JOBNAME: JGS PAGE: 1 SESS: 10 OUTPUT: Wed Sep 26 15:07:22 2001
/hling/journals/geo/195/01041

Journal of the Geological Society, London, Vol. **158**, 2001, pp. 877–879. Printed in Great Britain.

Discussion on lithospheric flexure, uplift, and landscape evolution in south-central England

Journal, Vol. 157, 2000, 1169–1177

Michael J. Simms writes: Watts, McKerrow and Fielding (2000) have made an interesting suggestion, that much of the present topography of the Cotswolds and the clay vales to the west has arisen through Late Pleistocene (post-450 ka) uplift in the Midlands, but the evidence on which it is based is extremely weak. The basic premise on which their hypothesis is founded is that the Northern Drift Group in Oxfordshire originated from outcrops of Triassic conglomerates in the Midlands, with these two regions once being linked by a continuous river along which the clasts were transported. They also contend that such a river could not develop across strike unless close to sea level, an assumption they fail to justify, from which they conclude that Pleistocene uplift must account for the presence of the Northern Drift Group at altitudes today of >100 metres OD.

However, although the ultimate source of the exotic (pre-Jurassic) clasts is not in doubt, Watts *et al.* (2000), and others before them (e.g. Whiteman & Rose 1992; Bridgland 1994), fail to provide convincing evidence for the putative ‘Northern Drift River’. It seems that the only evidence for this supposed river is clast lithology and rather speculative interpretation of terrace gradients in the Evenlode valley (Whiteman & Rose 1992). A more parsimonious transport mechanism for these exotic clasts, that of ice movement from the NW, has not been accorded due consideration in any of these recent papers.

Although much of the Northern Drift Group clearly is fluvial in character, observations cited by Hey (1986) are far more reminiscent of till. They include striated boulders at several sites and sediments consisting ‘for the most part of unstratified reddish sandy clay with pebbles, the latter often matrix-supported’ (Hey 1986, p. 293). Even the sandy, cross-bedded, and obviously fluviatile sediments were described as occurring only ‘locally’. Elsewhere he commented that the configuration of the deposits ‘bears no vestiges of terraces, but follows the irregularities of the underlying bedrock in the manner of a ground moraine’. Even where he did recognize terraces he noted that they ‘may locally be underlain by materials resembling till’ (Hey 1986, pp. 294–295). It would seem that Hey was not entirely objective in his interpretation of the Northern Drift Group as fluviatile in origin since his own descriptions suggest a significant glacial component. His dismissal of any glacial emplacement mechanism seems no more than ‘special pleading’; the abundant clay and absence of bedding attributed to diagenesis, while the striated boulders had been ‘carried by floating ice’ (Hey 1986, p. 294).

Significantly, in respect of the paper by Watts *et al.*, subsequent interpretation of the Northern Drift Group (e.g. Whiteman & Rose 1992; Bridgland 1994; Sumbler 2001) has largely supported the idea of a former extension of the Thames headwaters into the Midlands. Yet if this basic premise remains unproven or doubtful, then any further hypothesis founded on it, such as the Pleistocene uplift proposed by Watts *et al.* is no more than a house of cards.

A far more parsimonious explanation expounded by Shotton *et al.* (1980), among others, is for transport across the Midlands by early or mid-Pleistocene ice, with exotic clasts subsequently reworked from thin tills into fluvial gravels on a local scale only. Coe (1996) even suggested that the Northern Drift Group might represent a braided glacial outwash complex, again implying ice transport. Since Watts *et al.* (p. 1169) concede that their proposed river originated ‘from the margins of an ice sheet in central England’ it seems odd that they do not envisage that this ice sheet might have extended further south towards the present location of the Northern Drift Group. This would eliminate any need to invoke prolonged fluvial transport and the inferences which Watts *et al.* draw from this. Analogous, fluvially emplaced, exotic sediments have recently been described from the Burren, western Ireland, where transport distances of more than 50 km are indicated (Simms 2000). Like the Northern Drift Group, the sediment source in Connemara and their present location on the Burren are separated by a major low, in this case Galway Bay, but there is no suggestion that these fluvial sediments represent anything other than reworking of glacial till.

