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MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Archaeological and Historical Evidence for Subsidence in Southern Britain

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Archaeological and historical evidence for subsidence in southern Britain

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Introduction

This paper is presented as a warning of the pitfalls which are involved in a too ready and uncritical acceptance of the evidence for apparent changes in relative land and sea level which has been derived from the archaeological and historical remains around the coasts of southern Britain. The general trends of relative sea level changes in the later Holocene are indicated; but I am concerned more to correct some of the misapprehensions and inexact conclusions which have been drawn from the often imprecise data, and to establish a wider recognition of the types of errors and inaccurate assumptions which have been promulgated in some publications, and which erroneously, albeit unwittingly, have been cited by specialists in other disciplines to reinforce or to substantiate conclusions derived from their different data.

The optimum conditions for establishing the former positions of relative mean sea level are found in deposits which can be shown to have formed in a known relationship to sea level as part of a continuous halosere from marine sands and clays to freshwater fen deposits (cf. Churchill 1965, p. 240). I would stress that estimates of sea level changes should be based primarily on the analysis of physiographical data; the archaeological and historical data may provide complementary and corroborative evidence of relative land and sea level changes, but they are generally too imprecise to stand alone as definitive indicators of actual mean sea level or tidal heights.

Changes in relative land and sea levels in the later Holocene

General trends

The general trend of changes in relative sea level in southern Britain during the Holocene period is of a positive continuous rise, although with some local interruptions, (cf. Jelgersma 1961, pp. 53–65; Shepard 1964; Akeroyd 1966). In general the heights inferred for stands of relative mean sea/tidal levels are highest along the southwest coast, lower on the south coast, and lowest on the east; but after about 4000 B.C. the divergences become less marked. Accurate conclusions are precluded by the often considerable degree of error in estimates of both the heights of mean sea level and tidal levels, as well as in the available methods of dating the deposits and the archaeological material therefrom.† After about 4000 B.C., however, estimates of mean

† There is, for example, a standard deviation of at least ±100 years for nearly all radiocarbon dates, and the method itself contains a number of known errors. Other sources of error in dating attributions are discussed below. *Re* the degree of error to be expected in estimations of mean sea/tidal level from marsh and other coastal deposits, it should be noted that since marsh can form at any level down to mean tide level, the error may exceed half the spring tidal range. This means that there may be an average possible error for heights inferred from deposits along south British coasts of ±2 to 3 m. It was assumed as a working hypothesis that tidal ranges in the past were the same as now, but this assumption is recognized not to be universally valid; had the tidal range been smaller, for instance, mean sea level would have been accordingly higher. Even if one ignores (as one mostly has to, for lack of evidence) the effects of compaction and drainage, changes in tidal range, presence or absence of coastal

sea level for most given periods from sites on all three coasts tend to fall within a 1.5 to 3 m vertical range (figure 1). It would appear that if there has been differential tilting in southern Britain the younger deposits have been only slightly affected, the movements apparently having been localized rather than part of an overall subsidence of the land mass, and that the rate of subsidence and the angle of tilt have been different from those previously postulated. I concur with criticisms expressed of Valentin's (1953) paper (cf. Gordon & Suthons 1963; Hafemann 1954, pp. 298–308); according to his estimates there should have been an overall subsidence of about 15 m, whereas I would accept as feasible a change of about 9 m. I also have serious

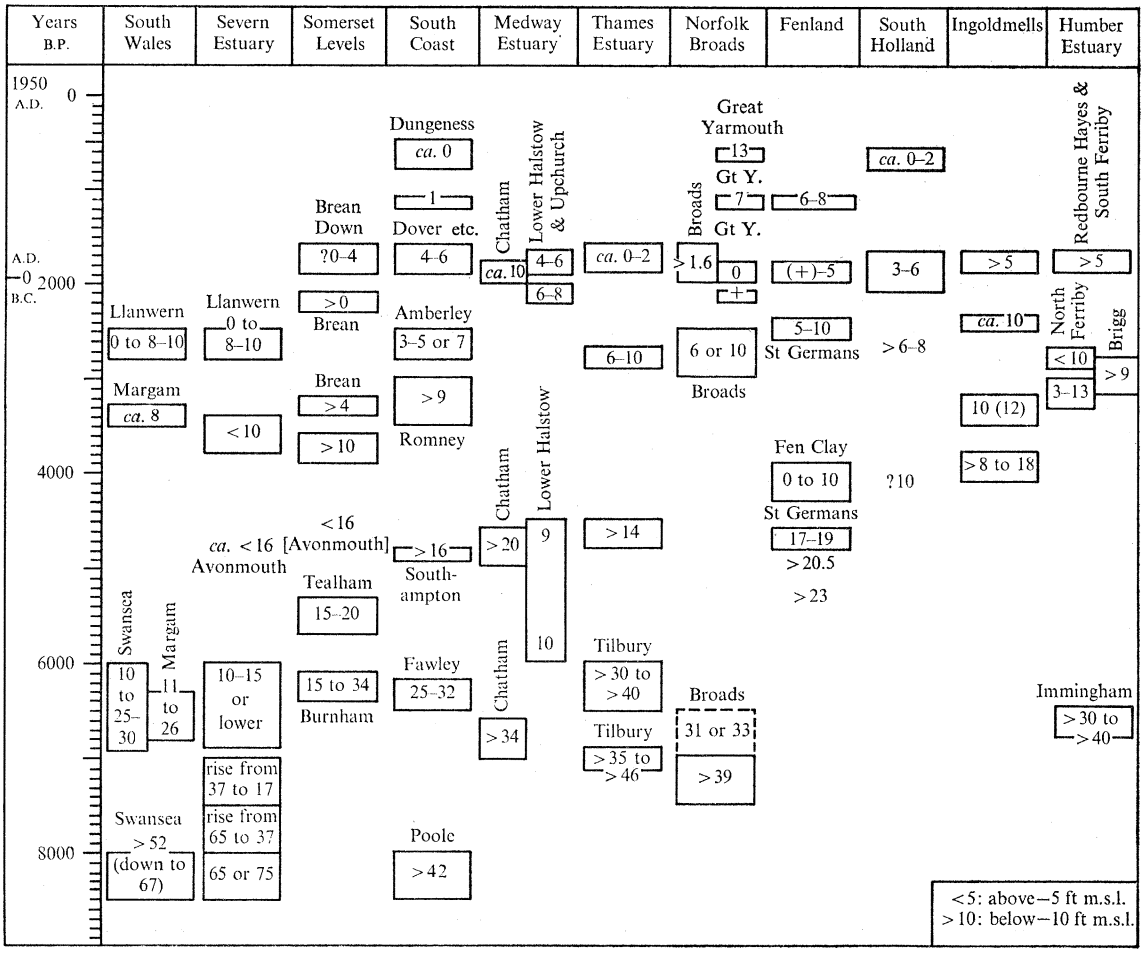

FIGURE 1. Estimates of mean sea level at different periods over the past 9000 years derived from deposits in different coastal areas in southern Britain outside the region of isostatic uplift. All numbers are feet below m.s.l. 1 ft = 0.3 m.

barriers, coastal erosion or accretion, changes in inland environments and ecology, climatic changes – to name but a few of the factors which can affect depositional levels, land and sea junctions, and the heights of relative and absolute sea level – the possible error contained in estimates of sea-level heights is considerable in proportion to the overall changes of level which have actually occurred over the past 6000 years, that is an overall rise of *ca.* 30 ft (9 m), and especially so in relation to the possible changes over the past 2000 years, which are in the order of some 5 to 8 ft (1.6 to 2.6 m). Following conventional usage mean sea level, mean tidal level and ordnance datum have been used synonymously, since it is often not possible to determine the actual datum used at a given site. This introduces yet a further degree of error, but this is likely to be relatively small in relation to the other known errors – although the cumulative effect could be quite considerable in some cases.

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reservations about Churchill's (1965) paper, primarily because of some of the basic premises upon which his thesis rests. In my estimation the relative positive rise in sea level along the southwest and east coasts over the past 6000 years has been probably at average rates of < 10 cm and < 13–16 cm per century respectively. These estimates include, for instance, the effects of compaction and subaerial erosion, of long-term tectonic movements and of isostatic readjustments of the land mass, as well as of eustasy, and therefore the rate of the real eustatic rise of sea level has been rather lower. But it must be stressed that since neither the constancy nor the uniformity of such rates can be assumed the average rate will not necessarily be valid for any given area nor for any given period.

