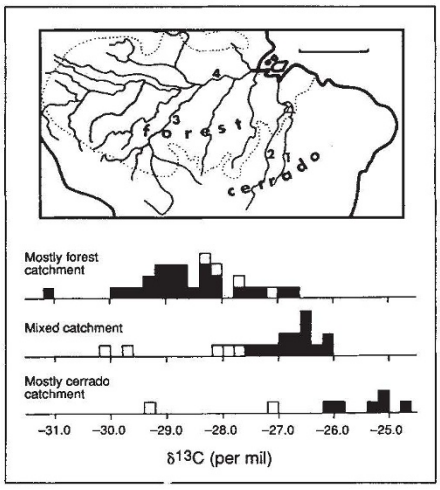

Carbon isotope results and study area. 1, Tocantins; 2, Araguaia; 3, Madeira; 4, Amazon rivers. Scale bar, 1,000 km. Dotted line, present extent of forest; triangle, general area in which sampling was undertaken for this study. The $\delta^{13}C$ results are reported in per mil, relative to the PDB standard. Open boxes, dry season; closed boxes, wet season. Data for forested catchments from ref. 5. Data for cerrado catchment (Tocantins) from this study. Data for mixed catchments from this study (Araguaia, and two unnamed streams south of Porto Franco-Pará) and ref. 5 (Madeira).

−12‰ (ref. 4).

The $\delta^{13}C$ values of particulate organic carbon (POC) in fluvial sediments will depend upon the proportion of C_3- and C_4-derived carbon in the vegetation and soils of the tributary catchments (algae are characterized by low $\delta^{13}C$ values, but do not contribute greatly to the carbon budget of rivers in the Amazon basin[5]). Therefore, if the Amazon forest contracted to isolated 'refugia' during the LGM, and was largely replaced by cerrado-style vegetation, a shift to more positive $\delta^{13}C$ values should be observed in sediments of that age.

To test this hypothesis, suspended sediment and bottom sediment samples were collected from the Tocantins/Araguaia river system, on the eastern margin of the basin. This is the only major tributary of the Amazon with a catchment that is not predominantly forested, and one of the few tributaries for which there is not already a substantial $\delta^{13}C$ database. The samples were pretreated and analysed according to the procedures outlined by Hedges *et al.*[5] to make the results directly comparable with the data from the other major tributaries detailed in that study.

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The figure shows that there is a difference of 2–4‰ between the $\delta^{13}C$ values of POC from rivers draining forest versus cerrado catchments during the wet season, but no difference during the dry season. The lack of difference in the dry season results from the fact that most rivers in the cerrado region are fringed by a C_3-dominated strip of forest, which provides the bulk of the carbon exported during the dry season (−27 to −30‰). During the wet season, high runoff rates transport C_4 carbon to the river from more remote areas leading to $\delta^{13}C$ values as high as −24.6‰.

The $\delta^{13}C$ value of the POC in rivers draining forested catchments is the same as that of the forest vegetation during both the wet and dry seasons. However, in rivers draining cerrado catchments, the $\delta^{13}C$ values of POC are consistently lower than in the bulk vegetation (cerrado soils have $\delta^{13}C$ values between −15 and −25‰). This is due to the above-mentioned bias towards C_3 carbon derived from close to the river, preferential metabolism of C_4 carbon by microorganisms in the river, and a small contribution from low-$\delta^{13}C$ algal biomass.

While the $\delta^{13}C$ value of POC from rivers draining cerrado catchments does not accurately reflect the bulk $\delta^{13}C$ value of biomass in the catchment, the cerrado $\delta^{13}C$ signature can nonetheless be readily distinguished from the $\delta^{13}C$ signature of POC in rivers draining forested catchments. Therefore, the $\delta^{13}C$ value of organic matter in ancient fluvial sediments can potentially provide a basin-wide history of forest growth/collapse during the Quaternary both in the Amazon basin and in other tropical regions. Interpretation of $\delta^{13}C$ trends in ancient sediments also need to take into account changes in the concentration and $\delta^{13}C$ value of atmospheric CO_2 (refs 1, 6) changes in the proportion of previously respired CO_2 re-utilized by forest vegetation[7], and the possibility of diagenetic modification of the $\delta^{13}C$ value of POC after burial.

