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The Clacton-on-Sea (Essex, UK) GCR site and SSSI: New data and continuing importance

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ABSTRACT

The complex Geological Conservation Review (GCR) site at Clacton-on-Sea, Essex, was notified in 1986 as a Site of Special Scientific Interest. It is an internationally important geosite and Britain's only Lower Palaeolithic type locality, giving its name to the Clactonian stone-tool industry. Fossil- and artefact-bearing channel-fill deposits laid down by the River Thames ~420,000 years ago, during the Hoxnian Interglacial (Marine Isotope Stage 11c), have been observed in foreshore and cliff exposures, and beneath developed and open ground in an inland arcuate footprint. These sediments provide a record of the lower reaches and estuary of the Thames during this lengthy and warm interglacial, an important partial analogue for the Holocene. Palaeoclimatic and palaeoecological evidence has been obtained from assemblages of fossil molluscs, ostracods and vertebrates, together with pollen and plant macrofossils; Clacton is also the type locality for several of the represented animal taxa, including the biostratigraphically significant ostracod *Scottia browniana* and a large subspecies of fallow deer, *Dama dama clactoniana*. This paper provides an overview of the continuing importance of the Clacton GCR site and Site of Special Scientific Interest (SSSI), summarizing recently acquired data that have enhanced understanding of the Hoxnian and the palaeoenvironments that prevailed at the time of deposition. The wider geosite has benefitted from sustained Palaeolithic archaeological interest, with the local planning authority mandating investigation of the sediments as a condition for development projects. SSSI status ensures that the significant collections of palaeontological and archaeological material amassed from the Clacton deposits over almost two centuries can be related to their context, and studies of both these archived collections and new material from the protected *in situ* sediments continue to provide new data and contribute to the development of cutting-edge techniques.

1. Introduction

The Geological Conservation Review (GCR) was conceived as a scientific audit of nationally and internationally important British Earth heritage sites, which would in turn provide the scientific basis for the designation and conservation of geological Sites of Special Scientific Interest (SSSIs; Wimbledon et al., 1995; Ellis et al., 1996; Ellis, 2011; Prosser, 2013). The GCR was launched in 1977 by the Nature Conservancy Council and continues as an active process under its successor, Natural England, with new sites being added and those already listed subject to review. The complex GCR site at Clacton-on-Sea was notified in 1986 for a variety of reasons (detailed below), foremost amongst which were its abundant early Middle Pleistocene palaeontological and archaeological remains and the need for further research to understand better these critically important sequences (see Bridgland, 1994, 2013). The resulting Clacton (cliffs, foreshore and golf course) GCR site covers ~26 hectares in three separate areas, two in the now-developed cliffs and foreshore within Clacton-on-Sea and Jaywick, and one in the southwest corner of Clacton Golf Course (Fig. 1). The GCR site itself does not confer statutory protection on the preserved sediments; this is provided through designation as a Site of Special Scientific Interest (SSSI), in this case the Clacton Cliffs and Foreshore SSSI, designated in the same year and covering the same areas as the GCR site. The important distinctions between GCR site selection, SSSI designation and their importance to the ongoing safeguarding and management of geosites have been outlined by Brown et al. (2018).

In the four decades since the Clacton GCR site was established, work at the three areas has continued through monitoring of exposures, formal interventions as part of redevelopment projects (*e.g.*, trial-pit excavation, coring, watching briefs and related sampling; Table 1), and research based on archived sediments and museum collections of fossils and artefacts (*e.g.*, White, 2012). This paper provides an updated

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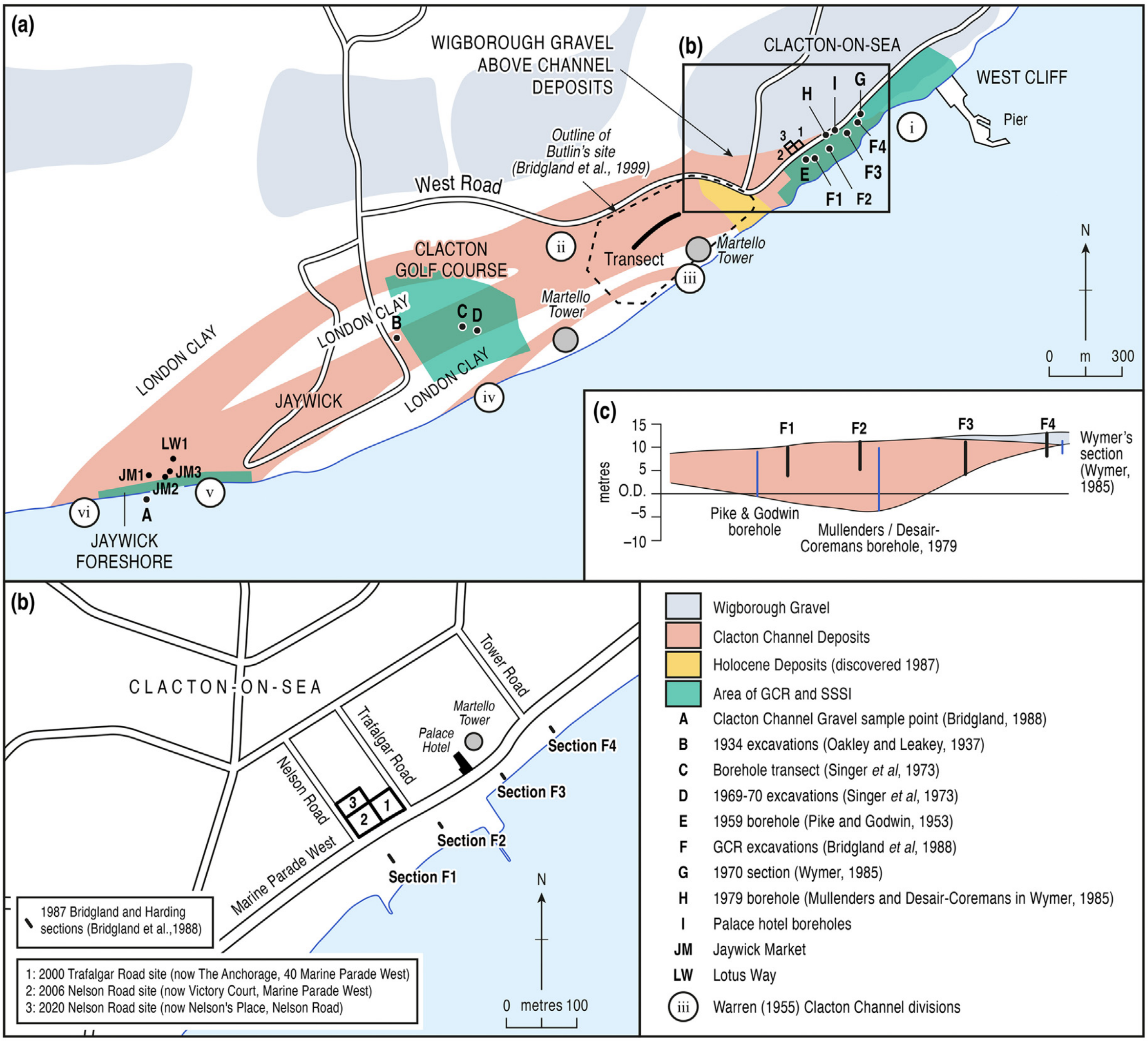

Fig. 1. Map of the Clacton-on-Sea district showing (a) the footprint of the complex of interglacial channels overlain by the areas protected by the SSSI; (b) an enlargement of the area around Marine Parade West, showing the locations of recent development sites that have yielded new data (see Figs. 4 and 5); (c) the section through the channel also derived from those exposures and neighbouring boreholes.
Modified from Allen et al. (2022).

assessment of the value of the Clacton geosite, providing details of recent discoveries from the locality. These are given context through a review of earlier work at Clacton and consideration of its regional importance as part of a network of fluvial sites that represent the Lower Thames during the Hoxnian Interglacial (=MIS 11c), demonstrating that the status of the site and knowledge of its geological

Table 1
Project work on the Clacton Channel Deposits and associated sediments since SSSI designation.

