and burial. But these arguments have largely been laid to rest^{5,6}, at least to the extent that they do not prove that marine carbon storage has increased greatly during the past century.

Discrepancies

It seems to be easier to point out additional discrepancies in our understanding of the land-ocean carbon balance than to answer the questions raised by Ittekkot's report¹. Besides their POC load, rivers carry an approximately equal load⁷ of dissolved organic carbon (DOC) — about 200×10^{12} grams per year. If all this were to reach the ocean and if it were as resistant to degradation as is POC, it would take less than 3,000 years to 'fill up' the oceans' reservoir of DOC by rivers alone. But DOC in the deep Pacific is reported to have an average radiocarbon age of 6,000 years and is believed to be mostly (90 per cent) of marine origin⁸. Although many qualifications could be added, it seems that there is much more organic matter coming down the rivers than can be accounted for in the ocean. Where does it go?

The complex physical, chemical and biological processes at the interface between fresh and salt water in estuaries and deltas can only dispose of part of the load. Neither near-shore burial rates nor oxidation and attendant release of nutrients are high enough to accommodate the excess carbon. Deep-sea fans are one place to look for it. Another, more provocative, supposition is that the ocean is comparable to a heterotrophic organism. That is to say that it depends on an import of terrestrial organic matter to maintain its level of metabolism, because there is an excess of respiration over primary production of organic matter. Indeed, it has recently been suggested⁹ that much of the near-shore ocean shows net heterotrophy. It could also play a role in the high productivity of river plumes. Waters originating in the Amazon River plume retain elevated concentrations of natural pigment for up to a year after their departure from the river mouth while drifting thousands of kilometres into the Atlantic¹⁰. The high production associated with these waters may in part be sustained by slow release of nutrients from land-derived dissolved organic matter. □

1. Ittekkot, V. *Nature* **332**, 436–438 (1988).
2. Berner, R. A. *Am. J. Sci.* **282**, 451–473 (1982).
3. Deuser, W. G. *Org. Geochem.* **1**, 243–247 (1979).
4. Walsh, J. J. *et al. Deep Sea Res.* **32**, 853–883 (1985).
5. Peng, T.-H. & Broecker, W. S. *J. geophys. Res.* **89**, 8170–8180 (1984).
6. Rowe, G. J. *et al. Nature* **324**, 559–561 (1986).
7. Meybeck, M. *Am. J. Sci.* **282**, 401–450 (1982).
8. Williams, P. M. & Druffel, E. R. M. *Nature* **330**, 246–248 (1987).
9. Smith, S. V. & Mackenzie, F. C. *Global biogeochem. Cycles* **1**, 187–198 (1987).
10. Muller-Karger, F. E., McClain, C. R. & Richardson, P. L. *Nature* (in the press).

W. G. Deuser is in the Department of Chemistry, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, USA.

London's Roman amphitheatre

SEVERAL months of digging by archaeologists in the centre of London have just been rewarded by the discovery of the remains of the amphitheatre of Roman London. Close to the historic Guildhall, now the home of the Corporation of London, and at a depth of more than five metres, just a short section of the curved brick- and stone-built walls sufficed for the reconstruction of the plan of an elliptical arena about a hundred metres long. The photograph shows the main area of the excavation: VW, Victorian wall; D, drain; TW, inner wall of theatre; AW, wall of antechamber; AS, arena surface. The doorway in the wall of the theatre, leading from the antechamber to the arena, can be clearly seen.

The arena was not a towering mass raised on vaults, tunnels and arches like the Colosseum at Rome or the arenas of Arles and Nîmes. London's amphitheatre was enclosed merely by banks of earth on which temporary stands of seating were erected. Arenas of this type were known in many parts of the Roman empire, for example in Romania (Ulpia Traiana), Hungary (Aquincum), Austria (Carnuntum) and Germany (Xanten on the lower Rhine), and examples in Britain are found in Cirencester, and near the legionary fortresses at Caerleon in south Wales and Chester in north-west England.

The London arena lies next to the Cripplegate military fort, which may have accommodated army personnel seconded to the staff of the provincial governor, whose Thameside residence is now partly overlain by Cannon Street railway station. Conceivably, the amphitheatre began life as a special arena (*ludus*) that would have been used for military training and exercises, though in its main civil phase it was much larger than known examples of this type.

A city's amphitheatre was intended to house the great popular entertainments, gladiatorial combats, the hunting and killing of wild beasts and the execution of condemned persons. This last was held as generally having less entertainment value and was often reserved for the luncheon interval during the great festivals. Games were paid for by leading citizens, and although many of the educated classes affected to despise the vulgarity of the arena, it was their decision to sustain it that made the games such a distinguishing feature of Roman public life.

Londonium was a creation of the Romans, a flourishing port for merchants and commerce in the years following conquest by the emperor Claudius in AD 43. Yet little is known of its buildings and layout, apart from a great forum and basilica on Cornhill, beneath the line of Gracechurch Street, a temple of the Persian god Mithras, unearthed more than thirty years ago, and the encircling walls, two bathblocks and several mosaic pavements which were discovered in the nineteenth century. It is to be hoped that some of the arena will be preserved for permanent exhibition, a reminder not only of how much (or possibly how little) tastes have changed, but also of a Roman origin which London shares with many of the principal cities of Europe. (Photograph courtesy of Jan Scrivener/Museum of London.)

John Wilkes

John Wilkes is a professor at the Institute of Archaeology, University of London, 31–34 Gordon Square, London WC1H 0PY, UK.