Local transgressions and regressions occurred – I use these terms to mean horizontal advances and retreats of the sea across a land surface and do not necessarily imply a change in the vertical height of absolute sea level. There is conflicting evidence of transgressive and regressive phases between both contiguous as well as widely separated zones of the coastline, but there is a reasonable degree of correlation between transgressions in the Early Bronze Age, the Iron Age and the Roman–British periods, although the actual dates of these events vary quite widely in different areas (figure 2). Since 4000 B.C., when the rate of the eustatic rise of sea level

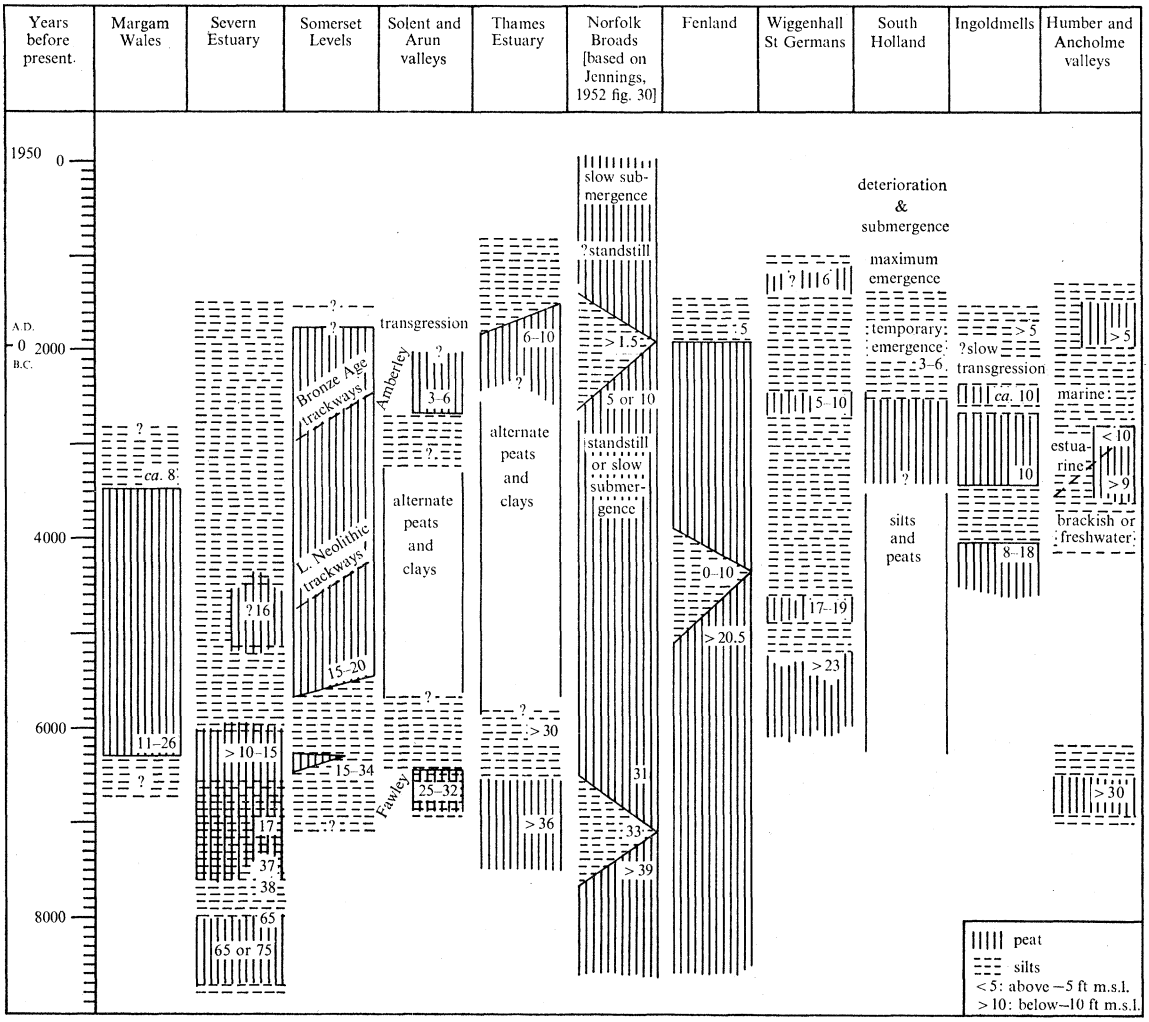

FIGURE 2. Transgressive and regressive phases in southern Britain. All numbers are feet below m.s.l. 1 ft = 0.3 m.

decreased, the occurrence of transgressions and regressions at any given site or in any given period has been controlled to a great extent by factors external to the eustatic and isostatic régimes. Variations in inland and coastal physiography and vegetation cover (produced, for instance, by changes in tidal régimes, by the frequency and height of storm surges, by alterations in the sediment supply to the off-shore zones, by the varying rates of sediment deposition or marsh and peat growth, by the height of the coastal plain, or by climatic fluctuations) may have produced local modifications in, or even apparent reversals of, the trend and effects of the rise in sea level (cf. Jelgersma 1961; Bennema 1954; Bakker 1954). During the later Holocene, but especially over the past 4 millennia, some of these contributory factors and hence their concomitant changes in the local relative juxtapositions and heights of land and sea may have been nullified, intensified or even initiated by the activities of man. I will refer only to the increase in sediment supply to off-shore zones or the effects upon inland drainage régimes which may follow changes in the inland vegetation cover caused by agricultural deforestation (cf. Jelgersma 1961, p. 48; see Pearsall (1965) *re* some anthropogenic influences upon the British environment), to changes in the levels of floodplain and coastal deposits consequent upon reclamation, protection and drainage works (cf. Bennema, Geuze, Smits & Wiggers 1954; Prus-Chacinski 1962; Jukes-Brown 1887, p. 103) and to the effects upon coastal and riverine water levels of river walls, outfall works and protective barriers (cf. Kestner 1962; Binnie 1964; Bowen 1972, this volume).

Changes in relative levels in the Thames Estuary

Changes in relative levels are apparently greater in London and the Thames Estuary than in other parts of the southeast, yet the history of the region has been subjected frequently more to speculation than to hard reason. It is not uncommon to find in both specialist and general publications examples of reasoning such as the following:

(*a*) Some Roman remains in London are now some 13 ft (4 m) below the present land level, or 2 m below high water level, or at low tide level; therefore London has subsided some 15 ft (4.5 m) (or the sea has risen some 4.5 m) since that period (even, indeed, therefore that the rest of the southeast has subsided at that rate).

(*b*) If rates of subsidence observed over the past century in the southeast are accepted at their highest value, 60 cm in 60 years, in 15 centuries all of London below the 15 m level will be submerged (see, for example, Taylor & Smalley 1969). (Since this rate relates essentially to the period during which man has wrought his most far-reaching effects upon the flood-plain, it would perhaps be equally valid – or invalid – to extrapolate this rate backwards, in which case one would expect a difference of some 19 m, not the observed 2 to 6 m, between some of the Roman levels and the present land and tidal levels.)

The general physiography of the Thames deposits has long been known (e.g. Spurrell 1889), but many of the earlier datings of these deposits were based on analogies with deposits elsewhere (e.g. Godwin 1956, pp. 67–68) or on the associated archaeological remains (e.g. Spurrell 1885, pp. 276–277, 1889, pp. 215–216) and consequently some of the attributions differed by 2000 or more years. As far as I am aware, it was not until the early 1960s that a few deposits were more closely dated by radiocarbon and pollen analyses (Churchill 1965, p. 242; Barker & MacKay 1963, p. 105; Banks 1961, p. 58). As yet there have been no interdisciplinary studies of the deposits as thorough as those carried out in East Anglia, Somerset and the Netherlands.

One of the major problems in the history of the Thames Estuary, and a source of much confusion in the archaeological and historical literature, has been the location of the tidal head in the Roman period. A number of the more fanciful speculations about the prehistoric site of London, have been satisfactorily disproved (cf. Ormsby 1924; Grimes 1956, pp. 137–138), and most modern authorities would agree with Spurrell (1889) that the alluvial plain was an area of marsh dissected by creeks, and that the tidal limit was further seaward than today, probably east of Crossness. Analyses of peats and silts (Kennard & Woodward 1908, p. 96; Kennard & Warren 1903, Ainsley *et al.* 1949, p. 39, 1953, p. 66; Shillitoe 1958, p. 24; Churchill 1965) have shown that, even in the Roman period, freshwater conditions prevailed not only at the site of London but as far downstream as Dagenham and Crossness. Much of the confusion has resulted from a circular argument, i.e. that because the Romans usually built at the heads of estuaries as they built their city at the site of London Bridge the contemporary tidal head was at or just below London Bridge (see, for example, Wheeler 1928, p. 14); but this is an untenable thesis. Even today there is still no firm agreement as to the exact location of the Roman bridge (see Merrifield 1970; Dawson 1971), nor about the extent of pre-medieval river works (for which Spurrell (1885, p. 302) could find no evidence above Gravesend) and hence of the comcomitant changes in the estuary, although many speculative conclusions have been advanced (cf. Reader 1903; Codrington 1915; Kenyon 1959). It is evident, however, that the northern bank at least was considerably altered by river works in the environs of the Roman city, e.g. around the Walbrook (Grimes 1956; Merrifield 1965).

