SITE FORMATION PROCESSES IN THE SEVERN ESTUARY LEVELS

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The Severn Estuary Levels share with conventional dryland archaeological sites such site-formation processes as the anaerobic preservation of organic materials in pits, wells, ponds and moats. Unique to the Levels, however, but to be expected in other tidal wetland areas, are a range of natural physical formation processes, some leading to the concealment and preservation of activity/occupation sites and others to the exposure and destruction of sites, and the modification of the assemblages of cultural debris they contain. These processes are sea-level change, sedimentation, wave-action, the wandering of estuarine channels and banks, channel meandering, and salt-marsh autocyclicity. Human interventions from Roman times onwards also contribute to site formation through the embanking and drainage of salt marshes. These interventions transformed the extensive Severn Estuary Levels from wetlands suitable only for seasonal activities to areas that could be farmed and settled, but at the increasing cost of drainage and sea defence demanded by sea -level rise.

INTRODUCTION

The Bristol Channel and the Severn Estuary today comprise a marine gulf that shades eastward and north-eastward into the estuary of the most important river system in south-western Britain. On the margins of this highly dynamic estuary lies a region – the Severn Estuary Levels – of some 840 km^2 in total extent, underlain by roughly 8 km^3 of postglacial, marine-brackish and some freshwater sediments typically 10 m thick, except where there are valleys incised into the bedrock in which thicker sequences accumulated. Dating from the earliest Mesolithic, the alluvial wetlands represented by these sediments have in all periods proved attractive to people, and the evidence for human presence and activities is now known to be widespread and varied within and upon the sedimentary pile (eg Coles and Coles 1986; Allen and Fulford 1990a; Rippon 1997; Nayling 1998; Nayling and McGrail 2004; Bell *et al* 2000; Bell 2007; 2013; Presley 2010). Work on these archaeological sites is challenging, not just logistically but mainly because few of the formation processes associated with them are shared with conventional and better understood dryland locations (Schiffer 1987).

In this paper we attempt to review what we regard as the more significant site formation processes that are peculiar to the Severn Estuary Levels, and that operated, and continue to operate, there. Some of these processes are highly destructive, but are not entirely negative in their effects, because they expose sites that might otherwise have remained hidden. Others lead to the burial and concealment of sites, but have a positive influence in that they bring new wetlands into existence for human exploitation. The Severn Estuary Levels present many waterlogged environments and consequently preserve organic materials such as wood and bone exceptionally well. In this the sediments of the Levels are no different from other anaerobic contexts, such as pits, wells and moats at dryland sites, and we consequently do not concern ourselves with this biogeochemical aspect of site formation.

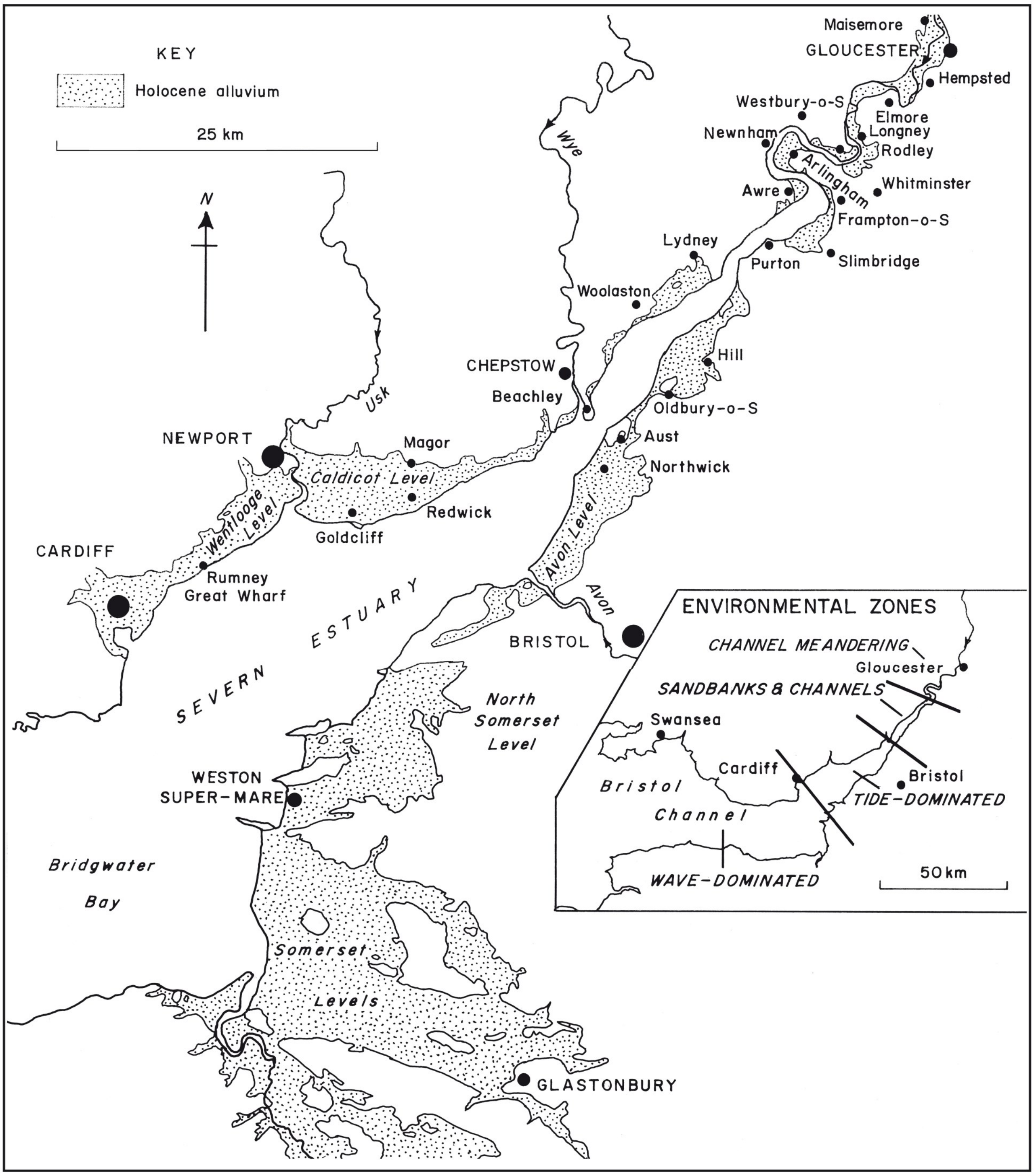

Figure 1 The Severn Estuary Levels, showing the outcrop of Holocene estuarine alluvium and the principal places mentioned in the text.

