New evidence of the Cretaceous overstep of the Mendip Hills, Somerset, UK.

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Abstract

The Mendip Hills, located on the north-western margin of the Wessex Basin, clearly show the onlap of Upper Triassic to Middle Jurassic sediments onto folded Palaeozoic strata. Recent field mapping on the crest of the Beacon Hill pericline at Tadhill, near Frome, augmented by a suite of shallow boreholes, proved up to 6.2 m of glauconitic grey and green silty sand. These glauconitic sands rest unconformably on Silurian volcanic rocks and Devonian sandstone. Lithological and palaeontological analyses of these glauconitic sands indicate that they are part of the Lower Cretaceous Upper Greensand Formation. This provides the first evidence for the Albian transgression across the Mendip Hills. The implications for the Cretaceous overstep on the margins of the Wessex Basin, and the analogies with the Upper Greensand succession in Devon are discussed.

1. Introduction

Today, the Mendip Hills, located 20-30 km south of Bristol form an elongated upland plateau that extends some 40 km from the Bristol Channel coast east to Frome (Figure 1). This plateau, developed predominantly on the Carboniferous Pembroke Limestone Group, sits at around 260 m above sea-level (asl) in the west (central Mendips), descending to around 180-200 m asl to the east around Beacon Hill. A series of isolated summits, largely developed on Devonian sandstones (Portishead Formation), rise up to 50-80 m above the plateau surface, reaching a culmination on Black Down at 325 m asl. Around Frome, the Palaeozoic rocks become buried beneath the overlying Jurassic strata and the hills lose their topographic identity in the surrounding landscape. To the south and east of the Mendip ridge, the landscape is dominated by a series of Jurassic and Cretaceous cuestas, culminating in the Upper Greensand escarpment and the Chalk Group outcrop around Warminster and Westbury.

The geology of the Mendip Hills has been well documented in geological survey memoirs (Green and Welch, 1965; Kellaway and Welch, 1993); in local society proceedings (Simms, 1997); in undergraduate level geological field-work guides (Savage, 1977; Duff et al., 1985): and more general guides (Farrant et al., 2008a,b). The Hills admirably display the progressive overstep of Triassic and Jurassic rocks across older Palaeozoic strata through a sequence of impressive unconformities, including the famous De la Beche unconformity at Vallis Vale (De la Beche, 1846). Hitherto, no rocks younger than the Middle Jurassic have been identified on the Mendip plateau, despite outcrops of Cretaceous strata occurring at Postlebury Hill [ST 735 431], a few kilometres to the southeast. Consequently the extent and nature of the Albian transgression over the Palaeozoic outcrop on the north-western margins of the Wessex basin has to date been a matter of conjecture. Moreover, its role in the origin of the present topography, notably the Mendip plateau surface, is unclear.

Figure 1 – Topographical map of the East Mendips based on NEXTMap Britain elevation data from Intermap Technologies. The high ground of the Devonian Portishead Formation outcrop forms the prominent ridge of Beacon Hill. The nearest outlier of Upper Greensand to Tadhill is at Postlebury Hill.

The Mendip Hills consist of four en-echelon periclines. The three westernmost periclines have exposed cores of Devonian sandstone, flanked by Lower Carboniferous limestones (Figure 2). In the easternmost pericline at Beacon Hill, Silurian andesitic lavas, tuffs and Wenlock age mudstones crop out (Coalbrookdale Formation), which are in turn overlain by or faulted against Devonian sandstone, and Lower Carboniferous limestones. To the south, the margin of the Palaeozoic outcrop is marked by a series of boundary faults which form the northern edge of the Wessex Basin. To the north, the Lower Carboniferous strata plunge beneath the North Somerset coalfield, itself partially buried by Mesozoic rocks.

The Palaeozoic rocks were folded and faulted during the Variscan Orogeny, creating the classic asymmetric periclines which are so well displayed on the geological maps of the area (Farrant, 2008a,b). These form part of the Variscan Front, a belt of intense deformation that extends across much of southern England. This thrusting and folding (Williams and Chapman, 1986) was followed by prolonged period of dissection and erosion. This created a rugged, deeply incised range of hills aligned along the periclinal crests, surrounded by low lying basins, much like the present day topography (Duff et al., 1985). During the Triassic, the flanks of these hills were gradually buried by marginal breccias which pass basin-ward into the red mudstones of the Mercia Mudstone Group (Green and Welch, 1965). At the end of the Triassic, sea-level rise heralded the start of the marine sedimentation across the region. Throughout much of the Jurassic, the Mendip region was a structural high (Duff et al., 1985). A series of marine transgressions during the Early and Middle Jurassic gradually overstepped onto this structural high (Figure 2); for example at the base of the Pliensbachian (*jamesoni* Zone), in the Hettangian–Early Sinemurian and in the Late Bajocian (Wall and Jenkyns, 2004). The gradual onlap of these Mesozoic rocks over the elevated relief of the Mendips created a suite of spectacular unconformities, as well as localised near-shore and littoral sediments that are the thin time-equivalents of thicker, deeper-water facies in the surrounding basins (Donovan and Kellaway, 1984). Some of these Triassic, Lower and Middle Jurassic deposits are preserved in sediment-filled fissures (‘Neptunean dykes’) within the Carboniferous Pembroke Limestone Group (Wall and Jenkyns, 2004). These fissures formed during pulses of tectonic extension in Late Triassic to Middle Jurassic times. They include Lower Jurassic sediments that elsewhere were removed by erosion during Middle Jurassic transgressions.

Figure 2. Schematic geological cross-section across the southern limb of the Beacon Hill Pericline, showing the relationship of the Carboniferous, Triassic and Jurassic rocks.

It is generally accepted that the Mendips were buried by a thick Late Jurassic, Cretaceous and Palaeogene sequence, of which little evidence remains (Green and Welch, 1965; Savage, 1977; Simms, 1997). Ford and Stanton (1969) suggested that in post Inferior Oolite times, marine sedimentation was almost continuous until the end of the Cretaceous. Simms (1997) thought this accumulation of sediment may have been up to a kilometre thick. These premises should be reviewed in the light of the evidence presented in this paper and ongoing research. Only in the last few million years, following uplift and extensive erosion, have the Mendip Hills re-emerged from their deep burial to give the present ‘exhumed’ topography (Farrant and Smart, 1997).

2. History of Research

For nearly 200 years it has been widely accepted that the Mendip Hills were probably covered by Cretaceous strata including the Chalk and Upper Greensand, despite an absence of in situ deposits younger than Middle Jurassic age. In 1824, Weaver, (1824, p. 365) thought that the cherty sandstone at Chewton Mendip (Harptree Beds), were ‘more allied to the iron and green – sandstone’ found to the east near the border of Somerset and Wiltshire. This was presumably a reference to the Corallian Group Westbury Ironstone and Upper Greensand Formation. He clearly recognized the possibility that Cretaceous rocks may have been deposited upon the Mendip Hills. Jukes–Browne (1892 p. 280) calculated that if the base of his Malmstone (the Cann Sand Member of the Upper Greensand Formation; Bristow et al., 1995) was projected to the west of Westbury, above Frome, it would intersect the centre of the Mendip Hills at about 820 feet (245 m) asl. He further recognized (Jukes–Browne and Hill, 1900, pp 406-407) the possibility that the Mendip hills may have been an island when the Lower Gault was being deposited. He speculated that the base of the Gault may have lain at about 730 feet (223 m) asl in the vicinity of ‘Warren House Hill’ (Warren Farm [ST 619 467]) to the north of Shepton Mallet, also noting that the Mendip Hills were probably submerged during the Albian or Early Cenomanian times (Jukes–Browne 1922, pp 327). The implication here if Jukes-Browne’s reasoning was correct and assuming no differential uplift, is that a Lower Cretaceous marine erosion surface may have been developed on Palaeozoic and Mesozoic strata across eastern Mendip.