Most of the archaeological discoveries, in particular from Roman London, which have been used to support theories of a marked change in relative tidal (or sea) levels are unsatisfactory. Many have been recorded under far from ideal conditions (cf. Merrifield 1970), and the problem has been complicated further by the considerable changes and damage caused by building and river works over the past two millennia. Merrifield (1965, pp. 32–50, 84–94, 108–117) has listed the Roman finds in the City and discussed the river environs, but it is evident from his recent plea (1970) that much material from riverine sites, especially in Southwark, has yet to be fully published. Relevant excavations of structures are few but, for example, those by Kenyon (1959) in Southwark and by Lambert (1920–1, pp. 70–72) on the north bank provide evidence of a 2 m change in high-water level since the Roman period, as well as showing that much of the rise which would have flooded some of the Roman occupation levels in Southwark had been accomplished by the medieval period. The classic site in London for estimation of past tidal levels is perhaps the Iron Age/Romano-British hut site on the foreshore at Brentford which Wheeler (1929) interpreted as evidence of a 4.5 m rise in high tide level. This is similar to the change evidenced by the Romano–British hut sites at East Tilbury (Spurrell 1885, p. 276; Royal Commission 1928, p. 38–9, 1937, p. 137). (However, recent evidence (Kent 1960) that the East Tilbury site contains Red Hill pottery suggests that these latter sites may have belonged to an intertidal salt industry and their status as habitation sites must be in some doubt). Wheeler (1928) rightly suggested (although only in a footnote) that part of the apparent change in tidal levels must be due to river and drainage works etc., but this proviso seems often to have been overlooked by later writers who have uncritically accepted and transferred elsewhere a figure for a post-Roman land subsidence of some 4.5 m. This proviso must, however, be stressed; besides the well-attested general changes in the relative land levels and tidal régime produced by man-made changes in the river and its environs the reconstruction of London Bridge in 1832 (cf. Steers 1964, p. 680) increased tidal ranges upstream by some 25 %.

There are anomalies about the London deposits, some of which may be due to inadequate recording or analysis, to differential subsidence, or to compaction resulting from natural or

Figure 3. Map of south and east Britain showing the location of sites referred to in Akeroyd (1966), some of which are also mentioned below. Those sites referred to in figure 4 are in italics on the checklist. It should be noted that there are many areas for which few or no data are available (especially in southwest and west England and Wales (not shown), although a true picture of the situation is not presented by the map since some areas, like the Fenland and the Norfolk Broads, are represented here by only a few specific sites whereas the relevant publications collate data from a number of sites.

31. Acle
13. Addlethorpe
59. Albert Docks
111. Amberley Wild Brooks
106. Angmering
3. Appleby
93. *Appledore Dowells*
116. Arundel
125. Ashlett
20. Barway
103. Beeding Bridge
94. Bodiam
105. Botolphs
47. Bradwell
104. Bramber
29. Brancaster
16. Bicker Haven
61. Brentford
2. *Brigg*
74. Burntwick Island
109. Burpham
115. Bury
33. Caistor-by-Sea
126. Calshot
81. *Canterbury*
53. *Canvey Island*
71. *Chatham*
128. Christchurch Bay
44. Clacton
122. Clausentum
66. Cliffe Marsh
97. Cliffend
55. Crossness
56. Dagenham
84. Dover
41. Dovercourt
87. *Dungeness*
101. Eastbourne
58. East Ham

64. *Ebbsfleet*
124. *Fawley*
119. Fishbourne
15. Fiskerton
114. Fittleworth
65. Gravesend
34. Great Yarmouth
8. Grimsby
113. Hardham
68. Higham Marsh
39. Hinderclay
19. Holbeach
121. *Hook, Warsash*
67. Hoo Marsh
48. Hullbridge
6. Hull
28. Hunstanton
57. Ilford
7. *Immingham Dock*
13. *Ingoldmells & Chapel Point*
40. Ipswich
21. Isleham Fen
45. *Jaywick Sands* (*Lion Point*)
112. Lickfold, Wiggenholt
60. London
73. *Lower Halstow*
88. Lydd
11. Mablethorpe
46. Mersea Island
76. *Minnis Bay*
86. New Romney
5. *North Ferriby*
110. North Stoke
117. Pagham
99. Pevensey (Anderida)
98. Pevensey Levels
63. Plumstead Marsh
107. Poling
129. Poole Harbour
120. Portsmouth
35. Postwick
52. Potton Creek
75. Reculver
1. Redbourne Hayes
91. Rhee Wall
78. Richborough
70. Rochester
85. *Romney Marsh*
27. Runcton Holme
36. Runham Vauxhall
37. Rushmere
95. Rye
10. Saltfleet
83. Sandwich
118. Selsey Bill
22. Shippea Hill
49. Shoeburyness
92. Snargate
50. Southchurch
123. *Southampton*
4. South Ferriby
62. Southwark
17. Spalding
9. Spurn Head
51. Stambridge
42. Stone Point
69. Strood
130. Studland Bay
79. Sturry
77. Thanet (Isle of)
30. Thorpe
54. *Tilbury*
72. Upchurch Marsh
14. Wainfleet
38. Walberswick
90. *Walland Marsh*
43. *Walton-on-the-Naze*
108. Warningcamp
24. Welney
127. Werrar
18. Whaplode
89. Wheelsgate
80. Whitehall
26. *Wiggenhall St Germans*
100. Willingdon
96. Winchelsea
82. *Wingham*
32. Winterton Ness
25. Wisbech
23. Wood Fen
102. Worthing

artificial factors. For example, the geological and archaeological deposits are apparently in part older and lower along the north bank, although the discrepancy is less marked in London itself where the main levels of occupation occur at similar heights on both banks. It may be noted, however, that throughout the Roman period the Walbrook showed signs of increased flooding, especially in the 2nd to 3rd centuries (Grimes 1956, pp. 137–138; Merrifield 1962), whereas Southwark, apart from areas below +3 ft (+1 m) O.D., was not affected until the late fourth century (Kenyon 1959).

In general the physiographical and archaeological data from the Thames Estuary, Canvey Island, and the Thames and Essex marshes suggest that mean sea level has risen some 35 ft (11 m) since the Neolithic period, about 5000 B.C., and some 5 to 8 ft (1.6 to 2.6 m) since the Roman period. In the Thames Estuary it was probably not above −6 ft (−1.8 m) O.D. in the Roman period – and could have been as low as −10 ft (−3 m) O.D. if the probable compaction in the deposits is disregarded. If the lowest estimate is accepted, the rate of subsidence since Roman times has been about 16 cm per century; if the higher level is taken, the rate is reduced to about 10 cm per century.

The subsidence in the Thames Estuary has been attributed to various factors – the London Basin syncline (Hafemann 1954, pp. 290 and 293), known lines of subsidence (Longfield 1932; Woodley 1960, p. 115) errors in geodetic levellings (Longfield 1932; Kelsey 1972, this volume). Some 2 ft (0.6 m) of the subsidence undergone by Roman remains in Southwark was attributed by Codrington (1915) to the effects of metropolitan drainage works. The effects of embanking and other river works upon the deposits and tidal levels have been stressed by Reid (1913) who attributed the position of Roman remains mainly to this factor, by Ormsby (1924, pp. 20–21), by

FIGURE 4. Estimates of probable and possible heights of mean sea level over the past 7000 years derived from archaeological and physiographical data from selected sites on the south and east coasts. The range in time and space depicted for each estimate shows the degree of error which may be involved in such calculations. Details of the deposits and archaeological sites from which the figures have been derived are given in the checklist; the location of the sites is shown in figure 3. [Based on Akeroyd (1966) figures 39–42.]

