St Agnes Beacon

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Highlights

Rare, non-marine Miocene deposits occur here, and provide unique evidence for the long-term evolution of South-West England's landscape. The survival of the St Agnes sands and 'clays' indicates that this part of the South-West cannot have been overrun by glacier ice nor inundated by the sea since the Miocene.

Introduction

St Agnes Beacon is an important site for the interpretation of Tertiary stratigraphy. The site is also of considerable geomorphological interest because the deposits and the underlying bedrock surface have significant implications for regional landscape evolution — especially for the age and mode of formation of the sub-deposit surface, for its relationship to other 'erosion' surfaces in South-West England, and for establishing the extent and intensity of Pleistocene glaciation in the region. On the basis of these merits, the site has attracted wide interest from Quaternary scientists; hence its inclusion in this volume. The site was apparently first referred to by Borlase (1758) and subsequently by Pryce (1778), Boase (1832), Hawkins (1832), De la Beche (1839), Belt (1876), Davies and Kitto (1878), Ussher (1879a) and Whitley (1882). It was also studied by Reid (1890), Reid and Scrivenor (1906), Müller (1922) and Boswell (1923). More recently, the site has been discussed by Mitchell (1965), Atkinson *et al.* (1974, 1975), Hall (1974), Atkinson (1975, 1980), Edmonds *et al.* (1975), Wilson (1975), Campbell (1984), Coque-Delhuille (1987) and Goode and Taylor (1988). A detailed account of the stratigraphy, sedimentology and palynology of the deposits and their significance was given by Walsh *et al.* (1987). Further investigation of part of the deposits was published by Jowsey *et al.* (1992). The site has also been referred to in general texts by Austen (1851), Whitley (1866), Davison (1930), Gullick (1936); Robson (1944) and Macfadyen (1970).

Description

Although formerly regarded as a single outlier, the deposits at St Agnes are now believed to comprise two distinct outliers; the St Agnes Outlier and the Beacon Cottage Farm Outlier (Walsh *et al.,* 1987; Jowsey *et al.,* 1992; (Figure 3.6) and (Figure 3.7)). The sediments in the St Agnes Formation consist mainly of sands and clays and are arranged in an arc around the north and east slopes of St Agnes Beacon. This outcrop covers 1.6 km^2 and has a residual volume of some 5 X 10^6 m^3 (Walsh *et al.,* 1987), reaching a maximum exposure thickness of *c.* 10 m. Active workings only occur in New Downs Pits (Doble's Sandpits) (*c*. [SW 706 509]). The following stratigraphy was proposed for the St Agnes Formation by Walsh *et al.* (1987):

3.	Upper Sands	— Beacon Member
2.	Middle 'Clays'	— New Downs Member
1.	Lower Sands	— Doble Member

The St Agnes Formation is underlain by Devonian slates ('killas') or by the St Agnes Granite. There is evidence that this sub-deposit floor is extensive; in New Downs Pits it is sub-horizontal and covers an area of some 1000 m^2. Its junction with the upper slopes of the Beacon appears to take the form of a steep stepped cliff, with an overall gradient of 45° or more (Walsh *et al.,* 1987). Davies and Kitto (1878) raised the possibility that the abrupt break of slope on the east side of the Beacon was a buried sea cliff. In New Downs Pits, the sub-deposit basement is stained red, lilac and orange to a depth of at least 1 m; derived clasts of stained killas in the overlying beds show clearly that the killas was weathered prior to deposition of the Doble Member (Walsh *et al.,* 1987).

The Doble Member is heavily cemented for a depth of up to *c.* 0.5 m at the base of the bed. The iron content sometimes exceeds 10% by mass and forms tubular structures up to 2 m long and 0.3 m wide — sometimes filled with uncemented yellow sand (Hosking and Pisarski, 1964; Atkinson *et al.,* 1974; Walsh *et al.,* 1987). Reid and Scrivenor (1906) recorded a bed of pebbles towards the base of the St Agnes deposit, although this is no longer evident.

The Doble Member (Lower Sands — bed 1) is around 5–6 m thick and consists largely of yellow or buff, well-sorted and fine-grained silty, quartz-rich sand. The bed becomes paler towards its junction with the overlying bed 2, with which it has a gradational contact (Walsh *et al.,* 1987). Epsilon-type planar cross-beds are evident, varying considerably in size; palaeocurrent directions indicate a source from the north-west (Walsh *et al.,* 1987). This sand bed is interrupted by a 10 cm-thick band, 1.8 m above the base of the bed, comprising rounded pebbles of vein quartz and sandstone and large angular cobbles of stained killas.