Although no evidence of in-situ Cetaceous strata has been recorded, circumstantial evidence of a former Cretaceous cover has been noted (Kellaway, 1991; Stanton, 1991; Stanton, 1999). During the geological survey of the Frome area (British Geological Survey Sheet 281) in the 1950’s, Ponsford noted spicular chert nodules in superficial deposits overlying Silurian volcanic rocks and Devonian sandstone around Tadhill [ST 679 462]. These he tentatively ascribed to being of Upper Greensand origin, and mapped as ‘Head’, but no in situ deposits of upper Jurassic or Cretaceous strata were identified or described. Ensom (1977) recorded possibly Cretaceous brown chert clasts in breccias at Barnclose Quarry [ST 6930 4775] and a brown, fossiliferous, possibly Upper Greensand chert west of Downhead [ST 6795 4582].

The formation of the prominent erosion surface that forms the Mendip Plateau around 250 – 280 m asl has been the subject of much debate. Smith (1975) recognised two schools of thought with regard to the age and formation of the plateau surface. Ford and Stanton (1969) postulated that following Miocene uplift, erosion removed all of the Cretaceous and most of the Jurassic strata and that the Mendip Plateau constituted a dissolution-lowered Pliocene – early Pleistocene surface. However, Donovan (1969a,b), thought that too little attention had been paid to the possibility that the plateau surface may have been a sub-Cretaceous feature. Across much of the central Mendips, outcrops of the Jurassic Lower Liassic and Inferior Oolite limestones have been replaced by chert. These cherts are known collectively as the 'Harptree Beds'. Both Ponsford (1970) and Kellaway (1991) associated the secondary silicification of these rocks with the Cretaceous seafloor. If this is the case, by inference, the outcrop of the Harptree Beds may provide an indication of the likely extent of Albian sedimentation over the East and Central Mendip Hills.

In the late 1970s possible Upper Greensand sediments and associated fauna were identified in a fissure/cave fill at Whatley Quarry (Ensom, 1977). Continuing fieldwork at Whatley Quarry in the late 1970s and early 1980s by P C Ensom, R P Shaw, and R D Vranch identified further fossiliferous glauconitic sediments infilling fissures developed within the Pembroke Limestone Group. Preliminary micropalaeontological studies of samples from one of these fissure systems yielded foraminifera which were tentatively assigned an Aptian age (P.

Copestake, pers. comm. 1985), suggesting a possible correlation with the Lower Greensand. However the quality of the micro-fauna was insufficient to allow a more precise age determination.

3. The Tadhill study site

The identification of chert clasts of possible Upper Greensand origin in field brash by Ponsford (Ponsford, 1970), and the recognition of Lower Cretaceous sediments in fissure fill deposits at Whatley (Ensom, 1977) led to the view that there should be a reassessment of the evidence for the occurrence of Cretaceous rocks on eastern Mendip. Detailed field mapping by R D Vranch identified Upper Greensand Formation chert in field brash throughout the eastern Mendip region from Frome as far west as the south flank of Beacon Hill [ST 643 454] at an altitude of c. 260 m asl, although none of it proved to be in situ. However, an area of orange-brown clay with traces of green sandy silt which yielded fragments of small oyster shells was identified at Tadhill, between Stoke St Michael and Leigh upon Mendip. This area, close to where Ponsford noted chert clasts of possible Upper Greensand origin in field brash, was selected for more detailed investigation.

An intensive geological mapping and drilling program was initiated, focussed on an area southwest of Tadhill [ST 679 462], 1.75 km southeast of Stoke St Michael. A 1.5 m deep trial pit was dug immediately south of the Old Wells Road [ST 6829 4638] at 229 m asl. This exposed bioturbated, orange/brown silty, sandy clay with localized patches of glauconite-rich sandy silt. In the basal 20 cm of the trench, sub-horizontal and vertical burrows with an average diameter of 1 cm were encountered. Each burrow was infilled with green, richly glauconitic silty sand in contrast to the surrounding silty sand in which glauconite grains were rare. The trial pit was extended with a deep, hand drilled auger hole (Borehole 7 – Table 1) which proved 6.17 m of glauconitic sandstone, silty sandstone and siltstone terminating in a basal conglomerate, possibly overlying weathered Silurian volcanic rocks, with no core recovery. To delimit the extent of these sands, the outcrop was mapped in detail using a hand held auger. This proved that the deposit was quite extensive (Figure 3), covering c. 0.5 km^2 on the crest of the plateau. The geometry of the outcrop indicates that these glauconitic sands rest unconformably on the Palaeozoic outcrop and is not a fissure fill deposit or the product of faulting.

These glauconitic sands rest on a gently sloping plateau that gradually descends eastward from 245 m asl down to c. 230 m asl, and is bisected by the Old Wells Road. This plateau lies on the eastern end of the Beacon Hill ridge, the easternmost of the four Mendip periclines, which rises to 295 m asl at Beacon Hill and 285 m near Cranmore Tower [ST 6764 4503].

The site is underlain by the Silurian Coalbrookdale Formation, which here consists of andesitic and rhyolitic lavas and tuffs (van De Kamp, 1969; Green, 2008) which have been shown to young to the north (Hancock, 1982). These are interbedded with tuffs and agglomerates and are underlain by marine sediments of Wenlock age. The northern half of the plateau is developed on the quartz conglomerates and sandstones of the Late Devonian Portishead Formation, which rest unconformably upon Silurian strata. To the south, a shallow valley drains eastwards, whilst to the north, the land drops down to a lower plateau developed on the Carboniferous Pembroke Limestone Group at c. 200-210 m asl.

Overlying the bedrock on the Tadhill plateau is an irregular shaped deposit of poorly sorted superficial gravels (‘Head’) of a type unique to the Mendip Hills, consisting largely of Cretaceous flint, Upper Greensand Formation chert, Tertiary ‘sarsen’ stones and gritty flint breccia/conglomerates set in brown sandy clay.

Figure 3. Geological map of Upper Greensand outcrop at Tadhill.

4. Lithology

To ascertain the thickness and lithology of the glauconitic sandstone and siltstone outcrop at Tadhill, six shallow boreholes were drilled using a lightweight, tracked Dando Terrier 2002 drilling rig (Table 1) in addition to the hand drilled auger hole. Cores were obtained using a percussion rig with a 102 mm core barrel. The borehole logs are shown in Figure 4 and are also available to view and download on the British Geological Survey's (BGS) borehole record viewer, accessed via the BGS website (http://www.bgs.ac.uk/data/boreholescans/). Figure 5 shows the complete sequence as seen in Borehole 5. These boreholes proved a variable amount of superficial gravelly Head overlying either the glauconitic sandstone or Palaeozoic rocks. The deposits encountered in the boreholes are described below.

Table 1. Borehole table

Figure 4. Tadhill borehole logs, correlated on the change from grey, silty, weakly glauconitic sand to darker green glauconitic sand. The boreholes are arranged from west (Borehole 1) to east (Borehole 3). The cores indicate that the basal unconformity with the underlying volcanic rocks has significant relief.

Figure 5. Upper part of Borehole 5, showing the glauconitic sand sequence exposed at Tadhill and the contact with the underlying Silurian volcanics. Top of borehole is upper left. Gradations on the scale bars are at 5 cm intervals.

4.1 Superficial deposits

Superficial Head deposits were noted in Boreholes 1 and 6, in the latter reaching a maximum proved thickness of 3.1 m. It consists of stiff, poorly sorted, mottled, reddish orange-brown, gravelly, sandy clay (Figure 6a). Numerous clasts of grey or white sub-angular to well-rounded chert similar to those present in the Upper Greensand outcrop around Devizes are present, which forms a good brash in ploughed fields. The clasts are typically small pebbles 0.5 – 4 cm diameter, but ranging up to small cobbles (typical maximum diameter of 10 cm) and are generally matrix supported. Most clasts are highly weathered or oxidised with a good weathering rind. Some well rounded quartz pebbles are also present, probably derived from the underlying Portishead Formation. The matrix is mostly pinkish-orange clay trending to reddish orange-brown, clayey, silty, gravelly sand with varying amounts of quartz granules and small chert fragments.

