THE ORIGIN OF THE CLAY-WITH-FLINTS: THE MISSING LINK

R. W. GALLOIS

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The Clay-with-flints has a patchy, but extensive, outcrop in southern England south of the limit of the Anglian ice sheets, and in northern France where it is referred to as the Argiles à silex. The deposit has been presumed since early Victorian times, when it was recognised that its principal components were clay and unworn flints, to have been derived from the dissolution of large volumes of chalk. It was also recognised, however, that that the clay contents of typical chalks were too low to have produced the clay-flint ratios of much of the Clay-with-flints. The additional clay, together with sand that could not have been derived from the Chalk Group, was therefore presumed to be of later origin. The solution hypothesis remained largely undisputed until the 20th century, even though there is no published example of an intermediate stage in the process, a layer of partially dissolved chalk. The age of formation of the Clay-with-flints has long been the subject of dispute. Partly because of the absence of palaeontological evidence, and partly because the name has been applied to a wide variety of lithologies including reworked and remobilised materials. Suggested ages range from Palaeocene in parts of northern France to Pleistocene in the London Basin. In east Devon and west Dorset, beds of partially dissolved beds *in situ* Upper Greensand and Chalk tens of metres thick are overlain by Clay-with-flints. They confirm the importance of large-scale solution as a contributing factor in the formation of the deposit in SW England. The partially dissolved layers and the Clay-with-flints were folded and faulted in the Miocene, and they can be seen to pre-date Pleistocene erosional features including hanging dry valleys and frost-wedge pipes. The principal phase of dissolution is presumed to have been in warm moist climates during Palaeocene-Eocene Thermal Maximum.

92 Stoke Valley Rd., Exeter EX4 5ER, U.K.

(E-mail: gallois@geologist.co.uk*)*

INTRODUCTION

The deposition of the Chalk Group in the Anglo-Paris Basin was followed in the latest Cretaceous and earliest Tertiary by a period of folding and regional uplift related to renewed pulses in the opening of the Atlantic Ocean, North Sea and Bay of Biscay (Ziegler, 1990). The Cretaceous phase was characterised by the reactivation of narrow fault zones: in contrast, the Palaeocene movements involved plate-wide, domal uplift with little faulting (Hansen and Clausen, 2005). In south-west England, a continuous sheet of Chalk Group sediments up to c. 500 m thick was reduced by a combination of fluvial erosion and dissolution to a few outliers in east Devon in which up to 75 m of Chalk is preserved. The youngest Chalk preserved onshore in the region is of early Coniacian (*Micraster coranguinum* Zone) age (Woods, 2002), but the former presence of chalks as young as Campanian (*Belemnitella mucronta* Zone) age is indicated by the presence of well preserved echinoids and belemnites in flints in the residual drift deposits that cap the Haldon Hills (Wood in Selwood *et al.*, 1984). Some of the most complete Chalk successions in the UK, up to 1200 m thick, have been recorded in boreholes in the Celtic Sea where chalks as young as Maastrichtian in age are preserved (Tappin *et al.*, 1994).

The sedimentology of the Turonian and younger chalks exposed in east Devon and west Dorset suggests that they were deposited in moderately deep (50 to 100 m depth) water on a stable marine shelf that occupied the of SW England. It is probable, therefore, that a complete Chalk succession was originally present, although thinner than that preserved in the Celtic Sea Basin. In the Hampshire Basin, where a Chalk succession up to 500 m thick is preserved, Senonian and Campanian chalks are overlain by fluviatile and brackish-marine Palaeocene and Eocene sediments. There is no proven correlative of these Tertiary deposits in SW England, but the local presence of laminated, stoneless clays, quartz sands and well rounded quartzitic pebbles within the Clay-with-flints, suggest that a widespread veneer of Tertiary deposits was formerly present. Woodward (1902) recorded sands and stony clays with chert, flint and quartz pebbles at Combpyne [302 922] that Woodward and Ussher (1911) correlated with the Eocene 'Bagshot Series' of Dorset.

The deposits shown as *Clay-with-flints* on geological maps of southern England and as *Argiles à silex* on those of northern France include a wide range of lithologies. Their distribution and stratigraphical relationships to the underlying rocks show that they were not all formed by the same process (or processes) and that they are not all of the same age. In SW England, the Clay-with-flints shown on the most recent geological maps can be divided into two types which are here described as Clay-with-flints *sensu stricto (s.s.)* and Clay-with-flints *sensu lato (s.l.)*. The first of these locally rests on thick beds of partially decalcified Upper Greensand and/or Chalk, the missing link in the process by which these Cretaceous deposits give rise to the Clay-with-flints *s.s*.

CLAY-WITH-FLINTS *SENSU STRICTO* AND CLAY-WITH-FLINTS *SENSU LATO*

The name Clay-with-flints was proposed by Whitaker (in Hull & Whitaker, 1861) to describe a red-brown clay with large unworn flints that rests with an irregular contact on the Chalk of the Chiltern Hills. The name was subsequently applied to a lithologically wide range of laterally and vertically variable deposits throughout southern England, only a few of which are predominantly composed of red clay and flint. These deposits have, nevertheless, been generally thought to have a common origin. The 'formation' rests with marked unconformity on the Chalk and/or Tertiary deposits. Its French correlative, the Argile à silex has been applied to an even wider range of materials in northern and central France that includes deposits locally described as *Formations résiduelles à silex* and slope deposits (*Biefs à silex*). These rest on rocks that range in age from Jurassic to Tertiary, and include Jurassic cherts and sandstones that are not represented in the Clay-with-flints.

