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The southern English Wealden (non-marine Lower Cretaceous): overview of palaeoenvironments and palaeoecology

Jonathan D. Radley [a,*], Percival Allen [b,1]

[a] School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK
[b] Postgraduate Research Institute for Sedimentology, The University of Reading, PO Box 227, Whiteknights, Reading RG6 6AB, UK

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ABSTRACT

Geological Conservation Review sites representing the non-marine Lower Cretaceous Wealden strata provide field evidence for the physical and biological development of what is now southern England, between approximately 120 and 135 million years ago. Knowledge of Wealden climates, palaeogeology, landscapes, hydrology and palaeobiology is synthesized and summarised, with reference to the Weald and Wessex sub-basins.

1. Introduction

New field and laboratory evidence from the Geological Conservation Review sites documented in this body of work, integrated with that accumulated over the last few hundred years (references in Topley, 1875; Allen, 1975, 1981, 1989, 1998; Batten, 2011 and our Geological Conservation Review accounts), has led to a broad understanding of the physical and biological conditions in and around the Wessex–Weald Basin during the Early Cretaceous. Much relates to surface and near-surface environments, with important implications for plant and animal ecology.

2. Wealden climate

A major underlying factor was plate tectonics which, by the Valanginian had moved the Wessex–Weald Basin to almost 22° south of its present latitude. Through Wealden times (Berriasian–Hauterivian–earliest Aptian) rainfall increased spasmodically and mean temperatures fell slightly, leading to a 'Mediterranean' type of climate characterised by warm wet winters and hot drier summers. As at similar latitudes and longitudes today, the summers were interrupted by brief rainy spells, probably more so than under the strictly monsoon conditions then prevailing on the far eastern side of the Eurasian landmass. Throughout the record there is no sign of frosts.

From mid-Purbeck (Berriasian) times onwards, vertical movements periodically rejuvenated the Londinian, Cornubian and Armorican massifs. Out in the Weald and Wessex sub-basins smaller elevations rose. Particularly significant was the Purbeck–Isle of Wight–Portsdown–South Downs 'High', which marks the boundary between the sub-basins, each with its differences of stratigraphy and to some extent of facies. Rainfall was generally greatest on the massifs creating, during the highest uplifts, extensive alluvial aprons that merged on at least two occasions. The first was during Hastings Beds times, when Armorican sand invaded the southern Weald; the second was during Weald Clay times when detritus from Cornubia overran both sub-basins. So far as is known, Armorican and Cornubian detritus never mingled directly in the area under view.

Details of the climatically significant pedological processes are unclear, but the type of weathering on the forested massifs had changed everywhere about mid-Purbeck times. This produced more acid soils, probably podsols, yielding bleached siliceous pebbles, quartz-sand, kaolinite and hydroxyl interlayered vermiculite. The change was relatively rapid, and may have developed diachronously northwards. Its causes are unclear. Many factors such as atmospheric compositions and airborne particle loads are unknown. Both southern English sub-basins' histories were punctuated by storms, floods, droughts and numerous relative stases. On the whole the Weald Sub-basin seems to have been the wetter place and there may have been subtle differences at

* Corresponding author.
E-mail address: j.d.radley@bham.ac.uk (J.D. Radley).
[1] Deceased.

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more local level, but their meteorological mechanisms (e.g. through topographic effects) are not understood. No evidence for extraterrestrially driven climatic rhythms (e.g. Milankovitch) has been found, even in suitable lithofacies such as finely laminated slackwater mudstones (e.g. Compton Bay–Brighstone Bay and Warnham sites; Warlingham cores). Significantly, similar soil types, and presumably climates, occurred at about the same latitudes as today.

3. Wealden geology and topography

Essentially, the three major massifs exposed upland cores of pre-Mesozoic rocks margined by lowlands of Upper Jurassic strata and more elevated Permian-Triassic in the west and south–west. Altitudes in excess of 1000 m may have been attained. Further out, the minor uplifts exposed only Jurassic sediments. Other movements affecting the basin included small-scale growth-faulting. The surface expression of structural unconformities within the Wealden is debatable.

4. Wealden hydrology, salinity and solutes

With some calcareous rocks in their catchments, the stream waters entering the sub-basins were low in salinity and neutral or mildly alkaline except at times during major arenaceous phases when heavy rains brought in more acid water from the upland podsols. Repeated exposure of the detritus at source and on the sandplains, followed by reworking along lake–lagoon strands enhanced the solution of even the most siliceous materials. Offshore and elsewhere, calcareous (especially aragonitic) shells were liable to attack by organic acids, notably in the dark and red muds of both sub-basins (Wessex, lower Vectis, lower Ashdown and Wadhurst Clay formations).