Figure 6. Borehole photographs of selected intervals in boreholes 4, 5 and 6. Gradations on the borehole photographs are at 5 cm intervals.

4.2 Glauconitic sandstone and siltstone.

All of the boreholes proved a sequence of glauconitic sandstone and siltstone, with the exception of Borehole 6. The thickest sequence was seen in Borehole 7, where 6.17 m was proved. A similar thickness, 5.7 m was proved in Borehole 3 nearby.

Two distinct glauconitic sandstone facies could be identified in the borehole cores, which can be correlated between Boreholes 3, 4 and 5 and in the hand drilled hole (Borehole 7). These are shown in Figure 4. The upper part of the sequence consists of firm, pale grey, greenish-orange, mottled, silty, fine-grained, well-sorted, glauconitic and weakly micaceous quartz sand (Figure 6b and 6c). This is well bioturbated with numerous burrows (*Chondrities* and *Thalassanoides*) infilled with dark bottle green glauconitic sand, especially towards the base of this unit. Some muscovite mica is present. Underlying this is much darker grey-green, glauconitic, slightly micaceous, fine-grained quartz sand (Figure 6b and 6c). Weathered glauconite or pyrite nodules form dark rusty brown spots. *Chondrites* burrows are locally present, and commonly infilled with grey clay (clay lined). The contact between these two facies is marked by a sharp bioturbated surface. Both units contain occasional bands of sediment containing small fragments of thin-shelled broken bivalves.

In Boreholes 3 and 5 the contact with the underlying Silurian volcanic rocks was seen. The base of the glauconitic sandstone and siltstone unit is marked by a basal breccio-conglomerate 0.3 m thick (Figure 6d), consisting of highly weathered porphoryritic andesite and rhyodacite clasts. These clasts are generally sub- to well-rounded pebbles, typically 5-10 cm in diameter. The interstices between the clasts are in-filled with dark green, glauconitic, fine-grained, silty sand. Clasts of weathered andesite were also encountered at the base of the hand-drilled Borehole 7.

4.3 Portishead Formation

In Borehole 6 the superficial deposits overlie the Portishead Formation, which in this area consists of moderately strong reddish to purplish brown indurated quartz sandstone. Some well rounded quartz pebbles were noted in the overlying superficial deposits which are probably derived from conglomeratic horizons within the Portishead Formation. Quartz conglomerates are known to crop out at Beacon Hill, 3.7 km to the west. The borehole was terminated at the contact with the Portishead Formation.

4.4 Coalbrookdale Formation

The Silurian succession in the Tadhill area is dominated by highly weathered, fractured orange-brown porphyritic andesite and rhyodacite. These massive lavas have weathered to a soft to firm clay containing many ghost phenocrysts of potassium feldspar (Figure 6e). This was soft enough to be drilled by a percussion rig to a depth of 8 m.

Detailed field mapping using closely spaced auger holes demonstrates that, unlike the Middle Jurassic unconformity exposed at Tedbury Camp quarry, the basal Upper Greensand unconformity surface at Tadhill is very irregular, with a relief of at least 6 metres. The margin of the glauconitic sand outcrop interdigitates with the adjacent Palaeozoic rocks in a very convoluted pattern (Figure 3), and the sand also occurs as isolated outliers across the Tadhill plateau. Similarly, small inliers of the Silurian volcanic rocks have been identified within the main glauconitic sand outcrop. Field mapping and the evidence from boreholes 4, 5 and 7 indicate that the glauconitic sandstone and siltstone unit thickens rapidly away from the southern margin of the outcrop on the south side of the Old Wells Road to c. 6 m adjacent to the road; a distance of a few tens of metres. It thins northwards to less than 5 m on the north side of the road. It is not present in borehole 6. The intricate outcrop pattern and rapid thickness variations may be due to localised faulting, but it is more likely that the sediments were deposited over a very irregular topography on the underlying unconformity.

5. Biostratigraphy

Ammonites and other diagnostic macrofossils are absent in the borehole core material. However, trial pits and surface brash in the field south of the Old Wells Road at [ST 681 463] yielded small bits of echinoid test and fragments of amphidontine oyster shells, probably *Amphidonte obliquatum* (Pulteney). One of the oyster fragments has ribs that project as thin extensions from the shell surface, and might be a fragment of *Gryphaeostrea canaliculata* (J Sowerby). Several horizons containing fragmentary mostly thin-shelled bivalves were identified in Boreholes 3, 4 and 5. Although fragmentary, some of the material from Borehole 5 is quite thick-shelled, and there are several fragments showing strong radial ribs and strongly serrated margins. One fragment has sharp spinose projections. The number of Cretaceous oysters showing the above features is not very extensive. The material might represent *Rastellum (Arctostrea) ex gr. carinatum* (Lamarck), which ranges throughout the Cretaceous. This is not typical of the Upper Greensand oyster fauna seen in the Shaftesbury–

Wincanton area, but the composition of the oyster fauna in the Tadhill material probably reflects the different environmental setting, possibly indicating higher energy (nearshore?) conditions.

5.1 Foraminiferal biostratigraphy

The foraminiferal biostratigraphy of the Late Albian of England is based on contributions by, for example, Hart (1973; 2000); Carter and Hart (1977); Price (1977); Frieg and Price (1982); Hart et al., (1989); and Hart and Harris (2012), and relies heavily on the distribution of key taxa in the Gault Formation. Unlike the Gault, the Upper Greensand Formation lacks rich and diverse microfaunal assemblages, as a result of unfavourable facies and decalcification at outcrop, so that calcareous microfaunas are biostratigraphically limited although attempts have been made to overcome these problems using borehole material (Woods et al., 2001; 2008; 2009; Wilkinson & Hopson, 2011). Wilkinson et al., (in press – this issue) have incorporated data from a series of boreholes across southern England in an attempt to identify a workable biostratigraphy (Figure 7). Although the Upper Greensand foraminifera recovered from the Tadhill site are very sparse, they can be compared to that zonation scheme. In this paper the macrofossil zonation follows that of Owen (1984), and not that suggested in recent revisions (Owen & Mutterlose, 2006), in which *H. varicosum* is regarded as a Zone.

Several samples were taken from each borehole for micropalaeontological analysis. In Borehole 3, microfossils were absent in the highest glauconitic sandstone sample examined, at a depth of 1.70 m. However, *Arenobulimina chapmani* was recorded at 3.8 m and although a long ranging foraminifer, it is not usually found above Foraminifera Zone UGS 4i, equivalent to Foraminiferal Zone 6 (upper) of the Gault Formation (Figure 7). It was found together with rare ostracods *Dolocytheridea* sp. cf. *D. bosquetiana* and *Schuleridea* sp. *Arenobulimina chapmani* was again recorded at a depth of 5.8 m where it was found with *Cribrostomoides nonionoides angulosa* a species that is characteristic of Gault foraminiferal Zone 5, but extends into Zone 6 (lower) where it goes into extinction. In terms of the Upper Greensand biostratigraphy, its extinction is within Zone UGS 2 (Figure 7).

Although rare, foraminifera were recorded throughout the Upper Greensand Formation of Borehole 4. *Cribrostomoides nonionoides angulosa* was found in all samples examined (at depths of 1.5, 2.1, 3.9 and 5.1 m); other species present were *Tritaxia singularis* (at 2.1 m) and *Haplophragmoides chapmani* and a fragment tentatively assigned to *Marssonella* sp. cf *M. ozawai* (at 5.1 m depth) together with a poorly preserved ostracod related to *Dolocytheridea* sp (at 2.1 m depth). The presence of *C. nonionoides angulosa* indicates that the succession in Borehole 4 does not range above foraminifera Zone UGS 2, approximately equivalent to Gault foraminiferal Zone 6 (lower). If the fragment of *Marssonella* at a depth of 5.1 m depth is correctly identified then the succession will fall entirely within Zone UGS2, but this is unclear at the moment.