In an attempt to separate out Whitaker's original Clay-with-flints in the Chiltern Hills from what had become a wide range of deposits of probable different origins and ages, Loveday (1962) proposed a Clay-with-flints *s.s*. He defined this as a yellowish red or red-brown clay with up to 50% of flints, a few flint and quartzitic pebbles, and small amounts of sand, that rests in the plateau areas on an irregular, solution affected chalk surface. Many of the flints in the lower, part of the deposit are unworn or only partially abraded: those in the upper part are commonly broken and eroded. Deposits that contained significant amounts of silt, sand and/or non-flint clasts were excluded. At many localities that he described, the Clay-with-flints *s.s.* was overlain by laterally variable mixtures of grey, brown and yellow clays, sand, silt, broken flints, and pebbles of flint and other lithologies including Triassic and Jurassic rocks that he classified as Plateau Deposits.

Lithology and thickness in SW England	**Origin**	**Classification, age**
Red-brown clay with unabraded flints, minor sand content and a few well-rounded quartzitic and other pebbles; rare traces of lamination; where not affected by later solution rests with marked unconformity on a planar erosion surface cut in Upper Greensand or Chalk. Mostly up to 2 m where undisturbed.	Remanié deposit derived largely from the dissolution of chalk; sand and pebble content derived from veneer of Tertiary deposits; locally chert- and sand-rich where partially derived from the Upper Greensand	Clay-with-flints *sensu stricto* Late Palaeocene to early Eocene
Complex, laterally and vertically highly variable mixtures of red-brown stony clay (as above) with the addition of broken, abraded and stained flints, sand and gravel, and yellow and brown clays; confined to plateau areas where it rests on an irregular, solution-affected chalk surface; where preserved, sedimentary structures almost all relate to secondary cryoturbation and solution collapse. Mostly <5 m, but up to 30 m in solution pockets.	Weathered *in situ* Clay-with-flints *sensu stricto* with the addition of younger (mostly Pleistocene) sand and gravel	Clay-with-flints *sensu lato* Palaeocene to Pleistocene
Clay-with-flints *sensu lato* with or without the addition of other locally derived materials; commonly crudely bedded with lenses of re-sorted sand and/or gravel; in SW England outcrops extend up to 1 km downhill from the break in slope that marks the Tertiary planation surface. Mostly up to 5 m at upper edge, locally up to 10 m in hollows.	Solifluction deposit	Head Deposits that should not be classified as Clay-with-flints Pleistocene with minor local Holocene modification
Heterogeneous mixtures of clay, sand, gravel, Jurassic chert and other insoluble materials derived from various non-Chalk sources that rest on Permo-Triassic to Quaternary rocks. Absent in SW England.	Solifluction deposits	Mostly Pleistocene Head Deposits that should not be classified as Clay-with-flints

Table 1. *Subdivision on the basis of origin of formation of the deposits described on geological maps as Clay-with-flints (UK) and Argiles á silex (France). See text for details.*

In France, Dewolf (1970) stressed the need to differentiate between those parts of the Argiles à silex that were of pedogenic origin and those that were detrital, and Laignel *et al*. (1998) described the Argiles à silex that crops out on valley sides (Biefs à silex of authors) as a Pleistocene solifluction deposit (a Head deposit in the UK terminology).

The term Clay-with-flints *s.s.* is used in the present account in a similar, but more restricted sense than that of Loveday (1962). It comprises red and red-brown clays (presumed terra rossa soils) with unweathered flints that have retained their original, commonly complex, shape and patina, and small amounts (mostly < 2% in SW England) of sand, and a few flint and quartzitic pebbles. Where undisturbed by later solution effects, the Clay-with-flints *s.s* rests on an early Tertiary planation surface. The wide variety of other deposits referred to as Clay-with-flints on geological maps are classified here as Clay-with-flints *s.l.* or Head Deposits (Table 1). Deposits that contain abraded or water-worn flints and/or other clasts; yellow, brown or grey clays; significant quantities (> 2-3%) of sand or pebbles, and which do not rest on an early Tertiary planation cut in the Chalk (on Upper Greensand in SW England) are, by definition, not Clay-with-flints *s.s.* Those parts of Loveday's (1962) Clay-with-flints *s.s* that contain broken and stained flints and those that crop out on the upper valley sides (on 2° to 7° slopes) are excluded from the definition used here. The outcrops of the deposits shown as Clay-with-flints on geological maps of SW England (*Clay with Flints and Cherts* on older maps) are classified here as Clay-with-flints *s.l.* In inland areas they were extensively remobilised in the periglacial climates of the Pleistocene with the result that there are no recorded inland outcrops of the Clay-with-flints *s.s.* Even in the extensive cliff sections in east Devon *in situ* exposures of Clay-with-flints *s.s.* rare due to later solution effects. In SE England, the bulk of the deposits shown on the geological maps of the Chiltern Hills (Sumbler, 1996) and North Downs (Ellison, 2004) that consist of stony clays, sands and gravels, are classified here as Clay-with-flints *s.l.*

CLAY-WITH-FLINTS IN SW ENGLAND

The Clay-with-flints caps a highly dissected plateau that that forms the high ground in east Devon, west Dorset and south Somerset (Figure 1). It everywhere rests on Cretaceous rocks with marked unconformity, locally on the Chalk in south east Devon, and on the Upper Greensand in the rest of the region. Around the edges of the plateau, the base of the deposit is marked by a prominent change in slope (Figure 2) that marks the outcrop of the Tertiary planation surface that removed much of the Chalk from the region. The top of the Clay-with-flints *s.l.* gives rise to a gently undulating surface that forms the highest ground in the region. The formation is poorly exposed the away from the coastal cliffs. Temporary sections inland mostly show 1 to 5 m of heterogeneous brown and red clays, sandy clays and sands with abundant broken and stained clasts of flint and/or chert ranging from granules to boulders. Flint clasts predominate in those areas where the Clay-with-flints rests on the Chalk, but are less common and more stained and abraded where it rests on the Upper Greensand. The formation is well exposed in the cliffs between Sidmouth and Lyme Regis, where the lower boundary is commonly disturbed by karstic and/or periglacial processes. Pockets and lenses of Clay-with-flints *s.s.* up to 2 m thick are locally present. In those areas where the Clay-with-flints *s.s.* rests on the Upper Greensand it overlies sand with blocks of unabraded angular chert, a remanié deposit derived from the *in situ* dissolution of calcarenites in the upper part of the Upper Greensand (Gallois, 2004).

