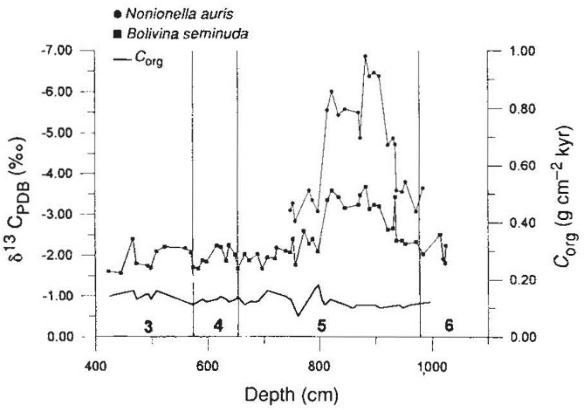
Clues to ancient methane release

SIR — One of the most fascinating results of the various studies on polar ice cores is the discovery of large-scale changes in atmospheric methane over the past few ice-age cycles[1–3]. Methane is a radiatively highly active greenhouse gas[4], and so changes in its concentration are thought to contribute substantially to climate change[5]. The role of the chief reservoirs of methane in producing atmospheric methane variations in the past is poorly understood, as is true for the present[6]. One large reservoir that must be considered is methane within the sea floor of coastal zones of high productivity.



Organic carbon content C_{org} and $\delta^{13}C$ values of benthic foraminifera in a core raised off Peru (ODP site 680 B, Leg 112), at a water depth of 252 m. Methane hydrates are abundant on the slope in this region[16]. The benthic foraminifers analysed are *B. seminuda* and *N. auris*. The $\delta^{13}C$-values of both species are unusually light during oxygen-isotope stage 5 (stratigraphy after ref. 17), that is, during the last true interglacial period. The excursion reaches beyond −5‰, which suggests an influence from methane release.

Enormous amounts of methane are thought to be stored as gas hydrates within the continental margin[7]. The stability field is such that the shallowest occurrences of gas hydrates are at water depths greater than 300 m (ref. 7). As temperature and pressure fluctuate within the sediment column (in response to ice-age climate cycles and sea-level variation), methane storage fluctuates similarly. Such changes have been invoked as a potentially strong positive feedback within the climate system, with warming leading to methane release[8,9]. Noting that pressure change could be more important than temperature change in moving clathrates to a different position within the stability field, others have instead proposed negative feedback[10]. Given the ice-core results that atmospheric methane content is high in interglacials[1–3], a negative feedback of seafloor methane seems to imply only a minor role for marine methane in modifying ice-age climates.

Clearly, an inventory of methane release as a function of climatic stage (or at least the sign of any release) on the sea floor would be of the greatest interest in deciding the question about the sign of the postulated feedback. The task is perhaps not as hopeless as it might seem at first blush. Methane within the continental slope is highly depleted in ^{13}C, with $\delta^{13}C$-values typically near −50‰ (−35‰ to −80‰, depending on proportions of CH_4 derived from fermentation, CO_2 reduction, or thermal fractionation[11]). If such methane reaches the sediment surface in unusual amounts, it should considerably decrease the $\delta^{13}C$ of ambient dissolved inorganic carbon when being oxidized in the pore space of surface sediments. In turn, this process would be recorded by benthic foraminifera living at or just below the sediment surface. Their sensitivity to ambient $\delta^{13}C$ is reflected in the fact that infaunal foraminifers have low $\delta^{13}C$-values compared with epifaunal ones[12,13].

That benthic foraminifers are indeed sensitive to the presence of methane is suggested by the extremely negative $\delta^{13}C$ values in the late Quaternary section (isotope stage 5) of the deep drilling site ODP 680 B, off Peru (see figure). This site is located on the shelf in a region of upwelling and upslope from known gas-hydrate occurrence. These values define a range well beyond the usual one of about 2‰ (ref. 14). The two species analysed, *Bolivina seminuda* and *Nonionella auris*, show parallel excursions; however, they are not sensitive to the same degree. Thus, the possibility emerges that certain species might be indicators for high concentrations of biogenic methane in pore-waters just below the sediment surface, from sources deeper in the sediment.

Could the negative $\delta^{13}C$ spike be a result of conditions other than the presence of methane? Conceivably, enough organic matter could be oxidized from sulphate reduction to depress the $\delta^{13}C$ of the CO_2 within the pore waters by more than 10‰ (at a depth of >20 cm (ref. 15). However, if this mechanism is to be called on to provide the unusual carbon-isotope ratios in *N. auris*, we must then assume that this species builds its shell at considerable depth within the sediment, that is, within an anoxic (and presumably H_2S-containing) environment. This seems unlikely. There is, in any case, no correlation between organic carbon content (C_{org}) and $\delta^{13}C$, which would be expected in the sulphate hypothesis. Instead, *N. auris* is highly abundant during negative $\delta^{13}C$ excursions of *B. seminuda*. We suggest that *N. auris* is an indicator for the presence of methane and is possibly specialized in feeding on methane-oxidizing bacteria.

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Holograms in algal suspensions

SIR — Photorefractive crystals can record holograms in the form of phase gratings arising from their response to an interference pattern. Absorption of light produces a local electric field which modifies the refractive index via the Pockels effect[1]. Algae exhibiting photo-induced taxis (movement in response to a light stimulus[2]) can be thought of as behaving in an analogous manner, except that by their presence or absence they change the local transmission of a sample, instead of its refractive index. We report here the recording of an optical grating in a suspension of algae and the subsequent reconstruction of a simple hologram.

The flagellate *Dunaliella primolecta* Butcher (CCAP 11/34) is usually contained in cuvettes of path length 1 cm at number densities of about $10^5 - 10^6$ ml^{-1}, corresponding to cultures of 2 – 6 weeks' growth from inoculation. Both positive and negative taxis can be seen, following illumination for periods of 15 min up to a few hours by the beam from a randomly polarized 2-mW 632.8-nm He-Ne laser. Inspection of the cuvette shows that in