Chapter 3 Pre-Quaternary and long-term landscape evolution

The pre-Quaternary inheritance

C.P. Green and S. Campbell

Introduction

The main outline of South-West England's landscape owes its origin to a combination of geological and tectonic controls and geomorphological processes in pre-Quaternary time. Together with other areas of southern Britain which escaped the major erosive and depositional effects of Pleistocene ice sheets, South-West England became a focus for numerous studies concerned with establishing the nature, distribution, ages and origins of various perceived erosion surfaces and related drainage networks (e.g. Balchin, 1937, 1946, 1952, 1964; Trueman, 1938; Wooldridge and Linton, 1939; Wooldridge, 1950; Bradshaw, 1961; Weller, 1959, 1960, 1961). These morphological studies mark an important stage in the development of geo-morphological thought and technique. However, over much of South-West England there are relatively few on-land pre-Pleistocene deposits, and the great majority of relict features in the landscape are erosional and therefore almost impossible to date precisely. Overwhelmingly, the morphological evidence has proved profoundly unsatisfying, and until recently has lacked any serious confirmation from deposits (Kidson, 1977). However, two sites in particular provide significant evidence for establishing the nature and timing of major pre-Quaternary land-shaping events and processes in the South-West, and are the subject of this chapter. St Agnes Beacon provides unique evidence for establishing the relative age(s) of erosion surfaces in the region (Walsh *et al.,* 1987; Jowsey *et al.,* 1992), while Beer Quarry shows a spectacular example of the controversial clay-with-flints, and has a major bearing on the pattern and nature of Palaeogene weathering processes. A brief synopsis of the early work on erosion surfaces and drainage networks, and a more detailed account of pre-Quaternary weathering residues, sediments and landform development are given here, both as an introduction to the subject and to the selected GCR sites. The long-term evolution of the characteristic granite terrains of the South-West merits separate consideration in Chapter 4.

Erosion surfaces and drainage networks: a brief history of research

Erosion surfaces have been recognized at a variety of heights throughout South-West England, up to and including the summits of Exmoor, Dartmoor and Bodmin Moor. The first examples were probably recognized by Reid (1890), who described a narrow shelf around the south and west coasts of Cornwall. The location of fossiliferous marine deposits in a valley cut in this shelf at St Erth, and the presence of what appeared to be a degraded cliffline backing the shelf above *c.* 430 ft (131 m), led Reid (1890) and Reid and Flett (1907) to suggest a marine origin and early Pliocene age for the surface (cf. Müller, 1922; Wooldridge, 1950). A similar coastal plateau was recognized around Torquay by Jukes-Browne (1907), while Barrow (1908) drew attention to possible marine erosion surfaces (Miocene) on Bodmin Moor at 750 and 1000 ft (229 and 305 m, respectively). The first proponents of a subaerial origin for surfaces in the South-West were Davis (1909) and Sawicki (1912).

The 1930s and 1940s saw a proliferation of erosion surface studies in the South-West: Gullick (1936), Balchin (1937, 1946) and Pounds (1939) described further surfaces in Cornwall; Green (1936) extrapolated Barrow's (1908) Bodmin surfaces to east Devon; while Macar (1936) and Hollingworth (1939) provided more general accounts and attempted wider correlations. In 1941, Green described the high platforms of east Devon, distinguishing at least six erosion surfaces between 440 and 920 ft (134 and 280 m): these were believed to range in age from Miocene to Pliocene and to be marine in origin (Green, 1941).

In 1952, Balchin provided details of planation surfaces in the Exmoor region, describing a 'staircase' of eight surfaces ranging in height up to *c.* 1225 ft (373 m) and being separated by bluffs or 'worn-down clifflines'. At this time, the assumption was that the lower six surfaces were marine in origin. The possibility was acknowledged, however, that the summit level and the surface below it could have been formed subaerially in 'sub-Cretaceous' and 'early Tertiary' times, respectively (Balchin, 1952). An acceptance that even the marine-formed surfaces had undergone substantial subaerial modification was by now becoming implicit in the literature (e.g. Balchin, 1952; Stephens, 1952).