No doubt late Tertiary or even Pleistocene uplift has been significant in some parts of the British Isles, as has been argued persuasively by Dewey (2000) for the west of Ireland, and it may have played a role in the development of the Severn Vale and Cotswolds. However, whereas Dewey’s conclusions were drawn from extensive field observations made over several decades, Watts *et al.* appear to have based their hypothesis on uncritical acceptance of previous interpretations of poorly exposed deposits. Watts *et al.* present no new primary observations of these deposits themselves and indeed Hey (1986), still the most definitive account of the Northern Drift Group, admitted to very few personal observations of these critical sediments *in situ*.

On the current available evidence the nature and mechanism of emplacement of the Northern Drift Group remains a contentious issue. Reworking of glacially transported material is a far more parsimonious explanation than the supposed cross-Midlands ‘Northern Drift River’, for which no evidence exists beyond the Evenlode valley. Furthermore, it does not necessitate the scale of Pleistocene uplift envisaged by Watts *et al.* Neither the fluvial nor the glacial hypotheses are new suggestions but, in the past 15 years, the former appears to have come into favour at the expense of the less dramatic, but ultimately far more plausible, glacial scenario. Watts *et al.* should look again with a more critical eye at published accounts of the Northern Drift Group before they propose such radical upheavals as this.

However, perhaps of greater significance than the minutiae of this particular geological problem is the way in which it demonstrates the dangers of uncritical reliance on secondary sources of information at the expense of primary fieldwork.

14 March 2001

A. B. Watts, W. S. McKerrow & E. Fielding reply: We thank Michael J. Simms for his contribution. He makes a comment concerning the origin of the Northern Drift Group which we will address here.

Recent developments in Pleistocene stratigraphy have enabled a better correlation to be made of terrestrial sequences with the much more complete marine sequences. Not only can sequences onshore be correlated with the marine oxygen isotope record, but it is now clear that there have been colder episodes approximately every 100 000 years throughout the Pleistocene. We must no longer therefore think in terms of just 4 or 5 individual glacial events. Bowen (1999) summarizes a number of these developments as they relate to both the onshore and offshore of the British Isles. Our new interpretation of landscape evolution in south-central England takes into consideration not only the latest Pleistocene ages of the terrace formations of the Thames Valley, but also the deposits of the Celtic Deep in the south part of the Irish Sea.

The Northern Drift Group, which include clasts that can be sourced to the Birmingham area, form the highest (and oldest) terraces of Pleistocene age in north Oxfordshire. The work of Hey (1986) and Whiteman & Rose (1992), together with our own field observations (e.g. McKerrow & Baden-Powell 1953), suggest that the Northern Drift Group in north Oxfordshire is of fluvial rather than glacial origin. This is supported by the following.

(1) A glacial origin is *not* required in order to explain why the clasts in north Oxfordshire are higher than their present outcrop around Birmingham. The increased elevation could be explained instead by later Pleistocene downcutting, tectonic uplift and subsidence or, some combination of these factors.

(2) The presence of striated clasts merely indicates the presence of material that has been derived from an earlier glacial event. Their presence does *not* indicate a particular glacial event as there could have been many such events.

(3) Although the type locality of the Waterman's Lodge member on Stag's Plain in the Cornbury Park Estate is now obscured by vegetation, early descriptions by Arkell (1947) and Hey (1986), together with our own field observations, suggest that it is a well-sorted, bedded, deposit. Variations in bedding at other localities would be expected in thin, unconsolidated, sediments that have been exposed to a peri-glacial climate.

(4) Most glacial deposits are found with distinctive styles: for example, moraines, eskers and, drumlins. There are no such features associated with the Northern Drift Group of north Oxfordshire.