Year	Location	Reason	Sediments	Activities	Outcome	Publication
1987	Butlin's Holiday Camp	Redevelopment	Clacton Channel Deposits and later sediments	Trial pits and watching brief	Recording, serial sampling and casual discoveries	Holmes (1996) Bridgland et al. (1999)
1987 to 1999	Jaywick foreshore	Natural exposures	Channel iii–iv	Monitoring of exposures	Recording of sediments and recovery of fossils	Allen et al. (2022)
2000	Trafalgar Road (The Anchorage)	Redevelopment	Clacton Channel Deposits (full thickness)	Sieving of spoil heaps	Recovery of fauna and plant fossils	Allen et al. (2022)
2006	Nelson Road (Victory Court)	Redevelopment	Clacton Channel Deposits (full thickness)	Monitoring of boreholes	Ostracods, foraminifera, *Bithynia* opercula	Allen et al. (2022)
2011	Butlin's Holiday Camp and Golf Course	Offshore wind farm development by DONG Energy	Clacton Channel Deposits (full thickness)	Desktop assessment	No intervention	Unpublished report
2017	Lotus Way, Jaywick	Redevelopment	Holocene estuarine sediments	Trial pits and coring	Holocene sequence sampled and analysed	Allen et al. (2022)
2020	Nelson Road (Nelson's Place)	Redevelopment	Clacton Channel Deposits (full thickness)	Monitoring of exposures	Wigborough Gravel studied	Allen et al. (2022)
2021	Jaywick Market	Redevelopment	Holocene estuarine sediments	Trial pits and coring	Holocene sequence sampled and analysed	Allen et al. (2022)

importance have been significantly enhanced since it was first notified. The Clacton area has seen enormous change in the last few decades, with increasing pressures from developments in the town itself and from further afield in the form of off-shore wind farms. The potential impacts of such developments on the surviving Clacton Channel Deposits have been considerably lessened by the protected status afforded to the site, whilst the associated scientific interventions have provided important new data.

1.1. Discovery and early (pre-GCR) research

The initial discovery of fossiliferous Pleistocene deposits at Clacton was made in the early 19th Century (Brown, 1838, 1840, 1841; Dalton, 1880) at a time when the hinterland of the naturally eroding cliffs had yet to be developed into a seaside town. The palaeoenvironmental potential of these fossil assemblages was noted at an early stage by Brown (1840, 1841), who observed a change from freshwater molluscs in the lower sediments to a mixture of freshwater and marine shells higher in the sequence, and Jones (1850), who provided an early report on ostracods from the deposits. Several other early workers cited the fossiliferous Clacton sediments, including Owen (1846), Wood (1848), Wood Junior (1866), Dawkins (1868, 1869) and Fisher (1868). The fossiliferous sediments exposed in the Clacton cliff were described and illustrated by Dalton (1880), importantly showing them to be both underlain and overlain by gravel. Subsequently Ransome (1890) and Hinton (1923) described mammals from the site, molluscs were further documented by Webb (1894, 1900) and Kennard and Woodward (1923), and plant macrofossils by Reid and Chandler (1923).

Clacton is also Britain's only Lower Palaeolithic type locality, having given its name nearly a century ago to the Clactonian Industry (Warren, 1926; Breuil, 1932a, 1932b). Kenworthy (1898) was the first to record Palaeolithic artefacts from the Clacton deposits but it was not until the site was studied in detail, and over a wider area, by Samuel Hazzledine Warren that its true archaeological importance was realised (Warren, 1911a, 1912, 1922, 1923, 1924, 1926, 1933, 1940, 1951, 1955, 1957, 1958). Warren would now be described as a ‘citizen scientist’ and a geoarchaeologist, although neither term was in use in his day; in an appreciation of his contribution, O'Connor (2003, p. 255) described him as "an ‘amateur’ in the sense that he received no regular income from his geological labours and had never undertaken any formal geological training, but pursued geology for the love of the subject”. She also noted his devotion to the Clacton site, which he continued to monitor throughout his life (O'Connor, 2006, 2007); without Warren's assiduous work our knowledge of the site would be considerably poorer. Warren clearly recognized the temperate-climate character of the Clacton deposits from the outset but first applied the term ‘interglacial’ to them in the 1950s (Warren, 1951, 1955), the episode being identified, towards the end of his career, as the Hoxnian (West, 1956; Turner and Kerney, 1971). Prior to the definition of that named stage, Clacton had already yielded the first Hoxnian pollen diagram under the name ‘Penultimate Interglacial’ (Pike and Godwin, 1953). Indeed, despite the prominence given to palynological data in the decades that followed, Clacton was first correlated with European Holsteinian sequences on the basis of similarities in their molluscan faunas (Woldstedt, 1950a, 1950b). Warren (1923, 1955) also showed that the Clacton interglacial deposits could be traced westwards, in truncated form, to Jaywick Sands, ~3 km to the WSW of the original discovery site (Fig. 1), and that they occupy an arcuate area inland between these places, representing the fill of one or more fluvial channels. He attributed this at an early stage to the Pleistocene Thames–Medway (Warren, 1933, 1940, 1955), having originally thought that it represented a smaller stream (Warren, 1923).

The characteristic artefacts of the type-Clactonian industry have been recovered from the basal gravels of the ‘Clacton Channel’ from both ends of its outcrop, in the West Cliff section and the Jaywick Sands foreshore (Warren, 1923, 1955; Bridgland et al., 1988), from excavations in the inland part of the channel at Clacton Golf Course, undertaken in 1934 (Oakley and Leakey, 1937) and 1969–70 (Singer et al., 1973) and in a more recent geo-archaeological rescue investigation following the demolition of the former Butlin's holiday camp (Bridgland et al., 1999). The industry is characterized by core-and-flake assemblages that contain chopper-cores and unstandardized flake tools (Fig. 2) but definitively lack handaxes (White, 2000). The Jaywick exposure famously yielded a spear tip fashioned from yew wood, an extremely rare example of a British Lower Palaeolithic wooden artefact, found by Warren (Warren, 1911b; Oakley et al., 1977; McNabb, 1989; Allington-Jones, 2015). He also reported and illustrated bone tools (Warren, 1951), which, like wooden artefacts, are exceedingly rare. These were dismissed by Wymer (1985) as the products of natural agencies and fell into obscurity; however, they have recently been reassessed using modern microscopy and interpreted as hammers used in the production and re-sharpening of flake tools, making them the earliest known examples of soft knapping hammers associated with a core-and-flake industry (Parfitt et al., 2022). A Lower Palaeolithic assemblage that includes non-stone artefacts of both wood and bone is indeed rare; at Clacton this is linked to the nature of the context, which includes fine-grained fossiliferous sediments that preserve shells, bone and plant fossils, a list that includes the materials from which these artefacts were fashioned.