The 1960s saw substantial interest in the erosion surfaces and drainage networks of the South-West, with an increasing emphasis on measurement and statistical correlation. Detailed studies were undertaken on Bodmin Moor and in east Cornwall by Weller (1959, 1960, 1961); in north Devon (Arber, 1960); in west Cornwall (Everard, 1960b); in the Lizard Peninsula (Fryer, 1960); and in north-west Devon (Bradshaw, 1961). This work on erosion surfaces was to become intimately related to models concerning the development of drainage networks (e.g. Waters, 1951, 1953, 1960c; Kidson, 1962; Brunsden, 1963; Brunsden *et al.,* 1964). Fryer's (1960) study is notable in that it rejected a marine origin for all surfaces, save the 430 ft (131 m) level (cf. Reid, 1890), and invoked a single extensive surface, formed subaerially as a peneplain from Triassic times onward: this echoes views put forward by Jones (1951) concerning the evolution of the Welsh landscape. This shift in thinking is to some extent mirrored in subsequent studies. Orme (1961, 1964), for example, recognized four high-level planation surfaces around southern Dartmoor (Chapter 4): the upper two belonged to the early and mid-Tertiary respectively, the lower two to the late Tertiary. All were believed to have been formed subaerially. According to Orme (1964), the late Tertiary landscape was then drowned in early Pleistocene times to a height of *c.* 700 ft (213 m): a 'staircase' of forms below this level marked stillstands of the falling Pleistocene sea. Although Wooldridge (1950) noted similar surfaces up to heights of 1200 ft (366 m) (Calabrian), he ascribed the lower levels to retreat stages of the Pliocene sea.

In contrast, Kidson (1962) found no evidence in the South-West to support sea levels or marine planation above the general level of 210 m. The latter level was regarded as the most prominent surface in the region, representing the limit of an early Pleistocene marine transgression (Kidson, 1962, 1977; Brunsden, 1963; Brunsden *et al.,* 1964). Even the latter ascription has not gone unchallenged: Simpson (1964) dismissed this feature as an exhumed shoreline of Upper Cretaceous age (see below). Such datings would seem all the more unconvincing in view of the evidence from St Agnes Beacon, which shows that any geomorphologically significant transgressions of the sea above *c.* 75 m OD in post-Miocene times are highly unlikely (see St Agnes Beacon; Walsh *et al.,* 1987; Jowsey *et al.,* 1992).

Neither have attempts to link drainage development to the erosion surfaces and to general schemes of denudation chronology proved particularly rewarding. While many of the earliest studies on drainage systems were largely incidental to enquiries on the age and origin of the region's erosion surfaces (e.g. Clayden, 1906; Dewey, 1916), several notable attempts at a more holistic approach have been made. These include the work of Waters (1951, 1953, 1960c) in south-west Devon, and Wooldridge (1954), Brunsden (1963) and Brunsden *et al.* (1964). In general, an hypothesis of a falling, albeit oscillatory, base level from late Tertiary through Pleistocene times, producing both erosion surfaces and river rejuvenations, has been upheld (Balchin, 1964, 1981): Brunsden (1963) claimed that up to 17 separate stages in this development could be recognized in the catchment of the River Dart.

Pre-Quaternary weathering residues, sediments and landform development

Introduction

A more precise reconstruction of pre-Quaternary landform development, however, has been based on the nature and distribution of pre-Quaternary weathering residues and sediments and upon structural information. Evidence of weathering and soil formation is particularly useful since it may demonstrate the presence and environmental significance of palaeosurfaces. Datable, unconsolidated deposits found at given locations within the landscape, for example, the Miocene and Oligocene sediments of St Agnes Beacon, provide not only evidence of processes and environments at the time of deposition, but also important constraints on the extent and magnitude of later events and processes: in the context of St Agnes Beacon, it is highly unlikely that the sands and clays there could have survived a significant post-Miocene marine transgression or an incursion of Pleistocene ice. The importance of the age of the relict deposits remaining both as conformable and unconformable outcrops in the landscape is immediately evident. In the subsequent section, a brief outline of the chief surviving sedimentary evidence is given, followed by a possible model for pre-Quaternary landform development: the latter relies heavily on the synthesis given by Green (1985).

Pre-Quaternary sedimentary evidence in South-West England

In situ and reworked clay-with-flints

The oldest outcrops of post-Cretaceous/pre-Quaternary sediments in the South-West are found in east Devon, south Somerset and west Dorset. Here, relatively large areas of clay-with-flints and -chert cap the Chalk and Upper Greensand. Where in *situ,* these deposits have been classified as the Combpyne Soil (e.g. Isaac, 1979, 1981, 1983a, 1983b) and the Tower Wood Gravel (Hamblin, 1973a, 1973b) (Figure 3.1). Residual flint gravels also occur in solution pipes formed in Devonian limestone near Kingsteignton ((Figure 3.3); Brunsden *et al.,* 1976). A Palaeocene age for these residual deposits has been established from several lines of evidence (see Beer Quarry), but not least because locally they underlie Upper Eocene–Lower Oligocene beds of the Bovey Formation (Edwards, 1976; Isaac, 1981). In many areas, these residual deposits were reworked by Palaeocene and Eocene fluvial processes, giving rise to a series of deposits which include the Peak Hill, Mutters Moor, Buller's Hill and Aller gravels (Edwards, 1973; Hamblin, 1973a, 1973b; Brunsden *et al.,* 1976; Isaac, 1981). Although evidence for dissolution of the Chalk and the redistribution of weathering residues is fragmentary and dispersed, Beer Quarry has been chosen by the GCR to demonstrate both an excellent example of in *situ* clay-with-flints and a spectacular series of solution-formed, clay-filled chalk pipes.