Borehole 5 penetrated a micaceous Upper Greensand with bivalve chips at 1.4 m depth. This “gaize” lithology (a friable micaceous sandstone containing quartz, mica, glauconite, sponge spicules and globular silica) yielded rare *Cribrostomoides nonionoides angulosa, Arenobulimina chapmani, Haplophragmoides chapmani* and *Tritaxia singularis* together with a single valve of the ostracod *Cythereis* sp. As with the other two boreholes, the assemblage fits best with Foraminifera Zone UGS 2; Hart (2000) showed *C. nonionoides angulosa* to range up into the base of Gault Bed XIII and foraminiferal Zone 6 (lower). Samples from 2.4 m and 2.9 m depth were very shelly and despite the fact that bivalve chips were abundant in the microfossil preparations, both samples were barren of foraminifera and ostracods.

Figure 7. The relationship between the lithostratigraphy of the Upper Greensand Formation of southwest England, ammonite and foraminiferal zonal schemes ([1]after Wilkinson et al., in press; [2]after Hart, 1973a, 2000; Carter and Hart, 1977). The grey areas indicate where the Upper Greensand is not preserved. The age of youngest preserved Upper Greensand is variable, influenced by erosion in relation to local structural features, for example the Mid Dorset Swell, and more widespread erosion at the Albian – Cenomanian boundary.

6. Sedimentation and correlation.

The lithology of the deposit, coupled with the evidence from the macro- and micro-palaeontology clearly indicates that these glauconitic sands are part of the Upper Greensand Formation. Across the western part of the Wessex Basin the Upper Greensand Formation has been divided into four members (Bristow, 1985). These are (in ascending stratigraphical order): the Cann Sand Member, Shaftesbury Sandstone Member, Boyne Hollow Chert Member, and the Melbury Sandstone Member. The last named is Cenomanian in age, and is now regarded as part of the Chalk Group (Hopson, 2005). The resulting tripartite division can be mapped across the Upper Greensand outcrop between Shaftesbury and Westbury (Bristow et al., 1995, 1999; Hopson et al., 2007). The Cann Sand Member of the type area near Shaftesbury is 25 to 30 m thick and dated as *H. varicosum* Subzone (Bristow et al., 1995). The typical lithology is poorly consolidated, fine-grained, glauconitic, micaceous sand (Hopson et al., 2008). The overlying Shaftesbury Sandstone Member, 10 to 25 m thick in its type area, comprises coarse-grained, glauconitic silt to fine-grained sand and weakly calcite-cemented sandstone, capped by hard, oyster-rich, calcite-cemented glauconitic sandstone, traditionally termed the 'Ragstone' (Bristow et al., 1999). Above is the Boyne Hollow Chert Member, a glauconitic sandstone characterised by the development of horizons of chert and siliceous concretions, and locally beds of chert up to 0.6 m thick (Bristow *et al*., 1999). Northeast of Westbury, this tripartite division can no longer be recognised. Around Potterne and Devizes, the basal Cann Sand Member can still be identified but the rest of the sequence is subdivided into the Potterne Sandstone Member and Easterton Sandstone Member (Woods et al., 2008). The latter, a glauconitic sandstone, notably lacks chert.

The microfauna preserved in the Upper Greensand Formation at Tadhill suggest that the in situ sediments belong to the *Mortoniceras inflatum* Zone, probably within an interval within the *orbignyi* to *varicosum* subzones (Owen, 1984) although the *cristatum* subzone cannot be ruled out. This, coupled with the fine grained nature of the sediment and the lack of in situ chert nodules suggest that the sediments at Tadhill can be correlated with the Cann Sand Member. The lack of a complete sequence precludes detailed lithological correlation and it is not known whether the change in facies seen around Devizes extends across the Mendip high. However, the abundance of Upper Greensand chert in the overlying superficial deposits strongly suggests that the upper part of the sequence, corresponding to the Boyne Hollow Chert, was formerly present across the region.

7. Implications for the Cretaceous overstep of the Wessex basin margins.

The presence of the Upper Greensand Formation resting on Palaeozoic rocks at an altitude of c. 225-240 m asl has implications for the Cretaceous overstep of the Mendip Hills and other Palaeozoic ‘highs’ along the north-western margin of the Wessex Basin. These deposits at Tadhill are analogous to the Upper Greensand in Devon where the Upper Albian succession overlaps the Middle Albian and overstepping the Jurassic and Triassic to rest on Carboniferous and Devonian strata on the eastern side of the Bovey Basin (Hancock, 1969; Selwood et al; 1984). The nature of the sub-Albian unconformity exposed in Devon, and in particular the trace fossils preserved on its surface suggests not only that is was a regionally significant erosion surface, but one that was available for marine colonization for a considerable period after it had been cut (Gallois and Goldring, 2007). This overstep is associated with marked facies variations across Dorset and into east Devon. These are documented by Bristow et al., (1995); Gallois (2004); Hamblin and Wood (1976), and Wilkinson et al., (in press – this issue). The tripartite division seen around Shaftesbury changes over the Mid-Dorset swell and cannot be recognised in the Blackdown Hills, where a different lithostratigraphy is used (Gallois, 2004). This comprises the Foxmould Member, which represents part of a shallow-marine sand-bar complex that was influenced by weak tides and rare storms (Woods and Jones, 1976); the Whitecliff Chert Member and the Bindon Sandstone Member. Each of these members is separated by hardgrounds and omission surfaces. Further west, outliers of the Upper Greensand Formation in the Haldon Hills and on the eastern margin of the Bovey basin show continued thinning and attenuation towards the Cornubian landmass, with a highly variable sequence of Late Albian to Cenomanian sandstones and gravels probably associated with a marine flooding event. These have been divided into four members (Hamblin and Wood, 1976; Hopson et al., 2008). The lower two are considered to correlate broadly with the Foxmould Member. However, the deposits seen at Tadhill appear to be more indicative of the Shaftesbury sequence (Cann Sand Member) rather than the East Devon successions.

The progressive change from areally restricted deposition in the Weald and Channel sub-basins during the Aptian to more regional sedimentation across the whole of southern England in the Albian is documented by Ruffell (1992). This transgression occurred in an east to west direction with a series of transgressive/regressive pulses, and was most rapid during the Albian (McMahon and Underhill, 1995). Six major unconformity surfaces in the Lower to mid-Cretaceous of the Wessex Basin can be identified. Of these, only the upper two have been recognised in the wider East Mendip – Westbury area (Figure 8). Apart from the previously mentioned tentative assignment of an Aptian age for foraminifera obtained from a fissure deposit at Whatley Quarry, the present western limit of the Lower Greensand to the north of the Mendip Axis occurs around Seend and Devizes. Here it consists of a few metres of medium to coarse grained, poorly sorted, locally ferruginous and pebbly sand (Booth et al., 2011). It is overstepped by the Gault Formation, which in turn oversteps the Kimmeridge Clay and Corallian strata between Westbury and Frome. To the south of the Mendip Axis, Lower Greensand is also present in the Vale of Wardour, between Childe Okeford and Cann near Shaftesbury where it is also preserved as scattered pockets beneath the Gault Formation (Bristow et al., 1995, p.92; Hopson et al., 2007), and as far west as Lulworth Cove on the Dorset coast. The Gault Formation is still present on Postlebury Hill, near Cloford, 6.5 km to the southeast of Tadhill, where it rests on the Oxford Clay, but is demonstrably absent over the crest of the Beacon Hill pericline. No evidence for the Gault Formation has been found across East Mendip or in any of the fissure fills in the Carboniferous limestones (Wall and Jenkyns, 2004). Similarly, there is no evidence for much of the Upper Jurassic which, if deposited, was eroded away prior to the deposition of the Upper Greensand.