The succeeding New Downs Member (bed 2) is a pale-grey deposit up to *c.* 3.5 m thick. It has frequently been described as a clay, but in fact comprises mostly silt and sand with some clay. Isolated vein quartz pebbles occur towards the top of the bed, which is sharply truncated. Sediments from this bed have yielded a Miocene microflora. It is a poorly sorted deposit, and exhibits only faint stratification, with a consistent dip of 3–8° to the north (Walsh *et al.,* 1987). Davies and Kitto (1878) noted that the 'clays' were subdivided into two beds in one exposure north of St Agnes Beacon (Site 16; (Figure 3.7)).

The overlying Beacon Member (bed 3) is represented by *c.* 3 m of cross-bedded, very well-sorted, fine- to medium-grained yellow and orange sand; the sediments are closely comparable to the basal member (bed 1). Some of the sand is weakly iron-cemented, and irregular lenses of green silty sand are also present. Stratification in this bed is usually less marked than in bed 1 (cf. Coque-Delhuille, 1987), especially near the junction with the overlying head, where the sediments are greatly distorted. Where the bedding is relatively undisturbed, foresets are dominantly inclined to the SSE or south (Walsh *et al.,* 1987).

The capping Pleistocene head (up to 1.5 m thick) is an unsorted deposit comprising dominantly angular and subangular clasts of killas and the St Agnes Granite set in sand (Figure 3.8). It displays cryoturbation structures, with sands of the New Downs Member thrust up into the head in places (Coque-Dellluille, 1987).

The Beacon Cottage Farm Outlier (Figure 3.7) has no current exposures: the stratigraphy and interpretation of these beds therefore rests heavily on historical records (e.g. the field notes of H. Dewey and the work of Davies and Kitto (1878)), 61 boreholes and trenches (Jowsey *et al.,* 1992) and the palynological evidence, which shows clearly a flora of mid-Oligocene age. The relationship of this outlier to the St Agnes Outlier has been clarified by Jowsey *et al.* (1992), who have demonstrated that the two formations are discrete and that there is no overlap by the Beacon Member on the deposits of the Beacon Farm Outlier as had been thought by Walsh *et al.* (1987) (Figure 3.6) and (Figure 3.7). The boreholes and trenches excavated by Jowsey *et al.* (1992) revealed that the Beacon Cottage Farm Outlier is up to 8.9 m thick and comprises two members: Basal Sand which is often pebbly and Candle Clay, which in fact comprises sandy silts. These deposits are overlain by up to *c.* 6.4 m of head. The Candle Clay has yielded a mid-Oligocene flora (BGS Sample MR 10401; Mitchell, 1965; Walsh *et al.,* 1987).

Interpretation

William Borlase in 1758 (Macfadyen, 1970) regarded the St Agnes beds as marine, having been formed by an event that could be 'no other than the universal deluge'. The sediments were also referred to by Pryce (1778), Boase (1832) and Hawkins (1832), the latter considering them to be 'alluvial'. Davies and Kitto (1878), however, returned to the proposition that the sands had formed in a marine environment, with the clay having been deposited in 'a sheltered embayment of the sea'. An apparently 'shingle-worn' cliff some 4–8 m high and a postulated sea-stack, caves and hollows — exposed by mining in 1875 to the east of the Beacon — led Davies and Kitto and, later, Reid and Scrivenor (1906) to regard the sands overlying and banked against these features as marine. Such an explanation for the beds was supported by particle-size analyses and by the interpretation that individual sand grains showed signs of marine abrasion (Müller, 1922). Such an origin was considered likely by Boswell (1923), who also noted that a dune (aeolian) origin was feasible. Recently, Coque-Delhuille (1987) favoured a marine origin. In marked contrast, Atkinson *et al.* (1975) and Goode and Taylor (1988) favoured a fluviatile origin. Such an origin for the 'clay', with its consistent northerly 3–8° dip of bedding structures, would require post-depositional tectonic action for which there is no evidence. Detailed analyses of quartz grain surface textures (Campbell, 1984; Walsh *et al.,* 1987) show an aeolian origin for the sands and a colluvial (i.e. slope-wash) origin for the 'clay'. The latter contains a mixture of grains of aeolian origin (presumably derived from the underlying sand) and of source rock origin (rock weathering products transported downslope). Similarly, mainly aeolian and colluvial origins were suggested respectively for the Basal Sands and Candle Clay of the Beacon Cottage Farm Outlier by Jowsey *et al.* (1992).