PARTIAL DISSOLUTION LAYERS IN THE CHALK IN SW ENGLAND

Karstic features are common in the Chalk of the Anglo-Paris Basin, especially in northern France and in the unglaciated areas of England south of the River Thames (Sperling *et al*., 1977). Solution pipes and solution-widened fractures occur down to depths of 100 m or more in the chalk cliffs of the Channel coast (Mortimore *et al*., 1989), to the levels of former (mostly Pleistocene) water tables. In addition, in east Devon and west Dorset beds of partially dissolved, *in situ* Chalk up to 30 m thick are present at two stratigraphically well-defined levels, in the Holywell Nodular Chalk and Lewes Nodular Chalk Formations (Figure 3). Both formations are comprised of highly bioturbated chalks in which 3-dimensional networks of mineralised burrowfills are set a less lithified chalk matrix that is more susceptible to solution than the burrowfills (Gallois, 2005). The adjacent, more planar bedded, New Pit Chalk and Seaton Chalk Formations contain thin beds (mostly 5 to 10 mm thick) of argillaceous chalk that have acted as aquitards and prevented large-scale partial dissolution of these formations. There are few records of what might be the equivalent of the partially decalcified layers elsewhere in England. Whitaker (1862) described c. 6 m thick bed of “reconstructed chalk” (rubbly and blocky chalk with irregular lines of flint) overlain by Eocene Reading Formation in a quarry near Reading, and surmised that the 'reconstruction' must have occurred prior to the deposition of the Reading Formation.

The partially decalcified chalks in east Devon are interpreted here as an intermediate stage in the formation of the Clay-with-flints. Their age of formation cannot be directly demonstrated but, they occur as discrete beds within a Chalk succession that was planed off by the Palaeocene erosion surface on which the Clay-with-flints *s.s.* rests. Ussher (in Woodward and Ussher, 1911) showed that the Clay-with-flints in SW England had been affected by faulting and gentle folding (Figure 4), and concluded that the deposit was likely to be largely Eocene in age. His well-documented field observations were ignored by most subsequent British authors who concluded that the Clay-with-flints was a Pleistocene deposit. Recent geological surveys in SW England have confirmed Ussher's mapping and have proved displacements of up to 60m in the sub-Tertiary planation surface (Figure 5). The latest phase of tectonic activity of this magnitude in southern Britain has been dated as early Miocene (Anderton, 2000). The deformation is well displayed in the cliffs at Beer where the partially decalcified Lewes Nodular Chalk and the Clay-with-flints are involved in a fold that is cut by Quaternary erosion features, hanging dry valleys and deep frost-wedge pipes (Figure 6).

Partially dissolved *in-situ* chalks with relict bedding and jointing similar to that exposed in east Devon occur on the Chalk outcrop throughout England. However, none of those described to date occur in stratigraphically defined beds, but are confined to valley floors where they formed by differential solution along more fractured zones during the Pleistocene (Gallois, 2005).

ORIGIN AND AGE OF FORMATION OF THE CLAY-WITH-FLINTS

Whitaker (in Hull and Whitaker, 1861) concluded that the insoluble clay and flint residues produced by dissolving large volumes of Chalk were a major component of the Clay-with-flints. In contrast, Jukes-Browne (1906) thought that the deposit had been almost entirely derived from Eocene clay, with the addition of flints from the Chalk, and that comparatively little Chalk had been removed by solution. Subsequent research has resulted in numerous descriptions of the lithological, stratigraphical and geomorphological characteristics of the Clay-with-flints, region by region, and of its origin, age, and modification by cryoturbation and solifluction in the Pleistocene.

In a comparison of research carried out on the Clay-with-Flints and the Argiles à Silex, Pepper (1974) concluded that whereas most British authors had regarded the Clay-with-flints as a Pleistocene deposit, most French authors had concluded that the Argile à Silex was an early Tertiary deposit. There are published descriptions of Argile à Silex that rests on Chalk and is overlain by palaeontologically datable sediments that range in age from Palaeocene to Eocene, but the interpretation of the lithological and stratigraphical relationships preserved in many of these sections has been questioned (e.g. see Pepper, 1974). As with the Clay-with-flints in England, many of the differences of interpretation arise from the inclusion of a wide range of deposits of dissimilar origin and age in the Argiles à Silex. This was recognised at an early stage by De Mercey (1879) who recommended that the name should be restricted to flint-rich clays that could be shown from their stratigraphically relationships to be of early Tertiary age. This definition is similar to that of the Clay-with-flints *s.s.* of Loveday (1962) and the present work. More recent examples of well-documented occurrences of Clay-with-flints *s.s.* of proven early Tertiary age include a flint-rich terra rossa in Northern Ireland that rests on the Chalk and is overlain by basalts that have been radiometrically dated as Palaeocene (Smith and McAllister, 1995), and a similar deposit in the Paris Basin that is overlain by silcretes that formed before the late Eocene (Thiry and Simon-coinon, 1996).