The Bovey Tracey and Petrockstow basins

Significant outcrops of post-Cretaceous/pre-Quaternary sediments are found in the Bovey Tracey and Petrockstow basins (Figure 3.1). These freshwater Eocene gravels and Oligocene sand, clay and lignite deposits, lie in fault-guided basins which were tectonically active at various times in the Tertiary: in places, these sediments overlie residual gravels of proposed Palaeocene age. They contain weathering products which have a bearing on the development of adjacent landmasses, especially the granite terrain of Dartmoor.

St Agnes Beacon

Mid-Oligocene and Miocene sands and clays occupy an area of some 1.6 km^2 around St Agnes Beacon in west Cornwall. Although the age and origin of these sediments have long been disputed, recent work has established the presence of two distinct Mid-Oligocene and Miocene outliers, the sediments in which were formed by a variety of lacustrine, aeolian and colluvial processes (Walsh *et* ca., 1987; Jowsey *et al.,* 1992). The site, described in detail in this chapter, is of great significance for constraining the age of landforms and erosional surfaces in the region.

St Erth

The St Erth Beds consist of sands and clays located in a valley at a height of *c.* 30 m OD in west Cornwall (Figure 3.1). The clays contain a rich marine fauna with strong Mediterranean affinities and many extinct species. Reid (1890) argued that the fauna indicated water depths of around 90 m, and postulated that the sediments had been laid down in a sea which was also responsible for cutting an extensive platform at about 430 ft (131 m) OD (Reid, 1890; Reid and Flett, 1907; see above). Reid correlated the St Erth Beds with the Lenham Beds of south-east England and ascribed both to the Pliocene.

Reid made no reference to earlier suggestions that the clay at St Erth was a 'boulder clay' containing marine shells. However, this possibility was revived by Mitchell (1965) who argued that the fauna had been deposited during the Cromerian and had been reworked by an ice sheet of Anglian age. Subsequently, Mitchell *et al.* (1973a) re-examined molluscs, foraminifera and ostracods from the clay and concluded, like Reid, that the deposits were marine in origin and Pliocene in age: a water depth of only 10 m, however, was suggested, giving a projected sea level some 45 m above present OD (Kidson, 1977).

Although a glacial origin for any part of the St Erth sequence is no longer considered likely, considerable controversy still surrounds the chronostratigraphic classification of the beds. In this context, the site is particularly significant in providing evidence for arguments over the position of the Pliocene/Pleistocene boundary which, in the United Kingdom succession, has a particularly controversial history. Currently, the boundary is based on a stratotype section at Vrica in southern Italy, which establishes an age of *c.* 1.6 Ma BP, more or less coincident with the end of the Olduvai magnetic event (Aguirre and Pasini, 1985). In the North Sea region, however, there is much evidence to suggest that the boundary should be older: exact definitions vary, but the base of the Praetiglian Stage (2.3 Ma) (Zagwijn, 1989; Gibbard *et al.,* 1991) or the transition between the Matuyama and Gauss magnetic polarity chronozones at 2.45 Ma BP (Harland *et al.,* 1982) have been suggested (Balson, 1995).

Recent work on planktonic foraminifera indicates an age for part of the Red Crag between 3.2 and 2.4 Ma BP, that is Late Pliocene by either definition (Funnel, 1987, 1988). Foraminifera from the St Erth Beds indicate an age of *c.* 2.1–1.9 Ma BP (Jenkins *et al.,* 1986) — Pliocene according to the international definition of the boundary, but Pleistocene by most current United Kingdom practice. The St Erth site has been selected as part of the Pliocene GCR site network and will be described in the *Tertiary of Great Britain* stratigraphic volume of the GCR Series. The St Erth deposits, however, have been described widely in Quaternary and geomorphological literature pertaining to the region, and further consideration of their relevance is given below.

Crousa Common and Polcrebo Downs

There are other localities in South-West England where high-level deposits of post-Cretaceous/pre-Quaternary age are found. The most notable, perhaps, are found on Crousa Common and Polcrebo Downs in west Cornwall. The deposits on Crousa Common were described as early as 1843 by Budge, and consist of yellow clay with copious quantities of water-worn quartz pebbles (Stephens, 1980; Campbell, 1984), and occur at a height of about 110 m OD. Unlike the Polcrebo deposits (*c.* 152 m OD), they contain fossils (spores and pollen) but their age and origin are also unknown (Scourse, 1996b). Correlations, however, have been made between the Crousa/Polcrebo deposits and those at St Erth; a Pliocene age has often been alluded to (Hill and MacAlister, 1906; Reid and Scrivenor, 1906; Müller, 1922; Hendricks, 1923). Both marine and fluvial agencies have been suggested to account for the deposits, and although recent Scanning Electron Microscopy (SEM) work upholds a waterlain origin for those at Crousa Common (Campbell, 1984), precise environmental and age inferences cannot yet be made. Bowen (1994b) speculated that the deposits on Crousa Common could be glacial in origin, formed during an Early Pleistocene (Oxygen Isotope Stage 16) ice advance.