1. Norfolk Broads: Lower Peat (Godwin 1940, 1943, 1960; Lambert & Jennings 1960; Ellis 1965; Green & Hutchinson 1960, 1965.)
2. Tilbury: peat at −35 ft (−10.7 m) O.D. (Spurrell 1889; Godwin 1956; Churchill 1965.)
3. Norfolk Broads: during and at the end of the Lower Clay deposition. (References as 1.)
4. Immingham: peat at −30 ft (−9 m) O.D. (Godwin & Willis 1961.)
5. Tilbury: clay/peat contact at −30 ft (−9 m) O.D. (Churchill 1965.)
6. Fawley: clay at −25 ft (−7.6 m) O.D. (Churchill 1965.)
7. Tilbury: wood in peaty clay at −27 ft (−8.2 m) O.D. (Churchill 1965.)
8. Fenland: base of Lower Peat at −23 ft (−7 m) O.D. (Godwin 1940, 1943, 1961; Godwin & Willis 1959, 1960, 1961, 1962; Willis 1961.)
9. Chatham: Middle Peat at −20 ft (−6 m) O.D. (Evans 1953.)
10. Fenland: base of Lower Peat at −20 ft (−6 m) O.D. (References as 8.)
11. Wiggenhall St Germans: peat at −17 ft (−5.2 m) O.D. (Godwin & Willis 1961, 1962; Willis 1961; and as for 8.)
12. Southampton: maximum height of mean sea level in L. Mesolithic/E. Neolithic. (H. & M. Godwin 1940; Godwin 1943; Oakley 1943; Everard 1953.)
13. Canvey Island: peaty clay at −9 to −11 ft (−2.7 to −3.5 m) O.D. (Akeroyd 1966, Appendix I.)
14. Lower Halstow: peat and saltmarsh at *ca.* O.D. (Burchell 1925, 1954, 1957.)
15. Walton-on-the-Naze: pre-Neolithic marine clay. (Warren *et al.* 1936; I. Smith 1955; Zeuner 1962.)
16. Ebbsfleet: peat at *ca.* −4 ft (−1.2 m) O.D. (Barker & MacKay 1963.)
17. Romney Marsh: Forest Beds. (Reid 1913; Gilbert 1933.)
18. Fenland: surface of Fen Clay at −3 ft (−1 m) O.D. (References as 8.)
19. Ingoldmells: top of Lower Peat at −6 ft (−1.8 m) O.D. (Swinnerton 1931; Godwin 1943; Churchill 1965; Wright & Churchill 1965; A. Smith 1958*a*.)
20*a*, *b*. Essex: Lyonesse surface. (Vaughan 1958; and as for 15.)
21. Subboreal Forest Beds in general. (Reid 1913; Godwin 1956; Barker & MacKay 1959.)
22. Ingoldmells: *Phragmites* clay at *ca.* O.D. (Godwin & Willis 1964; and as for 19.)
23. North Ferriby: boat support at −3 ft (−1 m) O.D. (Wright & Churchill 1965.)
24. Wingham: muds at ? +4 ft (+1.2 m) O.D. (Godwin & Willis 1960; Greenfield *et al.* 1960.)
25. Walland Marsh: peat at +3 ft (+1 m) O.D. (Callow, Baker & Pritchard 1964.)
26. Appledore: peat at +3 ft (+1 m) O.D. (Callow *et al.* 1964.)
27. Brigg: Lower Peat at −3 to −9 ft (−1 to −2.7 m) O.D. (A. Smith 1958*a*, *b*.)
28*a*, *b*. Norfolk Broads: top of Middle Peat. (References as 1.)
29. Amberley: clay/peat contact at +5 ft (+1.6 m) O.D. (Godwin 1943; Godwin & Willis 1964.)
30. Ingoldmells: *Scrobicularia* shells at +1 and −9 ft (+0.3 and −2.7 m) O.D. (Godwin & Willis 1964; and as for 19.)
31. Ingoldmells: tree in Upper Peat at *ca.* +1 ft (+0.3 m) O.D. (Godwin & Willis 1961; and as for 19.)
32. Wingham: peat at ? +6 ft (+1.8 m) O.D. (References as 24.)
33. Wiggenhall St Germans: peat at −5 ft (−1.6 m) O.D. (References as 8 and 11.)
34. Minnis Bay: Early Iron Age village *ca.* −3 ft (−1 m) to O.D. (Worsfold 1943; Connolly 1943; Hodson 1962.)
35. Norfolk Broads: Upper Clay. (References as 1.)
36. South Holland: deposition of the Upper Clay from −7 to +7 – +10 ft (−2.1 to +2.1 – +3 m) O.D. (S. Hallam 1958–59, 1961, 1964.)
37. Dover Roman Quay, Roman villas in Sussex, Roman remains in Canterbury etc. (Amos & Wheeler 1929; Rahtz 1958; Jenkins 1951, 1954; Frere 1952; Winbolt & Goodchild 1937; Cunliffe 1965.)
38. Lower Halstow: Roman occupation level at +6 ft (+1.8 m) O.D. (References as 14.)
39. Humber estuary and Ingoldmells: peat and Roman level at +5 ft (+1.6 m) O.D. (Swinnerton 1931; A. Smith 1958*a*; Baker 1958.)
40. Lower Halstow: Iron Age occupation at +3.5 ft (+1 m) O.D. (References as 14.)
41. Canvey Island: Red Hill at +3 ft (+1 m) O.D. (R. Smith 1917; Linder 1940*a*, *b*; Helliwell 1956.)
42. Thames: Roman level at and above +3 ft (+1 m) O.D. (Spurrell 1885; Codrington 1915; Lambert 1920; Kenyon 1959; Merrifield 1965.)
43. Hook: saltern sites. (Fox 1937.)
44. Wiggenhall St Germans: peat at +4 ft (+1.2 m) O.D. (A. Smith 1958*a*; and as for 8 and 11.)
45. South Holland: mediaeval sites. (H. Hallam 1954; Kestner 1962; and as for 36.)
46. Thames & Canvey Island: mediaeval levels. (Linder 1940*a*, *b*; Helliwell 1956; Grieve 1959; Cracknell 1959; MacLeod 1965.)