In east Devon, Isaac (1981) described a succession of Tertiary weathering and depositional events that produced lateritic soils, silcretes and fluvial gravels. The state of the exposures at the time of the present survey was such that none of these events could be confirmed. The railway cutting at Combyne [SY 300 923] that exposed the type section of the Palaeocene Combyne Soil was backfilled in the 1980s; that of the Seven Stones Soil [SY 1055 8789] at Mutters Moor, Sidmouth could not be located; and blocks of Tertiary silcrete (sarsens) are relatively common on the Clay-with-flints, but none were seen *in situ*. The type section [SY 109 867] of the Peak Hill Gravel at Peak Hill Cliff near Sidmouth is still well exposed. The 'gravel' comprises a heterogeneous mixture of clay, sand, flints and cherts that is typical of the Clay-with-flints *s.l.* of the region.

The question of whether or not solution of the Chalk could produce the Clay-with-flints depends on which definition of Clay-with-flints is used. In SW England, where the siliciclastic-rich Glauconitic Marl and Chalk Marl facies of the Lower Chalk are absent, the insoluble residues derived from dissolving bulk samples of chalk mostly comprise 0.5 to 2 wt.% of clay minerals, and < 0.1 wt.% of silt and sand (e.g. Weir and Catt, 1965) and up to 40 vol.% of flint. Estimates of the volumes of insoluble residues that would be produced by the dissolution of the Chalk formations that crop out in the region, and that from formations that were formerly present, are shown in Table 2. In those parts of SW England where the Clay-with-flints *s.s.* rests on the Upper Greensand, the dissolution of the Holywell Nodular Chalk and New Pit Chalk would be sufficient to explain the thickness of the preserved Clay-with-flints. In those areas on the Chalk outcrop where the Clay-with-flints *s.s.* rests on the Lewes Nodular Chalk and/or Seaford Chalk, the upper part of the Seaford Chalk and part of the Newhaven Chalk would need to be dissolved. Estimates of the volume of Chalk that would be required to produce the equivalent of Clay-with-flints *s.l.* have come to similar conclusions. Laignel *et al*. (1999) calculated that the preserved thicknesses of Argiles à Silex deposits in the Paris Basin that range in age from Eocene to Pleistocene would have required the *in situ* subaerial weathering of 20 to 200m of Turonian to Maastrichtian chalks.

In a few sections, the lithological succession in the Clay-with-flints *s.s.* reflects the stratigraphy of the nearest preserved Chalk. For example, at Black Ven, Charmouth [SY 5059 5620], red clay with distinctively shaped horn and spiky flints that are characteristic of the upper part of the local New Pit Chalk overlies almost flint-free red clay that was probably derived from the solution of the almost-flint-free lower New Pit Chalk and flint-free Holywell Nodular Chalk. Similar sections have been recorded in France where Quesnel *et al*. (2003) examined the microfaunas in chalks preserved in holes in flints in the Argiles à Silex and found that at some localities the flints retained the stratigraphy of the underlying Chalk.

In SW England, the Clay-with-flints *s.l.*, as defined here, contains large volumes of sand and abraded flints that could not have been obtained from the dissolution of the Chalk. These additional materials are presumed to have been derived from extensive former outcrops of Upper Greensand and Chalk during post-Miocene times. Extensive further dissolution of the Chalk in the Pleistocene, mostly in periglacial climates, produced grey clays that became oxidised yellows and browns, and loose cherts and flints that were broken *in situ* by freeze-thaw processes. These materials were extensively redistributed by meltwaters and solifluction processes. In the extensive exposures in East Devon cliffs the Clay-with-flints *s.l.* up to 25 metres thick is preserved in solution pockets in which little (mostly < 1vol.%) or no Clay-with-flints *s.s.* is preserved.

Formation	Average thickness in SW England	Estimated average insoluble content	Potential thickness contribution to the Clay-with-flints *s.s.*
Culver Chalk*	90 m	10 vol.%	9.0 m
Newhaven Chalk*	60 m	10 vol.%	6.0 m
Seaford Chalk*	70 m	10 vol.%	7.0 m
Lewes Nodular Chalk	40 m	10 vol.%	4.0 m
New Pit Chalk	25 m	7 vol.%	1.8 m
Holywell Nodular Chalk	15 m	2 vol.%	0.3 m
Beer Head Limestone	0.6 m	2 vol.%	negligible

* not wholly preserved in SW England; nearest Hampshire Basin thickness based on Mortimore *et al*. (2001)

***Table 2**. Estimated thicknesses of the Clay-with-flints layers that would be produced by the dissolution of the Chalk formations exposed and presumed to have been formerly exposed in SW England.*

In SW England, the Clay-with-flints *s.l.*, as defined here, contains large volumes of sand and abraded flints that could not have been obtained from the dissolution of the Chalk. These additional materials are presumed to have been derived from extensive former outcrops of Upper Greensand and Chalk during post-Miocene times. Extensive further dissolution of the Chalk in the Pleistocene, mostly in periglacial climates, produced grey clays that became oxidised yellows and browns, and loose cherts and flints that were broken *in situ* by freeze-thaw processes. These materials were extensively redistributed by meltwaters and solifluction processes. In the extensive exposures in East Devon cliffs the Clay-with-flints *s.l.* up to 25 metres thick is preserved in solution pockets in which little (mostly < 1vol.%) or no Clay-with-flints *s.s.* is preserved.

SUMMARY AND CONCLUSIONS

A wide range of heterogeneous deposits composed of laterally and vertically variable mixtures of clay, sand and gravel with flint and other clasts have been mapped as Clay-with-flints in southern England and as Argiles à Silex in northern France. Most outcrops rest with an irregular, solution-affected contact on the Chalk Group, and they commonly cap high ground. This group of loosely defined deposits can be divided into three broad types on the basis of their composition, stratigraphical relationships and geomorphological setting: a *sensu stricto* form, a *sensu lato* form, and a remobilised form that should be classified as a Head deposit. The presumed stages of formation of Clay-with-flints *s.s.* and *s.l.* are summarised in Figures 7 and 8.