Similar gravels above 82 m OD in the Bristol district have been described by Palmer (1931). Mitchell (1960) correlated gravels at Hele near Barnstaple (56 m OD) with the St Erth Beds (Pliocene) and argued that neither ice nor sea level had attained this height since their emplacement. Kidson and Wood (1974), however, have argued that the Hele gravels are not marine but glacio- fluvial in origin, and have ascribed them to the glacial sequence which includes the Fremington Clay (see Chapter 7).

A controversial sandy flint gravel has also been described at Orleigh Court near Bideford in north Devon. This small outcrop, some 1.2 km long by 0.4 km wide, was regarded by Ussher (1879b) as re-sorted Cretaceous material of Tertiary age; by Boswell (1923) as Eocene; and by Rogers and Simpson (1937) as a derived deposit of at least post-Eocene age. Although the age and origin of these deposits are poorly understood, it is possible that they can be correlated with residual flint gravels of proposed Palaeocene age in the Haldon Hills (Tower Wood Gravel) and Beer/Sidmouth area (Combpyne Soil) (Edwards and Freshney, 1982; Green, 1985).

Pre-Quaternary landform development in South-West England. a synthesis

The pre-Quaternary origin of significant elements in the relief of the British Isles is now widely accepted. Historically, there have been two main schools of thought regarding the shaping of the pre-Quaternary landscape, and debate has centred on the key question of whether the bulk of denudation took place in the Palaeogene (e.g. Pinchemel, 1954) or in the Neogene (e.g. Wooldridge and Linton, 1955). On the Palaeozoic rocks of South-West England, there is clearly the added possibility that some landforms could be of Mesozoic age (Guilcher, 1949; Linton, 1951; Green, 1985). Recent work throughout southern England has certainly raised considerable doubts concerning the reality and age-range of the various geomorphological 'staircases' which have been proposed (see above; Jones, 1980; Green, 1985), and sedimentary and landform evidence from South-West England, in particular, has been fundamental in shifting opinion towards the Pinchemel school of thought. Although it is beyond the scope of the present work, which is overwhelmingly concerned with reviewing the Quaternary evidence, to examine all aspects of work and field evidence concerning pre-Quaternary landscape evolution, the following synthesis highlights the most important aspects with respect to the landforms and deposits of the South-West.

Pre-Tertiary geomorphological development There is significant evidence that Permian-Triassic erosion effected the primary shaping of the present relief of the Palaeozoic rocks of western Britain: massive denudation of the rocks of South-West England occurred at this time. The granites of Dartmoor (Chapter 4) range in age from Late Carboniferous to Early Permian (Hawkes, 1982) and are believed to have been intruded at depths of between five and nine kilometres below the surface. Despite this depth of intrusion, debris from the Dartmoor igneous complex occurs in Early Permian sediments, indicating substantial erosion and exposure of parts of the pluton within a surprisingly narrow time interval (Laming, 1982; Green, 1985). Material from the Dartmoor igneous complex is also present within Triassic conglomerates, and both Permian and Triassic sedimentary rocks locally provide excellent and familiar evidence of geomorphological and climatic conditions at the time of their deposition: breccias, aeolian and fluvial sands, conglomerates and mudstones indicate deposition under semi-arid conditions around the margins of a dissected upland (Green, 1985). Certainly, by the end of Triassic times, the rocks of South-West England appear to have been reduced to a surface of very low relief: progressive denudation is reflected in the passage upward in the thick (> 1000 m) Permian succession in Devon from basal breccias through sandstones to mud-stones (Green, 1985).

Only relatively minor modifications to the Permian-Triassic landscape of South-West England are believed to have occurred during Jurassic and Lower Cretaceous times. Hart (1982) argued that South-West England remained a land area for much of the Jurassic: most of the Jurassic rocks of the Wessex Basin are marine shelf/shallow water sediments, and any terriginous inputs, such as clay minerals, appear to have originated from a landmass of low relief (Cosgrove, 1975). Certainly, no surfaces of Jurassic age can be recognized on the Palaeozoic rocks of the South-West, and evidence of Jurassic terrestrial weathering in southern England is confined to the Lulworth Beds of the uppermost Portlandian in south Dorset (Green, 1985).