While we fully concur with Simms on the necessity for primary field work, we believe that a broader view is required in order to understand landscape evolution in south-central England. In particular, Pleistocene studies onshore and, importantly, offshore the UK need to be integrated with modern ideas of the relative role of sea-level changes and tectonics in controlling the nature of the stratigraphic record. We showed in our paper that tectonics, in the form of flexure, could account for a number of wide-ranging observations relating to landscape evolution in south-central England. In particular, flexural unloading due to the excavation of soft sediments from the English Midlands could explain:

(1) the outcrop of a fluvial river deposit, the Northern Drift Group, on a tilted plateau surface in north Oxfordshire;

(2) the change in strike of Jurassic rocks from north–south in Northamptonshire through NE–SW in north Oxfordshire, to north–south in east Somerset and Dorset;

(3) local uplift in the Cotswolds and, possibly, the Forest of Dean;

(4) the 'switch' that occurred when southeast flowing river systems in the English Midlands (e.g. the ancestral Avon) were deflected away from the Thames Valley and towards the Bristol Channel. The timing of this change in river flow is indicated by the 450 ka age of the oldest Pleistocene deposits in the Celtic Deep (e.g. Tappin *et al.* 1994).

We recognize, however, that tectonics contributes to topographic relief on a range of temporal and spatial scales. The challenge in the future will be to separate local effects associated with river excavation and unloading from more regional effects such as those associated with late-glacial rebound following retreat of the main ice loading centres in Wales and Scotland and tectonic subsidence and uplift in the nearby North Sea and Irish Sea basins.

10 May 2001

D. T. Donovan writes: Watts *et al.* (2000) suggest that the elevation of the Lower and Middle Jurassic Cotswold scarp between Gloucester and Northampton was due to Late Pleistocene crustal uplift in response to the unloading of the vales of Gloucester and Evesham by denudation of 'soft' Triassic and Liassic rocks.

Recent authors have postulated more widespread uplift of southern England and Wales. Watts *et al.* cite Maddy (1998), though only in connection with the age of the Northern Drift. Maddy maintained that the downcutting of the Upper Thames was a response to uplift, and that the river terraces could be used to provide a time scale for the downcutting. In a comment on Maddy's paper, Kiden & Törnqvist (1998) supported his general idea though they were sceptical of his quantitative conclusions.

Maddy's uplift, however, was regional for southern England, and was said to be in broad agreement with conclusions of Preece *et al.* (1990) regarding Quaternary uplift of the coastal region of SE England.

Long ago Wooldridge & Linton (1955) recognized a Pliocene marine surface in SE England at about 180 m OD, necessitating elevation by that amount during the Quaternary. Their ideas have since been much criticized (Jones 1999), but Jones wrote (pp. 19, 20) 'At some time after 2 Ma . . . While eastern East Anglia suffered subsidence, the remainder of southern England experienced differential uplift to a maximum of at least 250 m . . .".

The Cotswold scarp continues southwards to Bath from the region studied by Watts *et al.*, with elevations similar to those further NE. West of the scarp in this area the Trias and Lias are much thinner (Trias, *c.* 30 m, Kellaway & Welch 1993; Lower Lias, 90–120 m, Donovan & Kellaway 1984), than the *c.* 1000 m assumed for the vales of Gloucester and Evesham by Watts *et al.*, and the operation of an unloading mechanism seems less likely. At the foot of this north–south section of scarp there are faults throwing down to the east, not shown on the BGS 1:50 000 maps but revealed by ammonite zonal evidence (Donovan 1947 and unpublished). These would not seem to agree with an 'unloading' hypothesis. How far laterally did the effect of unloading extend?

2 May 2001

A. B. Watts, W. S. McKerrow and E. Fielding reply: We thank Donovan for his comments. He raises the question of the lateral extent of the uplift that was caused by the excavation of 'soft' Triassic and Liassic sediments from the English Midlands. The uplift clearly did not affect *all* of southern England since much of the Pleistocene in East Anglia and the Somerset levels is marine (e.g. Bowen 1999).