Figure 8. Overstep of the Albian unconformity across the north-western margin of the Wessex Basin onto the Palaeozoic outcrop. IO – Inferior Oolite Group, GO -Great Oolite Group. Inset: Cross-section of the intra-Aptian-Albian unconformity across East Mendip-Salisbury plain and Hampshire.

The evidence from the Tadhill area suggests that the higher parts of the Mendips were not overstepped until the Late Albian. This postdates the submergence of the London Platform (Ruffell, 1992), and is comparable with the age of the marginal Upper Greensand facies seen in Devon and East Dorset (Gallois, 2004). Here, overlying Mercia Mudstone Group, the Foxmould Member at the base of the Upper Greensand comprises 25 to 30 m of fine- and medium-grained, weakly cemented sandstones of *M. inflatum* Zone age.

Wall and Jenkyns (2004) suggest that there is a correlation between the development of extensional fissures and transgressive events. If true, then there should be evidence for Albian sediments preserved in fissure fills elsewhere in the region in addition to that identified at Whatley Quarry (Ensom, 1977). At Halecombe Quarry [ST 697 475] in 1980, a deep, c. 10 m, fissure was seen in the western face infilled with a green sediment which may have been from the Upper Greensand Formation but was quarried away before it could be investigated.

There is no evidence for any in-situ Upper Cretaceous strata, although the presence of Albian sediments strongly suggests that the Chalk Group once extended across the Mendips. Kellaway, (1971) recorded a fissure deposit at Holwell, [ST 728 450] containing Middle Chalk debris, whilst the presence of flint derived from the Chalk Group at Tadhill suggests a former Upper Cretaceous cover. Field work carried out during this study frequently encountered lumps of chalk up to 10 cm in size in field brash across the Eastern Mendips, although this is probably a consequence of agricultural land improvement.

The superficial cherty gravel deposits overlying the Upper Greensand Formation at Tadhill may be analogous to the chert and flint gravels that are preserved on the Haldon Hills (Hamblin, 1973) and around Sidmouth in East Devon (Isaac; 1981) which are thought to be Palaeogene in age. Here, the decalcification of the Upper Greensand has produced large amounts of sandy Head that locally cover much of the underlying succession. However, further work is required to determine the age of the superficial deposits at Tadhill, and they may simply represent periglacial solifluction deposits of Quaternary age derived from the degradation of the upper part of the Upper Greensand Formation sequence.

8. Conclusions

A series of shallow boreholes at Tadhill prove up to 6 m of glauconitic sand preserved in situ on the crest of the Mendip Hills at an elevation of c. 225-240 m asl. These rest unconformably on both the Silurian Coalbrookdale Formation and the Upper Devonian Portishead Formation. The evidence from the sedimentology and biostratigraphy clearly indicates that these are part of Upper Greensand Formation and can be correlated with the Cann Sand Member of the Shaftesbury area. Macro- and micro-palaeontological analyses indicate that these glauconitic sands are of Albian age, and belong to the *Mortoniceras* (*M.*) *Inflatum* Zone (*cristatum* to *varicosum* subzones). These sediments indicate that the Upper Greensand oversteps the Gault Formation onto the Mendip high, validating the predictions made by Jukes-Brown (1892 p. 280), Jukes-Brown and Hill (1900, p. 406-407) and Jukes-Brown (1922, pp 327) that the Mendip Hills may have been an island when the Lower Gault was being deposited.

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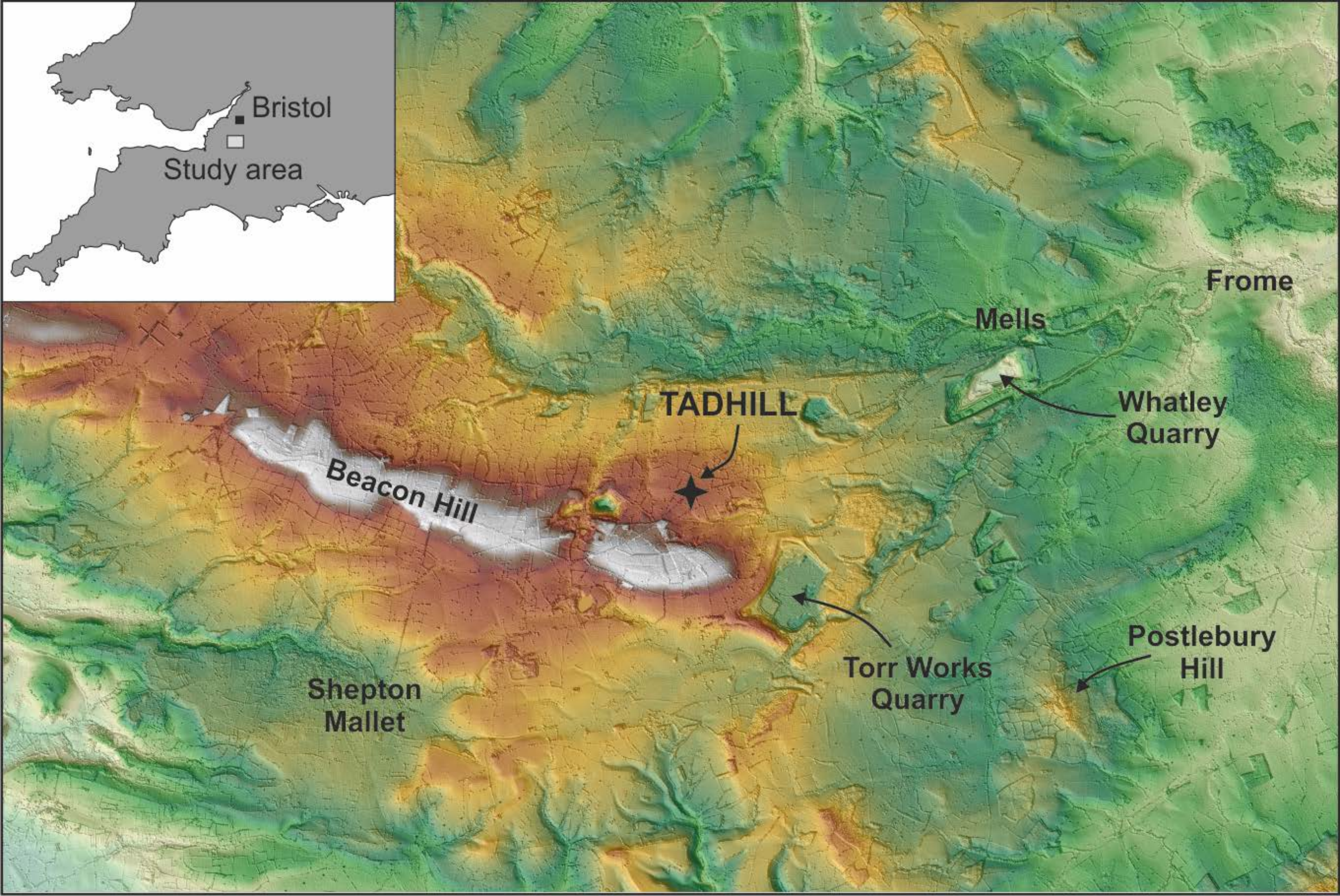
Tadhill No. 1	ST64NE_97	ST 67442 46474	Percussion	102 mm	3 m	241 m	3.2 m
Tadhill No. 3	ST64NE_98	ST 68166 46329	Percussion	102 mm	3 m	235 m	5.7 m
Tadhill No. 4	ST64NE_94	ST 68030 46402	Percussion	102 mm	3 m	237 m	5.0 m
Tadhill No. 5	ST64NE_100	ST 68059 46304	Percussion	102 mm	5 m	236 m	8.6 m
Tadhill No. 6	ST64NE_101	ST 67814 46393	Percussion	102 mm	2.8 m	237 m	3.1 m
Tadhill No. 7	n/a	ST 68291 46382	Hand auger	n/a	n/a	237 m	6.2 m