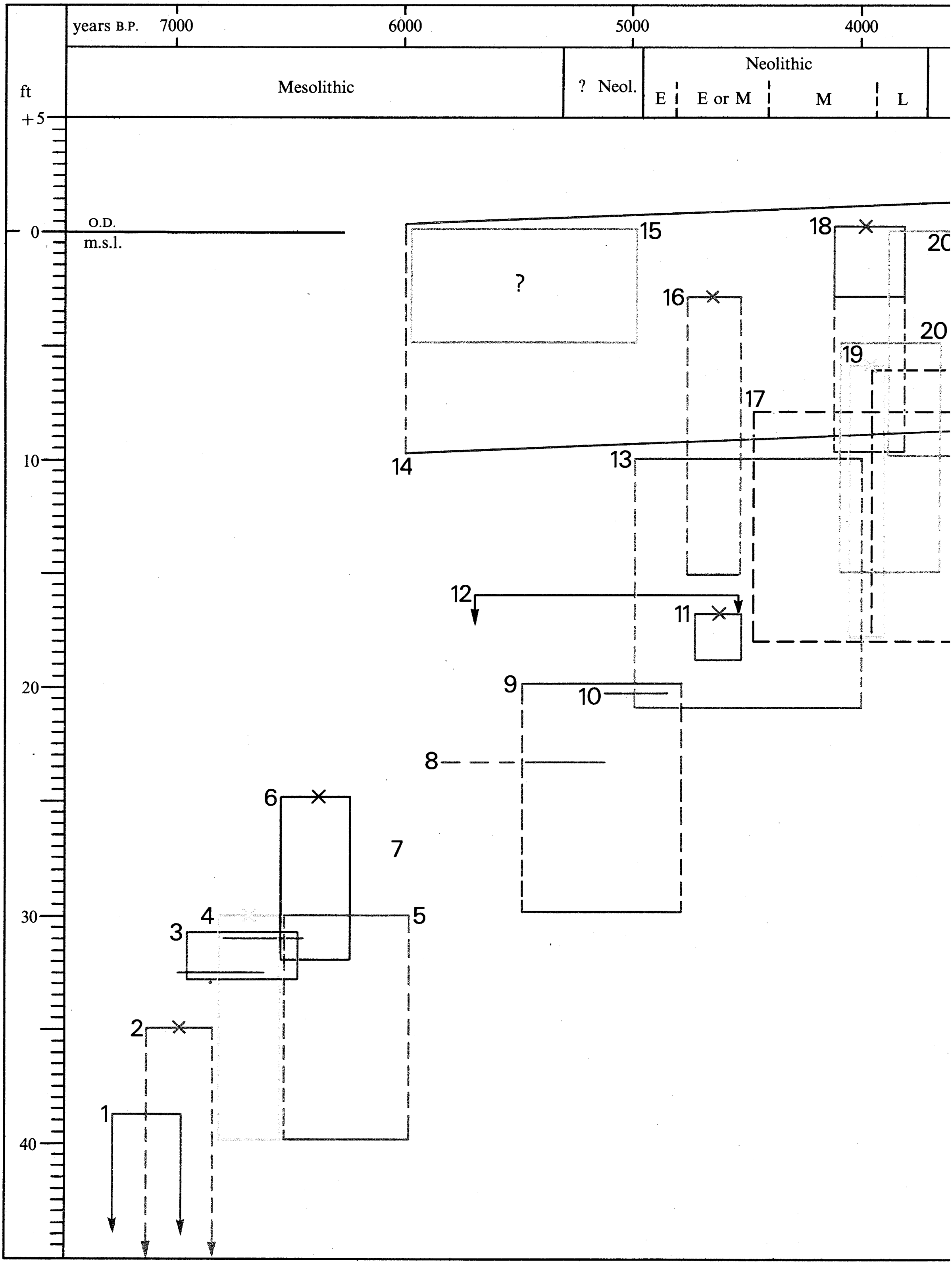

FIGURE 4. For legend se

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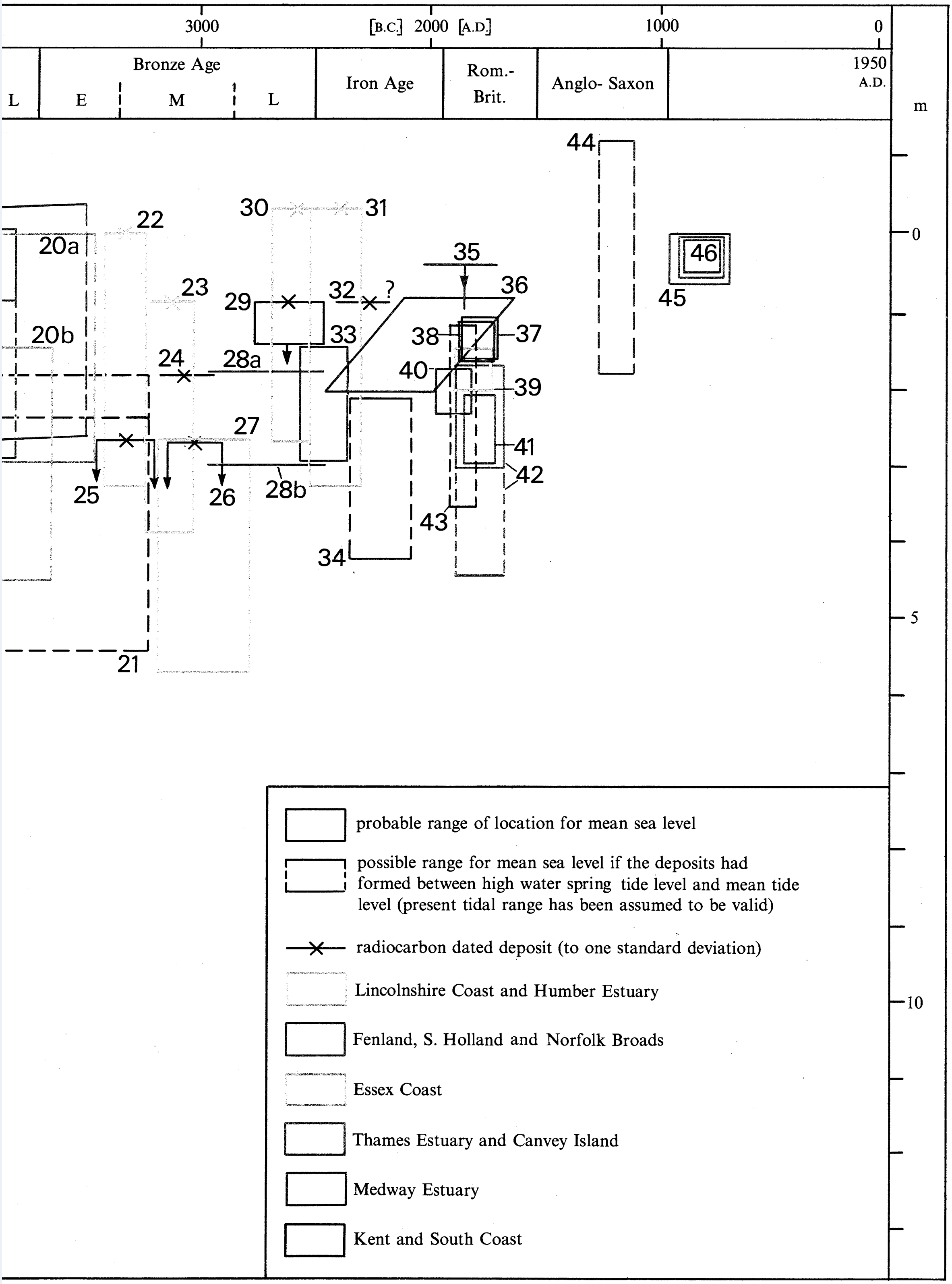

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Jones (1931) and recently by Woodley (1960, p. 115); yet in the calculation of rates of subsidence these sources of bias, as well as those resulting from coastal processes which may have affected past tidal and estuarine conditions, have often been ignored in secondary sources. It is not clear to what extent some of the high rates of subsidence observed which have been functions of the differential rates of compaction in the underlying deposits can be expected to be maintained, but there is no good reason to suppose that the apparent high rate of subsidence (about 40 cm per century; i.e. some 2 to 4 times higher than I would accept as an average for the past two millennia) which is in part based on inadequate interpretations of archaeological data is uniformly valid throughout the London Basin or in other parts of the southeast, nor that any rate measured will necessarily be valid for the future.

Mean sea level heights during the main historic periods

It must be concluded that the available data, within the known degrees of error, support the hypothesis of a relative rise in sea level with decreasing momentum throughout the later Holocene which was interrupted locally by regression phases but not by marked reversals of the positive trend; and that the occurrence of a transgression or regression in any given area or any given period was due to the combination of a variety of factors of which eustasy and isostasy are but two (figures 1, 2 and 4):

(*a*) Pre-5500 B.C.; in general mean sea level was still not above −38 ft (−11.5 m) O.D. and could have been considerably lower.

(*b*) By about 4000 B.C., the Late Mesolithic period, sea level was generally not above −25 to −30 ft (−7.6 to −9 m) O.D., although some estimates from South Wales and the Severn Estuary suggest that there it may have been as high as −10 ft (−3 m) O.D.

(*c*) By about 2500 B.C., Middle Neolithic period, sea level along the south and west coasts had reached about −16 to −10 ft (−5 to −3 m) O.D., and could perhaps have been as high as −6 ft (−1.8 m) O.D. in the west. In the Thames Estuary it seems not to have exceeded −14 ft (−4 m) O.D., and it was still lower in the Fenland.

(*d*) By about 1000 B.C., in the Late Bronze Age, it was probably still close to −10 ft (−3 m) O.D. along the east coast and at the same level or slightly higher in the west. Many of the 'Submerged Forest' beds exposed at low water were apparently submerged in this period, but some major areas like the Somerset Levels, the Fenland and the Norfolk Broads experienced a regression.

(*e*) 500 B.C. to A.D. 450; by the Iron Age the sea level in general had not exceeded −5 ft (−1.6 m) O.D. (with a few exceptions, e.g. at Amberley, Sussex). During the early Roman period it was still some 5 to 8 ft (1.6 to 2.6 m) below the present level along the south and east coasts, although there is some not conclusive evidence that the present level had been attained in parts of the southwest. The general transgression after the Late Bronze Age was in some areas divided into pre- and post-Roman phases, but by the 3rd to 4th centuries A.D. it had been widely experienced in all areas.

(*f*) Post-Roman period; the modern level was not attained in most places until the medieval period or later, since when there have been no marked changes. (The only evidence of a marked regression occurs at Great Yarmouth, but there is some disagreement about the interpretation and the conclusions are not substantiated by other evidence.) Any eustatic fluctuations which may have occurred have to a great extent been over-shadowed by variations in mean sea level caused by other factors, both natural and artificial.

Archaeological and historical evidence for subsidence: problems of interpretation

Three aspects have to be considered: (1) the interpretation of the archaeological remains; (2) the significance of the data in relation to the question of subsidence; (3) the interpretation, comprehension of and assumptions about the physiographical data and information derived from other disciplines.

Archaeological and historical material

The most suitable archaeological material is that which provides an *in situ* indication of occupation or habitation in areas of former marshland or peat bog or in areas later submerged or rendered uninhabitable by changes in tidal or ground water levels; stray finds of artefacts may be very misleading. Such sites would include midden sites, e.g. Westward Ho! (Churchill & Wymer 1965), and hut or village sites like Meare and Glastonbury villages (Dewar & Godwin 1963); brushwood trackways across peat bog or saltings like the Neolithic, Late Bronze Age and Romano-British trackways in the Ancholme valley and the Somerset Levels (e.g. A. Smith 1958*a*, *b*; Dewar & Godwin 1963); Roman villa sites like the palace at Fishbourne, Chichester, which was affected during the 2nd and 3rd centuries A.D. by rising ground water levels related to a rising sea level (Cunliffe 1965); or dock works, e.g. those of Roman Dover (Rahtz 1958, pp. 112–117; Rigold 1969) or Sea Mills on the Severn (Reade 1901, pp. 30–31; Boon 1945). Such remains, however, may furnish the archaeologist only with dates at which mean tide level could not have been above the ground level at which they stood; they usually afford no direct information about the height of the contemporary mean sea/tidal levels – except in the exceptional case of remains like dock works which have a known association with water levels – but they may provide a *terminus post quem* for any later transgression. They may provide confirmation of inferences drawn from other data; more rarely can they stand alone as direct indicators. They may indicate that a change in the relative positions and/or heights of land and sea has occurred since their construction or occupation, but the recorded changes in the position of off-shore features and of post-Roman occupation along the south coast alone show that great care is needed in the interpretation of archaeological sites and of their relationship to the contemporary sea levels.

Perhaps some of the best archaeological indicators of local interrelationships between land and sea, certainly since the Iron Age, are old saltern sites on coastal and estuarine marshes like the Red Hills of Canvey Island (see, for example, R. A. Smith 1917–18; Helliwell 1956) and the Medway marshes (Burchell 1954; Miles & Syddell 1969) and the Roman and medieval sites in Lincolnshire (Baker 1958; Rudkin & Owen 1959–60) for the associations of these sites with tidal levels is known. Yet it is these very sites which have been, and often still are, the origin of many of the erroneous calculations of past sea-level fluctuations, since they have often been erroneously interpreted as habitation sites, as cattle camps or as potteries (see, for example, Linder 1940, Evans 1949, 1953; Burchell (1954) discusses some earlier theories). It has often been assumed, therefore, that the contemporary high tide level must have been at least 5 ft (1.6 m) below the occupation levels and, hence, that mean sea level must have been much lower than that of today. It does not seem to be generally recognized that upper marshes are continuously exposed for minimum periods of at least ten days (Chapman 1960*a*, *b*) and that in summer they may be occupied for long periods without protection (cf. Jacobsen 1964, pp. 333–336). It is also possible for marsh to form at any level down to mean tide level. It has been clearly demonstrated (e.g. R. A. Smith 1917; Riehm 1961; Nenquin 1961) not only that these Iron Age, Romano-British and medieval sites were saltworks not potteries, but also that they were usually placed deliberately below high water spring tide level to obviate the need for transportation of the brine. By confusing an inter-tidal industry with settlement sites many writers have been forced further to postulate either a halt or fall in the contemporary tidal/sea levels and/or the presence of a natural or artificial coastal barrier. This is not to say that any of these situations might not have existed, but some substantiation of the assumption is necessary. Furthermore, often no allowance for the changes in relative land levels caused by compaction following land reclamation or the process of accretion and erosion has been made in calculations of heights of sea level and the conclusions reached by some recorders of these sites are misleading.