ENVIRONMENTAL ZONES

In discussing any estuarine system with bordering tidal wetlands the problem arises as to where and when lies the coastline. Is it where the highest tidal waters reach to the distal limit of the wetlands at their contact with the surrounding bedrock uplands, or at the limits of some lower water level, perhaps the proximal edge of the wetlands? Here we take the coast as roughly at the limits reached by mean high-water neap tides.

The coastline thus defined of the *present* Bristol Channel-Severn Estuary is divisible into four intergrading environmental zones in each of which a particular agency or factor exerts today a dominant but not exclusive medium-term influence at the shore. These are depicted in Figure 1, which should be consulted throughout the text. As far inland as Cardiff and Weston-super-Mare the coasts of the Inner and Outer Bristol Channel and Bridgewater Bay are *wave-dominated*. They are formed either of rock cliffs, gravel beaches or sand beaches, many backed by series of wind-blown dunes. Extending upstream from this zone as far as the Aust-Beachley narrows lies the *tide-dominated* outer estuary. Chiefly mud is deposited at the coast here. In the next zone inland, ranging upstream to the vicinity of Slimbridge, the wanderings of *sandbanks and channels* are considered to exert the main influence, with tidal mud dominating the coastal deposits. The innermost zone reaches upstream as far as the limit of tidal influence (currently Maisemore Weir, Gloucester). Here conventional *channel meandering* is the main control, with tidal mud and some sand appearing in the coastal deposits. In all zones a mixture of agencies is effective, but the balance changes from zone to zone. Sea-level change plays much the same role in all the zones.

SEA-LEVEL RISE

The extent to which these environmental zones were present during the development of the Bristol Channel-Severn Estuary system to its present ground plan will have been largely determined by the way in which postglacial sea-level rise governed the changing location and configuration of the coastline.

Global sea-level has risen by some 130 m since the Last Glacial Maximum (26,500 yrs BP). A not entirely reliable impression (because of sea-bed erosion) of the advance, or transgression, of the sea into the Bristol Channel-Severn Estuary region can be gained by combining a sea-level curve (eg Edwards 2006) with modern hydrographic charts to map and date submarine contours (Hawkins 1971; Allen 2000a, fig. 4; Bell 2007, fig. 1.4). These various reconstructions differ in their details but are in broad agreement. Deglaciation was rapid. By the start of the Mesolithic a ragged coastline seems to have stretched in a very gentle curve across the mouth of the Bristol Channel. This transient shore, facing the Celtic Sea, was probably wholly wave-dominated. Relative sea-level was then rising at a rate of the order of 10 mm/yr. The narrow funnel-shaped form of an estuary seems to have appeared soon afterwards and subsequently rapidly advanced eastward like a wedge, so that by the beginning of the Bronze Age the head lay well within the bounds of the modern Severn Estuary. The rate of relative sea-level rise had by then fallen to a few millimetres per year, not far short of its modern and still positive value. Probably all four types of coast distinguished above were present during this estuarine phase of development; they may be expected to have gradually marched inland in response to continuing sea-level rise.

The pattern of Holocene sea-level rise has two components. There is an underlying monotonic upward trend at a declining rate (Allen 2000a, fig. 4B), as summarized above, on which are superimposed, in the mid Holocene especially, fluctuations with periods of tens to hundreds of years and amplitudes of perhaps up to *c.* 0.9 m (Allen 1997a). The timing and extent of these fluctuations appears to have depended on both local and regional factors, as yet poorly understood, and are not expected to be either precisely synchronous or expressed environmentally in the same way everywhere within the sedimentary pile underlying the Severn Estuary Levels.

SEDIMENTATION

Many rivers introduce mud (predominant) and sand (subordinate) into today's Severn Estuary, of which the Severn, Usk and Wye Rivers, with their basins being under a predominantly agricultural regime, are the most important (Collins 1983, 1987; Harris and Collins 1988; Haslett 2011). Minor supplies result from erosion at the sea floor and bordering cliffs (eg Williams and Davies 1987). The total supply is estimated at roughly 2,450,000 tonnes annually (Allen 1990a, fig. 7), equivalent to 0.00123 km^3 of deposited sediment. Since the oldest wetland sediments date to at least about 8000 yrs BP, the estuary could since then have received from the river basins the equivalent of *c.* 10 km^3 of deposits, a figure that matches the roughly 8 km^3 estimated on stratigraphical evidence to be present today beneath the Severn Estuary Levels. Even allowing for the fact that a small proportion of this volume is of organic origin, it is arguable that the estuary has retained most of the detritus supplied to it over the Holocene, with comparatively little escaping westwards to the open sea. During this epoch, however, the sea rose significantly and the estuary migrated inland, as proved by the abandonment far out in the modern intertidal zone of landing places (Davies and Williams 1991; Fulford *et* a*l* 1996; Allen and Fulford 1996), fishweirs and traps (Nayling 1999a; Allen 2002; Brown *et al* 2010), and the basal infills of palaeochannels that can only have arisen within the context of salt marshes (Allen and Fulford 1996; Allen and Rippon 1997a, 1997b). These findings in combination point to the likelihood that the sedimentary pile beneath the Levels accumulated partly by a process of 'stratigraphic roll-over', during which earlier deposits were reworked by wave and tidal currents to contribute to later horizons (Allen 1990a). The modern estuarine water-body is therefore likely to contain elements of sediment the introduction of which dates from across most of the Holocene.

