ples come from near-shore environments south of Tokyo, so that they cannot compare the variations between the two techniques across the oceanographic DOC gradients reported by Sugimura and Suzuki and by Martin and Fitzwater.

High-mass fractions

Sugimura and Suzuki separated DOC into fractions of different relative molecular mass (M_r) using a gel-filtration technique in which low-M_r material is preferentially retained during the passage of a DOC mixture through a column. Sugimura and Suzuki claimed that much of the new DOC is high-molecular-mass material (M_r>20,000). Ogawa and Ogura concentrate two high-M_r fractions by forcing water under pressure through nanometre-sized pores (ultrafiltration). They find very little DOC with molecular masses above 10,000. Using each method they recover the same amount of carbon, both with M_r>1,000 and with M_r>10,000. The authors suggest that there might be no chemically refractory, high-M_r DOC at all in seawater.

Benner *et al.*, in *Science*[5], attempt to characterize DOC by concentrating the M_r>1,000 fraction using the same ultrafiltration technique as Ogawa and Ogura. They find that a third of the surface-water DOC falls in this size fraction, a result which agrees very well with Ogawa and Ogura's. This concentrate also contains much less nitrogen (C/N = 15) than the high-M_r fractions extracted by Sugimura and Suzuki[1,8] (C/N = 7). Benner *et al.* find that high-M_r polysaccharides make up about half of the M_r>1,000 fraction in surface water, whereas aromatic or olefinic carbons make up a high proportion of that fraction in deep water. Although they disagree with many of Sugimura and Suzuki's results, Benner *et al.* "concur that the high-M_r components in the upper ocean are reactive and support much of the heterotrophic activity in the surface ocean".

In all the new results, only two direct comparisons can be made. Both Martin and Fitzwater[3] and Benner *et al.*[5] measured water from the Hawaii Ocean Time Series station which was collected for the Joint Global Ocean Flux Study (JGOFS) DOC Workshop (Seattle, July 1991)[9]. Martin and Fitzwater report 152 μM for surface water, whereas Benner *et al.* report only 82 μM. The same level of disagreement exists for water at the O_2 minimum (86 compared with 38 μM) and for deep water (112 compared with 41 μM). Benner *et al.* subtract a system blank of 22 μM from their raw data, whereas Martin and Fitzwater do not subtract any such blank. It is noteworthy, perhaps, that the difference between Martin and Fitzwater and Benner *et al.* is almost the same for both the surface and deep samples (70 μM).

The subject of system blanks is probably at the heart of many of the disagreements arising from the catalytic method[9]. When ultrapure distilled water is run through the high-temperature catalyst, significant DOC levels can result. Suzuki *et al.*[10] report values of 15–30 μM; Ogura and Ogawa, 10 μM. Catalytic oxidation always recovers more carbon from distilled water than does wet oxidation. Suzuki *et al.* and Ogura and Ogawa assume that the carbon in their distilled-water blanks comes from the distilled water, and do not subtract any blank from their seawater measurements. Benner and Strom[11] conclude that the carbon in distilled-water blanks is actually carbon released from the catalyst itself. They observe blank values ranging from 10 to 50 μM from different catalysts. Benner *et al.*[5] treat their 22 μM blank as a system blank and subtract it from their seawater determinations.

High turnover

Is there a 'new' DOC pool, or is it an artefact of the measurements? It remains to be seen whether Sugimura and Suzuki[1] and Martin and Fitzwater's[3] high DOC levels suffer contamination by blank carbon. If their high DOC numbers are ultimately shifted down, the size of the global new DOC pool will shrink accordingly. In the end, however, the size of the pool is less interesting than its activity and its role in the marine carbon cycle and in marine ecosystems. The most intriguing aspects of Sugimura and Suzuki's and of Martin and Fitzwater's data are the large vertical and horizontal DOC gradients they reveal in the upper ocean. These gradients cannot be maintained unless large amounts of DOC production and remineralization are taking place. There is no reason at present to think that a blank correction, however large, will eliminate these gradients. The most pressing need is to verify that these gradients are real, and if so, to see how much of the variation is identified by wet oxidation. □

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1. Sugimura, Y. & Suzuki, Y. *Mar. Chem.* **24**, 105–131 (1988).
2. Toggweiler, J. R. *Nature* **334**, 468 (1988).
3. Martin, J. H. & Fitzwater, S. E. *Nature* **356**, 699–700 (1992).
4. Ogawa, H. & Ogura, N. *Nature* **356**, 696–699 (1992).
5. Benner, R. *et al. Science* **255**, 1561–1564 (1992).
6. Williams, P. M. & Druffel, E. R. M. *Nature* **330**, 246 (1987).
7. Tsuchiya, M. *et al. Prog. Oceanogr.* **23**, 101–147 (1990).
8. Suzuki, Y. *et al. Mar. Chem.* **16**, 83–97 (1985).
9. Williams, P. M. *US JGOFS News* **3**, 1 (1991).
10. Suzuki, Y. *et al. Deep-Sea Res.* **39**, 185–198 (1992).
11. Benner, R. & Strom, M. *Mar. Chem.* (in the press).

DAEDALUS

Not making waves

SOME while ago Daedalus devised a 'slippery ship'. Its port and starboard surfaces were electrodes. A current passing between them covered them with a layer of tiny electrolytic gas bubbles, reducing skin-friction almost to zero. In a final stroke of ingenuity, Daedalus propelled his ship electromagnetically. Magnets in the hull surface interacted with the current-carrying water, forcing it backwards and therefore thrusting the ship forwards.

Electromagnetic propulsion has since been taken up in other quarters, notably Japan. So Daedalus is maintaining DREADCO's lead by a further cunning development. A properly designed electromagnetic boat, he claims, need not even make any waves. The last major source of drag can thus be eliminated.

As it advances, a conventional ship pushes water out of the way to make room for its own volume. The water is forced upwards; the resulting waves run endlessly away from the ship, taking energy with them. A submarine has no such losses. The water that it displaces cannot go upwards — the volume that it might occupy is already full. Instead it goes backwards. It flows round the hull at high speed, and decelerates again behind it. The process radiates no energy.

So DREADCO's hydrodynamicists are optimizing the field-pattern of their electromagnetic ship. They are working out the distribution of current density and magnetic-field intensity that will accelerate every element of the water near the ship in the precise pattern expected for the equivalent submarine hull. The mathematics are desperately hard: but success will be wonderful. For the resulting vessel will travel at any speed without making waves. Instead, it will thrust the level water directly backwards around it.

This form of propulsion is utterly efficient. It puts power into accelerating the water around the bow of the vessel, and recovers it again by regenerative electromagnetic braking at the stern. The water is left calm and undisturbed; there is no wake. The vessel will lose no energy to turbulence, and only a little to viscous shear, for its field system imposes perfect laminar flow on the water at every point. Silent and ghost-like, it will seem to slip through the water without even parting it, and will reach vast speeds on almost no power.

The waveless ship will be rapidly adopted by ferry and sea-freight companies. Its furtiveness will also appeal to the world's navies. With no propeller noise, and not disturbing the sea for miles around, it will be that much harder to spot from submarines, aircraft or satellites.

David Jones