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Contribution to the Sheet Description of theWells-next-the-sea district (Sheet 130) - Upper Cretaceous: Chalk Group (revised version of report IR/04/112)

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Contribution to the Sheet Description of the Wells-next-the-sea district (Sheet 130) - Upper Cretaceous: Chalk Group (revised version of report IR/04/112)

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Summary

This report is a revised version of report IR/04/112. It describes the stratigraphy of the Chalk Group in the Wells-next-the-Sea district (Sheet 130), and forms a contribution to the Sheet Description and Sheet Explanation.

1 Introduction

Chalk is typically a very fine-grained, white limestone, predominantly composed of the disaggregated skeletal remains (coccoliths) of tiny planktonic algae that flourished in the seas of the Late Cretaceous. The Chalk Group is composed of almost pure calcium carbonate in the form of low magnesian calcite, except the lower part, which contains up to 30% clay. Flints, clay-rich horizons (marls), beds of indurated, mineralised chalk (hardgrounds), and coarsely bioclastic chalk horizons also occur, and some of these are geographically extensive marker-horizons. The Chalk of north Norfolk, including the Wells district, in part belongs to the 'Northern Province' of Mortimore *et al*. (2001). This designation recognises differences in lithology and fauna of the Chalk of Yorkshire, Lincolnshire and northern East Anglia compared to southern England ('Southern Province'); differences that begin to appear in the Chalk extending north-eastwards from the Marlborough and Berkshire Downs into southern and central East Anglia ('Transitional Province'). In general, the Chalk of the 'Northern Province' is more indurated; a consequence of the secondary infilling of pore spaces by clacite, although the mechanism by which this has occurred is still unclear (Mortimore *et al*., 2001). Stylolites are also a feature of the Northern Province Chalk, as seen in the core of the Bircham Borehole at the southern margin of the Wells district (Fig. 1), and demonstrating that locally extensive pressure solution has occurred. Flints occur at lower stratigraphical levels in 'Northern Province' Chalk compared to southern England, and are more frequently of tabular form (Mortimore *et al*., 2001). However, not all of the north Norfolk Chalk succession is of Northern Province type, and it seems likely that the boundary between the Northern Province and Transitional Province fluctuated with time (Mortimore *et al*., 2001).

Although a separate lithostratigraphical classification is applied to the Chalk of the 'Northern Province' compared to southern England (Rawson *et al*., 2001; Table 1), as yet there is no agreed Chalk lithostratigraphy for the 'Transitional Province'. In the Wells district, an extensive cover of Quaternary sediments has prevented detailed mapping of the Chalk Group, the only mapped subdivision being the boundary between the Grey and White Chalk subgroups. However, sporadic outcrop and borehole data show that it is possible to locally recognise greater variation in the Chalk Group than is capable of being mapped (Fig. 1). Locally, a feature occurs above the base of the White Chalk that may equate with a level at or slightly below the 'Chalk Rock', and thus approximate to the base of the traditional 'Upper Chalk' (Table 1).

In the absence of outcrop data, biostratigraphy has historically been the key to understanding the Chalk of north Norfolk. The work of Peake and Hancock (1970) showed that macrofossil collections from more than 200 localities could be used to construct a biozonal map of the Chalk for the northern part of East Anglia. This work provides a more detailed picture of stratigraphical variation in the Chalk than can generally be achieved from feature mapping, and is a guide to correlation with successions to the north and south, and with the BGS Trunch Borehole [TG 2933 3455], a key reference borehole for the Chalk of north Norfolk (Wood *et al*., 1994). Figure 2 shows the occurrence and biozonal classification of localities in the Wells district, including those used in the construction of Peake & Hancock's biozonal map. The biozonal classification used by Peake & Hancock (1970), and in part employed on Fig. 2, differs from the standard macrofossil scheme; its relationship to current nomenclature is shown on Table 1. Microfossil samples from some of the localities on Figure 2 (numbered 1 to 10) were examined by I P Wilkinson for biostratigraphically significant foraminifera (Wilkinson, 2004). The results generally confirm previous biozonal assignments by Peake & Hancock (1970). An exception is the Titchwell Parish Pit [TF 762 433] (Locality 3 of Figure 2), assigned by Peake & Hancock (1970) to the *P*. (*S.*) *plana* Zone, but actually belonging to the *M. coranguinum* Zone on the basis of microfossil evidence (Wilkinson, 2004) and macrofossil data (Mortimore et al., 2001).