The Clay-with-flints/Argiles à Silex *sensu stricto* comprise red clays of presumed terra rossa origin that contain unabraded flints and small (mostly < 2%) amounts of sand and gravel. In SW England, the Clay-with-flints *s.s.* rests on a Palaeocene fluvial planation surface and is locally underlain by stratigraphically constrained beds of partially dissolved Chalk up to 30 m thick. These beds are interpreted here as an intermediate stage, a previously undescribed missing link, in the formation of the Clay-with-flints *s.s.* Similar beds were probably formerly present over much of southern England, but were removed by erosion during the Tertiary and Quaternary. Similarly, the Palaeocene erosion surface that is such a prominent feature in SW England was largely removed by later Tertiary transgressions and/or erosion following Miocene folding in the Hampshire Basin and post-Miocene uplift in SE England.

Whitaker (in Hull and Whitaker, 1851) concluded that the Clay-with-flints of the Chiltern Hills was formed *in situ* from the insoluble residue obtained from the dissolution of large quantities of Chalk. However, this was disputed when the deposits that came to be classified as Clay-with-flints and Argiles à Silex on geological maps (the *sensu lato* form of this account) were shown to contain materials that could not have been derived from the Chalk simply by solution or not from the Chalk at all. These include water-worn flints and other stones, and large amounts of clay, sand and gravel. The formation of what is now the Clay-with-flints *s.l.* may have been initiated on a Palaeocene erosion surface as a solution residue, but most of the original deposit has been lost by erosion or has been incorporated in more complex mixtures by the addition of materials from ongoing solution of the Chalk, and the erosion and reworking of Tertiary and Quaternary deposits. In many regions, remobilisation in periglacial climates during the Pleistocene resulted in extensive Head deposits derived from the Clay-with-flints.

There is no direct evidence for the age of the Clay-with-flints *s.s.* in SW England, but the erosion surface and the partially dissolved beds were folded and faulted during the Miocene. Elsewhere in the Anglo-Paris Basin there are published descriptions of lithologically similar deposits that rest on Chalk and are overlain by datable Palaeocene or Eocene deposits. In France, this led Tricart (1956) to conclude that some of the Argile à Silex formed during warm humid climates in the Paleocene and early Eocene during the time that has come to be known as the Paleocene-Eocene Thermal Maximum (PETM).

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FIGURES

Figure 1. *(a) sketch map of the Clay-with-flints outcrop in east Devon, west Dorset and south Somerset showing the positions of locations referred to in the text. (b) Digital Terrain Model (DTM) of the same area showing the deeply dissected nature of the Clay-with-flints outcrop. DTM prepared by Michael Hall, British Geological Survey, using NEXTMap Britain elevation data from Intermap Technologies. Copyright BGS.*

Figure 2*. The dissected East Devon Plateau showing the prominent feature break that marks the position of the former Palaeocene planation surface. Oblique aerial view NW from near Weston Mouth, Devon. In the foreground, the planation surface in Weston Cliff has been largely removed by dissolution of the Cretaceous rocks, probably during the Pleistocene, and has left pillars of intact Chalk surrounded by collapsed clays, sands and gravels (Clay-with-flints s.l.). Photograph Paul Whitney, British Geological Survey (BGS), copyright BGS.*

Figure 3*. Generalised vertical section for the Chalk Group of east Devon showing the principal partial dissolution layers.*

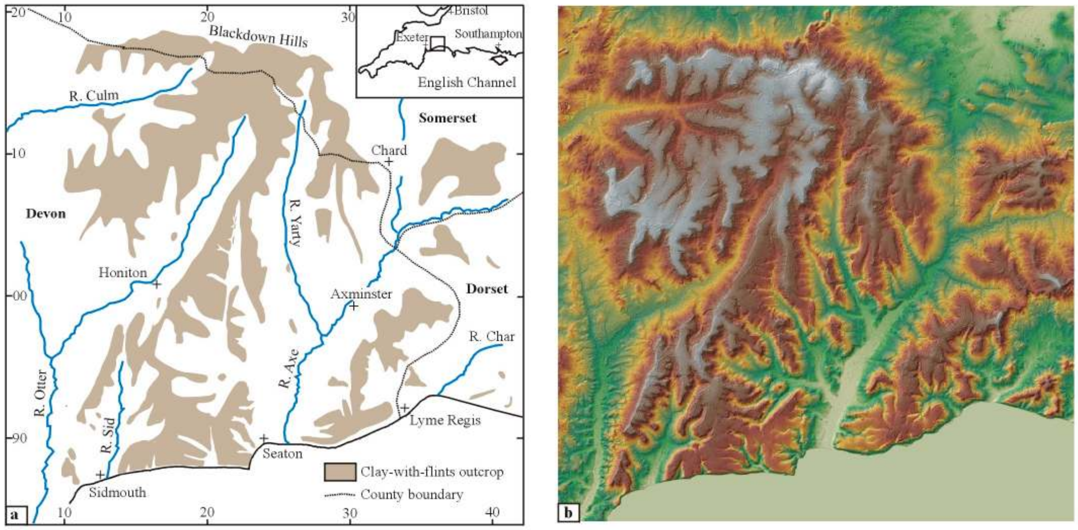
Figure 4*. Geological sections across the Axe Valley Fault Zone drawn by Ussher (in Woodward and Usher, 1911) to illustrate the tectonic deformation of the Clay-with-flints outcrop.*

Figure 5*. Contours on the folded and faulted Palaeocene planation surface on which the Clay-with-flints rests in east Devon, west Dorset and south Somerset. Within the N-S trending Axe Valley fault zone the base of the Clay-with-flints is displaced by up to 60 m across a single fault. The last reactivation of the fault zone is presumed to have been in the Miocene, the most recent major tectonic phase in southern England.*

Figure 6*. Geological sketch section to illustrate the relationship of the partially decalcified layer of Lewes Nodular Chalk to the underlying intact New Pit Chalk and the overlying drift deposits at Beer, Devon.*