The Clactonian Industry has also been recognized at Swanscombe (Fig. 3B), where it occurs stratigraphically beneath deposits containing handaxes (Smith and Dewey, 1913, 1914; Dewey and Smith, 1914; Chandler, 1929, 1932; Dewey, 1932). This led to the realisation that these two famous sites are lateral equivalents, separated by ~75 km downstream distance within the Thames system (Kerney, 1971; Turner and Kerney, 1971; Bridgland, 1980, 1988, 1994, 2006), with equivalent sediments later recognized at East Hyde, Tillingham (Roe and Preece, 1995; Roe, 2001; White et al., 2013; Fig. 3B). The Swanscombe locality was designated as a geological National Nature Reserve (NNR) in 1954, having been donated to the nation by its former owners Associated Portland Cement Company (Bridgland, 1994) following the discovery there of human fossils: refitting skull fragments found in 1935, 1936 and 1955 (Marston, 1937; Swanscombe Committee, 1938; Ovey, 1964). Clacton, in contrast, enjoyed no formal protection until it was selected by the GCR and designated as a geological SSSI in 1986 (Bridgland, 1994).

1.2. Geoconservation status

GCR selection resulted in the designation of a complex SSSI at Clacton, incorporating the original West Cliff locality, the foreshore at Jaywick Sands and part of the inland Clacton Golf Course, where the above-mentioned archaeological excavations had demonstrated the presence of the Clacton Channel Deposits (Bridgland, 1994; Fig. 1). The necessity of including the original West Cliff discovery site stems from the erosion of the higher parts of the Clacton stratigraphy in the area further to the south-west, where the surface height falls by several metres. The foreshore exposures have seldom been seen in recent years, thanks to deliberate measures to encourage beach growth, but they remain invaluable as a means to compare the multiple channels, mapped by Warren, that make up the Clacton geosite complex, as exemplified by the results, published recently (Allen et al., 2022), of careful monitoring. Much of the investigation of the Clacton deposits in the past few decades (Table 1; Fig. 4) has taken advantage of redevelopment of the built environment above their outcrop, often making use of developer funding arising from the close links between archaeology and planning (see Last et al., 2013). Nonetheless, the unexcavated and undeveloped land at the golf course, included within the GCR site, represents an important reserve of sediments for future research.

The Clacton geosite is of additional importance because it sits at the downstream end of a network of sites that represents the Lower Thames

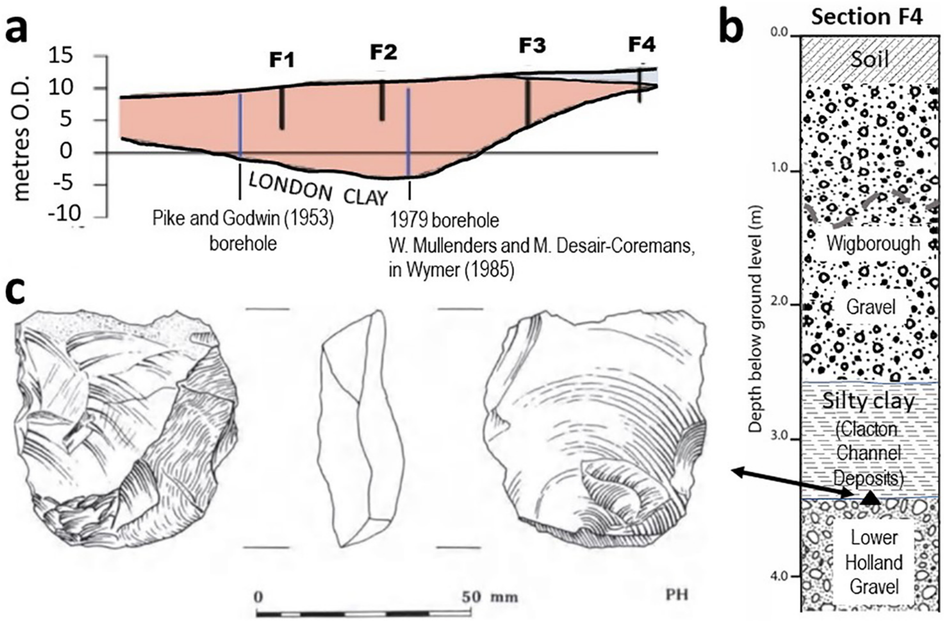

Fig. 2. Feather edge of the Clacton Channel Deposits in the West Cliff (see Fig. 1): a. GCR excavations, April 1987 (after Bridgland *et al.* (1988); b. Details of GCR Section F4; c. Flint flake found *in situ* in Section F4, located in part b (drawing by P. Harding, reproduced from Bridgland, 1994).

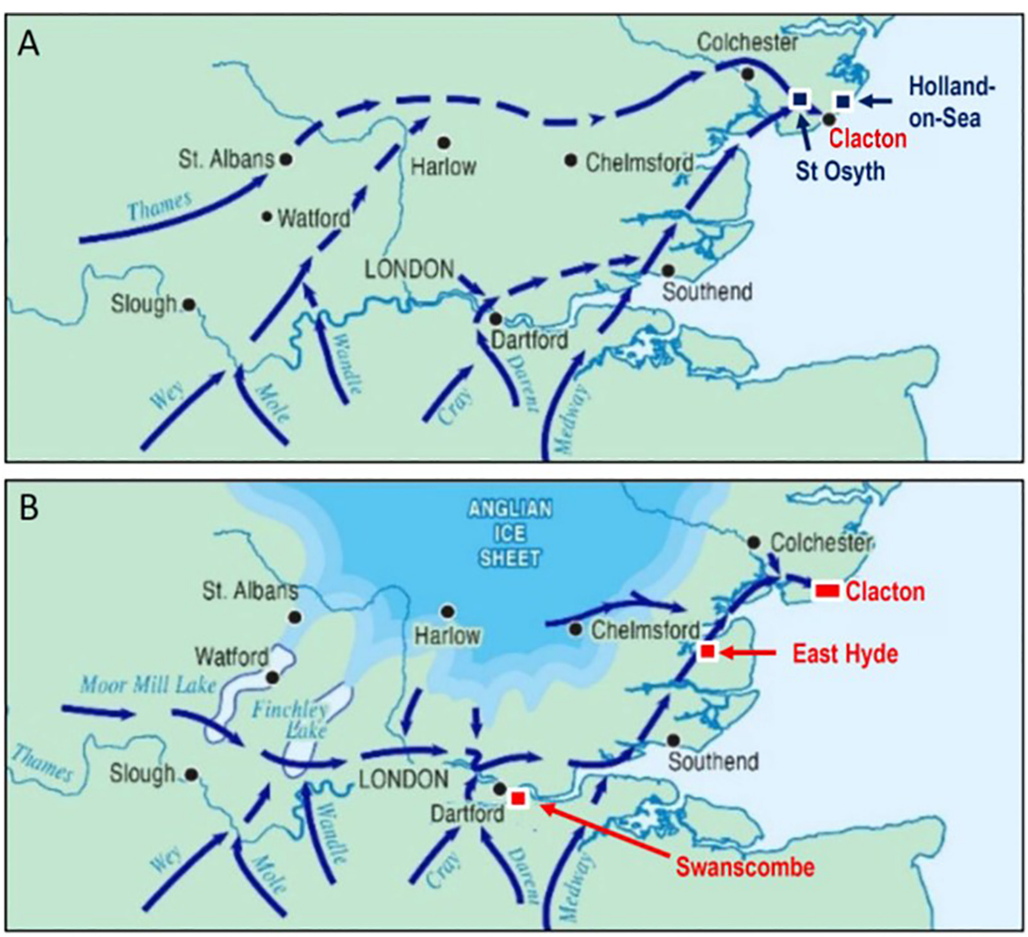

Fig. 3. The location of the Clacton locality in relation to the Anglian (MIS 12) diversion of the Thames. A – Drainage pattern immediately before the Anglian glaciation, showing (in dark blue) the locations of the St Osyth and Holland-on-Sea GCR sites, which represent the final pre-diversion Thames and its replacement with an Anglian glacial outwash stream. B – The extent of the Anglian ice sheet, the location of ice-dammed lakes and the immediate post-diversion course of the Thames. The trio of Hoxnian (MIS 11c) sites that preserve the Rhenish molluscan fauna (see text) is identified in red.
Modified from Allen et al. (2022).

