily movement to depth — known as diel vertical migration — is thought to reduce the risk of visual predation[1,2]. Determining the biogeochemical consequences of this phenomenon on a global scale has proved difficult, in part because of the limited availability of field data on zooplankton and micronekton migration. Writing in *Nature Geoscience*, Bianchi *et al.*[3] use acoustic and model data to show that diel vertical migration exacerbates oxygen depletion in low-oxygen areas of the global ocean.

In the well-lit surface ocean, phytoplankton take up carbon dioxide and nutrients, and generate organic matter. Some of this organic material is transported downwards into the mesopelagic zone, between about 100 and 1,000 metres depth. Here, microbes and animals reverse the process, releasing nutrients and carbon dioxide, and consuming dissolved oxygen. As a result, vertical oxygen profiles exhibit a minimum in the mesopelagic zone over much of the global ocean[4].

Most of the downward transport of organic matter is thought to result from the gravitational sinking of dead phytoplankton, faecal pellets and other detrital particles[5]. This sinking particle flux declines rapidly with depth through the mesopelagic ocean, and only a small fraction escapes to the deep sea. Dissolved organic carbon produced in surface waters may also be physically mixed into the mesopelagic zone by deep winter convection[6]. However, most carbon budget estimates indicate that the metabolic demands of the mesopelagic biological community cannot be met by these two carbon sources alone[7,8]. Diel vertical migrators may help to meet this energy demand by excreting dissolved and particulate organic carbon — originally consumed at the surface — at depth, as well as by serving as food for mesopelagic carnivores (Fig. 1). However, biogeochemical

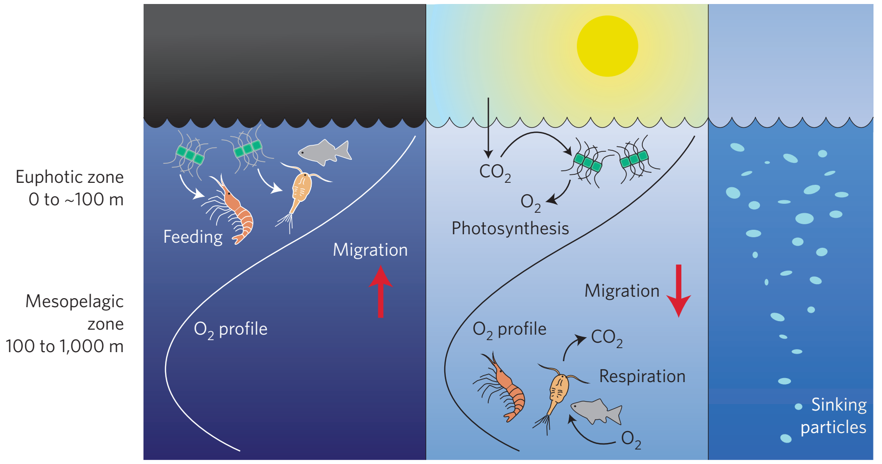

Figure 1 | Marine diel vertical migration. Many small marine animals reside in the surface, euphotic ocean at night, where they feed on plant and other smaller plankton (left panel), but migrate to deeper, mesopelagic waters during the day (middle panel). In the process, these animals transfer organic carbon consumed at the surface ocean to depth. The metabolic breakdown (respiration) of this organic carbon by both the migrators and the mesopelagic community lowers oxygen levels at depth, where O_2 concentrations are already low (shown schematically by the O_2 profile with lower values to the left). This downward transport of organic carbon by diel migrators serves as an alternate pathway to the gravitational sinking of detrital particles (right panel). Bianchi *et al.*[3] use acoustic profile data to show that the depth of diel vertical migration varies with region across the global ocean, and mirrors spatial patterns in the depth of subsurface low-oxygen waters, such that migrators descend to the upper range of low oxygen waters.

fluxes in much of the mesopelagic zone are notoriously under-sampled relative to the surface and even, to some extent, relative to depths below 1,000 metres.