Localities near Stiffkey and Warham show that the youngest Chalk in the Wells district equates with the basal part of the Portsdown Chalk of southern England (Wilkinson, 2004), an interval in which marl seams typically occur. Marl seams have been recorded in the slightly younger *B. mucronata* Zone equivalent of the Portsdown Chalk in the Trunch Borehole (Wood *et al*., 1994), but there is no lithological data for the Wells district.

2 Stratigraphy

Boreholes at South Creake [TF 8573 3401] and North Creake [TF 8566 3863], in the southern and central parts of the Wells district, show the Chalk Group to be between 140 and 160 m thick thereabouts. Younger Chalk Group strata occur further east, making the maximum thickness of the Group about 300 m based on biozonal thickness data (Peake & Hancock 1970; Wood *et al*., 1994). Following Rawson *et al*. (2001), the Chalk of the Wells district has been subdivided into Grey Chalk Subgroup and White Chalk Subgroup, but extensive cover of Quaternary strata has prevented the mapping of formational boundaries. Nevertheless, a more detailed understanding of the succession can be gleaned from sporadic outcrops, boreholes and archival data.

GREY CHALK SUBGROUP

In the Bircham Borehole, just to the south of the Wells district, the Grey Chalk Subgroup is about 13 m thick (Fig. 1), compared to about 50 m in southern East Anglia (Bristow, 1990), and more than 70 m in southern England (Mortimore *et al*., 2001). A similarly thin Grey Chalk Subgroup occurs in the Trunch Borehole, and represents a regional trend of increasing condensation and induration of this interval in north Norfolk (Wood *et al*., 1994). The Subgroup comprises hard, marly chalk with stylolites, hardgrounds and shell-rich intervals. Its lithology is typical of the Grey Chalk Subgroup in the 'Northern Province' (= Ferriby Chalk Formation; Table 1), and several regionally developed marker beds can be recognised.

The basal part of the Grey Chalk Subgroup in the Bircham Borehole is represented by fragments of very hard, nodular and glauconitised chalk. This probably represents the Paradoxica Bed, named for the abundance of burrows of *Thalassinoides paradoxica* (Woodward) and seen at the base of the Chalk Group in the cliffs at Hunstanton, just west of the Wells district (Gallois, 1994). Above this, the Bircham Borehole contains a few metres of shell-rich chalk that probably represent the Lower and Upper Inoceramus beds, seen at Hunstanton and traceable into the Lincolnshire succession north of The Wash (Gaunt *et al*., 1992; Gallois, 1994). These bioclastic beds are largely formed or the fragmental remains of the bivalve *Inoceramus* ex gr. *crippsi* Mantell, but may include other forms.

The Totternhoe Stone is a widespread marker in the Grey Chalk Subgroup of northern, eastern and parts of southern England. In the Bircham Borehole it appears to be represented by 0.3 m of grey, marly and silty chalk with glauconitised pebbles overlying a glauconitised hardground. At Hunstanton the Totternhoe Stone is 0.7 m thick, and just over a metre thick in the Trunch Borehole (Gallois, 1994; Wood *et al*., 1994). The base of the Totternhoe Stone equates with the junction of the West Melbury Marly Chalk and Zig Zag Chalk formations in southern England. The higher part of the Grey Chalk Subgroup contains the Nettleton Stone, an indurated unit of slightly gritty chalk with an oyster-rich marl at its base. In the Bircham Borehole, a 0.2 m thick marl, containing oyster remains, occurs less than a metre above the inferred Totternhoe Stone, and might represent the base of the Nettleton Stone. The Nettleton Stone has been described at several localities in the adjacent King's Lynn district, including Dersingham [TF 7013 3092] and Heacham [TF 688 368], just to the west of the Wells district (Gallois, 1994), and it is widely developed in the Chalk north of The Wash (Whitham, 1991; Gaunt *et al*., 1994).

WHITE CHALK SUBGROUP

The White Chalk Subgroup probably has a maximum thickness of about 285 m in the Wells district, based on borehole and biozonal data. Although poorly exposed in the district, data from abandoned chalk pits and borehole records from adjacent areas provide some insight into the detailed stratigraphy.

