Ocean ecology

Fixation of CO_2 in dark midwater zones of the ocean

from Paul Tett

IF the ocean began as a rich organic soup, it has since become so poor that many organisms have difficulty in getting enough energy and organic matter for growth and reproduction. The evolution of photoautotrophy must have been a breakthrough, allowing the light-driven uptake of simple inorganic compounds of carbon, nitrogen and phosphorus to supply the entire food needs of many planktonic plants. The illuminated superficial waters of the sea (the 'euphotic zone') are thus commonly seen as the main region of primary production, particularly by phytoplankton, whereas the deeper waters are seen as a zone of consumption in which heterotrophic animals and bacteria meet their energy demands by the oxidation of organic carbon supplied from the euphotic zone. On page 54 of this issue of *Nature*, Karl and his colleagues present evidence to suggest that bacteria in the midwater between the two zones can intercept the organic particles falling from the euphotic zone and, despite the absence of light, use the energy trapped in them to convert additional carbon dioxide into organic carbon (chemolithotrophy)[1].

As the earliest living organisms, prokaryotes probably exploited both inorganic and organic sources of energy and carbon until the development of the eukaryotes with their greatly improved efficiency of photosynthesis at high oxygen concentrations. That probably caused many of the remaining bacterial prokaryotes to specialize in heterotrophy — hence the traditional view of modern oceanic prokaryotes as degraders, consuming organic material originally produced by eukaryotic phytoplankton. Recent investigations of the smallest phytoplankton have, however, shown the importance of the prokaryotic cyanobacteria (once called 'blue-green algae') in oceanic primary production[2,3]. And incorporation of carbon dioxide by thermophilic bacteria, using energy obtained by oxidizing locally enriched sulphide, iron or manganese, has been suggested as a source of primary production in food chains found near volcanic vents in deep water[4,5]. From careful analyses of sedimenting material collected by free-floating traps at depths between 50 and 2,000 m in the eastern tropical Pacific Ocean south-west of Mexico, Karl *et al.* now add the suggestion that energy initially harnessed photoautotrophically by euphotic-zone phytoplankton for the incorporation of inorganic nitrogen (as well as carbon) can subsequently be chemolithotrophically used by midwater microorganisms to fix additional carbon dioxide[1].

The chemolithotrophic microorganisms involved are probably denitrifying bacteria using the ammonium produced by the action of heterotrophs on the organic material sinking down from the euphotic zone. By oxidizing this NH_4^+ to NO^-_2 the bacteria can obtain sufficient energy to take up carbon and reduce it to organic compounds. This chemolithotrophic use of nitrification to provide energy for carbon incorporation is less efficient than photosynthesis which, under optimal conditions, yields 0.08 moles of organic carbon for each einstein of light. Karl *et al.* cite yields of 0.03–0.06 moles of carbon fixed for each mole of ammonium–nitrogen oxidized, and estimate that potential chemolithotrophic production by microbes in their study region requires a maximum ammonium flux of about 0.8 mmol per m^2 per day. This flux, if completely supplied from photoautotrophically produced material with a carbon to nitrogen ratio of 7:1, requires an annual photosynthetic production of about 30 g carbon per m^2, close to lower estimates of tropical oceanic primary production. The greatest estimated chemolithotrophic production, about 0.4 mg carbon per m^2 per day, is equivalent to an annual average of 146 mg carbon per m^2, clearly only a small proportion of phytoplankton production. The suggestion by Karl *et al.* that "the flux of energy out of the euphotic zone may greatly exceed that nominally contained in particulate organic detritus" thus overemphasizes the importance of midwater chemolithotrophy, but these microbial processes may well influence the organization of midwater food webs.

Chemosynthesis has, of course, been known for many years and may, in unusual regions, such as the Black Sea, rival photosynthetic production[6]. Oceanic chemolithotrophs have ample supplies of their carbon source; their problem is to find at near-normal oxygen concentrations a sufficient concentration of energy source. In the Black Sea, chemosynthesis makes use of the high concentration of reduced material accumulated in the deoxygenated waters. The thermophilic bacteria of the deep-sea volcanic vents probably exploit local enrichments of reduced compounds[4,5]. Perhaps the major novel contribution of Karl and co-workers is to document precisely a mechanism whereby chemolithotrophs can, through oxidizing ammonium associated with sinking particles, obtain sufficient energy for growth in the oligotrophic ocean. ☐

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Igneous petrology

Turbulence in petrology — the behaviour of komatiites

from E.G. Nisbet

CONSIDER the business of stamp-collecting: an elegant and harmless occupation of considerable economic benefit to countless post-offices, a source of endless diversion and speculation to the philatelist. Consider now the effect on that peaceful hobby of the discovery, somewhere to the east of Laputa, of a whole new continent filled with hitherto unknown national post-offices. Imagine the excitement and confusion of innumerable collectors scurrying in for examples. Eventually order is restored, what purports to be a comprehensive philatelic history is written and the hobby settles down to its normal delightful ways — until someone points out that some of the new stamps, though not exactly forgeries, are subtle but highly misleading overprints. But it is not clear how to identify them. Is history to be rewritten? Confusion returns.

Igneous petrology may not quite be stamp-collecting but it, too, has its excitements, as when komatiites were discovered fifteen years ago. This sent many field workers scurrying to collect samples from which much has been learnt about the chemical properties of komatiites. Now Huppert *et al.*, on page 19 of this issue of *Nature*, cast doubt on some (but not all) of the current notions about the chemistry of komatiites from an examination of the physical properties of komatiite liquids[1]. More reassuringly, they also provide some explanation of how komatiite lava flows can produce extraordinary large plate-like ('spinifex') crystals of olivine, thereby resolving a conflict between experimental results and cooling models.

When discovered, komatiites were a