matters arising

Middle Pleistocene stratigraphy in southern East Anglia

ROSE, Allen and Hey[1] proposed a revised chronology for the Middle Pleistocene, based largely on the presence of a rubified sol said to be developed in a temperate climate, but no supporting chemical or palynological evidence was produced.

Extensive surveys conducted by ourselves and colleagues (Institute of Geological Sciences, Geological Survey Sheets 223, 240, 241) have shown that the following sequence of drift deposits is present.

The sequence below is the optimum

Interpretation	Lithological unit
Weathered profile or solifluction deposits	7, Heterogeneous brown flinty sandy clay
Late phase fluvioglacial deposits	6, Poorly sorted sands and gravels
Till, dominantly of the lodgement type	5, Chalky boulder clay variably decalcified at base
Flow till	4, Brown and grey mottled sandy clay with angular and rounded flints, involution structures
Proglacial lake deposits	3, Laminated sands, silts and clay
Proximal outwash braidplain deposits with local flow tills	2, Sands and gravels with localised developments of (4) and (5), including the basal chalky Maldon Till which may be of the lodgement type
Distal outwash deposits	1, Fine micaceous sands

development but field evidence shows elements of this succession consistently through the area. All these deposits (1–6) are therefore considered to show integral parts of one (Anglian) glacial cycle of events.

A reddish colouration is developed at a number of horizons particularly where sandy clays have suffered remobilisation or eluviation has taken place from the lowest clay bed in the sequence. The eluviation process was apparently accompanied by dissolution of limestone material from the permeable beds where the ground-water was not lime-saturated. It seems unlikely that each of these horizons could be regarded as indicating a warmer period.

The thin and localised development of the Anglian fluvioglacial deposits suggested by Rose, Allen and Hey[1] is questionable for an area near the margin of an active ice-sheet. There is evidence for the former presence of an active ice sheet in the Thames Estuary[2] area which may have influenced the outwash drainage of the main East Anglian ice and thus account for the deduced north-eastward flow[1] of the lower gravels.

R. D. LAKE
R. A. ELLISON
B. S. P. MOORLOCK
*Institute of Geological Sciences,
5 Princes Gate,
London, UK*

1 Rose, J., Allen, P. & Hey, R. W. *Nature* 263, 492–494 (1976).
2 Lake, R. D., Ellison, R. A., Hollyer, S. E. & Simmons, M. *Rep. Inst. geol. Sci. U.K.* (in the press).

ROSE, ALLEN AND HEY REPLY—In response to Lake *et al.*[1] we wish to clarify the following points:

(1) Recognition of the temperate palaeosol is based not only on red colouration but on clay enrichment, iron enrichment, and clay skins on the upper sides of pebbles. These properties are considered characteristic of the illuvial horizon of a *sol lessivé* formed over a long period in a humid warm temperate climate. We are aware that iron stained horizons are common at many levels in the lower sand and gravel unit, but unlike the palaeosols horizon, these levels are not accompanied by a significant clay enrichment or clay skin development, and their colour does not reach levels of redness as high as 2.5 YR or 10 R. These iron-stained horizons are not continuous and are not developed at any particular level, but are specifically associated with sedimentary structures along which ground water drainage has been localised. The properties of the rubified *sol lessivé* are developed independently of the sedimentary structures and the original particle size characteristics.

(2) Lake *et al.* state that "sandy clays have suffered remobilisation, or eluviation has taken place from the lower clay bed in the sequence", to account for the "reddish colouration". If these processes were responsible, however, reddish colouration should be continuous along the interface of the sands and gravels and the overlying till. This is not the case. At certain localities the palaeosols horizon is cut-out by till. At other localities it is overlain by the upper sand and gravel unit and is thus not associated with a 'clay bed'. As the palaeosols horizon is cut-out by glacial and glacifluvial erosion, and as blocks of the palaeosol form erratics in the overlying till, rubification has occurred before ice invaded the locality.

(3) The observation that "the eluvial process was apparently accompanied by dissolution of limestone material from the permeable beds where the groundwater was not saturated" is incorrect, as fresh, hard limestone pebbles have been observed in all parts of the lower sand and gravel unit.

(4) An arctic structure soil is superimposed on the *sol lessivé*. This consists of an horizon of involutions, ice wedge casts, and sand wedges and is associated with coversand, loess, and wind polished stones. This indicates a long period of sub-aerial weathering in addition to the *sol lessivé*, and also demonstrates that the sequence of deposits were not formed in a single "glacial cycle of events".

(5) The revision of the stratigraphy is not solely based on the recognition of the palaeosols horizon. The glacifluvial sands and gravels above the palaeosols can be distinguished from the underlying periglacial river deposits on the basis of particle size, stone content, primary sedimentary structures, secondary sedimentary structures, palaeocurrent directions[2], and heavy mineral assemblage (J. A. Catt, personal communication). The heavy minerals in the lower sand and gravel unit show a restricted residual suite, whereas the range