The tidal frame in an estuary is the vertical interval at any one time between the lowest (LAT) and highest (HAT) of the astronomical tides. Today in the Severn Estuary that interval approaches 15 m, but the observed tidal range at a place, controlled by the relative motion of Moon and Sun, varies on semi-diurnal, spring-neap, semi -annual and multi-annual scales and is also strongly influenced by meteorological factors (Allen 1990b). A host of studies using various environmental proxies (eg Haslett *et a.* 1997, 2000; Druce 1998; Bell *et al* 2000; Allen and Haslett 2002, 2007; Bell 2007) have shown that *all* the Holocene sediments that underlie the Severn Estuary Levels have formed close to HAT, neither far below nor far above, on high tidal mudflats, salt marshes, peat marshes at or just below HAT, and just supratidal peat marshes, forested marshes and raised bogs.

The sediments thus accumulated constitute the Wentlooge Formation (Allen and Rae 1987) which, together with some post-Roman morphostratigraphic units, can be recognized throughout the Levels from Somerset and Monmouthshire, and into Gloucestershire. The Wentlooge Formation is divisible informally into three parts. The lower part is mainly of silts with locally a basal peat. Silts and peats interbedded on a decimetre-to-metre scale comprise the middle Wentlooge Formation. Chiefly silts return in the upper part. The stratigraphic succession is siltiest in proximal locations but becomes more peat-rich distally toward the bordering drylands. Beneath this sequence is a dissected land surface marked by soils developed on strata modified periglacially – ice-wedge casts and boulder gardens can be found – during the Pleistocene (Allen 1987a; Bell 2007). Fluvial sands and gravels occur locally in some of the valleys cut into the pre-Holocene surface.

Archaeologically, these various wetland sediments have on a multitude of occasions provided platforms on which human activities and occupation have taken place. Their continuing accumulation has also shrouded and concealed the sites of occupation and activity, including those of Mesolithic and Bronze Age dates now known to have been present on the former land surface below (eg Allen 1998a; Brown 2003; Bell 2007). There is some evidence also for Upper Palaeolithic sites. The narrow sample afforded by Neumann's (2000, 282-321) intertidal peat survey along the Wentlooge and Caldicot Levels implies that, over the Severn Estuary Levels as a whole, there are probably thousands of prehistoric and early-historic archaeological sites that are unknown for this reason. The proportion of known to concealed sites is likely to be very small.

Examined in more detail, human exploitation of the wetlands seems to have been especially marked at the time of the interleaved silts and peats of the middle Wentlooge Formation. In proximal settings, as on the coasts of the Somerset Levels (eg Druce 1998), the Wentlooge and Caldicot Levels (eg Allen 2001a) and Oldbury Levels (Brown 2007), peats and silts are found interbedded on a vertical scale of decimetres to a metre or so. In these settings, the thinner peats appear to pass laterally into as yet poorly understood 'stasis horizons' or proto-soils (eg Locock 1999); these are more organic than the normal salt-marsh silts but are not rich enough to qualify as peats. Traced distally, the peats deposits thicken and fuse toward the interior of the wetlands and the bedrock margins, the silts correspondingly wedging out (eg Coles and Coles 1986; Allen 2001a). Two patterns of environmental change can be found among these beds (Allen 2002; Allen and Haslett 2007). Some peat-silt-peat sequences exhibit unbroken deposition and a symmetrical sequence of depositional environments from highest intertidal/ supratidal organic marshes, through lower salt-marsh silts with expanding and then shrinking networks of tidal creeks and gullies (Allen 2000b; D'Alpaos *et al* 2006), back to highest intertidal/ supratidal organic wetlands. In others the environmental pattern is asymmetrical. The peat at the base is followed by a surface of non-deposition/erosion, overlain by the silts of mudflats and salt-marshes that gradually rose in the tidal frame before returning to highest intertidal/supratidal peats, again accompanied by the growth and decay of creek networks. The creeks and larger palaeochannels that threaded their way through the salt marshes proved ideal for fishing activities, as witness the varied prehistoric and early historic wooden structures and related artefacts profusely reported from them (Allen and Bell 1999; Bell *et al* 2000; Bell 2013). Here and there sites dry enough for temporary occupation were afforded by the slightly-elevated silty levees of these palaeochannels (Allen 1996).

The most important archaeological finds associated with the middle Wentlooge Formation are probably seasonal occupation sites at the uppermost, highest intertidal/supratidal levels of the so-called main peat in the Wentlooge and Caldicot Levels, at or close to the overlying transgressive tidal silts of the upper unit, which overlay and preserved them. These include the cluster of middle Bronze Age rectangular buildings with evidence for animal husbandry at Redwick (Bell 2013), another cluster of a similar character and function of Iron Age date at Goldcliff (Bell *et al* 2000) also on the Caldicot Level, at Rumney Great Wharf on the Wentlooge Level a Bronze Age roundhouse (Allen 1996) and the enigmatic, perhaps temporary, oval shelter known as Structure 6 (Nayling 1999b), and Bronze Age roundhouses at Chapeltump and Collister Pill (Bell *et al* 2000). Among the evidence for animal husbandry at some of these sites are the footprint-tracks of domesticated animals found around the buildings within the silts and on the tops of the peats (Bell 2013). Similar evidence occurs at many other levels and places within the area (Allen 1997c) and numerous human and bird footprint-tracks are now known (Bell 2013). The quality of preservation of these footprint-tracks in the Wentlooge Formation depends critically on the physical properties of the sediment at the time it is trodden and the fact that whatever activity is represented took place in an environment of active sedimentation.

Whereas the Welsh sites mentioned above arose in a comparatively proximal estuarine wetland setting, the substantial prehistoric-early historic settlements, trackways and salt-making sites discovered, partly as the result of peat-digging and drainage activities, in the Somerset and North Somerset Levels were by contrast created in association with thick peats and some silts of a typically more distal origin (Coles and Coles 1986; Rippon 1997, 2000). In the inner Somerset Levels, reaching back deep into well-watered uplands, freshwater influences were marked and protracted.