Bianchi *et al.*[3] use measurements from shipboard acoustic Doppler current profilers (ADCPs), originally deployed to measure ocean currents, to create a global inventory of diel migration depths of small marine animals (specifically zooplankton, micronekton and small fish). They find that the depth of diel migration is positively correlated with the depth of the subsurface oxygen minimum, such that migrators dive deepest in regions where the subsurface oxygen minimum occurs lower in the water column. In the vicinity of oxygen minimum zones, migrators dive only as deep as the upper bounds of the low-oxygen waters, where they may be sheltering from predators that are less tolerant of low-oxygen conditions. By incorporating the data-derived relationships between migration depth and subsurface oxygen levels into a numerical ocean model, Bianchi *et al.* show that by clustering in the upper margins of oxygen minimum zones, vertical migrators accentuate organic matter breakdown (i.e. respiration) in these waters, strengthening the oxygen deficit.

However, the application of the single-frequency ADCP data to biological problems has limitations, the most significant being that the data provide little to no information on the taxa of zooplankton, micronekton or larger fish that may constitute the assemblage of diel vertical migrators. Acoustic data such as these still need to be 'ground-truthed' with other methods (such as nets) to determine, for example, the identity of the animals that undergo diel vertical migration and contribute to oxygen consumption at depth. Progress has been made using multi-frequency acoustic methods that allow identification of size classes and even major taxa[9], and by using towed camera systems. Now that our picture of the biogeochemical significance of diel vertical migration is being refined at a global scale, such technologies should be further employed to provide a better understanding of the identity and abundance of the migrators.

Such questions are becoming increasingly urgent given that the productivity, geographic range and composition of marine ecosystems are likely to shift as a result of global climate change[10]. At the same time, ocean warming is expected to lower subsurface oxygen levels, owing to a reduction in oxygen solubility and a slowdown in ocean circulation[11]. Already, tropical and subtropical oxygen minimum zones, which limit the habitat range of many marine species and support atypical water-column biogeochemical processes such as denitrification, may be expanding horizontally and vertically[12]. Ascertaining the response of migrating zooplankton, micronekton and fish populations to such large-scale environmental perturbations will require systematic monitoring of the mesopelagic zone, along with targeted studies aimed at resolving the distribution, diversity and biogeochemical function of organisms present in these dimly lit waters[13,14].

Bianchi *et al.*[3] show that the diel vertical migration of small marine animals accentuates oxygen deficiencies in subsurface waters, by focusing the breakdown of organic matter at the upper margins of existing oxygen minima. The findings emphasize the need for the ocean biogeochemical modelling community to move beyond a relatively simplistic representation of the biological carbon pump, in which sinking particles transport the majority of carbon to depth, to a truly mechanistic one, which incorporates sub-models of mesopelagic fluxes and transformations. ❐

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DEEP EARTH

Mantle fabric unravelled?

Mantle flow patterns may be reconstructed from mineral orientations. Experiments show that the high-pressure mineral post-perovskite can inherit texture from its lower-pressure counterpart, suggesting new ways of interpreting flow in the deepest mantle.

John Hernlund

In the deepest part of Earth's mantle, just two to three hundred kilometres above the boundary with the core, the D″ layer[1] hosts the transfer of heat and mass between the mantle and the core. The dynamics of this region are central to our understanding of unresolved problems, ranging from Earth's geomagnetism to its chemical composition, but seismology provides the only means for detailed analysis of this inaccessible and enigmatic region. Seismic shear waves passing through the D″ layer are anisotropic[2], that is, they move faster in some oscillation directions compared with others (Fig. 1a). This seismic anisotropy is thought to be caused by flow in the deep mantle. Writing in *Nature Geoscience*, Dobson *et al.*[3] use laboratory experiments to show that high-pressure forms of minerals can inherit textures from their lower-pressure counterparts and vice versa, and that these inherited textures may also contribute to the observed patterns of seismic anisotropy in the D″ region.

Our understanding of Earth's deep interior was revolutionized by the discovery of a phase transition in the lowermost mantle. Here, in the D″ layer, the abundant mantle mineral perovskite transforms to a high-pressure post-perovskite phase[1]. This transformation is thought to produce the