Figure *7. Average global deep-water sea-bed temperatures during the Tertiary and Quaternary based on oxygen-isotope measurements made on shells of benthic foraminifera. After Zachos et al., 2001.*

Figure 8*. Summary of the principal processes involved in the formation of the Clay-with-flints sensu stricto (Stage 2) and the Clay-with-flints sensu lato (Stages 3 and 4).*



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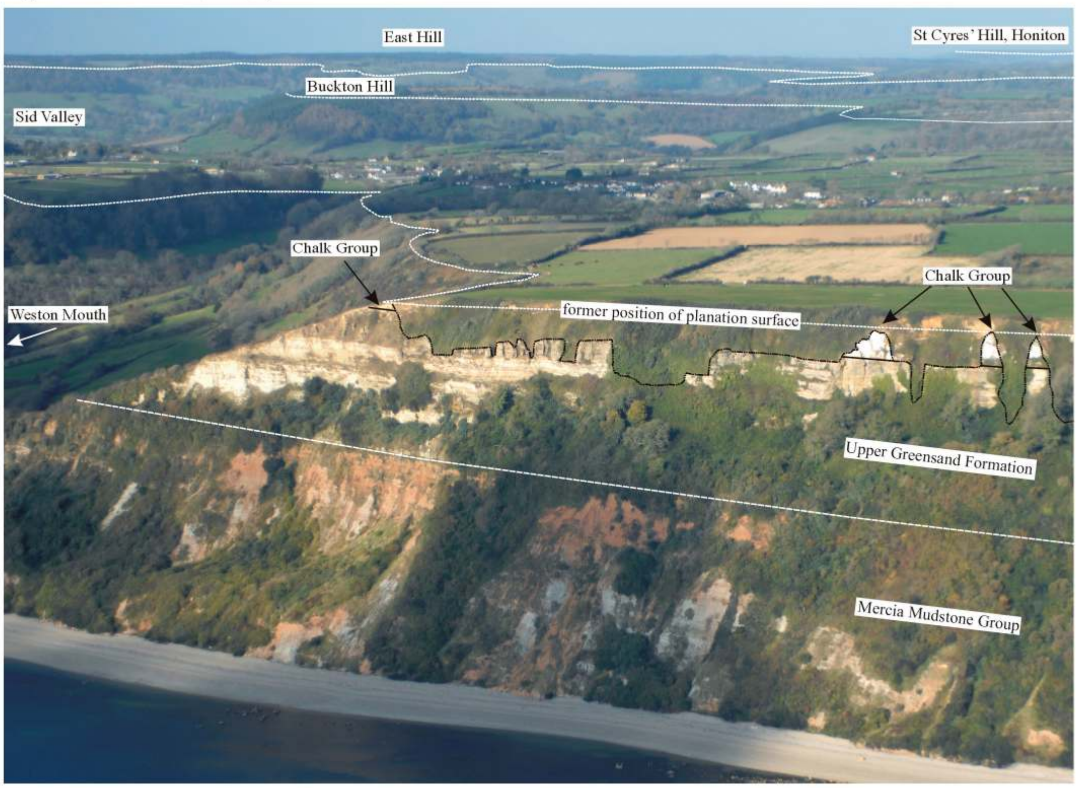

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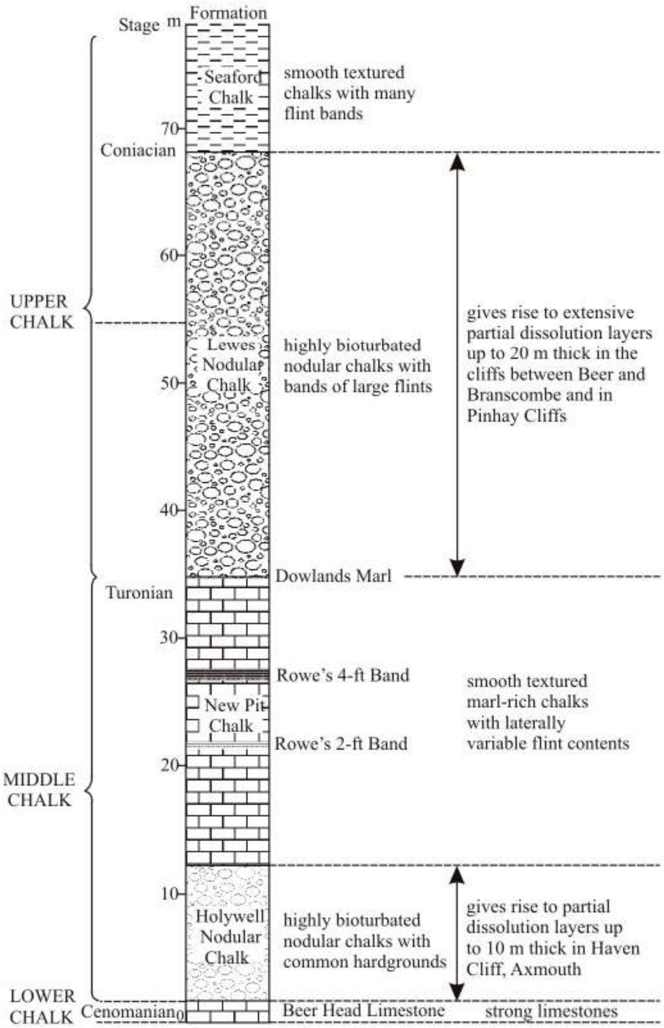
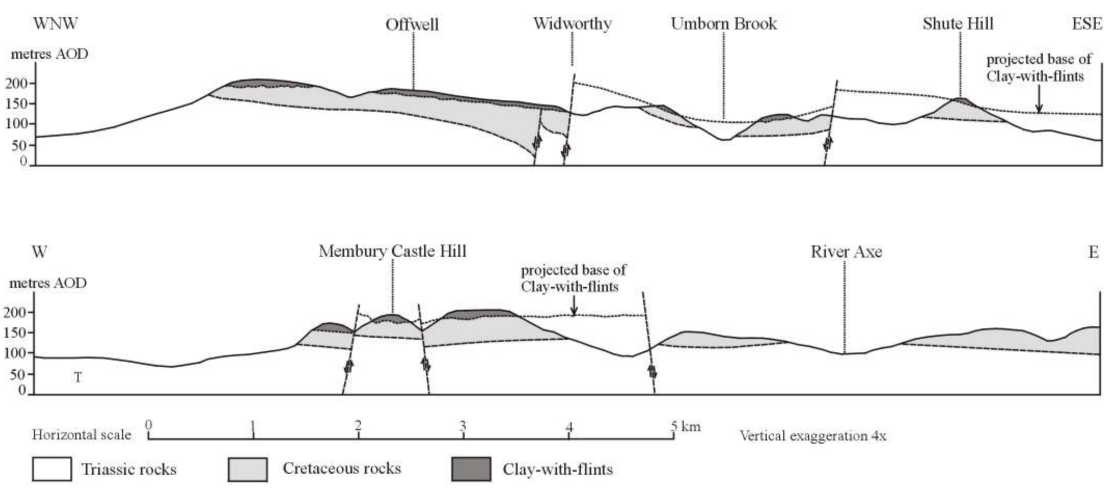