WAVE-ACTION

The waves seen at sea are travelling undulations on the water surface carrying energy to the shore, where it can be dissipated in a variety of ways. Waves grow in size with increasing wind-strength and the distance at sea (or fetch) over which the wind blows. Their combined potential and kinetic energy is proportional to the square of their height, making them a potent geological agent even when comparatively small. Atlantic swell reaches today as far into the Bristol Channel as Swansea Bay, but the waves seen further inland, dependent on regional or local winds, during storms can reach as much as 1-2 m in height. Wave-action is an important coastal archaeological agent in the Severn Estuary and Bristol Channel, because the region is directly exposed to the westerly and southwesterly winds that prevailed throughout most of the Holocene. It is dominant in the outer areas and, in the tide-dominated and other inner zones, significant during gales.

Archaeologically, wave-action is a two-edged agency of site formation. In the Severn Estuary it has both brought to light activity and occupation sites that would otherwise have remained unknown, but has also eventually modified and destroyed them through coastal erosion. Wave-action cuts cliffs in the salt-marsh silts exposed along the proximal edges of the wetlands of the Severn Estuary (Allen 1987b) and where the silts and resistant, shelf-forming peats of the middle

Wentlooge Formation are exposed at mid-tide levels (Allen 1990a). These cliffs are as much as 2 m tall and their rate of horizontal retreat can average decimetres to metres annually (eg Allen 2002; Bell 2013). Weakened by drying and frost-action, they are readily undermined by vigorous waves and caused to topple, the broken masses of silt becoming rounded and reduced in size as a kind of beach gravel, and eventually removed with the help of tidal currents. Peats on exposed shelves fail under wave action in an additional, unique way, breaking off along deeply penetrating, horizontal fractures as large, almost neutrally buoyant flake-shaped masses that travel far with the tide (Allen 1998b).

Among the more important wetland sites exposed because of wave-action are the prehistoric site at Oldbury Flats (Allen 1998a), the Romano-British occupations at Hills Flats and Oldbury Flats (Allen 1997b; Allen and Fulford 1987; Allen and Rippon 1997a), the medieval landing places at Woolaston (Fulford *et al* 1992) and Hills Flats (Allen and Fulford 1996), the Roman-medieval-early modern port at Magor (Allen 1998c, 1999, 2003; Allen and Rippon 1997b), the prehistoric buildings at Goldcliff and Redwick along the Caldicot Level (Bell *et al* 2000; Bell 2007, 2013), and the Romano-British settlement at Rumney Great Wharf on the Wentlooge Level (Allen and Fulford 1986; Fulford *et al* 1994). Primary contexts are accessible at the prehistoric sites but at the later ones erosion has bitten back through some if not all of the original horizontal extent of the occupation. In the latter case, the preservational outcomes are either that occupation debris is recoverable on the coast from primary contexts and as an intertidal strew, or that it can be collected only from a strew.

Occupation debris released into the intertidal zone effectively become sedimentary particles, that can be affected by a variety of modifying processes, challenging to the would-be interpreter. Chief among these are dispersion and sorting, and breakage and abrasion.

Dispersion is the spreading out of material from the point of input as the result of the action of wave and tidal currents. Wave swash and backwash tends to spread debris up and down the shore, whereas tidal currents tend to shift material parallel with it. The primary Romano-British context undergoing erosion at Oldbury Flats, for example, includes blocks of building stone, iron-smelting slag (slag basins, tap slag), and lumps of iron ore. These large and/or dense items have strayed no more than 5-10 m away from where they were released. Pottery sherds and bone fragments, on the other hand, have drifted away for tens or hundreds of metres. Likewise, the delicate flintwork from the intertidal prehistoric site is also widely dispersed along the shore. These contrasts illustrate the fact that sorting normally accompanies dispersion, the smallest and lightest components of an assemblage of occupation debris travelling the furthest and fastest. Stout fragments of storage jars tend at Oldbury Flats to occur nearer the point of entry than sherds from light, drinking cups.

Breakage and abrasion generally accompany dispersion and sorting, and especially affect the more delicate artefacts and those composed of weak materials. The degree of breakage and abrasion depends chiefly on the general strength of wave-action and the character of the foreshore on to which the occupation debris is released. Strong wave-action and a sandy or gravelly intertidal substrate favour the abrasion and breakage of the artefacts released. Abrasion is most obvious on pottery sherds, which become rounded along edges and at corners, and lose surface treatments. At Rumney Great Wharf on the Wentooge Level and Magor Pill on the Caldicot Level, for example, where the shores are moderately exposed and locally gravelly, the sherds of Romano-British pottery have lost their colour coatings and to some extent their surface ornamentation. At Magor Pill, the glazes on medieval and early-modern forms have been dulled and, in some cases, partly destroyed. Well-rounded sherds reduced in size at fresh, sharp-edged fractures afford the main evidence for breakage, a factor that can influence sherd counts and estimates of vessel numbers.

HUMAN INTERVENTIONS

Site formation begins with human processes at and in the neighbourhood of places of activity or occupation. Some of these processes seem to have had little significant effect on the regime of the Severn Estuary and its Levels, but others have been highly aggressive and offensive, in a strategist's sense, introducing permanent change.

There is abundant evidence that prehistoric exploiters of the Severn Estuary Levels mainly herded, hunted, wildfowled, fished and cut reeds there but, other than in the innermost Somerset Levels, did not permanently settle (Coles and Coles 1986; Bell *et al* 2000, Bell 2007, 2013). These peoples were responsive to the seasonally changing environmental conditions in the wetlands, but did not actively seek to change them in any significant or permanent manner. The cutting of reeds on the salt marshes, and the building of wooden fishing hedges and traps in the creeks, is unlikely to have affected tidal currents and sedimentation in other than minor, local ways.