Actual solute compositions must have varied with salinity. Mixing with seawater in the lake–lagoons and distal reaches of the streams resulted from lessened runoff, storms impeding flow, breaching of coastal barriers, local subsidence and short-term fluctuations of sea-level. Materials from demolished barriers may be represented by intercalations of Boreal sand and mud in the Weald Clay of the Weald.

5. Wealden landscapes

In earliest Wealden times the balance moved in favour of lower salinities as the alluvial hinterlands advanced and merged into largely freshwater facies, admitting steadily more mud, sand and plant debris from the massifs. Intermittent uplift, which generated small marginal and growth faults, led to increasing rainfall and more luxuriant vegetation, supporting highly diversified terrestrial faunas.

Seen on a journey down into the Weald Sub-basin from the forested Londinian hills, with their dinosaurs, gymnosperms, cycads, ferns and tracts blackened by wildfires (destined to become almost monospecific stands), a traveller in Hastings Beds times would have encountered rock outcrops (possibly with retreats for primitive mammals), mudslides and turbulent streams inhabited by spawning metre-long holosteans and other bony fish. Lower still, temporarily stable sand bodies bore spindly lycopods successfully coping with accumulating jumbles of sand, pebbles, cobbles and more or less disarticulated bivalves and fish skeletons.

At their mouths, the ghylls opened out on to a very different landscape of low sandy fan-deltas and extensive wetlands. Benthic faunas prospered in the streams, notably unionoid pond-mussels, adapted and distributed according to flow conditions and types of sediment. In and around the quieter pools and mazes of overbank water bodies, horsetails had gained a footing. Ahead, towards the distant skyline of the low Portsdown–South Downs ridge, water bodies predominated where the streams merged into a network of lakes and lagoons with no obvious connections with the sea.

Here and there the scene was diversified by dark clumps of cheirolepid and frenelopsid bushes growing on podsolised sandy mounds left by avulsion processes and attracting groups of foraging dinosaurs. At intervals, the landscape had been transformed by wildfires during droughts and destructive floods during rainstorms. Repeated burial and exhumation, trampling and abrasion had modified the debris as it was shuffled back and forth across the plain. On a closer look, some of the plant fragments betrayed evidence of adaptations to wildfire regimes. Between the channels, fluctuating water-tables were generating mottled gley soils and, very locally, laterite. Unlike the contemporaneous situation in Wessex, calcretes were rarely developed, possibly because the sub-basin was more closely hemmed in by uplands which gave it a somewhat wetter climate and higher and more stable water tables.

During several drier periods, the lowered massif relief reduced the sediment input and general decay of coastal barriers set in. This resulted in the lake–lagoon complexes transgressing northwards, and reaching the edge of Londinia soon after Hastings Beds times. Ultimately forming the Lower Weald Clay, these wetlands were studded with small sand bodies, perhaps marking the entrances to once active gullies that had debouched onto the braidplains. Amongst the maze of lakes and meandering waterways, only mud and small quantities of local Londinian sand were moved.

Much of the flora and fauna of the Weald Clay resembled their Hastings Beds predecessors, at generic level at least. Here and there ferny savannah-type vegetation developed, but frequent weak rises in salinity prevented the horsetails and lycopods from colonizing, except where flushes of freshwater constructed shoals. These shoals were advance guards of the great Cornubian "apron" which, having crossed Wessex, brought to the Weald its first uniquely western detritus (see below).

Animal life was still prolific in and around the watery Weald Clay wilderness, from dinosaurs to minute insects. The insects included midges, dragonflies and beetles, many of which escaped complete decay through carbonization in wildfires which raged from time to time. Association of types from different aquatic and terrestrial environments shows that some of the fires were extensive. Regeneration of plants could lead to monospecific communities like the charcolified *Weichselia* fern-savannah at Beare Green Quarry (Harris, 1981), now filled in. Reptiles were abundant and diverse and included large herbivorous dinosaurs and their predators, semi-aquatics such as turtles and crocodiles, whose salinity tolerances were presumably wide. Ample vegetation is implied, local or drifted, and this seems to have included primitive angiosperms. As in Wessex, dinosaur trackways and gastroliths from outside the sub-basin witness much movement in groups and singly.

Overall, Weald Clay salinities ranged from fresh to brackish as reflected by their fossils, particularly molluscs, ostracods and foraminifera. This suggests variable mixing with water from the Boreal sea, probably routed several times round or through the western end of Londinia (a path subsequently taken by the culminatory Aptian transgression). Highest salinities are registered about the middle and top of the succession. The top Weald Clay salinity rises broadly correspond with similar late Barremian–early Aptian (Vectis Formation) events in Wessex, suggesting that a single brackish 'inland sea' ultimately occupied much of the Wessex–Weald Basin. Some connection with the Tethys sea is suggested by the cassiopid gastropod *Paraglauconia*.

Compared with views from Londinia, the Wessex Formation floodplain seen from the dome of Cornubia was distinctly different. It usually featured fewer long-standing water-bodies, more dry