further, the five morphologies described above show a sufficient morphological range to imply that even in these Archaean sediments, a considerable variety in the population exists. The assemblage is similar to that described from rocks of nearly equal antiquity[6–9], and suggests that evidence for early Archaean life may be more widespread than was previously thought[15]. A comprehensive search for microfossils in other Archaean sediments in the east Pilbara Block is in progress.

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Very low salinity regions of estuaries: important sites for chemical and biological reactions

THE importance of biogeochemical interactions in estuaries is widely recognised[1,2,4–6]; in particular, theoretical models of estuarine speciation of trace metals[7] and of the pH–carbonate system[8] predict that sharp changes of thermodynamic equilibrium conditions should occur at very low salinities (<1‰). However, because of the limitations of conventional sampling strategies[12], the chemical properties of this freshwater–seawater interphase (FSI) have not been adequately characterised. Instead, the expected variability has usually been represented by a scatter of spatially and temporally unresolved data points[1,3,5,6]. Over the past two years, we have carried out periodic detailed investigations of the immediate mixing of the fresh and brackish water in the Tamar Estuary, South West England and we present data here for 11 determinands which point to the FSI as being an important site for chemical and biological processes in estuaries.

Interactive chemical processes involving the removal or addition of a dissolved constituent in estuarine waters have been inferred from nonlinear regressions of the dissolved constituent when plotted against a conservative index of mixing such as salinity or chlorinity[1,2]. Nonlinearity may also be attributed to: (1) variabilities of flux and composition of the freshwater end-member over time scales comparable to the residence time of water within the estuary; and (2) subsidiary inputs of compositionally different waters. Therefore, the unequivocal demonstration of non-conservative (that is interactive) behaviour using salinity regressions requires a precise temporal and spatial characterisation of the end-members of the theoretical dilution line and thus necessitates careful and frequent sampling at the seawards and, especially, at the freshwater ends of the estuary. The sampling strategy, described in detail elsewhere[12], is summarised in Figs 1 and 2. The inset chart in Fig. 1 shows the upper reaches of the Tamar Estuary and the positions of the 1.0‰ isohalines observed during four traverses of the estuary at different states of the tide on 17 and 18 August 1977. Oxygen supersaturation at the extreme seawards and freshwater ends of the estuary is a result of active primary production. The mid-estuarine O_2 deficiency is effected partly by the biological oxygen demand (BOD) of Plymouth sewage outfalls located at the mouth of the estuary (not shown on chart), and partly by increasing resuspension of bottom and intertidal sediments concomitant with approaching spring tide conditions. However, the most notable feature of Fig. 1 is the very sharp drop in O_2 which persistently occurs at the FSI, irrespective of the state of the tide or the position of the FSI along its ~13 km tidal excursion. It is unlikely that this enhanced O_2 depletion could have been generated by resuspension of anoxic bottom sediments because (1) it was absent in winter surveys, (2) resuspension, as measured by water column turbidity was found to be uniformly high (200–300 p.p.m.) and extended through the FSI and well into the fresh water, and (3) resuspension forces are not coupled to the salinity in the way the O_2 drop seems to be. In addition, there are no significant inputs of sewage in this area. Thus, the O_2 utilisation processes must be triggered in the water column at the FSI and are related to seasonal biological activity of the estuary.

Simultaneous profiles of O_2 and other chemical constituents obtained on 17 August are compared in Fig. 2. A stoichiometric balance of the oxygen deficit (ΔO_2) of 117 $\mu M\ O_2 l^{-1}$ generated in the 0.10–1.00‰ mixing segment against possible dissolved species which may undergo oxidation within this segment is shown in Table 1. The oxidisable inorganic constituents and the riverborne BOD entrained into the O_2 depletion zone together account for only 5.7% of ΔO_2. If, however, the non-conservative decrease in the DOC peak (ΔDOC) centred at 0.2‰ is assumed to result from microbiological decom-

Fig. 1 Inset map of the upper reaches of the Tamar Estuary and the positions of the 1.0‰ isohalines during four traverses on 17 and 18 August 1977 (Plymouth City is located ~25 km downstream from Calstock). The corresponding dissolved O_2 concentrations as well as the 100% O_2-saturation profile are plotted against salinity.