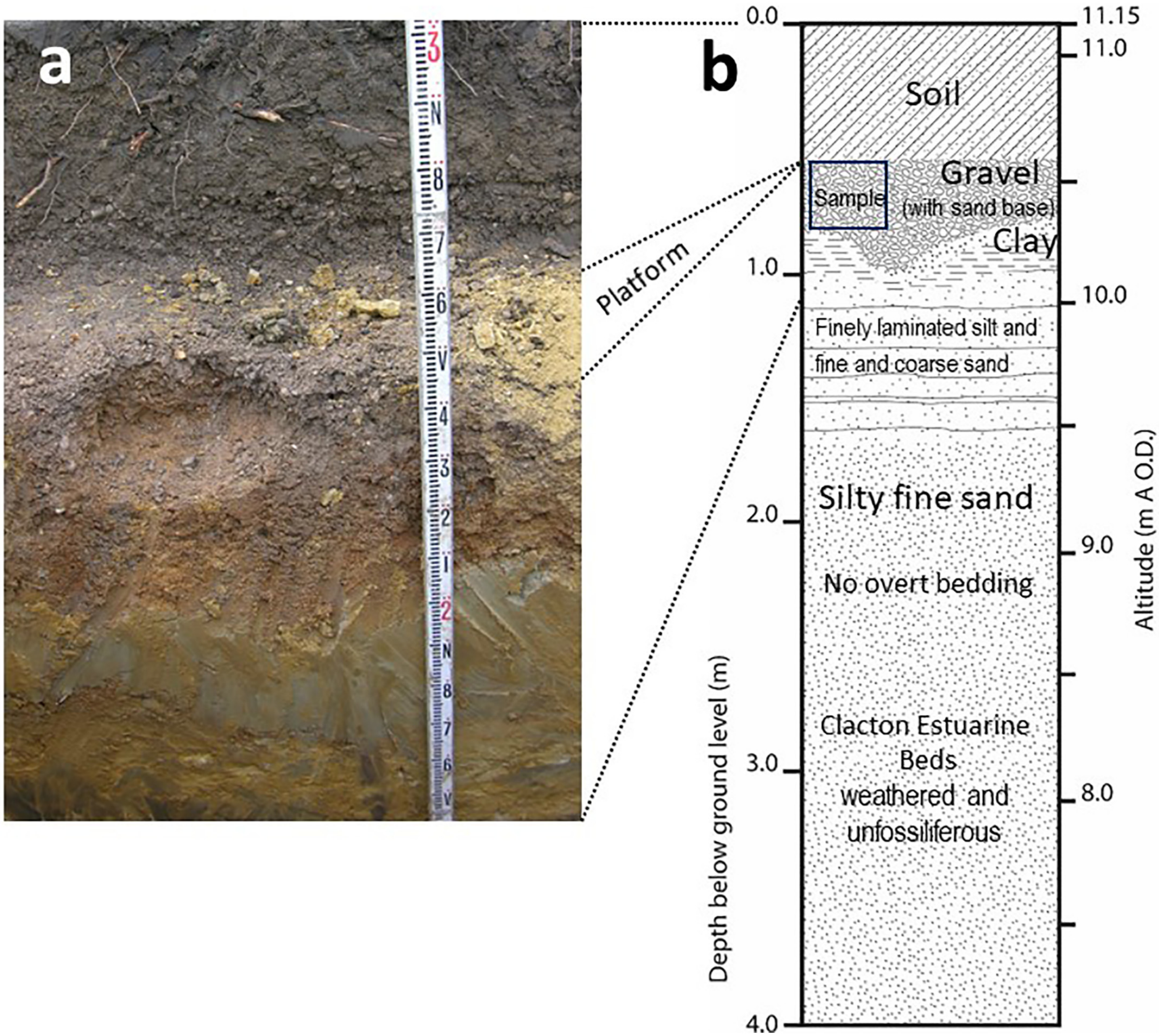

Fig. 4. Trial pit section from site assessment at Nelson Road, Clacton (Site 3, Fig. 1b), in January 2020: a. Photograph of the upper part of the trial-pit section, showing thin sandy gravel overlying weathered Clacton Channel Deposits (estuarine beds), beneath topsoil; b. Stratigraphy of the full trial-pit section, showing correlation with the part photographed. Note the location of the sample for gravel analysis, which confirmed that this represents a thin remnant of the Wigborough Gravel overlying the channel deposits here, a relationship previously observed only in the West Cliff (see Fig. 1c and Fig. 2; Bridgland et al., 1988). Image: Peter Allen.

prior to and following its diversion by Anglian (MIS 12) ice (Fig. 3), that diversion story being represented by a different network of GCR sites, located north of London (see Bridgland, 1994). The value of the site network is apparent from the research that has been undertaken in the years since the site was notified in the GCR as well as by visits made by research groups and learned societies (*e.g.*, most recently, in association with the 2019 INQUA Congress, from which the present special issue originates; Bridgland et al. 2019). One such visit, by the Geologists' Association in 1987, included temporary sections dug into the West Cliff at Clacton, near the easternmost limit of the SSSI, by kind permission of Tendring District Council (Bridgland et al., 1988). The Thames geosite network is described elsewhere in this issue and so will not be repeated here (see Cunha et al., this issue). Recent research related to the importance of the Clacton site will, however, be reviewed below. In particular, emphasis will be given to sites related to the climate cycle immediately following the diversion of the Thames, including the MIS 11 interglacial. This interglacial is of especial significance in that, uniquely in the late Middle–Late Pleistocene, it has been recognized as most closely resembling the Holocene in terms of its length and the astronomical forcing patterns that controlled its evolution (Droxler and Farrell, 2000; Droxler et al., 2003; Raynaud et al., 2005; Preece et al., 2007).

2. Post-GCR research and current thinking

More recent work at Clacton and over a wider area has largely confirmed Warren's findings. The arcuate footprint of the Clacton Channel is interpreted as a palaeochannel complex of Thames–Medway origin, the attribution of which to the Hoxnian Interglacial, or the earlier part of MIS 11 (see Ashton et al., 2008; White et al., 2013), can now be supported from multiple lines of evidence, much of it reinforced by work undertaken since SSSI designation. The investigation of the sediments beneath the former Butlin's holiday camp provided a link between the original discovery site and Jaywick and involved new work on pollen and molluscs, as well as plant macrofossils, fish and ostracods (Bridgland et al., 1999). This project provided new insights into changing palaeo-environmental conditions during the emplacement of the Clacton sediments, with the ostracod assemblages proving particularly informative, showing increased marine influence towards the top of the sequence, albeit with salinity values remaining quite low.