The base of the Subgroup is the base of the Plenus Marls Member. In north Norfolk, the member is much attenuated compared to the several metres of clay-rich chalk that is typical of the unit in southern England. In the Kings Lynn district, the Plenus Marls are just a few centimetres thick, and have been recorded at Barrett Ringstead [TF 6787 3979] and in the former pit at Heacham [TF 688 368], just to the west of Sheet 130 (Gallois, 1994). In the Bircham Borehole, the Plenus Marls are not clearly visible in the core samples, however, their horizon is inferred from a small inflection on the resistivity log, coincident with a downward change from shelly, coarse-textured chalk to smooth-textured chalk (Fig. 1).

Hard, nodular, shell-rich chalk, occurs above the inferred Plenus Marls in the Bircham Borehole. This interval is just over 20 m thick, contains sporadic nodular flints, and is clearly represented by a distinctive high resistivity interval on resistivity logs for this borehole and the nearby Manor Farm Borehole at Docking (Fig. 1). The same interval was also recognised by Barker *et al.* (1984) as forming the lower part of the Welton Chalk Formation in the Killingholme Borehole in Lincolnshire (Fig. 1). The lowest part of this shell-rich interval at Bircham probably corresponds with the similarly bioclastic Holywell Nodular Chalk of southern England. However, the higher part of the shelly chalk at Bircham contains *Inoceramus cuvieri* and *Conulus subrotundus*, fossils that are typical of the New Pit Chalk of southern England. Therefore, lithological , biostratigraphical and geophysical evidence indicates that in the Wells district it is no longer possible to separate the Holywell and New Pit Chalk formations of the southern England classification. Instead, the best correlation is with the 'Northern Province' Welton Chalk Formation, equivalent to the combined Holywell, New Pit and basal Lewes Nodular Chalk of southern England (Table 1).

The higher part of the core in the Bircham Borehole is poorly bioclastic. It contains a thick (c. 50 mm) grey marl seam about 10 m above the top of the bioclastic interval, and an old core log for the highest part of the borehole (for which no core survives) records a thick (c. 0.3 m) flint interval. This succession is probably similar to that described in the Swaffham and Thetford districts by Mortimore and Wood (1986). These authors recorded a succession of named marker-marls (based on the work of Ward *et al*., 1968) in strata equivalent to the middle and higher part of the Welton Formation, capped by thick flints. There are four principal marl seams, comprising (in ascending stratigraphical order): the Pilgrims Walk Marl, the Mount Ephraim Marl, the Twin Marl and the Grimes Graves Marl (Fig. 1). The lowest two of these probably occur in the Manor Farm and Bircham boreholes, in the south-western part of the Wells district, and most have been identified in the Trunch Borehole. The marls can be recognised by distinctive inflections on borehole resistivity and gamma logs and form an easily correlatable framework (Fig. 1). The succession is very similar to the higher part of the Welton Chalk Formation and basal Burnham Chalk Formation described by Whitham (1991) in north-east England, and marl seam correlations have been established with this and the southern England succession (Mortimore and Wood, 1986; Fig. 1). The thick flint in the higher part of the Bircham core may relate to the flint-rich interval that occurs in the Thetford area, named the Brandon Flint Series, which correlates with the junction of the Welton and Burnham Chalk formations in Lincolnshire and Yorkshire (Mortimore & Wood, 1986).

The remainder of the White Chalk mostly equates with the Upper Chalk of traditional classification; an interval that is largely masked by Quaternary deposits in the Wells district. Historically, recognition of the base of the Upper Chalk in north Norfolk has been problematic because of poor surface expression of the indurated horizon ('Chalk Rock') traditionally used to map this boundary (Whitaker *et al*, 1893; Whitaker & Jukes-Browne, 1899). However, a topographic feature believed to be broadly coincident with the Chalk Rock was traced during the present survey and this line is shown on the map as a horizon within the lower part of the White Chalk Subgroup. Nevertheless, the generally poor exposure has meant that biostratigraphical subdivisions have formed the basis for previous lithological discussion of strata equivalent to the middle and higher parts of the White Chalk Subgroup within the district (Jukes-Browne & Hill, 1904; Peake & Hancock, 1970; Wood *et al*., 1994), and in the absence of any current means of systematic lithological subdivision, this method is adopted herein. Thickness estimates for zones are based on data from Peake and Hancock (1970) for the whole of north Norfolk and the Trunch Borehole (Wood *et al*., 1994).