Economic and social factors

If some archaeologists and historians have been regrettably unsophisticated at times in some of their assumptions about coastal physiography – although it must be stressed that they are not alone in this – they have sometimes been equally at fault in their assessment of the reasons for the occupation or the abandonment of low-lying areas of marshland and coastal zones. It has been assumed too commonly that if marshland was embanked, or a coastal site abandoned, that this was in response to a rising sea level or a sudden change in water levels (see, for example, Thompson 1945) or to an increase in the frequency of storm surges (which is often taken to be caused by a rise in sea level). Similarly, the occupation of marshland has been thought to indicate a negative oscillation of sea level or a localized regression, although neither of these conditions is a necessary prerequisite for the pursuance of some economic activities like salt-making or sheep-herding. While geographical factors in the exploitation of marshlands were undoubtedly important, other factors were at least sometimes contributory, if not the predominant, motives behind the protection or abandonment of these areas, for these moves were at times as much a matter of economics and convenience as of necessity. Embanking on the main land Thames marshes had begun by the later 12th century (Grieve 1959, pp. 3–61); yet the shepherds on Canvey Island inhabited open saltings, and the islands were apparently not embanked and united until the 17th century. Even then, the embanking was a response not to tidal conditions but to economic factors, and was related to a change from sheep-herding to cattle-keeping (Cracknell 1959).

The artificial nature of the Norfolk Broads has been clearly demonstrated and many puzzling aspects of these features thus explained (Lambert & Jennings 1960; Green & Hutchinson 1960; C. T. Smith 1960). I will mention only the fact that, because these medieval turbaries were cut down to the lowest practical level, once they had been flooded by whatever agency – a storm surge, change in river régimes, a rise in sea level – drainage would have been impossible. Flooding ultimately made digging impracticable, even from boats; but their abandonment may have been hastened by economic and social changes as well as by the introduction of new fuels in the 14th to 15th centuries (C.T. Smith 1960, 1966).

The East Anglian fenland is an area which has been affected markedly by the activities of man and which has experienced many changes in the relative juxtapositions and heights of land and sea consequent upon drainage and reclamation works (cf. Fowler 1933, 1934; Godwin 1940, 1961; Willis 1961; Kestner 1962). It will suffice to refer to the work of Hallam (1958) which shows that the occupation of coastal areas does not depend upon their freedom from flooding. The settlement patterns of previous periods formed concentric bands about The Wash, the earliest being nearest the fen margins. Many of the Romano-British inhabitants were concerned with salt-making and therefore occupied low-lying, even inter-tidal zones, but even in the 4th century, when the deterioration of the inland drainage had forced the inhabitants to move onto the aggrading coastal silts and there had been a change to a pastoral economy, the occupation sites were situated on land subject to flooding.

The decline of the Romano-British salt industry along the Lincolnshire coast (Baker 1958–9; Nenquin 1961, pp. 76 ff.) may have been encouraged partly by economic factors. While the retreat there, as in other parts of the country, may have been at least hastened if not caused primarily by the Romano-British transgression, the development of the inland salt-mines, e.g. in Cheshire, could have been an additional incentive to abandon the coastal workings (or vice versa?).

Just as economic rather than physiographical factors may have been important influences in the occupation, exploitation and abandonment of marshlands and saltings,so may political and social factors. There is too little evidence for definitive statements to be made, indeed it is in the nature of archaeological evidence that this must be so (cf. Piggott 1965, Chap. 1), but it may be postulated that political factors might have been involved sometimes, for example in the abandonment of isolated sites. Alternatively, the occupation of relatively unfavourable ecological areas may have been favoured for political or social reasons. It is easy to rely on geographical explanations and, because the evidence is so slight, to ignore the other dimensions of man's environment – social, political, economic and cultural – when considering the motivations behind his actions in the past; but in the interpretation of the material evidence these other dimensions should also be acknowledged as potential causal or associated variables which may be independant of or complementary to the physiographical variables.

Dating of deposits and artefacts

The dating of geological and archaeological deposits may create additional problems for the assessment and interpretation of the data for subsidence. The scientific methods of dating like radiocarbon and pollen analysis contain known sources of error, but other methods such as analogizing with deposits of a type or at levels similar to the deposits under review, or dating them by their contained artefacts, may also result in considerable errors. Mistakes easily arise if it is assumed that an artefact is necessarily contemporaneous with the deposits with which it is associated (unless there is very clear evidence that this must be so), especially when the deposits have formed in peat or marshland. Artefacts may have fallen into creeks cut below the contemporary land surface; they may have been intentionally or unintentionally buried in artificial or natural hollows; they may have been moved from their original positions, for example by downward movement through a peat bed, by lateral erosion along coasts or water channels, or by the reworking of deposits. Redeposition of artefacts in some circumstances may take place at some considerable distance from their original locations. It has been suggested for example (see Steers 1964, pp. 270) that at least one exposure of the forest bed deposits of hazel twigs and nuts and red deer bones at Charmouth (Lang 1926) is probably a collection of detritus. A Mesolithic occupation site below high water mark at Werrar was covered with some 6 ft (1.8 m) of sterile estuarine clay, but the top 1 ft (0.3 m) of peaty clay which formed the modern marsh surface contained pottery sherds ranging in date from the Roman period to the 18th century, all of which had been derived by hillwash from a nearby hillock (Poole 1936, p. 562–567). A peat layer from a boring on Canvey Island which I had expected by analogy with Thames peats

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to be from the Roman period was shown by pollen analysis to have formed not earlier than the 18th century. As it lay at O.D. about 8 ft (2.6 m) below the present land surface, the level of many Roman deposits, the presumption must be that either it slipped into a marsh creek cut through earlier deposits or it formed in a channel below the level of the contemporary marsh surface. [Akeroyd 1966, Appendix I].

The dating of geological deposits by artefacts may also produce misleading conclusions, not only because the objects may not have been *in situ* but also because they may themselves have been wrongly dated. Redating frequently occurs, either because the original attribution was faulty, or because of reassessments made in the light of more recent knowledge and classification schema. The site at Southchurch, Essex (Francis 1925, 1931), where Late Bronze Age, Iron Age and Romano-British settlements were found under marsh silts around the edge of a freshwater mere, is often quoted as evidence of the Romano-British transgression (e.g. Steers 1959, pp. 317–322). It was suggested that a causeway there had been repaired in the Iron Age and it was said to have been overlain by 1st century A.D. pottery. On this evidence Francis (1932, p. 159) postulated that the creek became estuarine about A.D. 200 and that the marsh was deposited after a barrier had been constructed across the mouth of the creek in place of an eroded Pleistocene bar. The causeway, however, is now thought to be a medieval construction (Mr D. MacLeod, personal communication 1965). Another causeway found under road footings at Strood in Kent was attributed to the Roman period (Payne 1898, pp. 2–6); but it has recently been suggested that a section of what was thought to be the same causeway found under marsh silts might also be a 17th century road (Chaplin 1961). A Neolithic axe used to date deposits from Southampton Docks (Reid 1902, p. 48) and to support a post-Early Bronze Age breaching of the Purbeck land bridge was later shown to be from the Mesolithic period (Oakley 1943, pp. 56–57; Wainwright 1961, p. 134). In that case the redating was in agreement with the pollen dating of the peat bed in which it was found; but it is possible for a revision of a date or cultural attribution, which may be in the order of 500 to 2000 years or more, to conflict with datings of the geological deposits associated with archaeological remains and thus to result in an anomaly which may be incapable of resolution unless the opportunity to restudy the deposits should arise. In many cases the circumstances of the discovery may have precluded a detailed examination of the site, in others the deposits may no longer be accessible to re-exposure because of changed surroundings or, more commonly, because they may have been destroyed by man or nature. Destruction of the physical environment by excavation, for whatever end, is an unrepeatable operation; but it is an inevitable component of archaeological methodology. It may not be easy to discover whether material or deposits from any given site has been redated, even indeed whether there may be any doubt about the original interpretations of the objects or of the site itself, and conclusions about changes in relative land and sea level changes which are based on early papers may therefore in some instances rely unwittingly on inaccurate data.

Paradigm and fashion

Another source of possible error or bias in the interpretation and analysis of data is the constraints imposed by fashion, for archaeologists may be no less prone than other specialists to paradigm construction and maintenance (cf. Kuhn 1962; Barnes 1969). Rigold (1969) has recently alleged that Amos, influenced by the early 20th-century fashion for Saxon-shore forts, recorded such a 'fort' in Dover (Amos & Wheeler 1929) at a site on which it was geographically impossible for such a fort to have been built, and at a date before Saxon-shore forts could have existed, if indeed they ever did. Dover is now known to have been not a fort with an anchorage, but a proper port. Contrary to this view, however, Philp (1971, pp. 52–55) has claimed not only to have vindicated Amos by rediscovering the 'fort' (all traces of which having vanished so completely that it had been officially expunged from the record) but also to show beyond reasonable doubt that the Classis Britannica fort was largely or entirely superseded by the fourth century A.D. Saxon-shore 'fort'.