Although earlier descriptions involved more complex subdivision, including that by Warren (1923), the definitive sequence remains that of Warren (1955), with modifications derived from post-GCR research (Bridgland et al., 1988, 1999); N.B. - the Clacton Channel Deposits are represented by beds 1–4, indicated in the left column:

	Surface soil and 'trail' (='head')	(1–3 m)	
	Upper bedded gravel	(Up to 2 m)	(Mersea Island–Wigborough Gravel of Bridgland, 1988?)
(4)	Estuarine sand with shells, passing laterally into estuarine calcareous clay	(Up to 4 m)	Estuarine Beds
(3)	Estuarine laminated clay ('peaty shale'), containing a localized lens with freshwater fauna, Warren's (1923) 'bed 𝒸'.	(Up to 5 m)	
(2)	Loamy sands and clays, with much channelling	(Up to 4 m)	Upper Freshwater Beds
(1)	Clayey gravel and sand	(Up to 7 m)	Lower Freshwater Beds (Clacton Channel Gravel)
	Lower Holland Gravel (only beneath northern feather-edge of channel)		
	London Clay		

The basal part of the Lower Freshwater Beds equates with the Clacton Channel Gravel, recognized by Bridgland (1988, 2006) as similar in composition to the Thames–Medway (his Low-level East Essex Gravel) deposits further south. The Estuarine Beds occur only at the easternmost end of the complex of sites (Fig. 1), being well represented in the original West Cliff section (F1–F4 in Fig. 1), so that they do not reach the Golf Course (Bridgland et al., 1999; *contra* Oakley and Leakey, 1937). The main palaeontological evidence from these deposits, well preserved only in the easternmost locations, is from molluscs, ostracods and foraminifera. Warren (1923) recognized >100 species of non-marine Mollusca from beds 1 and 2 combined. These were identified by A.S. Kennard and C.P. Castell (*in* Warren, 1955) and included members of the group of freshwater molluscs that Kennard (1942a, b) had previously recognized at Swanscombe (his 'Rhenish' fauna), which he believed to be indicative of a link between the Thames and the Rhine. Until the discovery of contemporaneous deposits preserved in the Asheldham Channel at East Hyde, Tillingham (Roe and Preece, 1995; Roe, 2001; White, 2012), Clacton was the only locality at which the 'Rhenish' fauna occurred together with a reliable pollen record. However, correlation with the more detailed Swanscombe molluscan succession remained imprecise because much of the palaeontological evidence from Clacton lacked accurate stratigraphical control. Mollusc diagrams for Clacton, generated through careful correlation of published records, notably those of Warren (1955) and Bridgland et al. (1999), are published here for the first time (Fig. 5; see also White, 2012). Ostracod records have similarly been plotted from published data, together with new analyses of archived material that yielded foraminifera, as part of a composite diagram showing palaeontological evidence from well-provenanced sediment samples that can be accurately positioned relative to the stratigraphy (Fig. 6). Of note amongst the ostracods is the record of

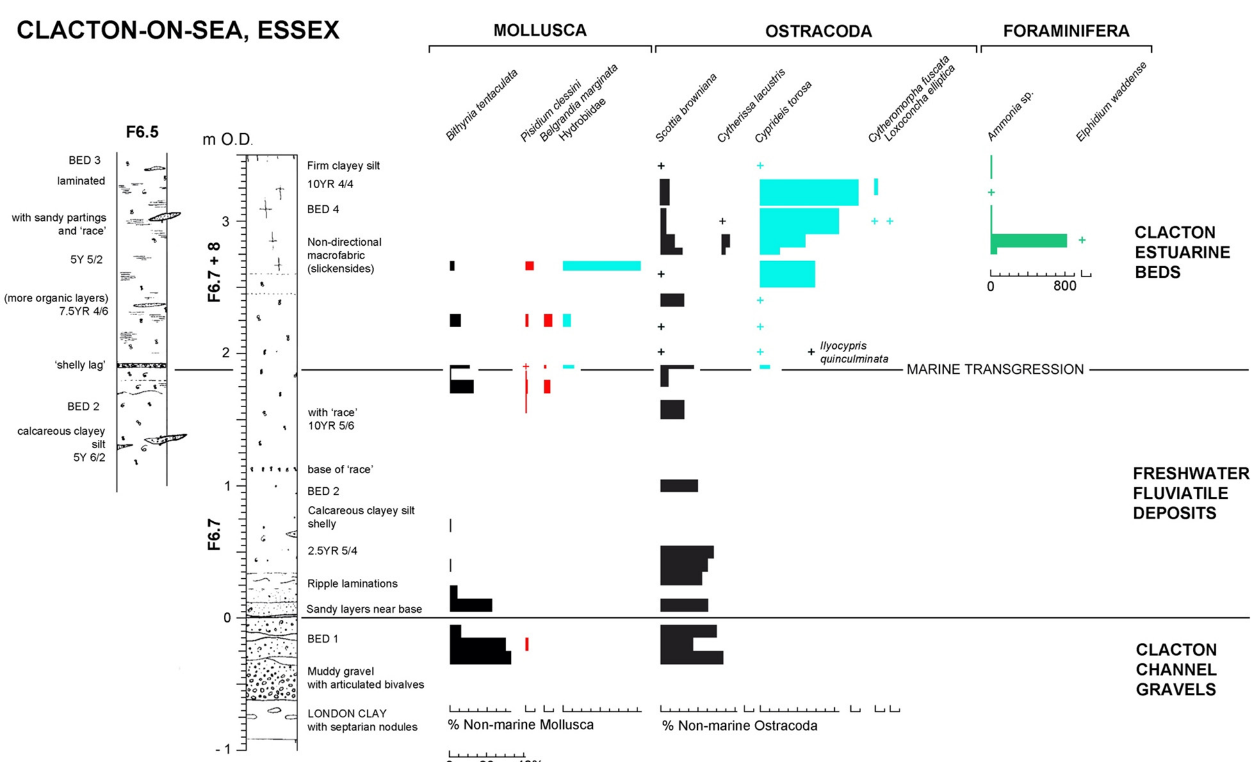

Fig. 5. The succession of selected invertebrate groups (Mollusca and Ostracoda) and of foraminifera from boreholes and excavations during the 1980s (Fig. 1a and c; see Bridgland et al., 1988, 1999), showing the clear transition from freshwater to brackish conditions. Declining frequencies of freshwater taxa such as the gastropod *Bithynia tentaculata* and the ostracod *Scottia browniana* in the Estuarine Beds are complemented by increasing frequencies of brackish taxa (shown in pale blue), notably the ostracod *Cyprideis torosa* and hydrobiid molluscs. Also note the first appearances of two members of the 'Rhenish' suite of freshwater molluscs, *Pisidium clessini* and *Belgrandia marginata* (shown in red); some 'Rhenish' species were not recorded in these boreholes, but a more complete composite succession from the wider Clacton site is shown in Figure 6. Foraminifera, probably representing a marine incursion into the Hoxnian estuary, are shown in green.

