## Oceanology

# Storms in the abyss

*from P.F. Friend*

ANY lingering notion that the dark waters of the deep ocean floors are uniformly calm should finally be dispelled by the vivid account of this remarkable environment provided by Hollister and McCave starting on pages 220 of this issue of *Nature*.

Their study concentrates on a 2 x 4 km area of the Atlantic Ocean, where it reaches a depth of almost 5 km, some 500 km south of Halifax, Nova Scotia. Although the surface waters there move generally eastwards, as part of the Gulf Stream, the deepest waters tend to move westwards as part of a distinctive deeper western boundary current that is cold (less than 1.9°C) and perhaps has its origins in the bottom water of the Antarctic. This cold bottom current has a remarkably high velocity of up to 0.73 m s$^{-1}$, similar to those measured in strongly moving surface tidal flows or in flooding rivers.

Another striking feature of the area is that it is subject to 'storm' periods of several days to a few weeks in which bottom currents intermittently reach speeds of over 0.3 m s$^{-1}$ and are often reversed. Calculations of the variance of current speed provide a measure of the so-called eddy kinetic energy of the system. It seems that high values of the eddy kinetic energy in deep waters are usually found in areas where the eddy kinetic energy at the surface is also high, as in the Gulf Stream. The kinetic behaviour of the deep currents in storms is perhaps best visualized as an intermittent and reversing surge; there is no sign of the oscillatory periods of several seconds that are typical of surface-storm kinetics.

Because the muddy ocean floor in the area studied is rich in organic nutrients, it supports many actively burrowing organisms that soon disrupt any sedimentary features. The fact that the top layer of the floor retains sedimentary features therefore indicates that it was recently and rapidly deposited. The concentration of sediment can be as high as 12 g m$^{-3}$ in these deep-bottom waters, similar to that in some muddy estuaries. These concentrations, coupled with the major variations in the small structures of the ocean bottom recorded in time-series of photographs, show that the vigorous movements of the bottom currents erode and transport large amounts of the fine-grained sediment. Indeed, careful examination of sediment cores from the ocean bed reveals the rapid rates of deposition of sediment and the occurrence of frequent episodes of erosion: several centimetres of mud may be deposited in the course of a few days and then removed equally rapidly. By such a process more than 3,000 times more material may have been deposited in

the 10,000 years of the Holocene than is apparent from the deposition rate of 5 cm kyr$^{-1}$ recorded in the sediments, according to the estimates of Hollister and McCave. It is common to find that the rates of short-term sedimentation (and erosion) are several orders of magnitude higher than those of long-term accumulation for the shallow-sea deposits in many old sedimentary basins but it has not hitherto been known that the same is true on the floors of deep oceans.

Considering all the deep oceans of the

Earth, Hollister and McCave point to seven discrete areas, most of them tens to hundreds of kilometres across, where the suspended load of the deep-ocean water is particularly high. All the areas occur below zones of high surface-eddy kinetic energy, and probably contain deep currents which move strongly and reverse intermittently. These few, rather small areas may be the prime sources of much of the suspended muddy material of the world's oceans just as a few land areas, which have erodible soils and intermittently strong winds, seem to contribute a large part of the very fine-grained suspended terrigenous materials in the Earth's atmosphere.                              □

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## Colour vision

# Direct recordings from the cone cells of a primate

*from J. D. Mollon*

FACED with the infinite varieties of hues and tints in a sunlit wood in spring, it can be difficult to believe that all our sensations of colour arise from just three unidimensional retinal signals. Nevertheless, our ability to see in colour depends on no more than a comparison of the relative rates of absorption of photons in the three types of cone cell within each local region of the retina and on the distribution of these ratios across the retina. The three types of cone cell contain photopigments with peak sensitivity in different parts of the visible spectrum; although direct measurements of their absorbance spectra have been possible for many years, Nunn, Schnapf and Baylor have achieved a great technical feat in obtaining the first direct electrophysiological recordings from a primate cone cell, reported on page 264 of this issue[1].

The existence of three types of retinal receptor was first suggested 200 years ago[2,3] and by 1886 the brilliant Arthur König had accurately deduced the spectral sensitivities of the cones from psychophysical studies of normal and colour-blind observers[4]. But the three types of cone remained, in effect, hypothetical constructs until the first direct measurements of the absorbance spectra of the different cone types were obtained by microspectrophotometry, in which a narrow monochromatic measuring beam is passed through the outer segment of an individual receptor cell. Nowadays relatively precise estimates of the three absorbance spectra are available for monkey and human retinas[5,6].

An absorbance spectrum — a plot of the optical density of the cell at different wavelengths — is not, however, necessarily

the same as an electrophysiological action spectrum, which shows the number of photons required at different wavelengths to produce a given electrical signal. For example, it might have been the case that the electrical signal produced by an absorbed photon was dependent on wavelength. Moreover, the steep long-wavelength limbs of the absorbance spectra can be followed only down to values around one-tenth of the maximum absorbance, whereas action spectra are not so limited and it is easy to measure the intense lights needed to produce a criterion electrical signal at long wavelengths.

It is physiological action spectra that Nunn, Schnapf and Baylor have now provided us with. To measure them in the tiny (perhaps 2 $\mu$m by 10 $\mu$m) pigment-containing outer segments of primate cones, they adapted a clever trick that Yau, Lamb and Baylor[7] introduced in 1977 originally to make recordings from the much larger photoreceptors of the toad. Instead of trying to put a microelectrode inside the outer segment, Yau *et al.* put the outer segment inside a micropipette, sucking it gently in and allowing the mouth of the pipette to form an electrical seal round the base of the outer segment. The signal thereafter measured is a graded reduction in the current that flows continuously into the outer segment in the dark.

In their samples of tissue from macaque monkeys, Nunn *et al.* have been able to record only middle- and long-wavelength cones; the peak sensitivities of the two types of record lie quite close together in the green (540 nm) and yellow-green (570 nm) regions of the spectrum, in good correspondence with both psychophysical