Beginning in the Roman period (Allen and Fulford 1986), and very locally perhaps from the Middle Iron Age (Locock and Walker 1998), the Severn Estuary Levels (*c*.840 km^2) were eventually in their entirety enclosed by seabanks and, as an intended consequence, permanently transformed and settled, with the creation of farms, hamlets and villages (Rippon 1997). The proportion of active marsh remaining today – Northwick Warth is perhaps the largest survivor – is minuscule. Early examples of this process are the Romano-British settlement with its well at Rumney Great Wharf on the Wentlooge Level (Allen and Fulford 1986; Fulford *et al* 1994), the defending seabank of which has been lost to coastal erosion, the occupations of the same period on the Avon Levels (Ritchie *et al* 2007), the settlements at Hills Flats and Oldbury Flats (Allen and Fulford 1987; Allen 1997b)), and the Anglo-Saxon occupation at Bridgemacote on the Elmore peninsula in the inner estuary (Allen and Fulford 1990b). Although Roman embanking affected many, widely scattered parts of the Levels, it was by no means general. Substantial areas seemingly remained unenclosed, especially in the Inner Bristol Channel and the outer estuary, and on these, salt-making thrived, leaving 'red mounds' with briquetage (eg Grove and Brunning 1998; Cox and Holbrook 2009).

The aggressive process of land-claim on the margins of the Severn Estuary had environmental consequences that are poorly understood, because the character of the unaffected estuary cannot be recalled, but likely to have been permanent and significant. The wide 'floodplains' afforded by the bordering wetlands are no longer available to absorb the waters of the higher astronomical and storm tides, for the artificial embankments, which exclude these flows, effectively fossilize the ground surface to landward, on which soils have now developed. The tidal flows are consequently narrowed, which could have the effect of either raising tidal levels and promoting erosion or dampening the tides and increasing sedimentation (eg Hood 2004). Definite negative outcomes, because sea-level is continuing to rise, are increasing risk of flooding, especially where seabanks have been neglected for a substantial period (Rippon 1997), and the need to keep raising these earthworks and improving drainage at an exponentially increasing cost (Allen 2001b). What began as an offensive land-grab in mainly Roman and medieval times, intended to increase economic potential, has now turned defensive, and consequently a drain on resources and a source of contention.

There is one peculiarly archaeological consequence of land-claim which should be mentioned. This process includes the drainage of embanked areas and the manipulation of water-tables by landowners, so as to maintain in good condition the arable fields and pasturage thus created. A lowered water-table, however, can lead to the loss through oxidation and bacterial-fungal decay of the organic components of archaeological sites that lie too near the ground surface, an issue long recognized in, for example, the peatlands of the Somerset Levels (Coles and Coles 1986; Brunning 2013).

Renewed tidal flooding of a former wetland leads to the burial and concealment of the activity/ occupation sites, field systems and soil horizons made possible through the initial embanking, a process that has certainly occurred at many places on the Severn Estuary Levels (Rippon 1997, 2000; Jordan 2007). Where the Levels have not been subject to multiple phases of embanking, however, occupations are found at sufficiently shallow depths within the alluvium that they can be field-walked, as in the case of Romano-British and medieval sites at Hill and Oldbury (Allen 1997b).

WANDERING OF CHANNELS AND BANKS

There is an inner zone in the Severn Estuary in which the wandering of tidal sandbanks and channels is considered to be the dominant process shaping the coastline (Fig. 1). The tidal channels and banks in this zone constantly shift in position over time as they slowly grow and decay. Where an active channel swings toward the shore it brings deep water and swift currents against the cliff-edge of the pile of wetland sediments, promoting undercutting and deep rotational slipping of the strata and uneven shoreline retreat in steps measuring metres at a time. When the channel decays, the active feature having migrated elsewhere, siltation is quickly resumed and it, and the adjoining bank, can swiftly grow up into the high intertidal zone to become a new and substantial area of mudflats and salt marshes. Sedimentation rates during this phase can measure centimetres to decimetres yearly, and an annual textural banding is typically visible within the deposit. There has consequently been a close interaction, recorded in the detailed morphostratigraphy of the wetlands and in historical sources, between these natural processes and human land-claim and subsequent activities in this interior zone. Seaward-facing clifflets and truncated seabanks on the wetlands proclaim coastal retreat and the ultimate landward positions of the shorelines created wherever channel-wandering has occurred; coastal retreat is also manifested where seabanks have been set back across field systems, such as medieval ridge-and-furrow (Allen 2001c). By contrast, redundant seabanks, and landward-facing ramps where these have been grubbed out, point to episodes of sedimentation and the creation of new salt marsh that could in turn be enclosed and farmed.

On the southeast bank of the Estuary, the frequent movement of channels and banks in the Frampton-Slimbridge area (Fig. 1), combined with human interventions in response, has created a complex wetland landscape. At Frampton and Saul Warths an eastward-looping channel in modern times cut back into medieval fields and truncated a presumed seabank of this if not earlier date, but not before these fields had been tile-drained in the mid-late nineteenth century (Allen 1990b). The ridge-and-furrow was subsequently deeply buried by tidal silts before a second seabank was raised on this alluvium in a deeply set-back position (Allen 1986). In recent decades the channel that pressed against the edge of the wetland has begun to wane and the shoal that lay to its west has started to build up, although not yet far enough up into the tidal frame that many halophytes can grow.

A more complex pattern of landscape change is recorded in the co-extensive area of alluvium at Slimbridge, several kilometres to the southwest (Allen 1986, fig. 5). A pre-medieval channel had looped deeply to the east into the wetland sequence, reaching more or less the position (deliberately?) adopted for the Gloucester & Berkeley Canal. This channel had waned and new mudflats and salt marshes built up to form what became known as Slimbridge Warth, before a part of these, including the documented Katharine Cooke's Leyes, were enclosed and farmed in the early fourteenth century. By the mid-eighteenth century Slimbridge Warth had been embanked for farming, but a major tidal channel, called The Gutt, had again looped eastward. This channel itself eventually halted and silted up and, together with the large shoal called The Dumbles that had built up in its embrace to the west, was in turn enclosed in at least two stages and used for pasture. Minor channel movements in recent decades at Slimbridge have been followed by some renewed salt-marsh growth.