The culmination of the Upper Cretaceous marine transgressions (Hancock, 1969) was a turning point of far-reaching significance in the long-term development of landforms in southern Britain (Green, 1985). The most elevated parts of the South-West Peninsula may have escaped submergence (Hancock, 1969), but over the rest of southern Britain a continuous cover of chalk was deposited. Towards the end of the Lower Cretaceous, the intensity of erosion appears to have increased in South-West England, presumably as a result of uplift: arenaceous sediments in the Lower and Upper Greensands reflect this intensification. In many areas of the South-West, the only evidence of a former chalk cover is the preservation of flint in residual deposits (clay-with-flints) or in later sediments derived from them (Isaac, 1981). Whatever the character of the relief across which the Cenomanian transgression extended, details of the subchalk surface must have been shaped by marine agencies. Although unconformities between the Upper Cretaceous rocks and older Mesozoic sediments are effectively planar, the planation effected by the transgression on the harder rocks of the Peninsula was less complete: some benches on the flanks of Dartmoor, however, have been explained as the product of the transgressive Upper Cretaceous seas (Simpson, 1964). The surviving evidence, however, fails to show whether the submergence of Cornubia was complete (Green, 1985).

Notwithstanding, it is highly unlikely that terrestrial surfaces and associated features of pre-chalk age in South-West England survived without some modification. However, the gross morphology of the region could well pre-date deposition of the Chalk and be the product of earlier Cretaceous or Mesozoic denudation (Green, 1985). It is also possible for rocks deeply weathered in pre-chalk times to have survived, and a pre-chalk age for the kaolinized granites of the South-West has been proposed (cf. Minot, 1970; Lidmar-Bergstrom, 1982; Esteoule-Choux, 1983; Chapter 4).

Chalk sedimentation in South-West England appears to have ended in mid-Campanian times (Figure 3.1). Since this is also likely to reflect the termination of marine conditions, removal of chalk by subaerial agencies could have begun as early as the Upper Cretaceous (late Campanian to Maastrichtian) (Green, 1985). Maastrichtian (Upper Cretaceous) and Danian (Lower Palaeocene) sediments are absent in southern England, but offshore they consist of pure limestones, consistent with denudation of chalk from contemporary land areas such as parts of South-West England.

Palaeogene geomorphological development The uplands of east Devon, south Somerset and west Dorset furnish some of the most compelling evidence in Britain for Palaeocene denudation of the Chalk cover under tropical climatic conditions (Green, 1985; see Beer Quarry). This weathering reduced the Chalk over the Palaeozoic basement to a mantle of weathering residues, essentially the widespread clay-with-flints, the Tower Wood Gravel found on the summits of the Haldon Hills (Hamblin, 1973a) and the Combpyne Soil of the Sidmouth and Beer area (Isaac, 1981, 1983b). Isaac

(1983b) places the formation of the Combpyne Soil and Tower Wood Gravel in the Danian (Lower Palaeocene), and regards this as a time of intense lateritic weathering, when any former chalk cover was reduced to a mantle of weathering residues: in a few places, he identified *in situ* lateritic weathering characteristics such as pallid and mottled zones overlying red earth horizons. A Danian age is inferred by analogy with lateritic weathering of that age in the Interbasaltic Formation of Northern Ireland (Isaac, 1983b), although there appears to be no good reason why weathering of the Chalk could not have begun earlier, in the Upper Cretaceous (Green, 1985).

Late Palaeocene and Eocene erosion then occurred under subtropical climatic conditions. Evidence for this comes from the Tertiary gravel deposits of south and east Devon. Resting on the Tower Wood Gravel of the Haldon Hills, and directly on the Upper Greensand in the Kingsteignton pipes (Brunsden *et al.,* 1976) and around the margin of the Bovey Basin, are flint-rich gravels, the Buller's Hill Gravel of Hamblin (1973b) (see (Figure 3.5)). These gravels, and their lateral equivalents, the Peak Hill Gravels, are thought to have been reworked by fluvial processes from the residual Tower Wood Gravels and Combpyne Soil, respectively. In the Kingsteignton pipes, the Buller's Hill Gravels are overlain by the Aller Gravels (Edwards, 1973; Brunsden *et al.,* 1976): these gravels appear to be overlain by the main part of the Bovey Formation ((Figure 3.5); Green, 1985).

Small amounts of Palaeozoic debris present in the Buller's Hill Gravel may indicate a renewed exposure of the basement at this time, and there are clear indications that the Late Palaeocene and Early Eocene saw repeated reworking of a thin veneer of sediments and weathering residues over substantial areas of the South-West. Isaac (1983b) has shown that kaolinite in deposits of the Bovey Formation, including the Buller's Hill Gravel, is less well ordered than in the *in situ* Tower Wood Gravel (residual). This has been taken to indicate a weathering phase separate from and shorter (or of lesser intensity) than the phase responsible for the Tower Wood Gravel and Combpyne Soil. Similar indications of in *situ* deep weathering profiles have been described beneath Oligocene Bovey Formation sediments in the Petrockstow Basin (Bristow, 1969), confirming the existence of a deeply weathered terrain in South-West England during the Palaeogene (Green, 1985). Silicified deposits (often termed Sarsens) are widespread in southern Britain, and most workers have proposed a Palaeogene age for their formation (see Beer Quarry; Clark *et al.,* 1967; Isaac, 1979, 1981, 1983a, 1983b).