***Figure 3**. Generalised vertical section for the Chalk Group of east Devon and the principal partial dissolution layers.*



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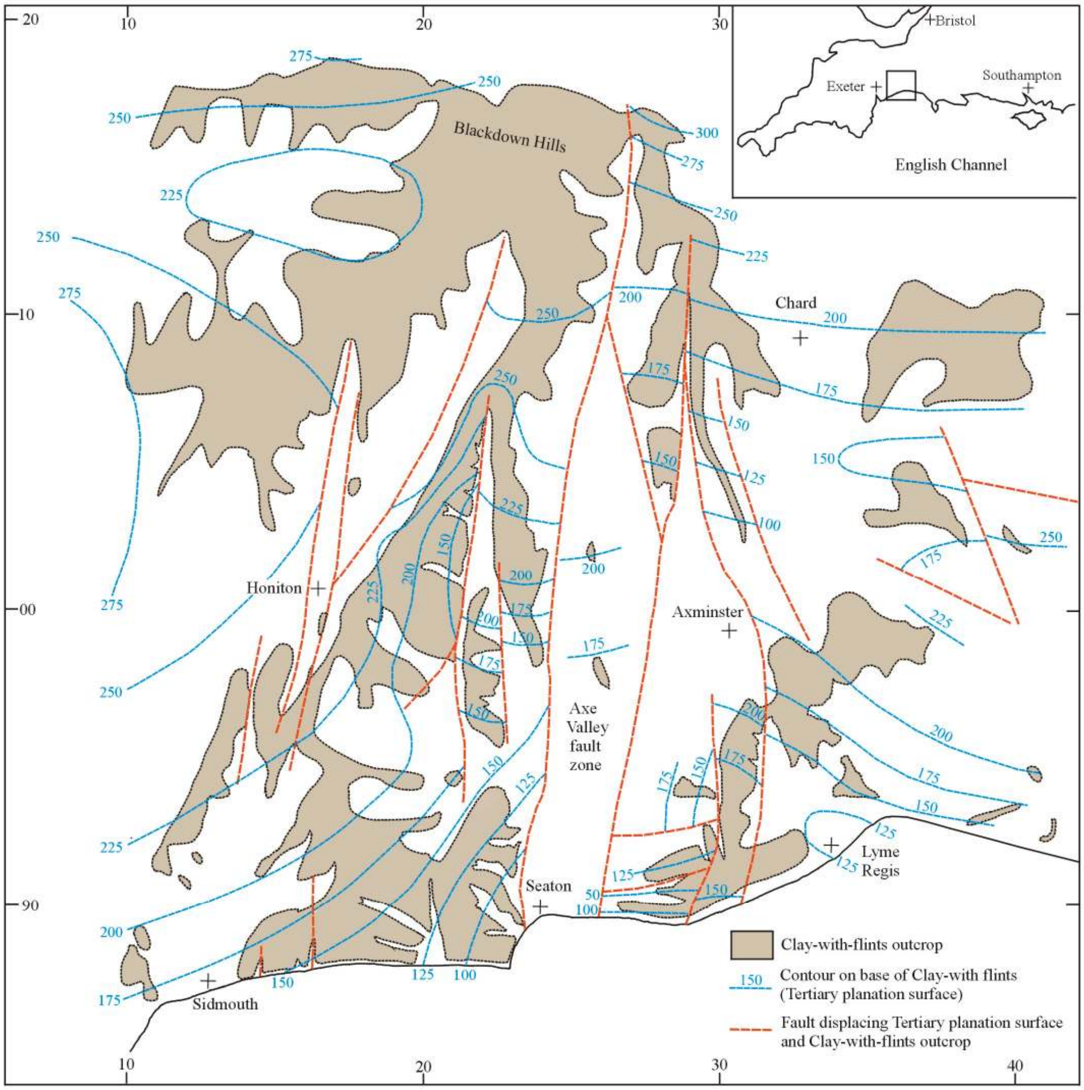