Although the calculations in Watts *et al.* (2000, 2001) are based on two- rather than three-dimensional models, they show that the maximum uplift occurs in the region of the greatest excavation. Therefore, the topographic depressions of the Vales of Gloucester and Evesham and the upper reaches of the Severn and Avon river valleys would have experienced the greatest uplift. Because of the strength of the lithosphere, however, the uplift extends up to 40–50 km *beyond* the edges of the excavated region. The Cotswold Hills, Northampton Uplands, the Lickey and Clent Hills and, the Forest of Dean, Malvern and Clee Hills are located within this flanking region and so, would also have experienced uplift.

The Cotswold Hills have a steep escarpment and a tilted plateau surface with a bedrock dip that is greater than the topographic slope, and they are the most prominent topographic feature that is now located within the region of flank uplift. We attribute this to their close proximity to the region of greatest excavation. What is surprising perhaps is why the uplift is so subdued in Northamptonshire and Leicestershire, where the thickness of the 'soft' Triassic and Liassic sediments is also high, and so prominent in south Gloucestershire and east Somerset where, as Donovan points out, the thickness of these sediments is low.

Although many of the limestone formations that make up the escarpment and the plateau surface of the Cotswold Hills become mudstones in Northamptonshire and Leicestershire and, hence, should be easily eroded, these regions show little sign of uplift. We believe, therefore, that the main factor that limits flank uplift to the NE of the Cotswold Hills is subsidence of the North Sea basin. Support for this suggestion comes from elevation profiles that suggest a regional downwarping of East Anglia and uplift of inland areas and the fact that, unlike north Oxfordshire, the entire Pleistocene sequence in regions such as Norfolk is marine.

The outstanding question is why the uplift is relatively well developed in south Gloucestershire and east Somerset. Donovan may be correct in suggesting that faulting in the Bath region is an important contributing factor. However, the Somerset levels and the eastern part of the Bristol Channel (including the Severn Estuary) form a broad low-lying topographic depression. Therefore, excavation of this region might have led to contemporary flank uplift in the Cotswold Hills south of Gloucester, the Mendip Hills, the Forest of Dean and, the eastern part of the South Wales coalfield. Unfortunately, the Pleistocene stratigraphy of these regions is still too poorly known (e.g. Bowen 1999) to constrain the age of the excavation and, hence, its associated flank uplift.

18 June 2001

References

Arkell, W.J. 1947. The geology of the Evenlode gorge, Oxfordshire. *Proceedings of the Geologists' Association*, **58**, 87–114.

Bowen, D.Q. (ed.) 1999. *A revised correlation of Quaternary deposits in the British Isles*. Geological Society, London, Special Reports, **23**

Bridgland, D.R. 1994. *Quaternary of the Thames*. Geological Conservation Reviews, **7**, Chapman and Hall, London.

Coe, J. 1996. The Northern Drift of the Evenlode Valley, Oxfordshire: an historical review. *Proceedings of the Cotteswold Naturalists' Field Club*, **41**, 106–117.

Dewey, J.F. 2000. Cenozoic tectonics of western Ireland. *Proceedings of the Geologists' Association*, **111**, 291–306.

Donovan, D.T. 1947. The Rhætic and Lower Lias rocks of Inglestone Common near Hawkesbury, Gloucestershire. *Proceedings of the Bristol Naturalists' Society*, **27**, 181–186.

Donovan, D.T. & Kellaway, G.A. 1984. *Geology of the Bristol district: the Lower Jurassic rocks*. Memoir of the British Geological Survey.

Hey, R.W. 1986. A re-examination of the Northern Drift of Oxfordshire. *Proceedings of the Geologists' Association*, **97**, 291–301.