Plesiocorys (*Sternotaxis*) *plana* Zone (25 to c 37 m thick): Exposures of this interval occur at several localities in the eastern part of the Wells district (Fig. 2). At Bircham Newton [TF 7695 3390] Jukes-Browne & Hill (1904) recorded hard, white chalk with grey, nodular and tabular flints at regular intervals and larger, Paramoudra-like flints. In the Trunch Borehole, the *plana* Zone succession compares closely with the Burnham Chalk of north-east England and many of the key flints and marls can be correlated between the successions. Locally, in the Wells district, the *P*. (*S*.) *plana* Zone is coincident with a feature, possibly formed by the 'Chalk Rock' and therefore marking the base of the traditional 'Upper Chalk'. North and north-east of Sedgeford, this feature is only 20 - 30 m above the base of the White Chalk Subgroup, but at least 40-50 m of White Chalk Subgroup probably occur below the *P*. (*S*.) *plana* Zone in the Bircham and Docking boreholes (Fig. 1). Evidence from the Trunch Borehole suggests that this discrepancy might possibly be explained by rapid northward thinning in the lower part of the White Chalk Subgroup.

Micraster cortestudinarium Zone (c. 20 m thick): There are no known exposures of this zone in the Wells district, but the fauna from this interval in the Trunch Borehole shares features with the succession in north-east England (Wood *et al*., 1994).

Micraster coranguinum Zone (51 to c. 76 m thick): Mortimore *et al*. (2001) recorded that the chalk of this interval resembled the Seaford Chalk Formation of southern England, and that flinty chalk with marl seams, equivalent to the basal part of the Seaford Chalk, occurred in the Titchwell Parish Pit [TF 762 433] in the north eastern part of the Wells district. Chalk belonging to the *coranguinum* Zone mostly occurs in the central part of the Wells district (Fig. 2), and at South Creake [TF 8553 3625] is 'rather hard chalk with layers of flint' (Jukes-Browne & Hill, 1904). The moderately high diversity of the fauna recorded at South Creake (Woods, 1998) might suggest assignment to the higher (Santonian) part of the *coranguinum* Zone. In the Trunch Borehole there are possible correlatives of named flint marker beds in southern England. This record of flint in the higher part of the *coranguinum* Zone, and its known occurrence in superjacent zones in north Norfolk, contrasts with the complete absence of flint in the partly coeval Flamborough Chalk Formation in north-east England (Whitham, 1993).

Uintacrinus socialis Zone (see *M. testudinarius* Zone for thickness): In north Norfolk, this interval comprises soft chalk, mainly lacking flint (Peake & Hancock, 1970, fig. 3). There is a record of the occurrence of this zone near East Barsham (Fig. 2).

Marsupites testudinarius Zone (28 to 42 m thick, including *U. socialis* Zone): There are at least four localities in the eastern part of the Wells district where chalk belonging to this zone has been recorded (Fig. 2). The chalk is apparently similar to that belonging to the *socialis* Zone (Peake & Hancock, 1970), but Jukes-Browne & Hill (1904) noted rather hard *testudinarius* Zone chalk at Houghton St. Giles [TF 9235 3542]. Faunas from Houghton St Giles include common oysters, especially *Pseudoperna boucheroni* (Woods, 1998), suggesting that the oyster-rich bioclastic facies that overlies the *testudinarius* Zone in the Trunch Borehole might here occur within this zone.

Uintacrinus anglicus Zone: There is no record of this zone in north Norfolk, although it probably occurs in the southern part of East Anglia and definitely occurs in north-east England (Mitchell, 1995). Any strata that do equate with this zone presumably form the basal part of the overlying 'Zone of *Gonioteuthis*' (sensu Peake & Hancock, 1970).

'Zone of *Gonioteuthis*' (78 to c. 97 m thick): The chalk assigned to this interval by Peake & Hancock (1970) equates with the (?*U. anglicus* Zone), *O. pilula* Zone, and the greater part of the *G. quadrata* Zone of southern England (Table 1). The highest part of the *quadrata* Zone, assigned to the 'Basal *mucronata* Chalk' by Peake & Hancock, 1970 (Peake & Hancock, 2000), occurs outside the Wells district. In the eastern part of the Wells district, 14 localities are assigned to the 'Zone of *Gonioteuthis'* (Fig. 2), the best exposure being the former quarry at Wells [TF 928 429]. Here, nearly 40 m of succession was visible, equating with the upper *O. pilula* Zone and lower *G. quadrata* Zone of southern England. The succession contained flint and marl seams, suggesting similarity to the Newhaven Chalk Formation of southern England (Peake & Hancock, 1970, 2000; Mortimore *et al*., 2001). A strongly developed marl in the Wells succession has previously been correlated with the Old Nore Marl in the Newhaven Chalk of southern England (Wood *et al*., 1994), but may in fact be younger, and closer to the top of the *pilula* Zone (Mortimore et al., 2001). In the Trunch Borehole, coarse-grained, bioclastic chalk occurs in the lower part of the *pilula* Zone, and this facies, characterised by common oyster remains, appears to occur at several localities near Wells and also at Great and Little Walsingham (Woods, 1998). Microfossil data from localities near Warham and Stiffkey show that the chalk thereabouts equates with the basal part of the Portsdown Chalk of southern England (Wilkinson, 2004; Table 1).