Data from other disciplines

If such errors can be made in the assessment and interpretation of sites like salterns for which there are reliable written records and contemporary information, even greater confusion may be engendered by the less readily verifiable and falsifiable evidence and hypotheses which are the basic data of archaeological reconstruction. Piggott (1965, p. 11) has stated succinctly: 'It is because of the imperfection of much of the archaeological evidence that prehistorians have necessarily to be much involved in techniques scientific or semi-scientific in character. The necessity of extracting the maximum from the fragmentary evidence at our disposal has led to a number of ingenious and elegant procedures being adopted to do no more than make the best of a bad job.' But it is in part this demand that archaeology makes for a broad understanding of principles of a wide range of diverse disciplines in the humanities, arts and sciences, which creates some of the confusion, for if some archaeologists and historians make naïve or erroneous assumptions about matters within their own fields of competence, when they venture into other specialist fields they are liable to make similar errors, based not only upon the works of other specialists which may be as subject to comparable bias or error as their own but also upon an imperfect appreciation of data from these disciplines (cf. Devons & Gluckman 1964, pp. 162–169).

A survey of the physiographical data, as well as of the nature of the errors which may arise in their interpretation, lies outside the scope of this paper but it has been documented elsewhere (Akeroyd 1966). Archaeologists and historians often have to rely heavily upon analyses of these data for evidence upon which to base or to substantiate their own conclusions but they are sometimes inclined to take too simple a view, even when first-hand specialist help is available to them, which it often is not. Rigold (1969) in a plea for less speculative work has pointed out in relation to Dover that: 'To set any Roman finds in their contemporary geographical context, it is necessary to distinguish physical features of earlier formation, elements that were unstable and sensitive to artificial modification or minor eustatic changes, which may have rendered the haven of the 14th century very different from that of the 2nd and, finally, elements of post-Roman formation.'

The geographers de Boer & Carr (1969, p. 19) in a discussion about the use of early maps as evidence for coastal changes have aptly stated: 'Because of an understandably inadequate appreciation of the physiographical aspects of coastal change there has been a great deal of confusion.'

This imperfect appreciation is in part related to the degree of comprehension of source material from other disciplines, and in part to the extent of the diffusion of that material. It is common for a few papers to become well known and hence often cited; more rarely do later papers which may fault or disprove them receive equal recognition. There is, for example, the case of *Scrobicularia plana* which has been found in a number of sites of archaeological importance (e.g. Ingoldmells: Swinnerton (1931), Godwin (1940), Godwin & Willis (1964, p. 129)). It has been widely accepted (e.g. Swinnerton 1931) that this mollusc normally lives below low water

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neap tide level, and it was on this assumption that Godwin postulated a high sea level some 2 m above the present after 700 B.C., and that Zeuner (1962, pp. 94–102) in part based his well-known interpretation of the deposits overlying the Lyonesse surface along the Essex coast. He concluded that they showed fluctuations of sea level with a stand at least as high as the present antedating the Neolithic and a high stand of +8 to +9 ft (+2.6 +2.7 m) after the Bronze Age. Recent work, however, has shown that at present far from inhabiting the areas below water level *Scrobicularia plana* is most abundant about mean tide level and on shores with sandy lower flats, e.g. Chalkwell, Essex, it may not live below that level (Freeman & Rigler 1957, p. 553). Churchill (1965, p. 239) even regards it as a saltmarsh species.

This situation has its parallels in the citation of inadequate archaeological data. To quote Piggott (1965, p. 2) again: 'It is perhaps worth reminding those who are not archaeologists that we are dealing with a discipline which is constantly and rapidly developing, which is dynamic and not static, and which continuously enforces on the research worker the necessity of keeping abreast of the new material or changed viewpoints circulating in conversation, correspondence or in publications, and of the assimilation of these within the existing framework of knowledge. This is a situation familiar enough to those who work in scientific disciplines, but is perhaps less apparent to those in other fields of learning where the tempo of discovery is slower,... a glance at the bibliography of this book will show how very few sources more than ten or fifteen years old have been included, and will emphasise the dangers in wait for the non-specialist who inadvertently uses out-of-date material'.

Conclusion

The recorders of archaeological and historical remains have failed frequently to allow for the many factors involved in the assessment of relative land and sea level changes in the past, or to appreciate fully the complex inter-relationship between man, society and the environment; their estimates of past sea level heights (and of other situational factors) must therefore reflect these omissions. Admittedly, such calculations are very complex, if indeed compensation for some of the variables can even be estimated (especially in the absence of detailed scientific studies to that end); and I must confess in my own work, for lack of evidence, to have omitted to make numerical allowance for factors like compaction. Rarely do circumstances permit this to be done adequately, if at all; there are for southern Britain too few inter-disciplinary studies of estuarine and coastal deposits as thorough as those from the Netherlands – let alone many studies which are multi-disciplinary from their inception.

What is serious, however, is that the apparent unawareness of the many variables involved which has been displayed by some archaeologists has given their statements a deceptive air of authority. It is tedious constantly to qualify conclusions, and provisos (as in the case of Wheeler's (1928) footnote) may be ignored, although they are still available in the primary sources; but failure to indicate at least an awareness of the complex nature of the problem is misleading. I will conclude with an example relating to London. Discussing a recent suggestion that the Saxons had rebuilt London Bridge some 150 yards (135 m) downstream from the old bridge, Merrifield (1970) wrote: 'A subsequent move 50 yards downstream...would be of the same order as the known moves of later times. The only surprise is that it should be downstream rather than up, but this may reflect a temporary reversal in Anglo-Saxon times of the steady rise in the tidal level.' This assumes (1) that the position of London Bridge was related more to tidal condition than to geological features or to economic, social or political factors, and (2) that any move downstream therefore meant a fall in tidal levels. Whether such assumptions are more than speculation is open to question.

I may perhaps have laboured the doubtful nature, not only of much of the archaeological and historical material evidence for subsidence, but also of many of the conclusions and inferences derived from these data; but these are points which may not be widely recognized. Much work in archaeology (and geology) is dependent upon earlier publications of material which is no longer available for reexamination and, therefore, while the criticisms and reservations expressed in this paper should not be taken to apply to all archaeological and historical publications, especially some of the more recent authoritative research, it has to be remembered that there is a considerable corpus of less reliable and/or secondary data which is often accepted by non-archaeologists and archaeologists alike. From a reading of the many papers which record such data and which often have purported to throw some light on the subject one is left with the impression of sea level all round the coast of Britain rising up and down like a yoyo – or rather like a number of unsynchronized yoyos – especially during the past three millennia. Yet the probability is that many of the transgressions and regressions, as well as many of the other apparent changes in relative land and sea levels, were related more to localized natural or man-made phenomena and situations than to dramatic fluctuations in the eustatic movements of sea level.

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The conclusions were derived from a study of the relevant physiographical and archaeological historical data from some 191 sites and areas in southern Britain from South Wales to the Humber, which were available up to early 1966. Owing to circumstances beyond my control I was unable to undertake the assessment and incorporation of much recent material into the first section, and it is possible that some modifications of my estimates might be necessitated by recent work on the physiographical evidence for subsidence.

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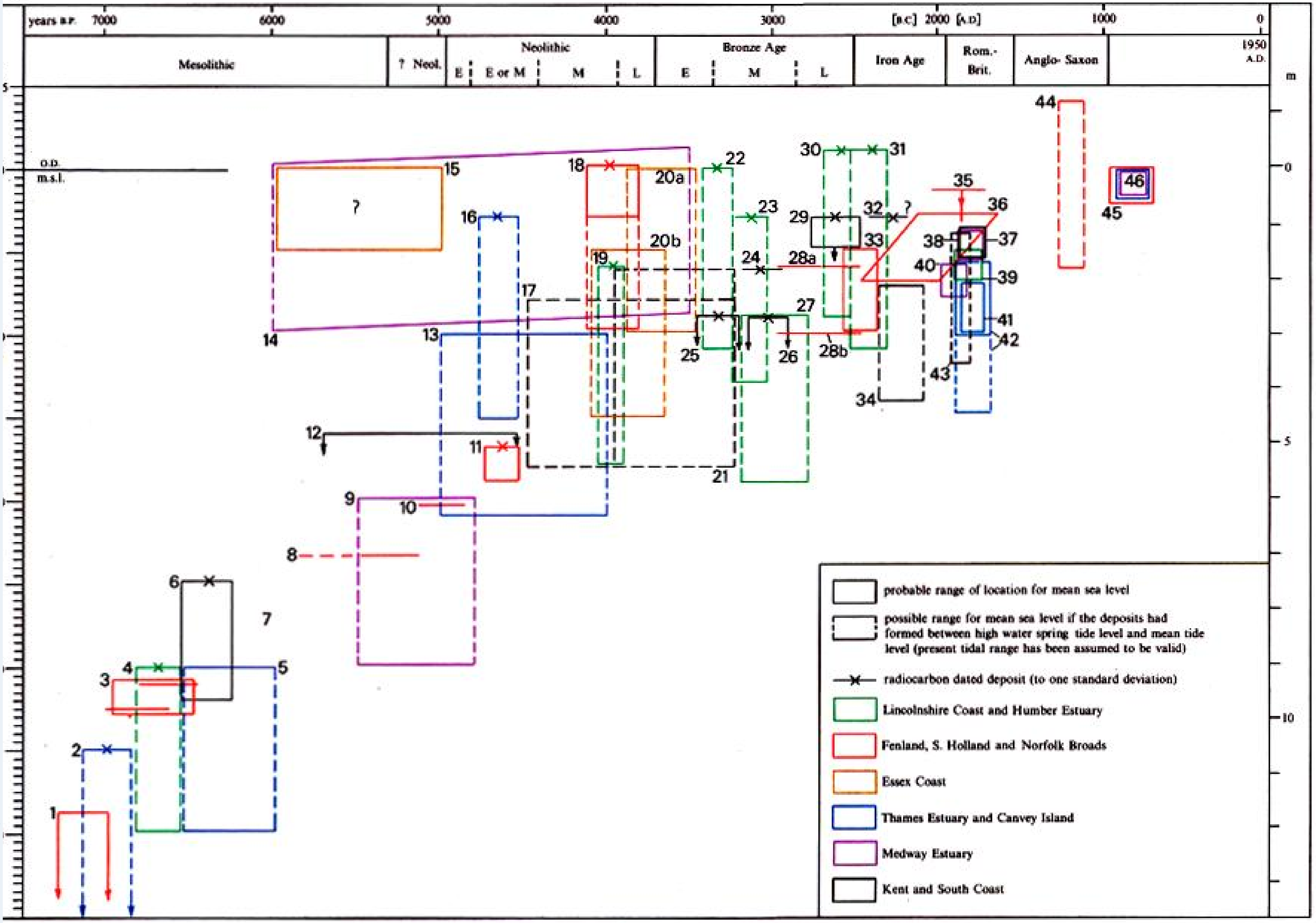