Bristol
Study area
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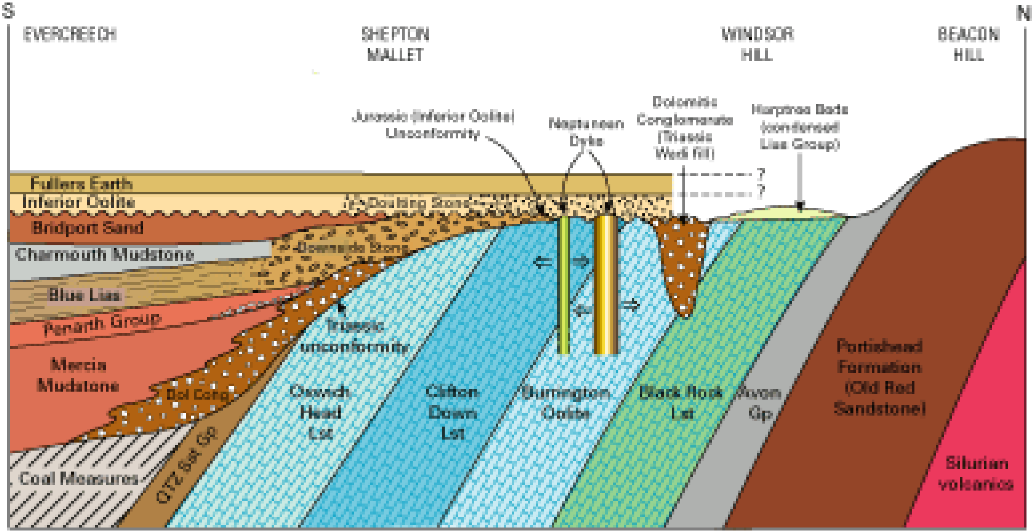
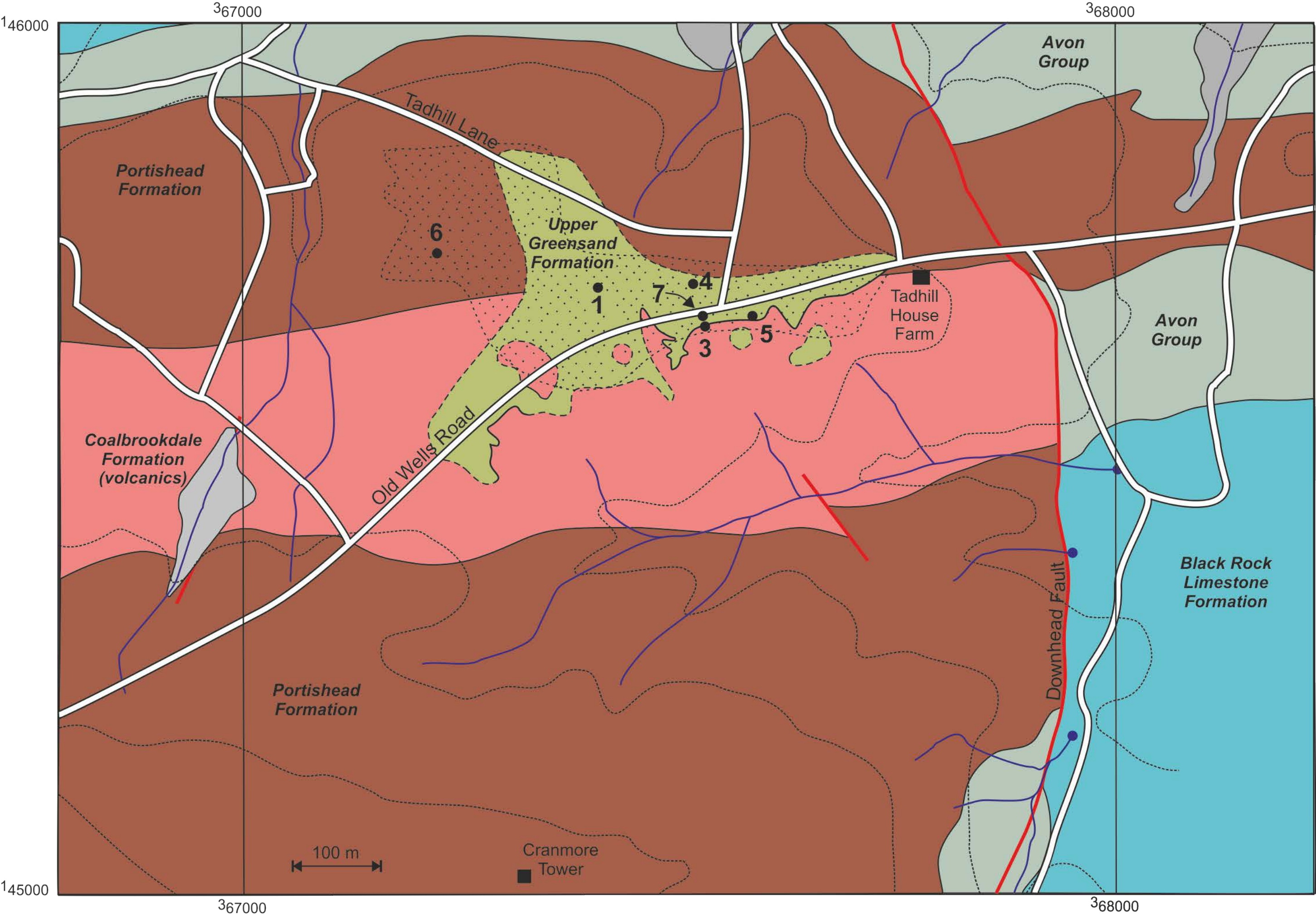
Mells
TADHILL
Whatley
Quarry
Beacon Hill
Torr Works
Quarry
Postlebury
Hill
Shepton
Mallet


S
N
EVERCREECH
SHEPTON MALLET
WINDSOR HILL
BEACON HILL
Jurassic (Inferior Oolite) Unconformity
Neptunean Dyke
Dolomitic Conglomerate (Triassic Wadi fill)
Harptree Beds (condensed Lias Group)
Fullers Earth
Inferior Oolite
Doulting Stone
Bridport Sand
Charmouth Mudstone
Downside Stone
Blue Lias
Penarth Group
Triassic unconformity
Mercia Mudstone
Dol Cong
Coal Measures
QTZ Sst Gp
Cromhall Head Lst
Clifton Down Lst
Burrington Oolite
Black Rock Lst
Avon Gp
Portishead Formation (Old Red Sandstone)
Silurian volcanics