The Lydney Level, on the opposite bank of the estuary (Fig. 1), has like Slimbridge Warth experienced a long and complex history of landscape change and site formation (Allen 2001c). Parts have been cultivated and others used historically, with the erection of appropriate buildings, for rearing cattle and sheep. There is evidence from elevation changes, soil colours and field patterns that the alluvium of the inner part of the Level was in existence by Roman and medieval times. At least four shorelines antedating the modern one can be traced across the Level and six episodes of land-claim, some short-lived, can be identified in the form of redundant or grubbed-out seabanks. The most conspicuous shoreline (III) takes the form of wide arcs concave to the Estuary and identifies the northwestward reach of the curving channels that encroached on the alluvium. This shoreline was in existence by the late seventeenth century but had probably been stable for some time. The channel that pressed against it had silted up and new and extensive areas of mudflats and marshes – the New Grounds, Lydney Marsh and the marshes around Aylburton Pill and Cone Pill – had built up. Seabanks were erected on Lydney Marsh and the New Grounds in the early nineteenth century, but the bank on the latter was set back a century later when two vigorous channels again looped landward. Over the last few decades other channels have been spawned by ebb-and-flood avoidance (Robinson 1960) on the landward side of Lydney Sand. These, near Aylburton Pill and Cone Pill, have now bitten deeply back into the alluvial sequence of the Lydney Level by up to *c.* 400 m on strongly curved frontages of many hundreds of metres, destroying much rich seasonal pasture. Also in the process, two private wooden jetties built by local farmers, probably for the transfer by water of produce and goods, were briefly exposed to view but then destroyed and lost.

CHANNEL MEANDERING

In the innermost of the environmental zones distinguished above (Fig. 1), the tidal channel of the Estuary is relatively narrow and meanders for 15 km downstream from Gloucester in a broad, shallow valley. As in an alluvial river, the shifting of the channel has involved the progressive but episodic accumulation of alluvium – but under mixed fluvial and strong tidal influences – on the inner side of the loop in harmony with erosion on the outer bank, in most of the meanders cut in places into bedrock. The presence in the alluvial sequence of mid Holocene peats has been proved locally (eg Hewlett and Birnie 1966), but the stratigraphy of these inner outcrops is in the main poorly known and nothing can be said of the old land surface on which they rest. Land-claim in most places right up to the tidal channel has created from Roman times onward large areas for settlement and cultivation.

The first two meander-loops downstream from Gloucester are at Hempsted and Minsterworth and are so far poorly known. The rise in elevation outward across the seabanks, however, is large enough as to suggest enclosure in the Roman period, and there is unquestionable evidence for medieval settlement on the alluvium in the form of Llanthony Priory of the early twelfth century (Allen and Fulford 1990a).

The large meander-loop at Elmore next downstream is known in fair detail (Allen and Fulford 1990a, 1990b; Hewlett and Birnie 1996). The alluvial sequence includes peat and Roman, followed by early medieval settlements – discovered by field-walking – were established on the surface of the embanked alluvium. Much ridge-and-furrow and a medieval activity site, in the form of rectangular enclosures with pottery strews, also occur on the surface. There is a large rise in elevation outward across the seabanks to the active salt marshes. The alluvium here appears never to have been reflooded.

The Holocene outcrop in the Longney area reaches inland far to the east around low bedrock islands and ridges (Allen and Fulford 1990a). The disposition of the seabanks points to three episodes of land-claim, two of the Roman period and the last, at Waterend in the north, in medieval times. Field-walking on the largest spread of enclosed alluvium revealed an extensive Romano-British settlement. Medieval ridge-and-furrow abounds.

The Holocene alluvium in the Whitminster area on the left bank of the Estuary has a substantial and complex outcrop, although lying within a deep embayment rather than a meander-loop (Allen and Fulford 1990a). Three episodes of enclosure, stepping in sequence westward toward the outfall of the River Frome, can be traced here by means of surviving or grubbed-out seabanks. The two oldest, with medieval ridge-and-furrow, appear to be Romano-British on the basis of the changes in ground level across them; one of these is overlooked by an early Romano-British settlement built close to the edge of the alluvium. The third is probably of early modern or perhaps late medieval date.

Next downstream, in the area of Westbury-on-Severn, comes the small, sharp loop of the river at Rodley followed toward Cleeve by a long, slightly sinuous reach along the north-eastern side of the Arlingham peninsula (Allen and Fulford 1990a). The oldest enclosure is certainly medieval in date, as it shows much ridge-and-furrow, and probably Roman on the basis of the rise in ground level across it to active marsh. The seabank has survived in places but on the alluvium along the Cleeve reach has been largely grubbed out, appearing in the fields only as a landward-facing ramp. Parallel with this reach a second seabank was erected closer to the river along the outcrop, probably in the mid nineteenth century. The saltmarsh here had accumulated episodically, as shown in air photographs by the several clifflets and associated damp areas that run along it, denoting the wavering positions of the tidal channel to the southwest. Blue Boys Inn and Farm at Rodley is the only settlement so far recognized on the alluvium; dry ground at the marsh edge is where other farms in the area are situated. Mid-Holocene peat and a forest bed appear in the alluvial sequence exposed in the river bank at Westbury-on-Severn (Prevost *et al* 1901).

A substantial alluvial outcrop lies within the great bend of the Severn at Arlingham (Allen 1990c; Allen and Fulford 1990a). Boreholes show that most of the outcrop is underlain by an alluvial sequence of sands, silts and peats that probably date from the early Holocene. An outer fringe comprises tidal silts over thick sands and is probably erosively related to the sequence lying inland. Most of the alluvial outcrop was embanked in the Roman period; the main Romano -British settlement lies beneath Arlingham village on a low, arcuate terrace of fluvial gravel, but there is a dated activity site on the alluvium to the west. Enclosure on a small scale has subsequently taken place at several dates up to and including the twentieth century, mainly in response to small shifts of the channel. The outcrop is remarkable for the extent and quality of the surviving medieval ridge-and-furrow. A ferry to Newnham was for long maintained at Passage Pill on the Arlingham bank but eventually fell out of use at about the time of the Second World War (Tucker 2008). The wooden landing-stage and spread of hard-standing for the ferry became buried by tidal silts and were for a time in the late twentieth century visible in the marsh cliff but are now eroded away or silted over.

The most downstream of the meander-loops of the Severn is at Awre (Allen and Fulford 1990a). The enclosure here, with much ridge-and-furrow, dates to the Roman period on the basis of the difference in ground level across it, but the seabank on the southeast side of the loop, in a set-back position at a sharp angle to the Roman line, is much later. Considerable erosion seems to have occurred on this side of the meander-loop, during which the Romano-British to medieval settlement of Whitescourt was destroyed, with the release of occupation debris into the intertidal zone.