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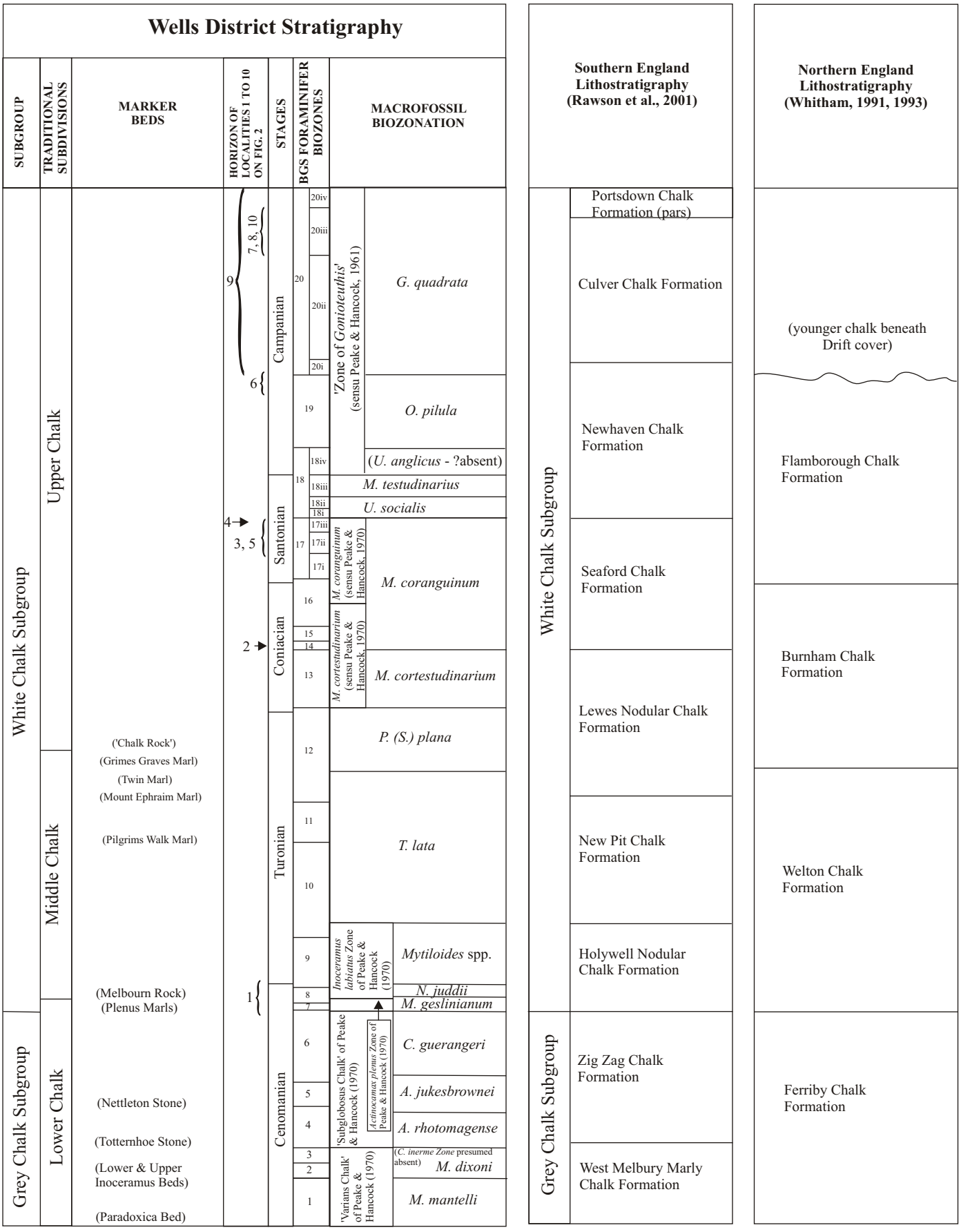

TABLE 1. The stratigraphy of the Chalk Group in the Wells district, and its relationship to lithostratigraphical subdivisions in southern England and north-east England.

