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A stacked Late Quaternary fluvio-periglacial sequence from the Axe valley, southern England with implications for landscape evolution and Palaeolithic archaeology

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ABSTRACT

The current model of mid-latitude late Quaternary terrace sequences, is that they are uplift-driven but climatically controlled terrace staircases, relating to both regional-scale crustal and tectonic factors, and palaeohydrological variations forced by quasi-cyclic climatic conditions in the 100 K world (post Mid Pleistocene Transition). This model appears to hold for the majority of the river valleys draining into the English Channel which exhibit 8–15 terrace levels over approximately 60–100 m of altitudinal elevation. However, one valley, the Axe, has only one major morphological terrace and has long-been regarded as anomalous. This paper uses both conventional and novel stratigraphical methods (digital granulometry and terrestrial laser scanning) to show that this terrace is a stacked sedimentary sequence of 20–30 m thickness with a quasi-continuous (i.e. with hiatuses) pulsed, record of fluvial and periglacial sedimentation over at least the last 300–400 K yrs as determined principally by OSL dating of the upper two thirds of the sequence. Since uplift has been regional, there is no evidence of anomalous neotectonics, and climatic history must be comparable to the adjacent catchments (both of which have staircase sequences) a catchment-specific mechanism is required. The Axe is the only valley in North West Europe incised entirely into the near-horizontally bedded chert (crypto-crystalline quartz) and sand-rich Lower Cretaceous rocks creating a buried valley. Mapping of the valley slopes has identified many large landslide scars associated with past and present springs. It is proposed that these are thaw-slump scars and represent large hill-slope failures caused by Vauclausian water pressures and hydraulic fracturing of the chert during rapid permafrost melting. A simple 1D model of this thermokarstic process is used to explore this mechanism, and it is proposed that the resultant anomalously high input of chert and sand into the valley during terminations caused pulsed aggradation until the last termination. It is also proposed that interglacial and interstadial incision may have been prevented by the over-sized and interlocking nature of the sub-angular chert clasts until the Lateglacial when confinement of the river overcame this immobility threshold. One result of this hydrogeologically mediated valley evolution was to provide a sequence of proximal Palaeolithic archaeology over two MIS cycles. This study demonstrates that uplift tectonics and climate alone do not fully determine Quaternary valley evolution and that lithological and hydrogeological conditions are a fundamental cause of variation in terrestrial Quaternary records and landform evolution.

1. Introduction

The typical configuration of Quaternary fluvial sediment bodies along the NW border of Europe is as river terrace staircases which decrease in age with decreasing altitude (Bridgland and Westaway, 2007) as is seen in the Severn, and Thames (UK: Bridgland et al.,

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2004), Seine and Somme (France: Antoine et al., 2000) and Middle Rhine (Germany: Westaway, 2002). This scenario would be expected in non-cratonic areas where regional uplift has occurred (Bridgland and Westaway, 2008). For example where, during the Quaternary, river systems are close to glacial margins or within permafrost-affected regions and have been subject to large fluctuations in sediment supply with or without uplift (Hancock and Anderson, 2002). Recent research and sediment dating has shown that this model is frequently complicated by intra-cyclic sediments forming compound terraces of two cold (stadial) phases (although rarely more) separated by channel fills, loess or landsurfaces (e.g. palaeosols) of interstadial or interglacial origin (Lewin and Gibbard, 2010). This staircase configuration is reversed below a hinge-line into subsiding basins, such as the southern North Sea (Rhine) and into lateral diachroneity in tectonically stable areas. Whilst this model was based upon the larger river systems in Europe it also holds for small river systems and for most of the rivers along the coast of England (Brown et al., 2010a,b) and France which drain into the Channel River (English Channel/La Manche; Fig. 1a). The only exception appears to be the River Axe which, as mapped by the British Geological Survey (BGS; Edwards and Gallois, 2004), contains only one terrace at 14–30 m above the Holocene floodplain, a small (unmapped) fragments of a lower terrace only 1–2 m above the floodplain and spreads of ‘head’ or solifluction gravels on the upper slopes (Fig. 2). These two gravel bodies make up the Axe Valley Formation (Campbell et al., 1998a) which is known from three quarrying locations Kilmington, Broom and Chard Junction Quarry (henceforth, CJQ). To the west the Otter and Exe valleys (Fig. 1) have altitudinal staircases of 10 and 8 terraces respectively (Edwards and Gallois, 2004; Brown et al., 2009, 2010; Basell et al., 2011) and to the east the Frome/Piddle and Stour systems (Fig. 1) also have altitudinal staircases of 12–15 terraces (BGS, 2000) as would be expected in a region that has undergone Quaternary regional-uplift (Westaway, 2010, 2011). The River Axe is also known for a remarkably rich intra-fluvial Lower Palaeolithic site at Broom (Reid Moir, 1936; Hosfield, 2008; Hosfield et al., 2011; Hosfield and Green, 2013) which has produced over 1800 bifaces and is only comparable to rivers to the east at Woodgreen on the River Avon, and Red Barns and Hill Head on the Solent River (Wenban-Smith and Hosfield, 2001). This paper presents the results of research at the only working quarry in the Axe valley which had the aim of explaining this anomalous situation (i.e. single compound terrace) and understanding its ramifications for both Quaternary landform evolution and Palaeolithic archaeology.