SALT-MARSH AUTOCYCLICITY

There is an important natural salt-marsh process that is significant archaeologically. The great majority of the active estuarine and coastal salt marshes found in Britain are terraced, that is, they exhibit a stair-like flight of levels, separated by seaward-facing clifflets, centimetres to decimetres high, that descend toward the open water (e.g. Allen and Rae 1987). On eroding cliffs, and on the sides of deep gullies, the clifflets are seen to be merely the uppermost parts of bold cliffs that descend through the deposits to gently sloping, wave-cut, erosional platforms at about the level of high-water neap tides. Thus the active marsh that caps each level, continuing to receive tidal silt, overlies a discrete body of sediment, the two together constituting a distinct morphostratigraphic unit. Although initiated at successively younger dates, all the units in such a sequence involve active marsh and go on building up, although at rates that decline with increase in their height within the tidal frame.

Terraced salt marshes abound on the Severn Estuary Levels and are best seen today at Aust and Northwick Warths, the largest surviving area of active tidal wetland (Allen and Rae 1987; Haslett, 2006; Allen and Haslett 2014). Here three actively-growing morphostratigraphic units can be recognized. The oldest, underlying the highest marsh level, is the Rumney Formation, composed of pale brown grading up to grey silts, and dating on evidence at the Wentlooge Level from the late seventeenth century. Next, involving marsh at an intermediate height, is the Awre Formation. This is composed of grey silts and dates on historical evidence from the latest nineteenth century. The youngest unit, named the Northwick Formation, consists of the lowest lying marsh above a thick sequence of grey silts. This morphostratigraphic unit on the evidence of maps and air photographs was initiated mainly during the middle decades of the twentieth century. Within the last decade or so a further unit has begun to form at the foot of the bold cliff that on the more exposed parts of Northwick Warth has been cut back into the Northwick Formation. The sequence of post-

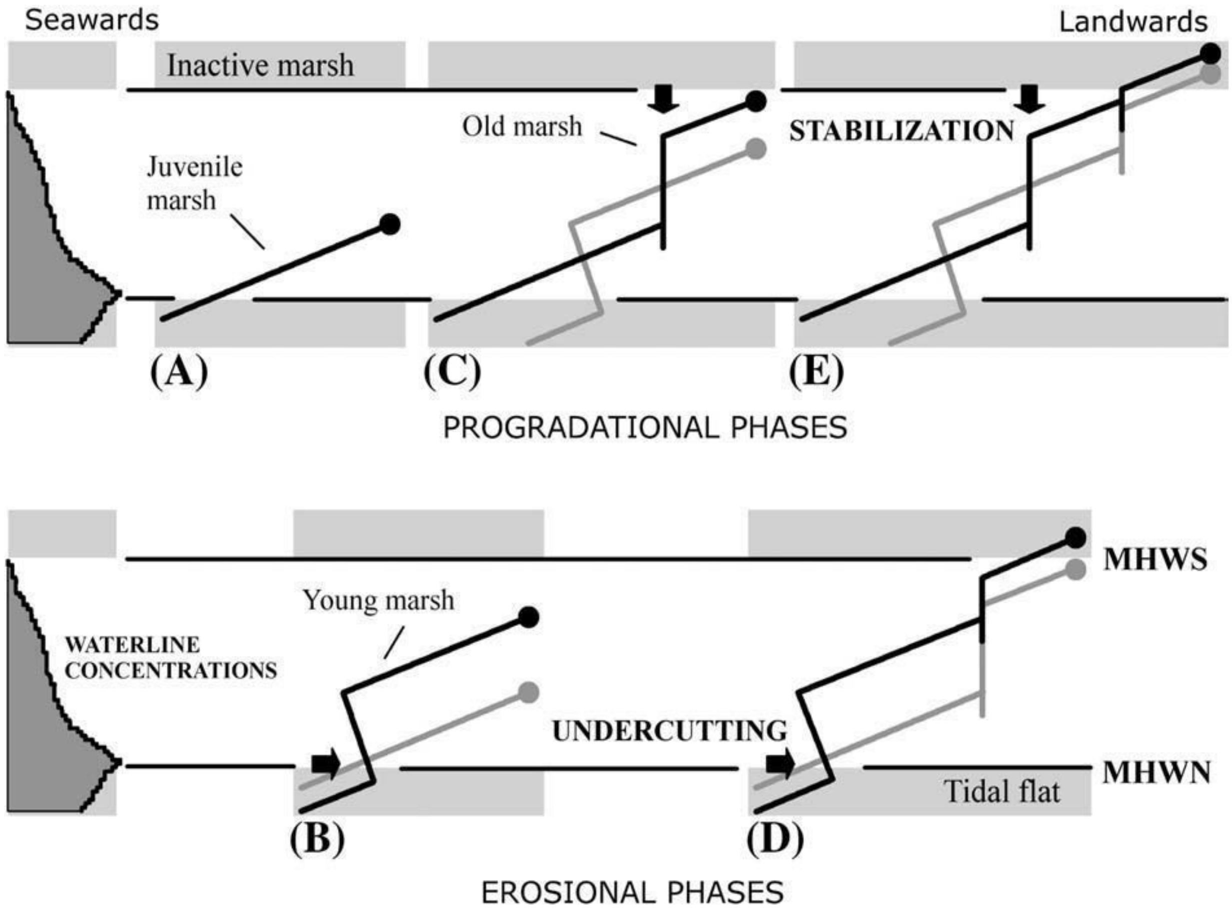

Figure 2. Schematic diagram of salt marsh autocyclicity: (a) sedimentation arises on a mudflat being colonized by salt-marsh plants; (b) the salt marsh grows up higher than the mudflat and an outward-migrating transition zone of increasingly steep slope develops and becomes sufficiently steep that wave-action begins to cut a cliff; (c) landward retreat occurs, resulting in the formation of a bold cliff; (d) the mudflat builds up again and the cycle is repeated; and (e) eventual cliff stabilization. MHWN = mean high water neap; MHWS = mean high water spring (reprinted from Singh Chauhan, 2009, with permission from Elsevier).