Deposition of the bulk of the Bovey Formation appears to have occurred during the Eocene and part or all of the Oligocene: throughout this period, sediment was derived from erosion of deep but relatively immature weathering profiles developed on both granite and Upper Palaeozoic metasediments under subtropical or warm temperate climatic conditions (Green, 1985). It is likely that the erosional morphology of the summit relief on these rocks was acquired during this interval. An extensive erosional surface in the region between Salisbury Plain in the east and Dartmoor in the west appears to have developed, becoming refined by Early Eocene (London Clay) times by marine and fluvial agencies (Green, 1985). In south-east England, the Chalk inherited its present summit morphology before the end of the Palaeocene, prior to quite deep burial beneath later Tertiary sediments. Areas of Palaeozoic rocks in the west were drained by rivers running into the Early Eocene sea of southern England: there is no evidence that this sea, even at its maximum extent in London Clay times, extended farther west than the basin of the upper Otter (Green, 1974b, 1985). Faulting contributed significantly to relief development at this time, and also later in the Tertiary (Green, 1985).

Throughout southern Britain, there are consistent indications that denudation of the Chalk was largely effected under tropical or subtropical conditions before the end of the Palaeocene. In the Late Palaeocene and Early Eocene, the Chalk around the western fringe of the Hampshire Basin, and the rocks exposed by the removal of the Chalk both to the west and north of the surviving chalk outcrop in southern England, formed an erosional province in which a surface of low relief was widely developed (Cope, 1994). During the same interval, the area occupied by the Chalk outcrop in south-east England became an essentially depositional province and was buried beneath the Thanet Sands, the Reading Beds and a substantial thickness of Eocene sediments, derived largely from the northern part of the aforementioned erosional province (Morton, 1982). Towards the end of the Palaeogene (mid-Eocene onwards), the area of marine sedimentation in southern Britain became progressively smaller (Murray and Wright, 1974), although there is no evidence for the substantial production of terrigenous sediment. In fact, in the offshore record of Palaeogene sedimentation in the English Channel (Curry *et al.,* 1970), carbonate rocks predominate throughout and form the whole recorded sequence for the Middle and Late Eocene. The volume of Oligocene sediments is small, comprising in addition to the onshore outcrops, only one offshore record — of freshwater limestone. This scarcity of terrigenous sediment when most of southern England formed a land area strongly suggests a Late Palaeogene terrain of low relief close to base level (Green, 1985).