The beds were first classified as Tertiary by De la Beche (1839). More specifically, Reid (1890) assigned the deposits to 'Older Pliocene' times: a summary of the early findings was given by Reid and Scrivenor (1906).

Mitchell (1965) referred briefly to pollen extracted from a lignite sample (originally collected by H. Dewey in 1932; BGS Sample MR 10401) from a poorly defined location at the base of the beds at Beacon Cottage Farm: the results indicated an Oligocene age for the beds — thus discounting Reid's view that the platform underlying the sand beds (the 130 m platform of Cornwall) was Pliocene in age, and that the St Agnes Beacon had been an island in the sea at this time. Further palynological examination of Dewey's sample (Atkinson *et al.,* 1975) led to a more precise ascription of the beds to the Middle–Upper Oligocene.

New dating evidence for the St Agnes beds was provided by Walsh *et al.* (1987). Their work shed additional light on the ages of the beds which have important implications for the long-term landscape evolution of west-central Cornwall. A re-analysis of the microflora in the BGS Sample (MR 10401) from sediments in the Beacon Cottage Farm Outlier confirmed a mid-Oligocene age for the flora (cf. Atkinson *et al.,* 1975) and suggested low-energy deposition for the 'clay' in a lacustrine environment (Walsh *et al.,* 1987), although later sedimentological analysis indicates a colluvial origin, as for similar deposits in the St Agnes Formation (Jowsey *et al.,* 1992). These sediments were tentatively correlated with equivalent beds of the Bovey Formation of Devon (that is of Palaeogene age).

By contrast, lignitic material from sediments in the New Downs Pits (St Agnes Formation) yielded an impoverished, although distinctive, pollen assemblage of probable Miocene age (Walsh *et al.,* 1987). These different dates, together with the lack of superposition, mean that the sand beds around St Agnes Beacon can no longer be regarded as a single formation — and the beds have been re-classified accordingly (see site description).

Walsh *et al.* (1987) argued that the prominent planation surface beneath the beds at St Agnes, which also occurs throughout much of Cornwall between *c.* 75–131 m, be termed the Reskajeage Surface. They concluded that sea level never reached this height in mid- and late Tertiary times, thus eliminating the possibility that the feature formed through marine activity. Rather, they suggested that the surface originated as a tropical or subtropical etch plain which was formerly covered by a saprolite of varying thickness with upstanding inselbergs (such as St Agnes Beacon), and had formed over a protracted period up to late Miocene times. The St Agnes sediments are thus considered to be small remnants of tropical or subtropical sub-aerial weathering products which underwent redistribution by wind action and slope-wash processes in mid-Oligocene and Miocene times (Walsh *et al.,* 1987; Jowsey *et al.*, 1992).

St Agnes Beacon is therefore not only of outstanding interest for Tertiary stratigraphy, but demonstrates important evidence for long-term landscape evolution in South-West England. The sediments of the St Agnes Outlier, with their microflora of Miocene age, are one of only five on-land Miocene deposits known in the British Isles (Walsh *et al.,* 1996): this has major implications for interpreting the Cornish landscape. Ascription of the Beacon Cottage Farm Outlier to an earlier date than the St Agnes Formation, despite similar sedimentological characteristics, hinges on a museum sample for which there is no good locational or stratigraphic control. Indeed, Coque-Delhuille (1987) regards the provenance of this sample as too uncertain, and on these grounds rejected an Oligocene age for the Beacon Cottage Farm Outlier. If, as suggested, however, the sand and 'clay' beds around St Agnes Beacon do comprise two distinct outliers of mid-Oligocene and Miocene ages (Walsh *et al.,* 1987; Jowsey *et al.,* 1992), then the relationship of the Reskajeage Surface to these sediments is vital to understanding the age and mode of formation of this important macro-element in the Cornish landscape. Although it is clear that the surface underlies the Miocene St Agnes Formation, until recently the relationship of the surface to the older (mid-Oligocene) Beacon Cottage Farm Outlier has been less certain. Walsh *et al.* favoured the view that part of the St Agnes Outlier overlay that of the Beacon Cottage Farm (Figure 3.6), the surface of the latter possibly representing a stained and deeply weathered soil of mid-Tertiary age underlying the sub-Miocene unconformity. This view, however, is no longer tenable as there appears to be no overlap of the two formations (Jowsey *et al.,* 1992). If, as Walsh *et al.* have suggested, the Reskajeage Surface had been cut in Miocene times, and the overlying Miocene sediments (windblown and colluviated) have never been subject to marine inundation, then the same must be true of the mid-Oligocene Beacon Cottage Farm Outlier which lies at a similar altitude (Walsh *et al.,* 1987). The surface cannot therefore have been formed by marine agencies in the interval between the mid-Oligocene and Miocene. This tends to demolish the often-expressed view that this surface is of marine origin; especially implausible is the suggestion of marine planation cutting across wide areas of hard Devonian metasediments and forming steep slopes in granite at Carn Brea, yet at the same time not also removing the weak Tertiary sands and 'clays' exposed on the northern slopes of the St Agnes Beacon (Walsh *et al.,* 1987). The simplest hypothesis then is to regard the Reskajeage Surface as a subaerial surface; by implication, any marine trans gression or fashioning of the west-central Cornish landscape by marine agencies has been confined to levels below the Reskajeage Surface, and/or to pre-mid-Oligocene times.