367000
368000
146000
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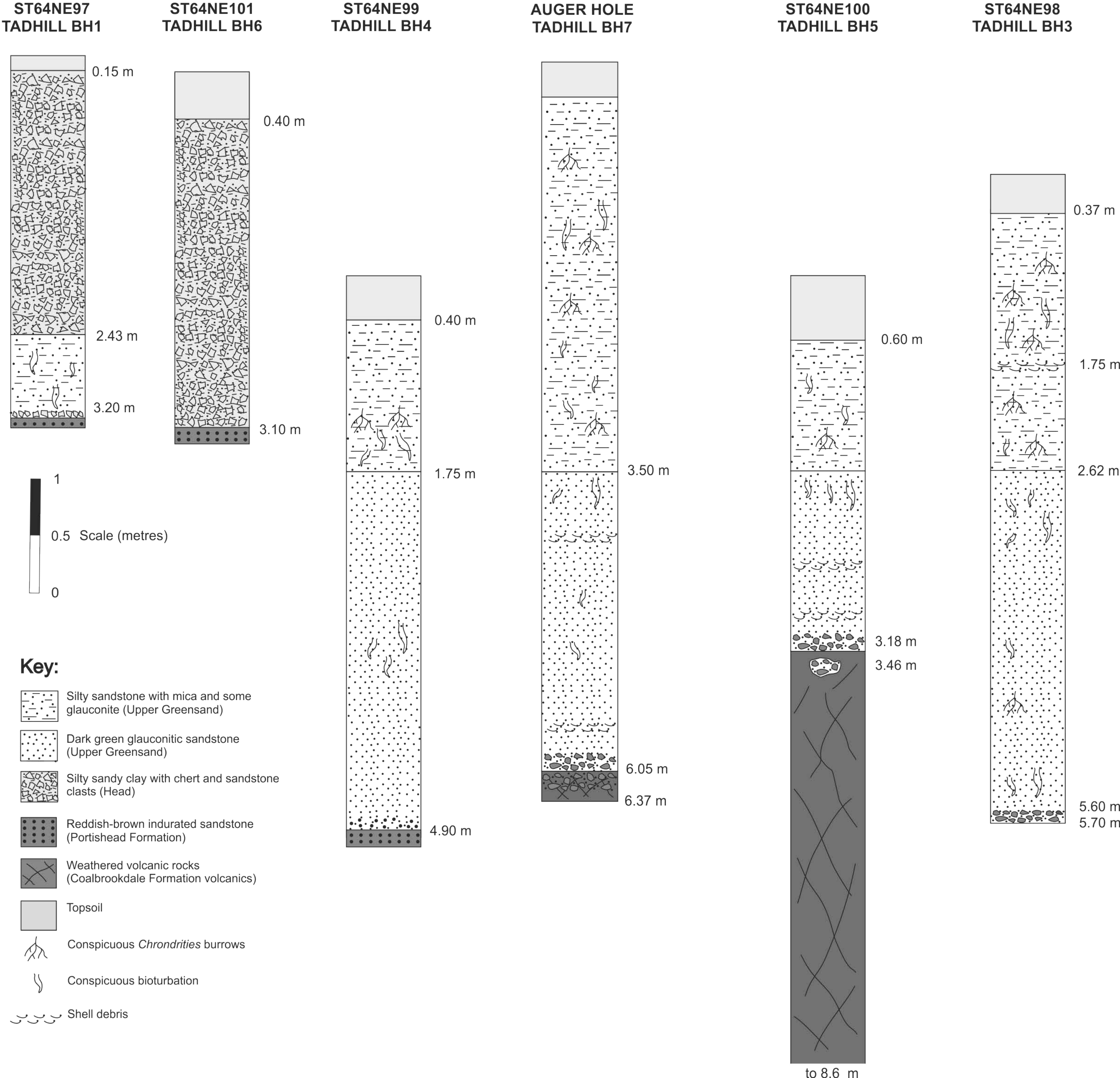
Avon Group
Tadhill Lane
Portishead Formation
Upper Greensand Formation
6
1
7
4
3
5
Tadhill House Farm
Avon Group
Old Wells Road
Coalbrookdale Formation (volcanics)
Black Rock Limestone Formation
Downhead Fault
Portishead Formation
100 m
Cranmore Tower
367000
368000


ST64NE97
TADHILL BH1
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TADHILL BH6
ST64NE99
TADHILL BH4
AUGER HOLE
TADHILL BH7
ST64NE100
TADHILL BH5
ST64NE98
TADHILL BH3
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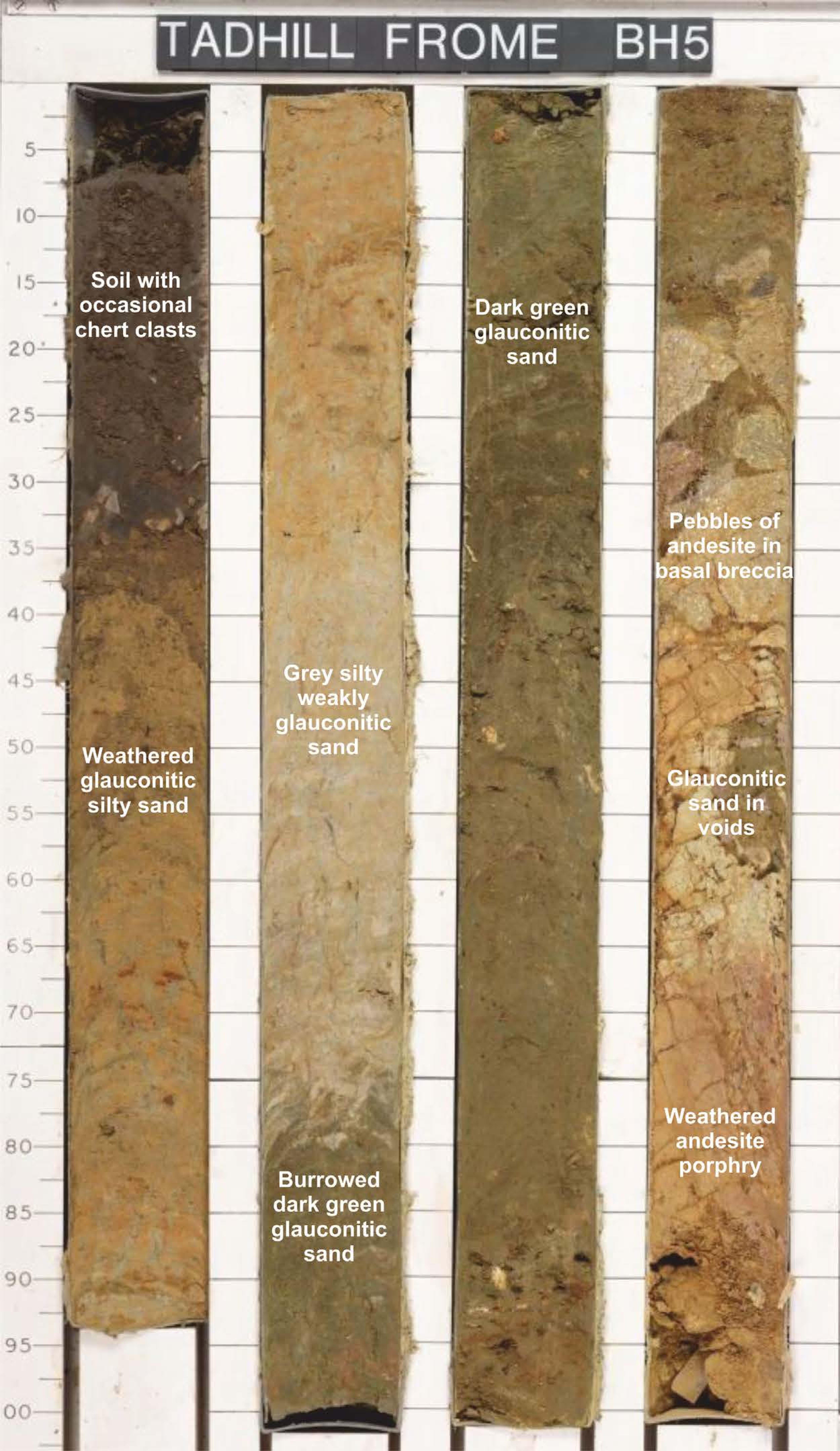
2.43 m
3.20 m
0.40 m
3.10 m
0.40 m
1.75 m
4.90 m
3.50 m
6.05 m
6.37 m
0.60 m
3.18 m
3.46 m
to 8.6 m
0.37 m
1.75 m
2.62 m
5.60 m
5.70 m
1
0.5 Scale (metres)
0
Key:
Silty sandstone with mica and some glauconite (Upper Greensand)
Dark green glauconitic sandstone (Upper Greensand)
Silty sandy clay with chert and sandstone clasts (Head)
Reddish-brown indurated sandstone (Portishead Formation)
Weathered volcanic rocks (Coalbrookdale Formation volcanics)
Topsoil
Conspicuous Chrondrities burrows
Conspicuous bioturbation
Shell debris