Neogene geomorphological development

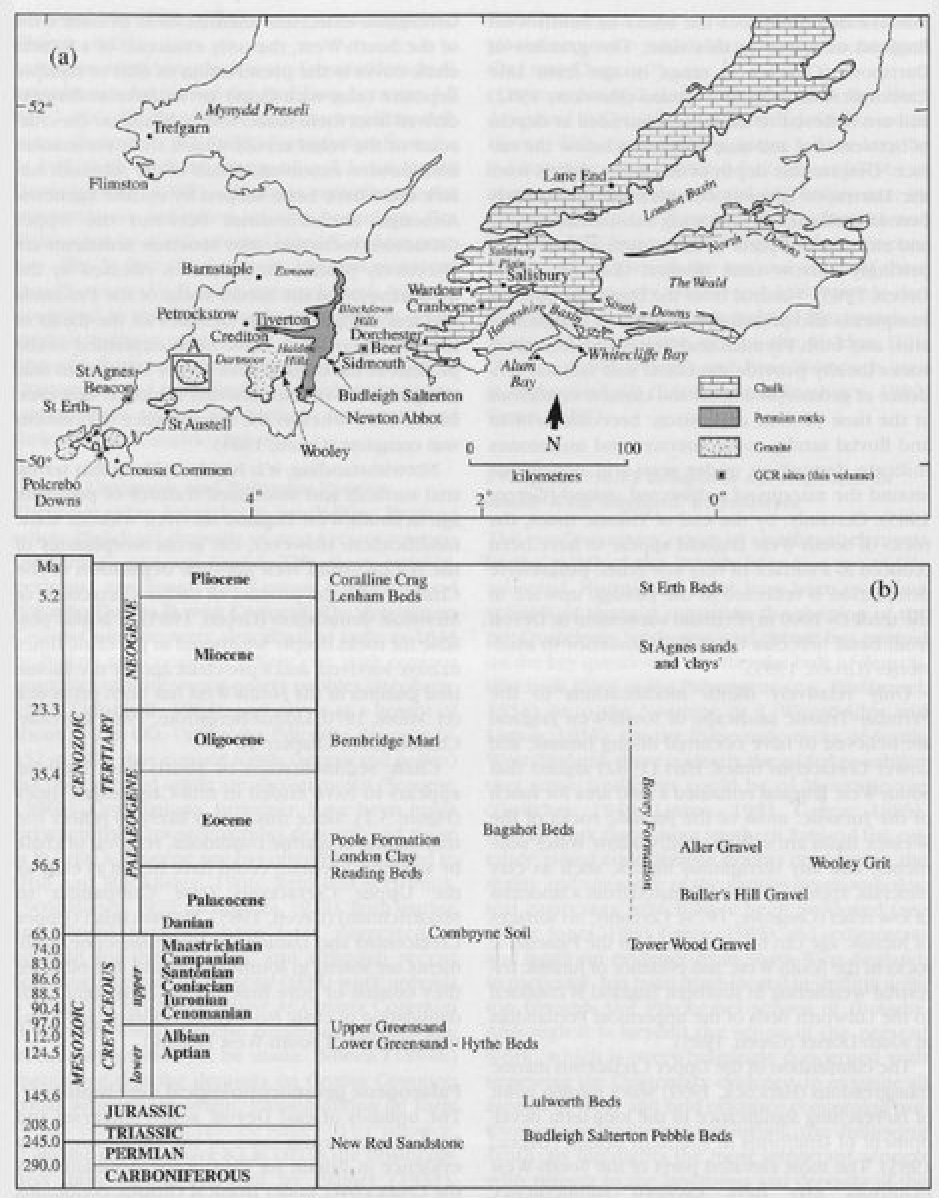
The record of Neogene landform development in southern Britain is extremely difficult to interpret. This arises both from the deficiencies of the sedimentary record and the possibility that the Neogene consisted of a prolonged morphostatic phase — a time in which geomorphological activity was limited through one mechanism or another. Certainly, Neogene deposits in Britain are limited and scattered (e.g. the Coralline Crag and the St Erth Beds), and until recently, Miocene sediments were only known offshore around southern Britain (Curry *et al.,* 1970; Evans and Hughes, 1984): St Agnes Beacon, west Cornwall, however, is one of five known sites in the British Isles where fossiliferous non-marine sediments (in the case of St Agnes Beacon, sands and 'clays') of possible Miocene age have been preserved (Walsh *et al.,* 1987; Jowsey *et al.,* 1992; Walsh *et al.,* 1996), while the St Erth Beds provide the only sedimentary evidence for the incursion of the Pliocene sea in south-west Britain.

However, the recognition of a supposed Neogene erosional surface on the Chalk of south-east England (the Miocene–Pliocene peneplain) was central to the work of Wooldridge and Linton (1955) and their belief that the bulk of post-Cretaceous denudation had occurred in the Neogene. The reality of this peneplain has often been challenged (Pinchemel, 1954; Clark *et al.,* 1967; Green, 1985), and most indications are that the bulk of chalk denudation occurred much earlier in the Tertiary (see above; Jones, 1980; Green, 1985).

Certainly in the South-West, the disposition of Cretaceous and Early Tertiary sediments and weathering residues in relation to the broad pattern of relief on the Palaeozoic rocks, seems inconsistent with the production of a significant part of that relief by Neogene erosion: indeed, relief elements which can be referred confidently to the Neogene are virtually absent throughout southern Britain, and in the South-West, the late Palaeogene surface survives without convincing evidence of either Neogene erosion or significant solutional lowering. However, in other areas of southern Britain, such as parts of the Weald, erosional surfaces do appear to have developed, and have removed evidence of older Palaeogene surfaces and deposits (Jones, 1980). Such erosional areas now form the summit relief and clearly pre-date the Quaternary terrace sequences found in many river valleys: a Neogene age is therefore indicated. The summit relief of southern Britain is evidently not everywhere of the same age: substantial areas of the South-West appear to have escaped significant Neogene modification, while the latter's effects elsewhere are more clearly demonstrable. The lack of Neogene landform development over large areas of the South-West is best explained by a generally low level of relief in relation to base level, while differential development of relief is most readily explained by localized structural activity (Green, 1985).