2. Previous studies

The Axe is one of several catchments which drained into the English Channel and southern North Sea since the breaching of the Weald-Artois anticline; but which lie just to the south of the maximum glacial extent of the British–Irish–Fennoscandian ice sheet (Fig. 1) and experienced periglacial conditions for most of the Late Quaternary (Mol et al., 2000; Renssen and Vandenberghe, 2003). The Quaternary evolution of the River Axe has received considerable attention over the last 50 years due to its valley morphology and importance in Palaeolithic archaeology. Its atypical nature (single terrace) was noted by Green (1974, 2013) and Shakesby and Stephens (1984) and one of the aims of these studies was to test the hypothesis first proposed by Mitchell (1960) and later by Stephens (1977) that the anomalously thick gravels resulted from overflow through the Chard Gap (Fig. 3) from a ponded proglacial lake, Lake Maw, in the Somerset Levels (Fig. 1). The gravels at Chard do not support this hypothesis for two reasons. Firstly there are no clasts from the north Somerset area and secondly the gravels continue upstream of the entry point of the Chard gap into the Axe Valley, and into upstream tributaries (Green, 1974; Campbell et al., 1998a,b; Green, 2013). What is certain from these studies is that the Axe Valley and CJQ contains only one major morphological terrace and an anomalously thick sequence of locally derived gravels, principally Upper Greensand chert and flint. OSL dating at Broom also showed that the sequence younged upwards and is therefore a stacked or vertically aggraded gravel body of Late Pleistocene age (Hosfield et al., 2006, 2011). The quarry at Chard Junction which has been operating since the 1950s has produced occasional finds of Palaeolithic artefacts but these were found out of context (not in the gravel faces) such as the twisted ovate found by J. J. Wymer in 1959 and cordiform biface he also found in 1974. Wymer (1999) clearly thought that the site had considerable potential probably due to its proximity to the well-known sites at Broom (Hosfield et al., 2011; Hosfield and Green, 2013). Other than these isolated finds out of sedimentary context there has been no archaeological recording of the sub-surface archaeology of the gravels at Chard Junction (Basell et al., 2007). Palaeolithic artefacts recorded in the county Historic Environment Records (HERs) supplemented by museum records were plotted onto the DEM/geology drape and it can be seen that a cluster of 11 existed in the CJQ area prior to this study (Fig. 2).

3. Catchment hydrogeology

The bedrock geology and hydrogeology of the Axe valley are of critical importance to its Quaternary evolution and so will be discussed in some detail. The English Channel cuts discordantly across the Cenozoic basins and axial structures (anticlines) that run from the Seine Basin to the Thames Basin and further west to the Wessex basin and Dorset plateaux (Fig. 1). This provides the well-known laterally time-transgressive Mesozoic section that is known as the Jurassic Coast. This mega-section youngs from the Upper Triassic at the west end (Exmouth Sandstone and Mudstone) to the Upper Cretaceous at the east end (Upper Chalk Group). The Axe catchment is located approximately mid-way along this sequence and is incised into a short outcropping section of mid-Cretaceous Upper Greensand and chalk which form the scarp slopes of the Blackdown Hills (Fig. 1c). The Upper Greensand is a sub-horizontal sequence of clays, weakly- and un-cemented sandstones, and tabular chert overlain by clay-with-flints of Eocene age. Large blocks of siliceous rock known as sarsens, are also found on the Blackdown plateau and it is believed that they are also of Eocene age along with the clay-with-flints formation (Isaac, 1979; Scrivener et al., 2011). The valley has incised through this sequence and is now floored by mudstones of Lower Jurassic age up to just above CJQ at Forde Abbey. This coincides with a nick-point at the upper end of the incised valley (Fig. 3) with the result that the valley-sides below this point are composed of a 120 m thick ‘layer-cake’ of clay, sands and chert, sand and a basal mudstone of low permeability. In contrast the catchments to the west are underlain by only sandstones and mudstones (no chert) and to the east by chalk or Palaeogene sediments. A particularly unusual feature is the sand-chert-sand alternation which occurs in the CJQ area at 90–160 m OD (metres above ordnance datum sea level) and which produces a lower and upper spring-line at the base of the two sandstone members (Foxmould Member and Bindon Sandstone Member, Fig. 1). These members are separated by mineralised erosion surfaces (hard-ground) forming hydrogeological discontinuities. Today minor seepage occurs from the upper spring-line but the lower spring-line has historically had enough discharge to power a number of mills and a gravity driven fountain at Forde Abbey. The chert is well exposed 5 km to the east of the Axe valley at Shapwick/Pinhay Quarry where it is a 30 m thick bed of cryptocrystalline silicate fractured into tabular bedded blocks along the bedding which