FIGURE 4. For legend see facing page.

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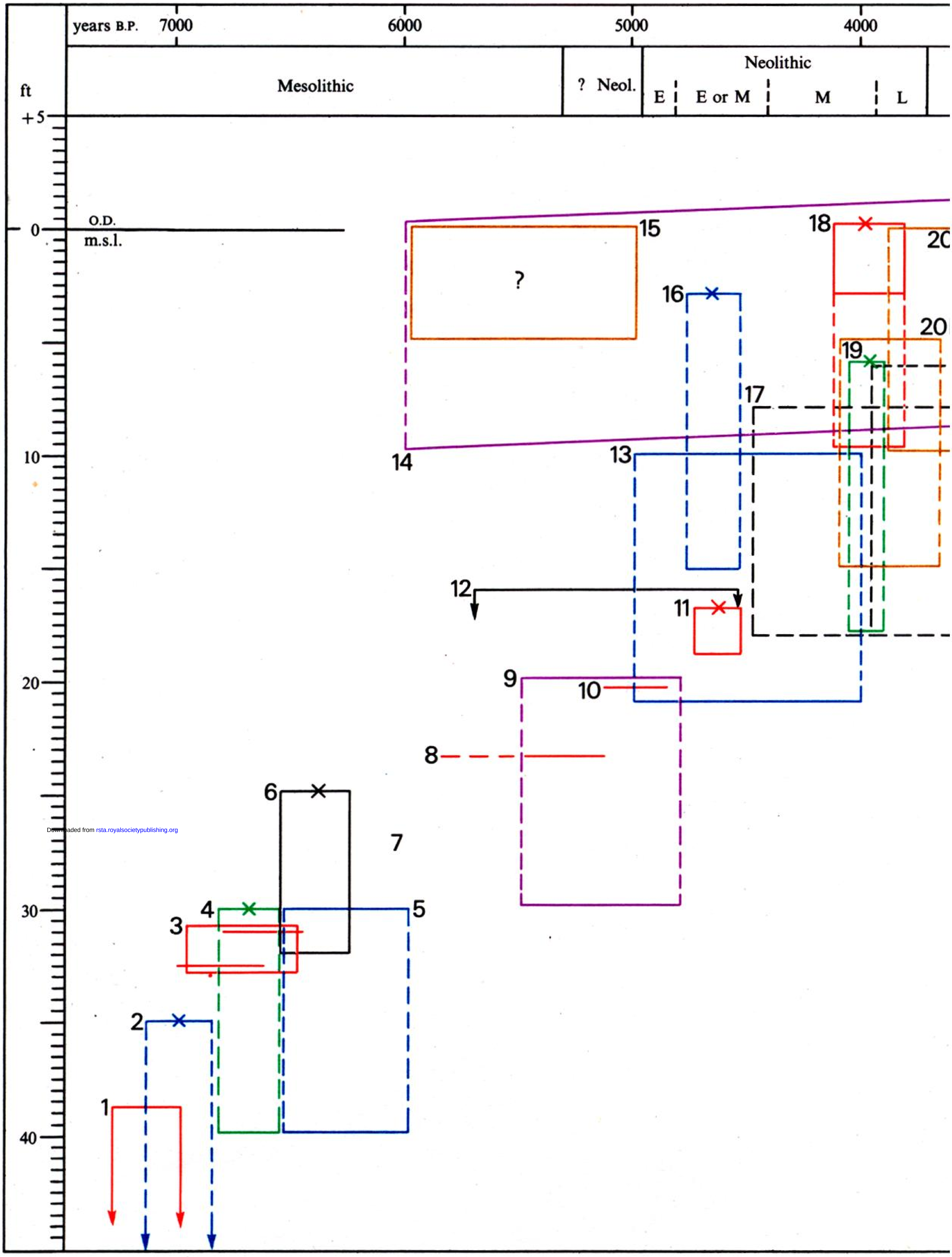

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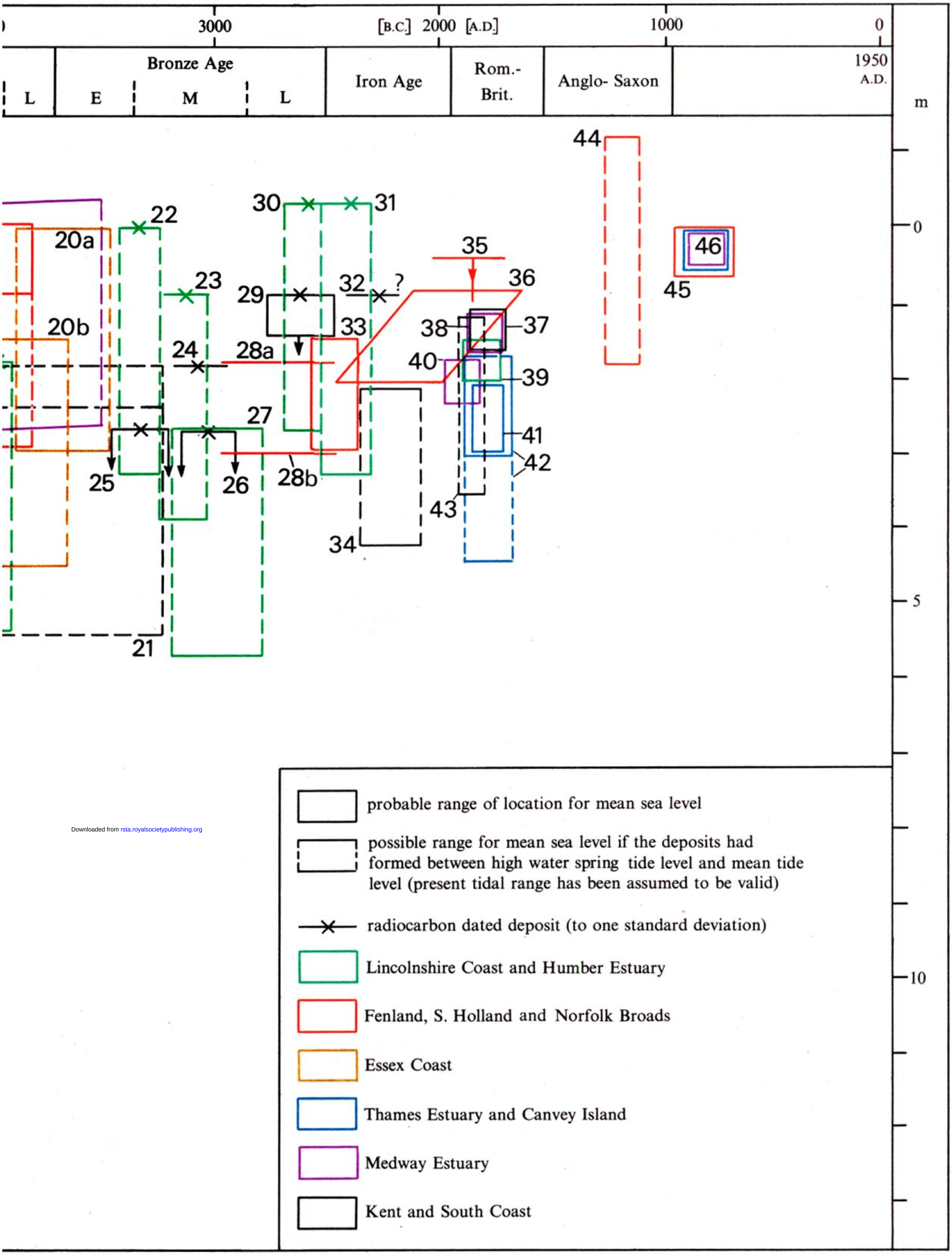

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