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1. Crowley, T. J. *Nature* **352**, 575 (1991).
2. Soili, H. (ed.) *The Amazon: Limnology and Landscape Ecology of a Mighty Tropical River and its Basin* (Junk, Boston, 1984).
3. Colinvaux, P. A. *Nature* **340**, 188 (1989).
4. Smith, B. N. & Epstein, S. *Plant Physiol.* **47**, 380 (1971).
5. Hedges, J. I. *et al. Limnol. Oceanogr.* **31**, 717 (1986).
6. Freidli, H. *et al. Geophys. Res. Lett.* **11**, 1145 (1984).
7. Van der Merwe, N. J. & Medina, E. *Geochim. cosmochim. Acta.* **53**, 1091 (1989).

Carbon suboxide in Halley

SIR — Crovisier *et al.*[1] conclude from an examination of the VEGA 1 IKS infrared spectra[2] that carbon suboxide (C_3O_2) is not present in the comet Halley ices at the abundance level suggested by us[3]. They show the measured spectrum near 4 μm and note the absence of the strong C_3O_2 line emission, relative to the CO_2 emission, that should be present if the C_3O_2 production rate was comparable[3] to that of CO_2. Key assumptions in this analysis are that C_3O_2 is released from the comet nucleus and has a scale length similar to the CO_2 scale length.

Our discussion[3], however, is based on a coma grain source for C_3O_2 peaking at a distance from the nucleus (R) of ~8 − 10 × 10^3 km. For a radial velocity of 1 km s^{-1}, the scale length of C_3O_2 is only ~2 × 10^3 km, whereas the scale length of CO_2 is ~4 × 10^5 km[3–6]. The concentration, c, of a species flowing radially outward from the surface of a sphere (with radius R_0) and decaying exponentially with a scale length H is[7]

$$c(R)=c(R_0)\,(R/R_0)^2\,e^{-(R-R_0)/H}$$

If CO_2 is released from the comet nucleus (mean R_0 ~7 km) and C_3O_2 enters the gas-phase at R_0~10^4 km with equal production rates, integration of the equation yields a maximum column density along the line of sight to the nucleus for CO_2 that is 10^4 times the calculated column density of C_3O_2. Even with the C_3O_2 fluorescence factor three times larger than CO_2, the C_3O_2 infrared emission should be much weaker at 4 μm than the CO_2 emission. This is consistent with the observational data shown by Crovisier *et al.*

Our brief analysis suggests that C_3O_2 can have a large coma production rate, relative to water, but still be hard to detect by remote sensing because of the large area over which it enters the coma gas-phase. A more detailed investigation taking into account the viewing geometry of the IKS experiment is needed to assess the expected infrared emission from C_3O_2 arising from a distributed coma dust source.

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1. Crovisier, J., Encrenaz, T. & Combes, M. *Nature* **353**, 610 (1991).
2. Combes, M. *et al. Nature* **321**, 266–268 (1986).
3. Huntress, W. T., Jr, Allen, M. & Delitsky, M. *Nature* **352**, 316–318 (1991).
4. Nakata, R. S., Watanabe, K. & Matsunaga, F. M. *Sci. Light* **14**, 54–71 (1965).
5. Hitchcock, A. P. & Brion, C. E. *Chem. Phys.* **45**, 461–478 (1980).
6. Lewis, B. R. & Carver, J. H. *J. Quant. Spectrosc. Radiat. Transf.* **30**, 297–309 (1983).
7. Haser, L. *Bull. Acad. R. Belg., 5e série* **43**, 740–750 (1957).