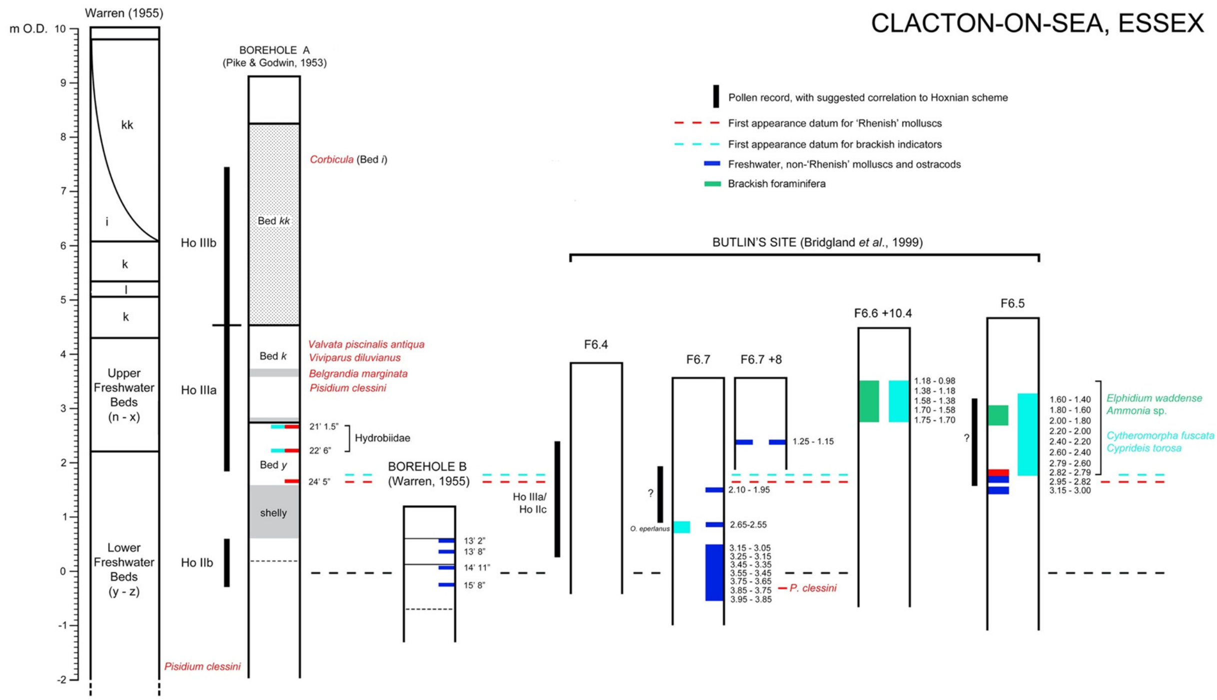

Fig. 6. The Hoxnian sequence at Clacton-on-Sea as recorded in various exposures and boreholes (Fig. 1), showing the transition from freshwater to brackish conditions, the first appearances of 'Rhenish' mollusc species and correlation with the Hoxnian pollen succession.

the extinct species *Ilyocypris quinculminata*, which is unknown in the British Pleistocene record after MIS 11 and has provisional biostratigraphical significance (Whittaker and Horne, 2009). The earliest appearance of 'Rhenish' molluscs is recorded in basal samples form Borehole A (Turner and Kerney, 1971) and Borehole F6.5 (Bridgland et al., 1999), at ~1.6 m O.D. The earliest indicators of brackish conditions appear a little higher in the sequence at ~1.8 m O.D., a situation similar to that demonstrated at Dierden's Pit, Swanscombe (White et al., 2013; Figs. 5 and 6). There are no quantified molluscan records from deposits above ~3 m O.D. at Clacton, although descriptions of assemblages observed in these levels include several 'Rhenish' taxa, including *Pisidium clessini*, *Belgrandia marginata* and *Viviparus diluvianus* (Warren, 1955).

The Clacton Channel thus represents the Thames, in Thames–Medway form, following its diversion as a result of the Anglian (MIS 12) glaciation into its modern lower valley through London (Kerney, 1971; Wymer, 1974, 1985, 1999; Bridgland, 1988, 1994, 2006; Bridgland et al., 1990, 1999; Fig. 3). This involved diversion of the Thames into the extended pre-Anglian River Medway (Bridgland, 1988). Warren had also recognized a smaller channel, his Channel iii–iv, filled with estuarine sediments and located on the seaward side of the main Clacton Channel. Warren's (1955) paper provided most detail on his observations of this channel, which he seems always to have regarded as part of the main Clacton complex. In that paper he recorded the occurrence in Channel iv of *Palaeoloxodon antiquus* and a profusion of shells, including the marine bivalve *Tapes decussatus* [now *Venerupis decussata* (L.)], forming what he called an 'oyster-bed', as well as noting the absence of non-marine molluscs. Bridgland et al. (1999) acknowledged the potential significance of this as an apparent difference between Channel iv and the estuarine sediments of the main Clacton Channel, which, despite their name, are invariably dominated by non-marine taxa. Bridgland (1994) and Roe (1994) had already suggested that Channel iii–iv might represent a later Colne deposit. *Venerupis decussata*, recognized in this channel by Baden-Powell (in Warren, 1955), has not been recorded from the main Clacton channel complex and in the Netherlands it occurs only in post-Holsteinian deposits (Meijer and Preece, 1995); this species was therefore a key line of evidence for suggesting a younger age for Channel iii–iv. This has now been confirmed from material collected from foreshore exposures of Channel iv by David Bain (see Allen et al., 2022), who monitored the Jaywick coastal area in the final years of the 20th century, before the exposures were covered by beach recharge in 1999. He observed the Channel iii–iv deposits to consist of ~0.5 m of mottled orange–grey silty clay with marine shells, notably *Ostrea* sp., *Cerastoderma edule* and *Mytilus edulis*, underlying widespread blue–grey Holocene estuarine clay with *Scrobicularia plana*. Exhaustive searches for Clactonian artefacts yielded none, despite copious sieving of the material. Also noted were the non-marine gastropods *Segmentina nitida*, *Anisus vorticulus*, *Truncatellina cylindrica* and *Vertigo angustior* and the bivalves *Pisidium clessini* and *Corbicula fluminalis*, the last in small numbers and abraded, suggesting that they were not indigenous to the deposit (D. Bain, *in* Allen et al., 2022). Vertebrate remains comprised *Bos primigenius*, *P. antiquus*, *Megaloceras giganteus* and *Ursus arctos*, as well as various small-mammal and herpetofaunal remains including *Bufo bufo*. Modest ostracod and foraminiferal assemblages, including un-noded valves of *Cyprideis torosa*, were suggestive of a stronger estuarine signature than the main Clacton Channel Deposits. The freshwater gastropod *Bithynia tentaculata* was recorded, despite Warren's assertion that non-marine molluscs were absent from Channel iii–iv, including opercula suitable for amino acid racemization (AAR) dating, which provided final confirmation of a Last Interglacial (Ipswichian; MIS 5e) age (Penkman et al., 2011, 2013; Allen et al., 2022). Amongst the small-mammal material were teeth of *Arvicola terrestris cantiana* from which measurements of the enamel thickness quotient/SDQ (Schmelzband-Differenzierung-Quotient) values provided further dating evidence in support of the AAR data.

3. Discussion

The Clacton GCR site would be a locality of national–international importance for its palaeontological record, even without it being the Lower Palaeolithic type locality for the Clactonian Industry. It is the type locality for several fossil taxa, notably the ostracods *Scottia browniana* (Jones, 1850) and *Cytherideis trigonalis* (Jones, 1850), both described for the first time during the early work on the Clacton Channel Deposits. The (large-sized) subspecies of fallow deer *Dama dama clactoniana* is also notable, with Clacton as its type locality (Dawkins, 1868; Falconer, 1868). The site is also important for the reconstruction of the palaeogeography and evolution of the Middle Pleistocene Thames and as a record of interglacial sea-level change at the lower end of that river. The value of the Clacton site is further enhanced by its inclusion within a network of sites that provide evidence for the stratigraphy and palaeoenvironments of the Lower Thames during the Quaternary, each representing different locations within the downstream profile of the river and different periods of time, together providing full representation of Middle and Late Pleistocene interglacial stages (Bridgland, 1994, 2013; Cunha et al., this issue). This Lower Thames network therefore represents one of the most complete terrestrial records of the Middle–Late Quaternary globally.