This interpretation supports very strongly the view that the Cornubian Peninsula was more or less in its present form as early as the Eocene (Freshney *et al.,* 1982; Walsh *et al.,* 1987), and has subsequently only undergone what may be regarded as minor geomorphological alterations. Post-Eocene landscape evolution must therefore have been extremely slow; the only evidence for marine incursion on to the peninsula is a minor transgression at St Erth (Mitchell, 1965; Mitchell *et al.,* 1973a) during the Late Pliocene, and even this left no obvious bevel in the landscape (Walsh *et al.,* 1987).

This interpretation of the west Cornish landscape finds a close analogue with work carried out in Wales by Battiau-Queney (1984, 1987). She argued that in Wales there is only one, polygenetic planation surface, the original constituent landforms having been shaped in a tropical or subtropical environment with associated weathering products (e.g. Trefgarn Rocks — see Campbell and Bowen, 1989). Large-scale attitudinal variations were attributed by her to late Tertiary warping along relatively few major structural axes, the smaller-scale landforms, such as the tom at Trefgarn and Preseli (St Davids), being regarded as true Inselbergs' (Battiau-Queney, 1984). Walsh *et al.* (1987) speculated that the Reskajeage Surface is also therefore present in Wales, citing tightly folded and planed Upper Palaeozoics in south Dyfed overlain by postulated Oligocene clays at Flimston (Murchison, 1839). This view has been strengthened by the recent discovery of fossiliferous Miocene deposits on Anglesey, which lends further support to the concept of a widespread 'Reskajeage/Menaian Surface', and to the possibility that large areas of Britain were formerly smothered by extensive sheets of Miocene sediment (Walsh *et al.,* 1996).