Jones, D.K.C. 1999. Evolving models of the Tertiary evolutionary morphology of southern England, with special reference to the chalklands. *In:* Smith, B.J., Whalley, W.B. & Warke, P.A. (eds) *Uplift, Erosion and Stability: Perspectives on Long-term Landscape Development*. Geological Society, London, Special Publications, **162**, 1–23.

Kellaway, G.A. & Welch, F.B.A. 1993. *Geology of the Bristol district*. Memoirs of the British Geological Survey.

Kiden, P. & Törnqvist, T.E. 1998. Can river terrace flights be used to quantify Quaternary tectonic uplift rates? (Comment on Maddy, 1998, with reply by that author). *Journal of Quaternary Science*, **13**, 573–575.

Maddy, D. 1998. Uplift-driven valley incision and river terrace formation in southern England. *Journal of Quaternary Science*, **12**, 539–545.

McKerrow, W.S. & Baden-Powell, D.F.W. 1953. Easter Field Meeting 1952: The Jurassic rocks of Oxfordshire and their Superficial Deposits. *Proceedings of the Geologists' Association*, **64**, 88–98.

Preece, R.C., Scourse, J.D., Houghton, S., Knudsen, K.L. & Penney, D.N. 1990. The Pleistocene sea-level and neotectonic history of the eastern Solent, southern England. *Philosophical Transactions of the Royal Society*, **B328**, 425–477.

Shotton, F.W., Goudie, A.S., Briggs, D.J. & Osmaston, H.A. 1980. Cromerian interglacial deposits at Sugworth, near Oxford, England, and their relation to the Plateau Drift of the Cotswolds and the terrace sequence of the upper and middle Thames. *Philosophical Transactions of the Royal Society of London*, **B289**, 55–86.

Simms, M.J. 2000. Quartz-rich cave sediments in the Burren, Co. Clare, Ireland. *Proceedings of University of Bristol Spelaeological Society*, **22**, 81–98.

Sumbler, M.G. 2001. The Moreton Drift: a further clue to glacial chronology in central England. *Proceedings of the Geologists' Association*, **112**, 13–27.

Tappin, D.R., Chadwick, R.A., Jackson, A.A., Wingfield, R.T.R. & Smith, N.J.P. 1994. *The geology of Cardigan Bay and the Bristol Channel*. British Geological Survey, London.

Watts, A.B., McKerrow, W.S. & Fielding, E. 2001. Discussion on lithospheric flexure, uplift, and landscape evolution in south-central England: Reply to J. C. W. Cope. *Journal of the Geological Society, London*, **158**, 725–727.

Watts, A.B., McKerrow, W.S. & Fielding, E. 2000. Lithospheric flexure, uplift, and landscape evolution in south-central England. *Journal of the Geological Society, London*, **157**, 1169–1177.

Whiteman, C.A. & Rose, J. 1992. Thames river sediments of the British Early and Middle Pleistocene. *Quaternary Science Reviews*, **11**, 363–375.

Wooldridge, S.W. & Linton, D.L. 1955. *Structure, surface and drainage in south-east England*. George Philip & Son Ltd, London.

Michael J. Simms Department of Geology, Ulster Museum, Botanic Gardens, Belfast BT9 5AB, Northern Ireland (e-mail: michael.simms@nics.gov.uk)

D.T. Donovan Department of Geological Sciences, University College London, Gower Street, London WC1E 6BT (e-mail: d.donovan@ucl.ac.uk)

A.B. Watts Department of Geological Sciences, University College London, Gower Street, London WC1E 6BT (e-mail: d.donovan@ucl.ac.uk)

W.S. McKerrow Department of Earth Sciences, University of Oxford, Parks Road, Oxford OX2 3PR, UK (e-mail: tony@earth.ox.ac.uk)

E. Fielding Department of Earth Sciences, University of Oxford, Parks Road, Oxford OX2 3PR, UK (e-mail: tony@earth.ox.ac.uk)

Scientific editing by Alex Maltman.