The attribution of the interglacial deposits filling the main Clacton Channel to MIS 11 further adds to their importance as records of palaeoenvironmental change, this period being one of the closest analogues to the present Holocene warm period. In work that has followed GCR site designation, the main Clacton Channel has been differentiated from satellite, smaller sediment bodies that are now attributed to the Ipswichian (MIS 5e) River Colne, an important refinement of knowledge about the Clacton complex (Bridgland et al., 1999; Allen et al., 2022; see above). Other advances and much of the work on the Clacton deposits in recent decades have arisen thanks to the rigorous attention given by Essex County Council and the local planning authority to the significance of archaeology as a material consideration in the planning system under the National Planning Policy Framework (NPPF) and subsequent updates (see Prosser, 2012; Last et al., 2013); indeed, the NPPF applies to Clacton in terms both of the natural environment and historic environment sections of the former. This planning guidance has resulted in predevelopment appraisal of various locations (Table 1) on the footprint of the Clacton Channel Deposits as mapped by Warren (1955). In addition to the confirmation that Channel iii–iv dates from MIS 5e, which stemmed largely from the results of citizen-science monitoring of natural exposures, these interventions have added to the corpus of data on the geology at Clacton, including other overlying post-Hoxnian sediments, notably Holocene tufa and creek-infill revealed as part of the Butlin's project in 1987 (Bridgland et al., 1999) and Holocene estuarine sediments at Jaywick Market and Lotus Way (Allen et al., 2022; Fig. 1).

Also worthy of note is the work carried out using archived sediment samples from the Clacton locality and on museum-curated specimens, be they fossils or artefacts. Reference has already been made to recent studies of bone artefacts, once regarded as putative but now confirmed as such (Parfitt et al., 2022), as well as to the repeated reappraisal of the Clacton spear, not to mention the substantial lithic-artefact collections. Equally important has been the analysis of archived sediment samples from the Butlin's watching brief and trial-pit excavations, themselves part of a project instigated by planning policy guidance; the work in question was undertaken by T.S. White as part of his doctoral research, using material archived at the University Museum of Zoology, Cambridge (UMZC). Careful assessment of these archived sediments and assemblages has enabled correlation of the Clacton sequence with those preserved upstream at East Hyde and Swanscombe, now understood as a critically important network of Lower Thames sites representing the Hoxnian (White, 2012; White et al., 2013). Underpinning all such work is the conservation of the Clacton Cliffs and Foreshore SSSI, which provides the opportunity to engage with the full stratigraphical sequence at the West Cliff, the multiple channel complex on the Jaywick foreshore and a reserve of unexcavated lower sediments at the golf course. Although no permanent exposures are maintained at any of the above, the ability to study them if required, and if an excavation can be justified and funded, is of fundamental importance.

3.1. Sea-level evidenced from Clacton and related sites within the Lower Thames network

Faunal assemblages from the three fluvial-to-estuarine MIS 11 sedimentary sequences in the Lower Thames (Swanscombe, East Hyde and Clacton) represent a mixture of elements from truly freshwater to brackish estuarine environments. The first appearance within these sequences of brackish indicator species, such as the euryhaline ostracod *Cyprideis torosa*, hydrobiid gastropods, foraminifera tolerant of lower salinities and anadromous fish such as *Osmerus eperlanus*, provides evidence for the intrusion of saline waters associated with a mid-Hoxnian marine transgression (Figs. 4 and 5). This event can now be positioned with confidence within the Thames sequence, since it occurs at all three sites at a certain point relative to the 'Rhenish' molluscan succession during pollen zone HoIIIa (White et al., 2013). There is compelling matching of the evidence between the sites in this MIS 11 Lower Thames network, as illustrated, for example, by the occurrence of *Corbicula* much later in the Clacton sequence in Bed *i* (Fig. 6); this conforms to the pattern observed at Swanscombe, where *Corbicula* first appears later in the 'Rhenish' succession after the first appearance of brackish indicators (White et al., 2013). The same pattern has also been observed in fossils recovered from boreholes at East Hyde, Tillingham (White, 2012).

Progressive marine transgression is well recorded at Clacton. Eight fish species were identified in the fluviatile silts of Bed 2, forming an assemblage characteristic of the 'bream zone' of the lower reaches of meandering rivers, close to their estuaries (Bridgland et al., 1999). Notable amongst these is *Osmerus eperlanus* (European smelt), identified by its distinctive otololiths, which were also preserved in large numbers in the Lower Middle Gravel at Dierden's Pit, Swanscombe (White et al., 2013). The presence of this species in the pre-estuarine part of the sequence is easily explained, since it migrates to the limit of the tidal range in rivers to spawn. Within the Lower Thames Hoxnian network, smelt fossils therefore provide an indication of the extension of marine influence upstream; at Clacton, smelt fossils occur slightly earlier and as the sea-level rose during pollen zones HoIIc and into HoIIIa the fish were forced to migrate further upstream to Swanscombe in order to find the right conditions for spawning. Also present in Bed 2 are two other migratory fish, *Gasterosterus aculeatus* and *Anguilla anguilla*, both of which are compatible with a fluvial (freshwater) environment with access to the sea further downstream. The remainder of the Clacton Bed 2 fish assemblage comprises exclusively freshwater species (or taxa with a limited tolerance of brackish conditions) characteristic of slow-flowing lowland rivers, namely *Leuciscus* sp., *Alburnus alburnus*, *Scardinius erythrophthalmus*, *Abramis brama* and *Rutilus rutilus*.

3.2. Status of the Clactonian Palaeolithic Industry

The validity of Palaeolithic artefact assemblages as key components of Quaternary sediments, of general equivalence to palaeontological constituents and forming an element of the scientific importance of these deposits, has been a topic of debate and uncertainty in geoconservation circles (Last et al., 2013). Their credentials have been enhanced by the growing consensus that they can perhaps be regarded as 'trace fossils' that signal human presence in the absence of human remains (Bridgland and White, 2018) and some types are of value as age indicators, just as in the application of palaeontological material to provide biostratigraphy (Cunha et al., this issue). With reference to Clacton, the significance of the Lower Palaeolithic aspect of the GCR site somewhat hinges on the persistence of the separate definition of a 'Clactonian Industry', characterized by flakes and cores to the exclusion of handaxes and evidence for handaxe making. This is something that has been challenged and it must be admitted that this type of industry is rather more conveniently referred to as 'Mode 1' (after Clarke, 1969), although nomenclature based on type localities is fundamental within Earth science.

From its local origin as a name for the assemblage from Clacton (Warren, 1926), the term Clactonian was, for several decades, globally adopted to describe many assemblages without handaxes (a Clactonian culture), as well as large flakes within assemblages that showed heavy percussion with a stone hammer (a Clactonian technique; Breuil, 1932a, Wymer, 1968, Roe, 1981). It was also used as an indicator of antiquity, since simple flakes and cores that characterized both definitions were believed to be primitive and to pre-date Acheulian handaxe making (Breuil, 1932a; Wymer, 1974). It had also long been recognized that expecting the term to serve a multitude of purposes was a source of considerable confusion and inappropriate usage (Burkitt, 1936; van Riet Lowe, 1936; Leakey, 1947).