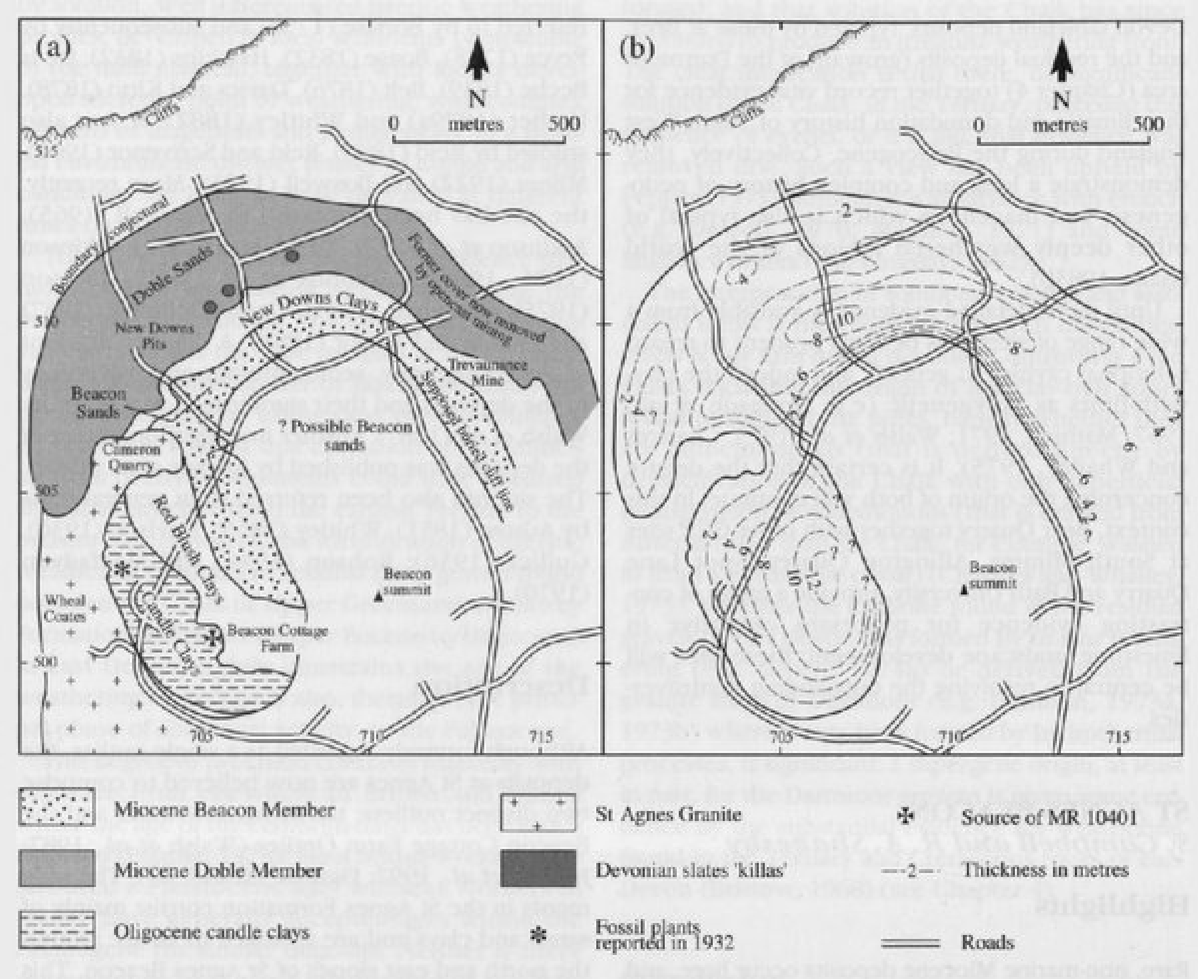
The Tertiary deposits near St Agnes Beacon therefore provide critical evidence to suggest that the macro-elements of the landscape in Cornwall (and perhaps farther afield) have changed comparatively little since the early Tertiary. In post-Tertiary times, geomorphological change has been essentially limited to comparatively small-scale modifications such as coastal denudation, valley incision and the redistribution of Tertiary weathering products (and less weathered rock) mainly by periglacial activity during Pleistocene cold phases.

The dating of the St Agnes beds as Tertiary, their highly eroded nature and location on a prominent headland on the north Cornish coast, make the proposition that Cornwall was ever inundated or even impinged on by a southward-moving ice sheet (even as early as the Anglian Stage) unlikely. The giant erratics of the Cornish coast (see Porthleven; Chapter 6), however, pose an intriguing problem as regards their mode of emplacement, as does the evidence for glacier ice having reached the nearby Isles of Scilly (e.g. Mitchell and Orme, 1967; Scourse, 1985a, 1987, 1991).