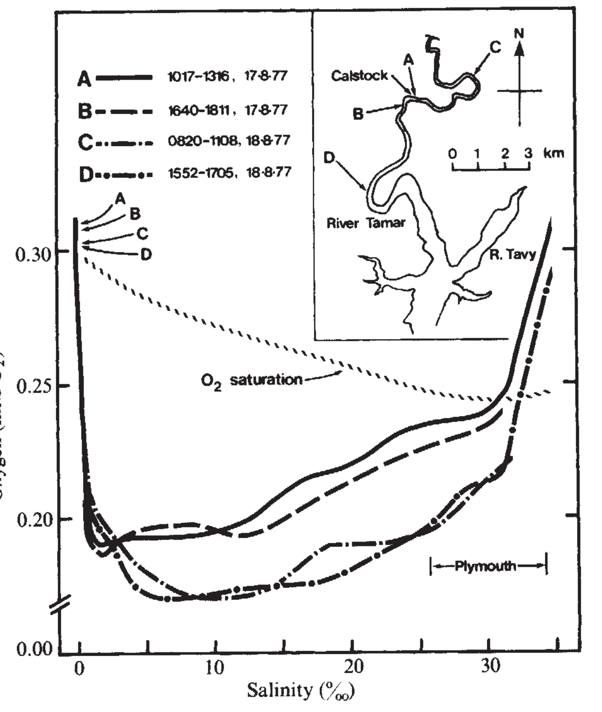

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Table 1 Oxygen balance for the 0.10–1.00‰ mixing segment of the Tamar Estuary, 17 August 1977

Reduced species	Concentration in R. Tamar (μM)	Oxidised form	O_2 requirement (μM)	% of ΔO_2 (ΔO_2 = 117 μM)
NO_2^-	1.0	NO_3^-	0.5	
NH_3*	2.1	NO_3^-	4.2	
Fe (II)*	2.3	Fe(III)	0.6	5.4%
Mn (II)	2.0	Mn (IV)	1.0	
Δ DOC–C	102	CO_2	81.6	69.7%
Δ DON–N	15.4	NO_3^-	24.6	21.0%
BOD*	44.0	CO_2	0.4	0.3%

ΔO_2 corresponds to the decrease in dissolved oxygen between fresh water and the 1.00‰ isohaline, as shown in Fig. 2. Maximum O_2 requirement for inorganic oxidation reactions were estimated by assuming all the dissolved Fe and Mn to be in the (+II) oxidation state, and that the oxidation product of NH_3 and NO_2^- is NO_3^-. ΔDOC is the non-conservative decrease of the DOC peak (see Fig. 2) by microbiological decomposition to CO_2, whereas ΔDON is the associated organic nitrogen estimated using N:C ratio of 16:106[14]. The mineralisation of organic matter to CO_2 and NO_3^- was assumed to be 80% efficient[26]. BOD 'concentration' is equivalent to the quantity of O_2 used in a 5 day incubation at 20 °C[16]. The corresponding O_2 used within the 0.10–1.00‰ mixing segment was calculated from the mean residence time $\bar{R}$ of 9.3 h for this segment. ($\bar{R} = \bar{F}/\bar{V}$; $\bar{F}$ (mean river flow at Gunnislake, 17 August 1977) = 3.096 $m^3 s^{-1}$; $\bar{V}$ (volume of 0.10–1.00‰ segment of the estuary at 1300, 17 August 1977) = 1.04 × 10^5 m^3.) O_2 production by photosynthesis and reaeration over time period $\bar{R}$ was estimated to be <2% of ΔO_2, and thus omitted from the calculations.

* Data obtained on 18 August from B. Milford, South West Water Authority.

position of the dissolved organic matter to CO_2 and NO_3^-, then it is possible to account for a maximum of ~91% of ΔO_2 (see Table 1 for details). The coincidence of the O_2 sag and the DOC peak with the chlorophyll fluorescence minimum within the 0.10–1.00‰ mixing segment suggests that they are coupled by a common mechanism. We hypothesise this mechanism to be a sequence of processes starting with mass mortality of fresh water halophobic phytoplankton incapable of withstanding the sharp sudden osmotic and compositional changes of the FSI. This results in a continuous plasmolytic release of easily degradable dissolved organic material, which, in turn, supports a localised, but active, population of O_2-utilising bacteria.

Applying this 'osmotic hypothesis' to our data, it follows that the release of ~100 μM DOC-C l^{-1} at the FSI would be brought about by the plasmolysis of a biomass of fresh water phytoplankton containing 40 μg chlorophyll-*a* l^{-1} (C: Chl-*a* = 60:1 (ref. 21); soluble cell contents = 50%). Comparable or greater levels of chlorophyll-*a* are encountered in productive rivers[28]. However, apart from isolated taxonomic observations[19,20] pointing to the absence of freshwater species of phytoplankton in estuarine and marine waters, there do not seem to have been any quantitative investigations of the fate of riverborne phytoplankton in estuaries. In steady-state conditions the 0.10–1.00‰ segment, which can be shown to be wholly contained within the second mixing compartment of a Ketchum-type estuarine tidal circulation model[22], is characterised by a hydrodynamic exchange ratio (r) equal to 0.89. The rate of reproduction necessary to maintain a constant