TADHILL FROME BH5
Soil with occasional chert clasts
Weathered glauconitic silty sand
Grey silty weakly glauconitic sand
Burrowed dark green glauconitic sand
Dark green glauconitic sand
Pebbles of andesite in basal breccia
Glauconitic sand in voids
Weathered andesite porphry
5
10
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95
00

A. Head with numerous chert clasts in brown silty clay, Borehole 6

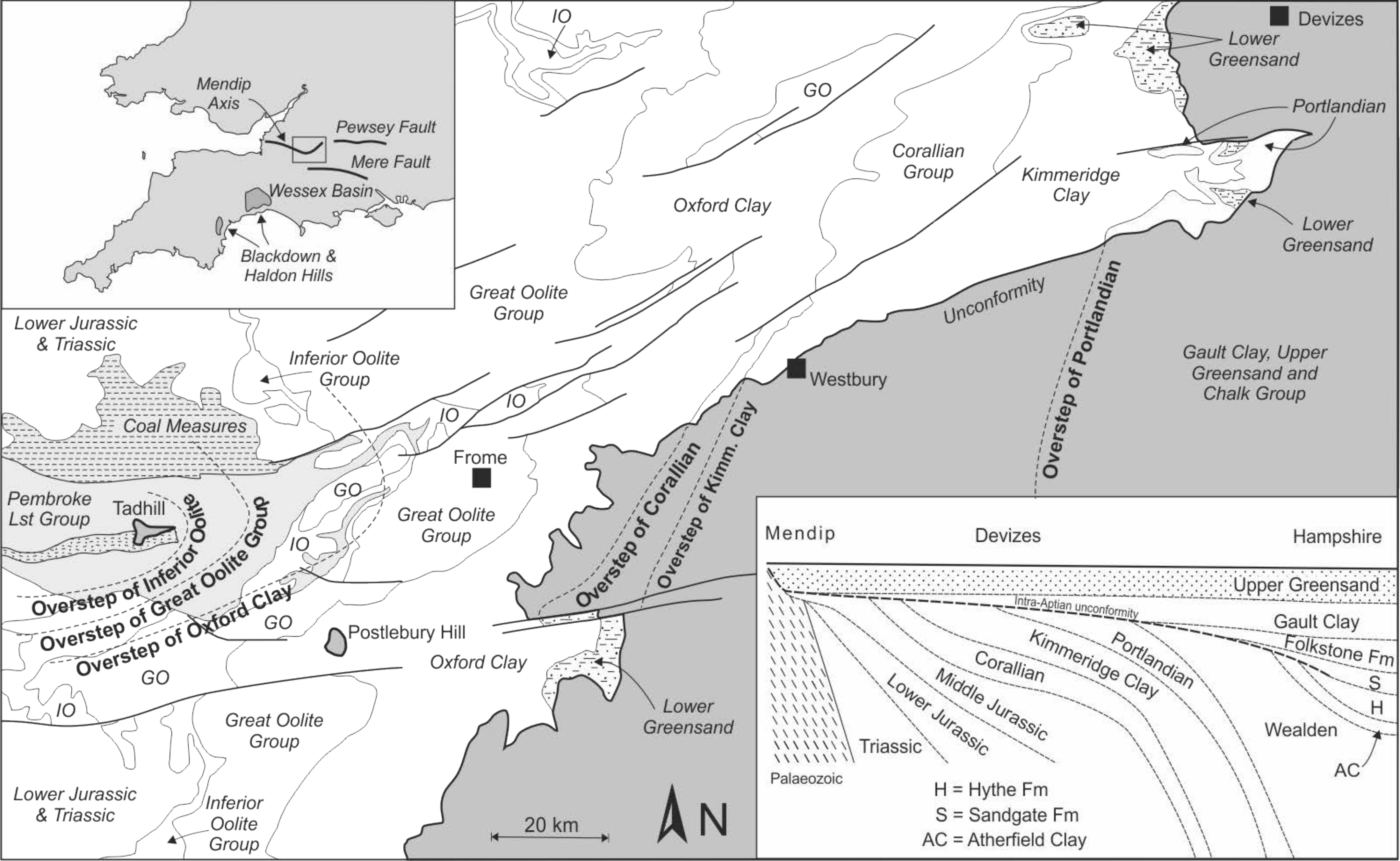
B. Contact between grey silt and glauconitic green sand, Borehole 5

C. Contact between grey silt and glauconitic green sand, Borehole 4

D. Contact between glauconitic sand and Silurian volcanics, Borehole 5

E. Weathered, fractured orange-brown porphyritic andesite, Borehole 5

Million Years	Stage	Established ammonite biozonation for the Late Albian (after Owen, 1984)		Ammonite biozonation for the Late Albian (after Owen and Muttterlose, 2006)		Foraminferal zones UGS[1]	Foraminferal zones Gault[2]	Lithostratigraphy W. Devon	Lithostratigraphy E. Devon	Lithostratigraphy Dorset	Lithostratigraphy Mendip	Lithostratigraphy Devizes
105	Late Albian	Stoliczkaia dispar	un-named	Stoliczkaia dispar	Arrhaphoceras (Praeschloenbachia) briacensis	UGS4ii	6 a	Bindon Sandstone Member	Eggardon Grit Member	Boyne Hollow Chert Member	*Not preserved*	Easterton Sandstone Member
			Mortoniceras (Durovarities) perinflatum		Mortoniceras (Durovarities) perinflatum	UGS4i	6 upper					
			Mortoniceras (M.) rostratum		Mortoniceras (M.) rostratum	UGS3	6 middle	Whitecliff Chert Member				
		Mortoniceras (M.) inflatum	Callihoplities. auritus	Mortoniceras (M.) inflatum		UGS2	6 lower	Foxmould Member	Shaftesbury Sandstone & Cann Sand Members			Potterne Sandstone Member
			Hysteroceras varicosum	Hysteroceras varicosum	Hysteroceras choffati						Upper Greensand Formation (undifferentiated)	Cann Sand Member
			Hysteroceras orbignyi		Hysteroceras binnum Hysteroceras orbignyi			Gault Formation (part)	Gault Formation (part)			Gault Formation (part)
107.5			Dipoloceras cristatum	Dipoloceras cristatum		UGS1	5a (part)					


Mendip Axis
Pewsey Fault
Mere Fault
Wessex Basin
Blackdown & Haldon Hills
IO
GO
Devizes
Lower Greensand
Portlandian
Corallian Group
Kimmeridge Clay
Oxford Clay
Lower Greensand
Great Oolite Group
Unconformity
Overstep of Portlandian
Lower Jurassic & Triassic
Inferior Oolite Group
Westbury
Gault Clay, Upper Greensand and Chalk Group
Coal Measures
Frome
Pembroke Lst Group
Tadhill
Overstep of Inferior Oolite
Overstep of Great Oolite Group
Overstep of Oxford Clay
Overstep of Corallian
Overstep of Kimm. Clay
Postlebury Hill
Oxford Clay
Lower Greensand
Great Oolite Group
Lower Jurassic & Triassic
Inferior Oolite Group
20 km
N
Mendip
Devizes
Hampshire
Upper Greensand
Intra-Aptian unconformity
Gault Clay
Folkstone Fm
S
H
Wealden
AC
Portlandian
Kimmeridge Clay
Corallian
Middle Jurassic
Lower Jurassic
Triassic
Palaeozoic
H = Hythe Fm
S = Sandgate Fm
AC = Atherfield Clay