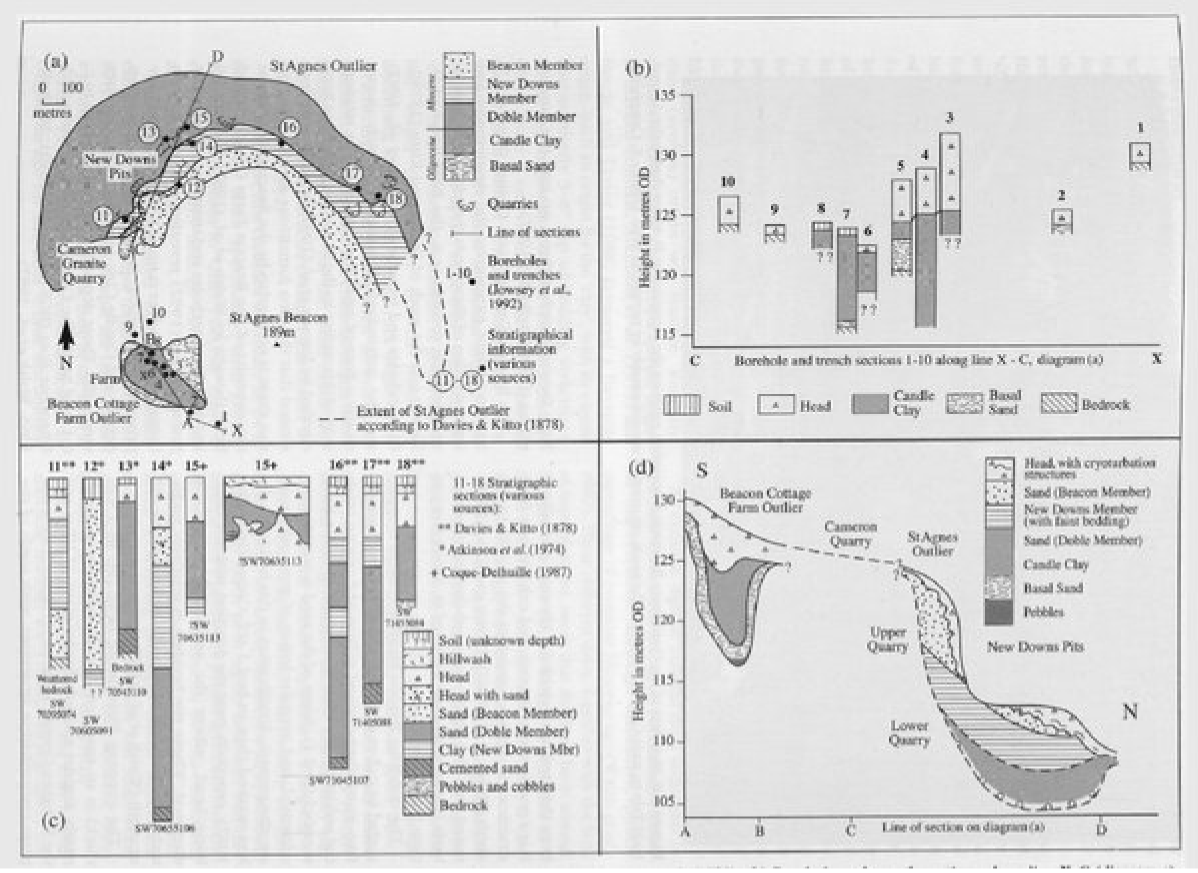
Conclusion

The St Agnes beds are not only of interest because of their Tertiary stratigraphy and implications for tectonic activity and high-level marine action, but also because of the important implications for land scape development during the Quaternary. First, the survival of these unconsolidated deposits on a promontory of the north Cornish coast is important evidence against glacier ice ever reaching Cornwall during the Pleistocene. Second, it also implies that repeated periglacial activity in the Pleistocene has been comparatively ineffective in redistributing unconsolidated sands and sandy silts on exposed slopes, even though freeze-thaw activity led to the production of angular debris from the bedrock slopes of St Agnes Beacon: thicknesses of up to *c.* 6.4 m of solifluction debris (head) were laid down and cryoturbation of upper sediment layers occurred. At the macro-scale, however, the implication is that the Cornish landscape has undergone only minor alteration to its late Tertiary form, notably with coastal modifications, valley incision and more limited alteration to general relief through periglacial action than some workers have advocated.

References



(Figure 3.6) (a) The geology of the St Agnes and Beacon Cottage Farm outliers as interpreted by Walsh et al. (1987). The area between Cameron Quarry and the Beacon was regarded as problematic and has been re-mapped by Jowsey et al. (1992) (Figure 3.7); (b) Isopachs of combined Tertiary and Quaternary sediment. (Adapted from Walsh et al., 1987.)



(Figure 3.7) (a) A revision of the St Agnes and Beacon Cottage Farm outliers by Jowsey et al. (1992). (b) Borehole and trench sections along line X–C (diagram a), adapted from Jowsey et al. (1992). (c) Stratigraphic sections along line D–C (diagram a), compiled from various sources. (d) Schematic reconstruction of the Beacon Cottage Farm and St Agnes outliers, based on Jowsey et al. (1992).

(Figure 3.8) Members of the Quaternary Research Association examine the sequence at St Agnes during the Annual Field Trip to west Cornwall in 1980. The sands are overlain unconformably by periglacial head. (Photo: S. Campbell.)