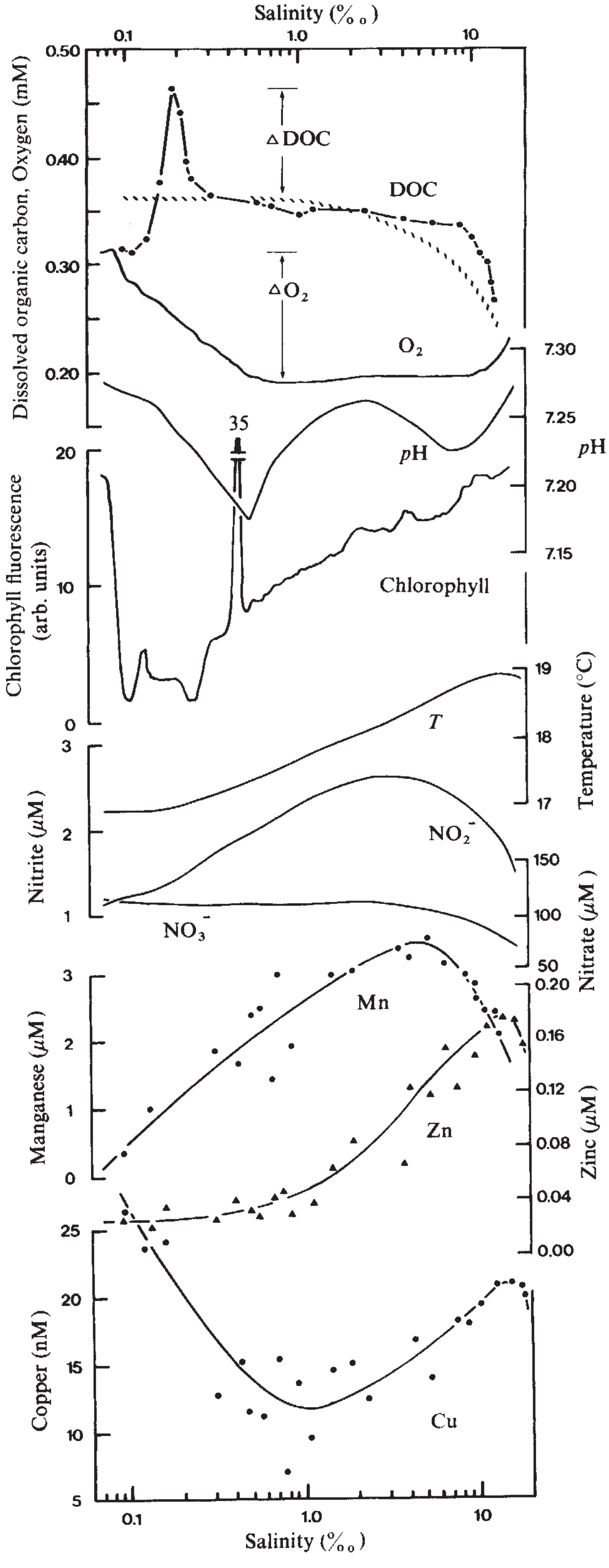

Fig. 2 The estuarine profiles for O_2, pH, relative chlorophyll fluorescence, temperature and the concentrations of dissolved organic carbon DOC, conservative DOC profile (- - - -), nitrate NO_3^-, nitrite NO_2^-, manganese, zinc, and copper obtained on 17 August 1977. These have been plotted against $\log_{10}$ salinity (‰) to resolve spatially the concentration changes which occur at low salinities. In conjunction with an Electronic Switchgear MC-5 salinity–temperature bridge, a chloride selective electrode (Phillips 1S 550-Cl) calibrated against standards of known salinity was used for indicating the degree of mixing in regions of low salinities. Continuous records of Cl^- electrode response, O_2 concentration (Model 57, Yellow Springs Instruments), pH (Pye-Ingold Model 400 series) and relative chlorophyll fluorescence (Turner Instruments) were obtained during the traverse. DOC in GF/C glass fibre filtered samples was determined in triplicate using a modified sea-going version of an automated photochemical analyser[17]. NO_2^- and NO_3^- were determined using conventional Technicon Autoanalyser® coupled to a continuous filtration system[13]. Mn, Zn and Cu were determined by preconcentration of membrane filtered samples on chelating resin (NH_4^+ form) followed by atomic absorption spectrophotometry[18]. Recoveries and calibrations for all determinands were checked using standard additions to samples of various salinities.

endemic population of bacteria in this segment in spite of continuous depletion by river run-off and tidal circulation may be derived from the equation[23] $k = -\ln(1-r)/12.4$ where k is the specific reproduction rate and is equal to $0.18\ h^{-1}$. The corresponding division time of 3.85 h is a measure of the microbiological activity required to maintain the sharp O_2 depletions shown in Fig. 1. It follows that the 'chemostatic' decomposition of ΔDOC shown in Fig. 2 would require an active population of $1-4\times10^6$ cells ml^{-1} (1 bacterium = 10^{-13} g C (ref. 25); growth efficiency = 0.25–0.75 (refs 26, 27 respectively)) which compares favourably with direct bacterial enumerations reported for the brackish regions of Kiel Fjord[24].