Roman marsh levels at Northwick and Aust Warths seems to be incomplete, however, for there is some evidence for a marsh level, formed in medieval times, that antedates the Rumney Formation. On the alluvium at Littleton-on-Severn and at Woolaston on the opposite bank a clifflet no more than a few centimetres high, associated with a distinct but subtle change in vegetation, can be detected on the inland side of the local outcrop of the Rumney Formation. This higher level of marsh is underlain by grey silts no more than a few centimetres thick that pass rapidly down into pale brown silts. Further up-estuary, at Hock Cliff near Arlingham (Allen 2001d), apparently the same unit is thickly exposed on an eroding cliff.

Using a sequence of historical maps and air photographs, combined with detailed geomorphological profiles, Allen and Haslett (2014) were able to relate the evolution of the salt marshes at Aust and Northwick Warths to a model of salt-marsh autocyclicity conceptualized by Yapp *et al* (1917) and developed quantitatively by van de Koppel *et al* (2005) (see Fig. 2). Essentially, this intrinsic process relates to the way in which a differential in sedimentation arises on a mudflat being colonized by salt-marsh plants on its higher parts. The halophytes trap and bind tidal silt, so that where they occur the sediment deposition rate is significantly higher than on the adjacent bare mudflat. Consequently, in the course of time, the salt marsh grows up higher than the mudflat and an outward-migrating transition zone of increasingly steep slope develops between the two environments. Eventually, the transition zone becomes sufficiently steep that wave-action begins to cut a cliff in it subject to undercutting and toppling, whereupon a galloping retreat landward occurs, resulting in significant loss of marsh and the formation of an eventually bold cliff. Subsequently, the mudflat to seaward of the marshes grows up again and the cycle is repeated, the marsh cliff stabilizing, on a time-scale of several decades to a few centuries. In a complex system like the Severn Estuary, however, this intrinsic process can be constrained by such external factors as decadal trends in windiness (strength and direction), and modulated by sea-level movements and channel wandering, as discussed above.

Archaeologically, salt-marsh autocyclicity is a two-edged process of site formation. On the one hand, it creates new wetlands for human exploitation while burying through progressive siltation sites initiated during the period of upward and outward marsh growth. On the other hand, during the phase of erosional retreat of the marsh edge, wetland is lost, primary archaeological contexts become exposed to view, and artefacts are released into the intertidal zone, to be dispersed, sorted and modified there.

Two recent cases of burial may be cited as examples. At Hills Flats (Allen and Fulford 1996) a young marsh is gradually spreading outward into the Estuary and in the process slowly burying a series of pocket beaches formed of debris derived from the local Triassic mudstones admixed with Romano-British pottery and other cultural material from a partly-destroyed occupation site. Upstream at Purton on the same bank, the build-up of the Northwick Formation to the extent of 1-2 m is slowly engulfing a large number of trows and other large vessels that had plied the Estuary, but were abandoned there from about the time of the Second World War (Parker 1998; Presley 2010).

The Romano-British cultural debris recovered from Oldbury Flats experienced a particularly complex post-depositional history (Allen and Fulford 1992). In a sort of cascade, some of it was recycled from primary contexts through the local Rumney, Awre and Northwick Formations, and from each of these into the present-day intertidal zone. The Romano-British cultural assemblage recovered at Awre also experienced recycling, in this case into the local Rumney Formation (Allen and Fulford 1987).

Finds of more than one period can become mixed as the result of salt-marsh autocyclic behaviour. On the coast of the Wentlooge Level can be seen the middle and upper Wentlooge Formation, the overlying Rumney Formation and the Northwick Formation (Allen and Rae 1987; Allen and Fulford 1986; Fulford *et al* 1994), the presence of the Awre Formation being uncertain. The Rumney Formation at Rumney Great Wharf yields artefacts at the erosional base and in abundance in sandy lenses part of the way up that accumulated as the result of storm overwash from local pocket beaches. The assemblage mixes prehistoric, Romano-British and medieval occupation debris. The Northwick Formation here is gradually spreading south-westwards along the foot of the bold cliff cut into the Wentlooge and Rumney Formations. In the process, it is gradually concealing the traces of the Romano-British field system (Allen 1987c; Bell 2013)). The Rumney Formation and younger marshes are also exposed to the northeast of Magor Pill. Sandy lenses in the Rumney Formation here locally yield an assemblage of medieval pottery.

It should not be supposed that salt-marsh autocyclicity, or autocyclicity heavily modulated, is confined to the last two millennia. There is evidence from exposures on the coast of the Caldicot Level for at least one constructional edge to a salt marsh dating to the middle Wentlooge Formation (Allen and Haslett 2002). Inland, a pattern of borehole records ranging for *c.*7 km parallel with the coast suggests the presence within the same beds of an erosional seaward limit (?cliff) to more than one silt-peat couplet (Allen 2001a). The middle Wentlooge Formation was deposited at a time of sea-level fluctuations, which could have distorted normal salt-marsh behaviour.

CONCLUSION

The review sketched above demonstrates that a wide range of physical processes, together with human interventions, have been involved in shaping the archaeological record so far known from the Severn Estuary Levels. Most require further study in terms of their archaeological role, and especially the way their relative importance has varied from place to place and period to period. Sea-level rise favours both siltation at high levels in the Holocene stratigraphic pile but also coastal erosion at low and intermediate levels. Tidal siltation leads to site burial and preservation, but also concealment from archaeological prospection. Coastal erosion brings to light activity/occupation sites that had become buried. The artefacts released into the intertidal zone, however, become dispersed, sorted and modified by the action of wave and tidal currents. Channel meandering, and the wandering of tidal shoals and channels, are processes involving siltation and erosion that are especially important in the more interior parts of the Severn Estuary. Salt-marsh autocyclicity is an intrinsic process that can be recognized throughout the Estuary, although subject to constraints and modulations by external factors. Both siltation and erosion are involved in this process of site formation. Wetland archaeology is a challenging discipline for many reasons.

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