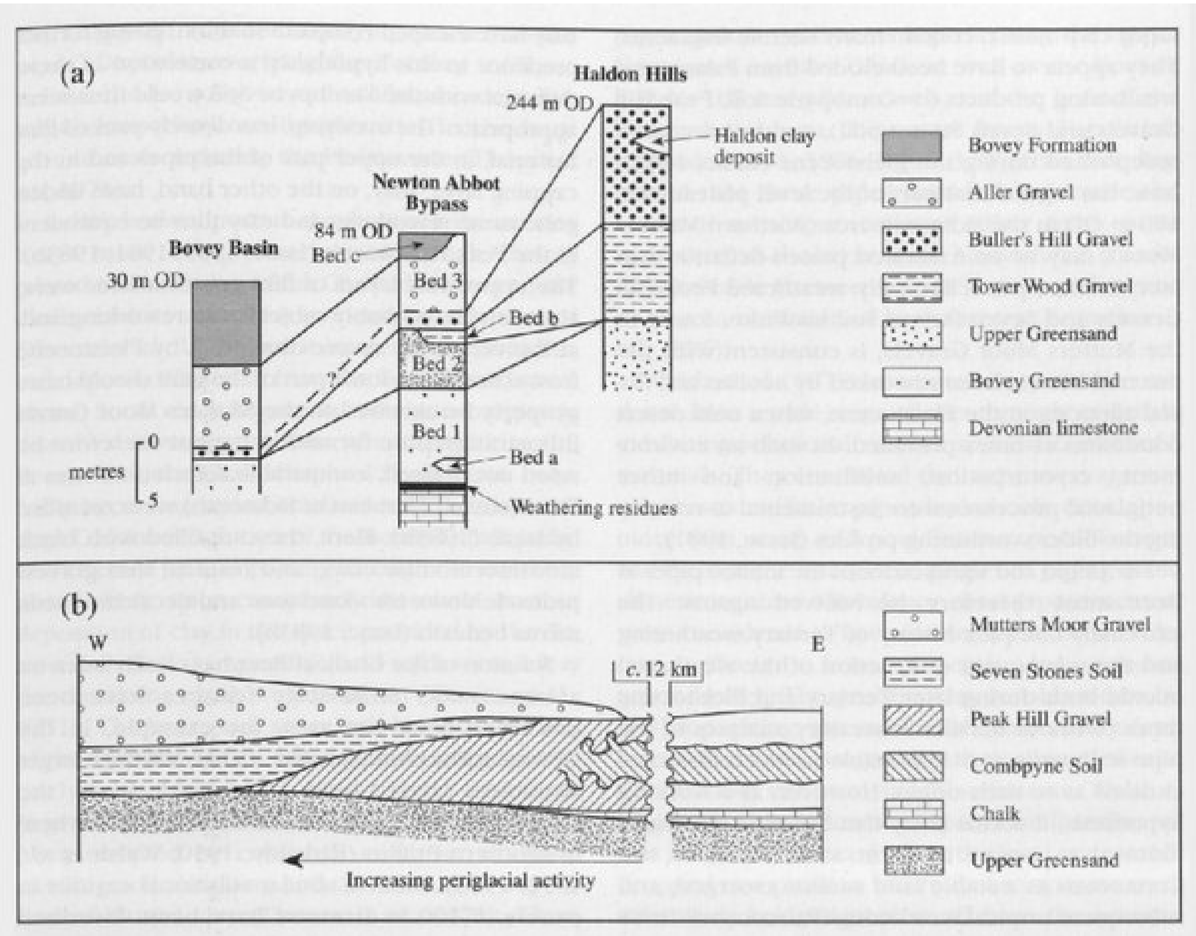
The evidence from St Agnes Beacon demonstrates very clearly that, excepting unexplained local structural activity, there can have been no significant regional marine incursions above the general level of *c.* 75 m OD since the Miocene: the largely unconsolidated Miocene sands there are unlikely to have survived such an incursion. Evidence for a subsequent marine transgression on to the Peninsula in Pliocene times is witnessed by the deposits at St Erth (and possibly by those at Crousa Common and Polcrebo Downs), but the wider geomorphological effects of this incursion are unknown. Although, through amino-acid geochronology, the raised beach deposits of southern Britain have started to provide a framework for determining the changing pattern of Pleistocene land and sea levels (e.g. Bowen, 1994b), the overwhelmingly erosional nature of the evidence lends vast uncertainty to determining the nature and timing of geomorphological conditions and events in later Tertiary and early Pleistocene times. The low-level erosion surfaces, shore platforms and raised beach deposits with a major bearing on these issues are the subject of Chapters 6, 7 and 8.

[References](#)



(Figure 3.1) (a) Southern and South-West England, showing localities referred to in the text, and selected geological outcrops. (b) Significant deposits and events in the geomorphological evolution of southern Britain. (Adapted from Green, 1985, with timescale based on Harland et al., 1982.)

(Figure 3.3) A large 'pipe' structure towards the western end of the north quarry face, showing the abrupt transition from chalk to the infill material (clay-with-flints). Even in monochrome, the profound darkening of the infill towards the pipe's margins can be seen clearly. (Photo: S. Campbell.)



(Figure 3.5) (a) Stratigraphic correlations of successions in the Bovey Basin, Newton Abbot bypass and Haldon Hills. (Adapted from Edwards, 1973, Hamblin, 1973b and Brunsden et al., 1976.) (b) Schematic representation (not to scale) of field relations of major lithostratigraphic units in the Sidmouth area. (Adapted from Isaac, 1981.)