The sharp increase in $[NO_2^-]$ starting from 1.0 μM $NO_2^-\ l^{-1}$ at the FSI and reaching a maximum of 2.7 μM $NO_2^-\ l^{-1}$ at 3.1‰ represents an intermediate stage in the oxidation of DON and NH_3 to NO_3^-. However, it is difficult to observe the subsequent production of NO_3^- as a positive deviation from the theoretical dilution line because analytical precision would have to be better than 1% for the very abundant background levels of NO_3^- (~120 μM $NO_3^-\ l^{-1}$) in the Tamar River.

The pH minimum of 7.18 centred at 0.5‰ is partly due to the mineralisation of DOC and partly to the sharp changes in the conditional stability constants of carbonic acid resulting from increasing ionic strength across the FSI[8,11]. Such perturbations in pH of estuarine waters have a profound effect, not only on the adsorption equilibria of trace metals with suspended particulate material[9] but also on their speciation and reactivity[7,10,15]. The Mn, Zn and Cu profiles in Fig. 2 are non-conservative. The mid-estuarine maxima common to all three metals and to water temperature correspond to a natural input of metal-rich solar-warmed pore water from the large areas of intertidal mudflats in the mid-estuarine regions of the Tamar. However, the estuarine chemistries of Mn, Zn and Cu within the 0.10–1.00‰ mixing segment are conspicuously different. It is difficult to quantify and identify which of the many potential parameters and reactions (such as, pH, S‰, redox and adsorption equilibria, and kinetic barriers[9,10]) could account for the observed differences at the interphase.

The fivefold increase in Mn is surprising when one considers its well established interactive nature with Fe[11], which is a highly non-conservative constituent of estuaries[1,2]. Preliminary experimental studies of Mn in the Tamar Estuary strongly suggest that the overriding process is a kinetically controlled heterogeneous redox mechanism, displaying a salinity dependence. In contrast, the electrochemically more inert Zn is conservative within the 0.10–1.00‰ mixing segment. A negative Cu slope preceding the mid-estuarine increase may indicate either removal of Cu from solution or, more likely, a change in Cu speciation into an analytically unavailable form (such as, Cu-organic complexes)[11].

Clearly, the FSI is a chemically and biologically interactive zone requiring greater attention and characterisation than has been undertaken in previous estuarine investigations. The development of more precise geochemical cycling models and the refinement of estuarine oxygen models used for management purposes are two important topics which would benefit considerably from a fuller understanding of these interactions occurring across the FSI.

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Information transmission in remote viewing experiments

TARG AND PUTHOFF[1-3] have described investigations of an extrasensory remote viewing ability which they claim may be widely distributed in the general population. We have carried out duplicate experiments, but our results do not verify their conclusions.

In their experiments on remote viewing of natural targets with Pat Price[1], and later with other subjects[2,3], the subject remained with an experimenter at Stanford Research Institute (SRI) and at a prearranged time gave a description of an undisclosed, remote site being visited by a team of two to four co-experimenters. Each of nine remote locations was selected from over 100 targets within a 30-min drive of the laboratory. At the end of each trial the subject was taken to the target site to provide feedback.

To evaluate the accuracy of the remote viewings, the descriptions and a list of the nine targets were presented to independent judges who visited each target location in turn. Each judge chose the best description from the set of nine at each location. Five judges produced a total of 24 correct matches for the Price series ($P = 8\times10^{-10}$). In a further judging procedure, another judge, Dr Arthur Hastings, was asked to rank each of the nine transcripts on a scale from 1 to 9 (best to worst match) against each target location. The sum of ranks assigned to the target-associated transcripts was obtained. For nine targets this sum can range from nine (for a perfect matching) to 81, chance being 45. The judge produced a sum of ranks of 16 for Price ($P = 2.9\times10^{-5}$)[4].

During a recent visit to SRI D.M. attempted to duplicate the ranking procedure using transcripts from the original experiments with Price reported by Targ and Puthoff[1-3]. After discussions with Dr Hastings, the Price series of transcripts was made available for examination and it was agreed that I (D.M.) should rank in order a subset of five transcripts against five target locations. The remaining four locations and transcripts

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