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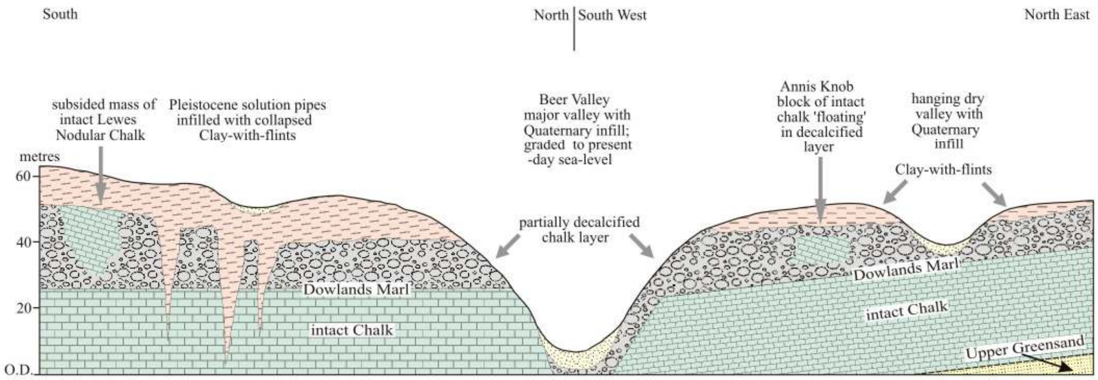
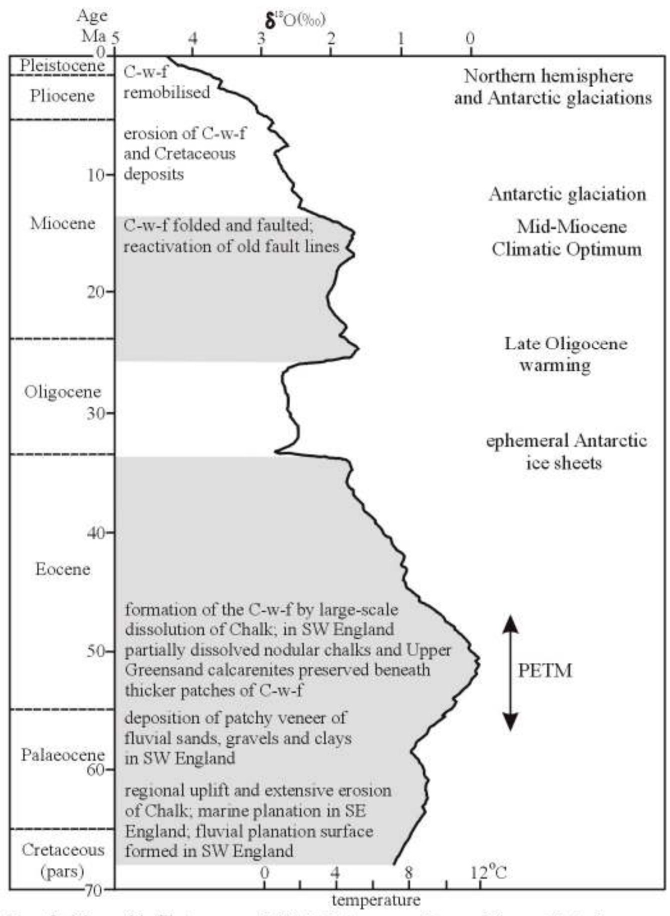


***Figure 6**. At Beer, the partially dissolved Lewes Nodular Chalk is overlain by Clay-with-flints that was extensively reworked during the Pleistocene*



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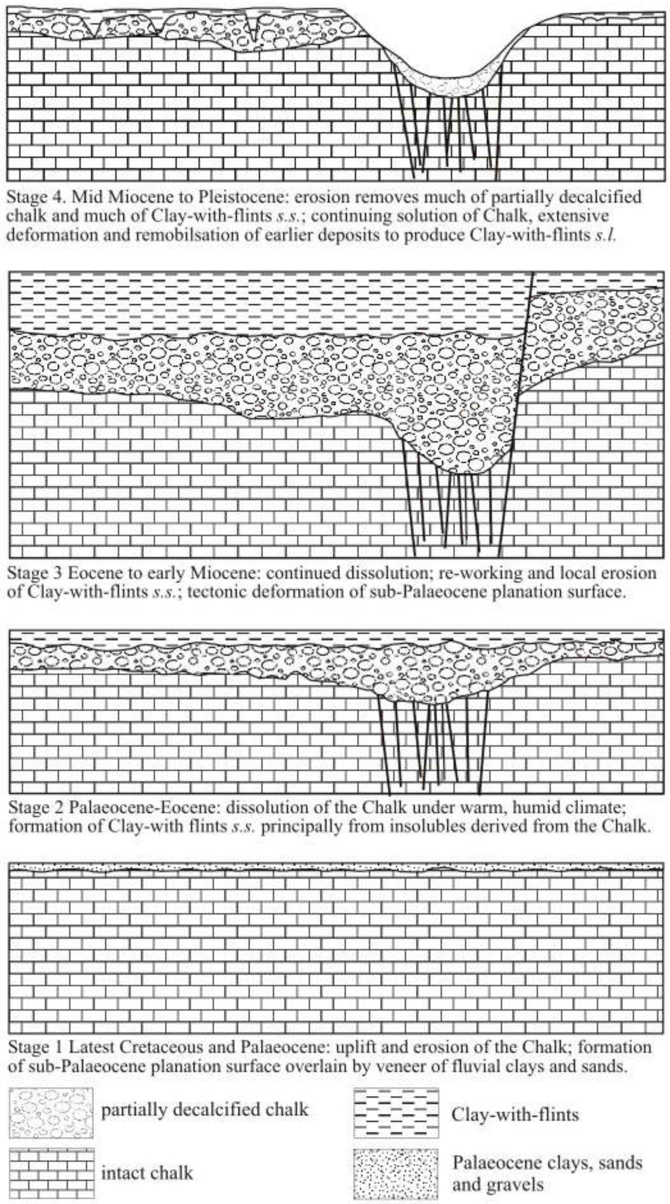

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