Reviews of the Clactonian during the 1970s and 1980s led to calls for its abandonment. Detailed technological studies by McNabb (1992, 2007) found that the flakes and cores in Clactonian assemblages could not be distinguished from those in the Acheulian (handaxe) industries, unless in the latter case they were flakes involved specifically in handaxe making which, by definition, are absent from the Clactonian. McNabb (1992, 1996a; McNabb and Ashton, 1992) also pointed to the rare occurrence of handaxe-finishing flakes and even handaxes at Clactonian sites, including examples from both the Clacton Channel Deposits (Singer et al., 1973; Wymer, 1985; Bridgland et al., 1999) and the correlative Phase I deposits at Swanscombe (McNabb, 1996b). Such 'non-classic' handaxe-like artefacts within Clactonian assemblages (Ashton and McNabb, 1994) clearly contradicted claims of technological differences, as well as the notion of a distinct cultural entity, even though the early workers who defined the industry were well aware that such oddities occurred (see White, 2000 for a review). At the same time, discoveries at Boxgrove (Roberts, 1986; Roberts and Parfitt, 1999) showed unequivocally that the Acheulian pre-dated the Clactonian in southern England, thus demolishing the notions of greater antiquity for the latter. Such observations led to suggestions that the Clactonian was merely a 'facies' within the Acheulian, reflecting sites where knapping did not involve handaxe making for functional or raw material reasons, although the same hominin groups might have made handaxes elsewhere (Ohel, 1979; McNabb, 1992).

Although popular in some circles, such views have now in turn been abandoned by many Palaeolithic archaeologists. This is largely because a simple functional or lithology-led interpretation fails to explain a pattern of occurrence in Thames contexts, in which non-handaxe assemblages are found early within the first two post-Anglian interglacial sequences (correlated with MIS 11 and MIS 9), only to be overlain by deposits with handaxes. This succession occurs first in the Boyn Hill–Orsett Heath terrace of the Thames, most famously at Swanscombe, the Clacton type locality being the downstream lateral equivalent of that site (*e.g.*, Wymer, 1968, 1999; Bridgland, 1994; White et al., 2013). These 'Boyn Hill' sites represent MIS 11, but similar Mode 1 assemblages occur again at sites such as Purfleet and Little Thurrock in the next highest terrace, the Lynch Hill–Corbets Tey, in which the interglacial represented is MIS 9 (Wymer, 1968, 1999; Bridgland and Harding, 1993; Schreve et al., 2002; Bridgland et al., 2013). This pattern was explained by White and Schreve (2000) in terms of immigration from different parts of the European continent during climatic amelioration phases within successive glacial–interglacial cycles, with initial hominin dispersals from central Europe (*i.e.*, from the east), where there was no Middle Pleistocene tradition for handaxe making, and later immigrants from the south (France and Iberia) bringing Acheulian technology. They were reluctant to call the MIS 9 non-handaxe phenomenon 'Clactonian', since this implied demographic links between the two that could not be assumed to have existed. It remains unclear whether environmental factors or the social dispersal conditions during the early temperate parts of these interglacials, rather than a long-lived cultural tradition, might explain this repeated absence of handaxes. Likewise, evidence for local sequences of interdigitating handaxe and non-handaxe assemblages, with no clear understanding of their behavioural or cultural significance (*e.g.*, at Notarchirico, Italy; Piperno et al., 1998), has also rendered the extrapolation of the Clactonian into Europe less secure than it once appeared. Within Britain, calls for the abandonment of the term depend more on theoretical position than any empirical evidence. The majority of workers are happy to retain Clactonian to describe the MIS 11 industry, stripped of its culture-historical baggage, but many are reluctant to accept that the MIS 9 occurrence is real or that it can be safely related to the Clacton industry, other than by its basic technology. Once again, this debate and its eventual resolution underline the importance of maintaining the Clacton GCR site and SSSI within the greater Thames network, this historically important locality continuing to provide key data, albeit that much of this comes from re-evaluation of existing collections and the sedimentary archive (see Dale et al., this issue).

As mentioned, arguments that the Clactonian represents the oldest evidence for human occupation of Britain have long been superseded by the evidence for a thriving pre-Anglian handaxe industry at Boxgrove (Roberts and Parfitt, 1999) and in several other high-terrace contexts, including those in the Black Park Terrace of the Thames (Wymer, 1957, 1968), at Fordwich in the Kentish Stour (Bridgland et al., 1998), at Farnham in the palaeo-Blackwater (Bridgland and White, 2018) and in the terraces of the pre-Anglian River Bytham (Davis et al., 2021; Lewis et al., 2021). The assemblage from Black Park Terrace localities in the Middle Thames includes flakes and cores that were once attributed to the Clactonian on the basis of technology, but cannot now be classified thus, following the observations of McNabb (see above). Similarly, the new assemblages from Pakefield (Parfitt et al., 2005) and Happisburgh (Parfitt et al., 2010), on the coast of East Anglia, are of Clactonian character but constitute insufficient material to make a positive identification, given that a single handaxe-related piece would lead to re-classification. As White (2000) observed, this means that discreet non-handaxe industries might well be represented amongst mixed debitage but cannot be positively identified as such once it is clear that Acheulian material is present.

The site at Clacton is also unique in terms of organic artefacts and remains the only site in Britain to have produced evidence of Middle Pleistocene wood working, in the form of the broken spear point (Warren, 1911b; Oakley et al., 1977). Long regarded as an oddity (Gamble, 1987), the Clacton Spear has assumed renewed significance and context following the discovery of 300,000 year-old (MIS 9) wooden spears, throwing sticks and 'handles' at the site of Schöningen, central Germany (Thieme, 1997; Conard et al., 2015, 2020). Most recently, Parfitt et al. (2022) confirmed Warren's suggestion (*contra* Wymer, 1968) that bone soft-hammers were present at Clacton, thus dispelling suggestions that the Clactonian industry reflected the technological shortcomings of its makers (*i.e.*, lack of soft-hammer technique).

4. Conclusion

The complex GCR site and SSSI at Clacton-on-Sea highlights the importance of the relationship between development, planning and geology/archaeology, clearly demonstrating the benefits of conservation of key sites in the face of increasing pressure from development, and as a resource for new research. This is particularly relevant to coastal areas such as eastern Essex, where sea-level rise associated with anthropogenic climate change is likely to have a significant impact in the future. How protected geosites such as Clacton will be impacted by major environmental changes in the future is unclear, although these impacts will surely be negative; this topic has long been recognized in literature concerning geoconservation and is now the subject of dedicated research (*e.g.*, Crofts et al., 2020; Gordon et al., 2022). This brief review has demonstrated that the Clacton GCR site retains national–international significance as a complex Quaternary geosite for the following reasons:

- It is the type locality for at least two biostratigraphically significant ostracod species and an extinct subspecies of fallow deer.
- It is the type locality of the Lower Palaeolithic Clactonian stone-tool industry.
- It is unique in the UK and extremely rare in NW Europe as a site that has yielded both wooden (spear tip) and bone (hammers) artefacts, together with lithic assemblages, all as components of clastic sediment.
- It is part of an important network of contemporary Lower Thames localities that record Hoxnian (MIS 11c) climatic and sea-level history, which together represent one of the most detailed terrestrial records of this interglacial.
- It is one of only three UK sites to have preserved the 'Rhenish fauna' of non-marine molluscs, characteristic of MIS 11.
- It is one of very few localities with a significant reserve of well-mapped *in situ* sediments, protected by the SSSI status, in which a range of palaeoenvironmental proxies (molluscs, ostracods, foraminifera, vertebrates, pollen, plant macrofossils) are preserved. These represent a critical resource for future research and the development of new techniques (*e.g.,* AAR dating using *Bithynia* opercula, clumped isotope analysis to measure past air temperatures, both reliant on biominerals).
- The SSSI conserves the context of the extensive museum archives of fossils, artefacts and sediments from the Clacton deposits.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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