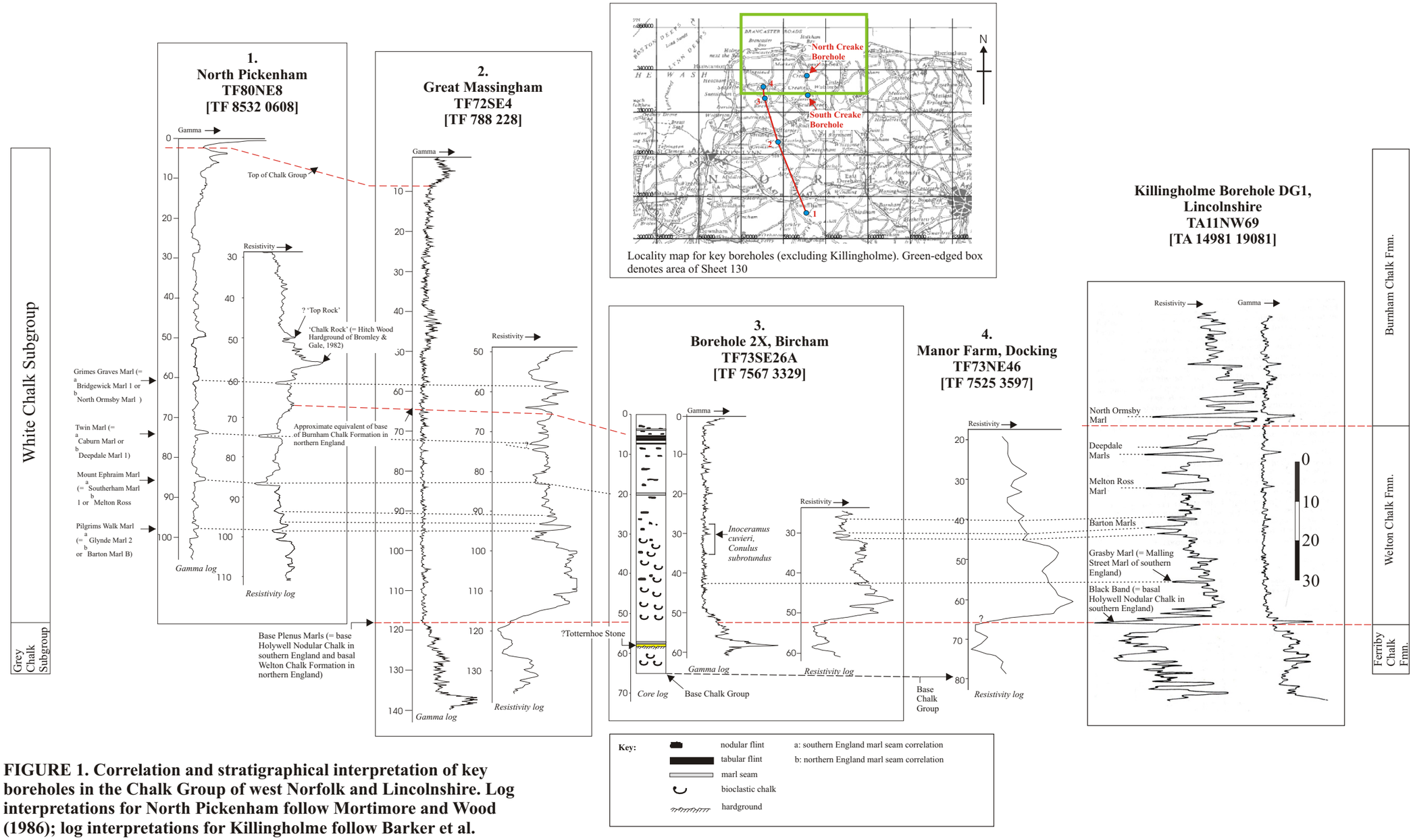

FIGURE 1. Correlation and stratigraphical interpretation of key boreholes in the Chalk Group of west Norfolk and Lincolnshire. Log interpretations for North Pickenham follow Mortimore and Wood (1986); log interpretations for Killingholme follow Barker et al. (1984).

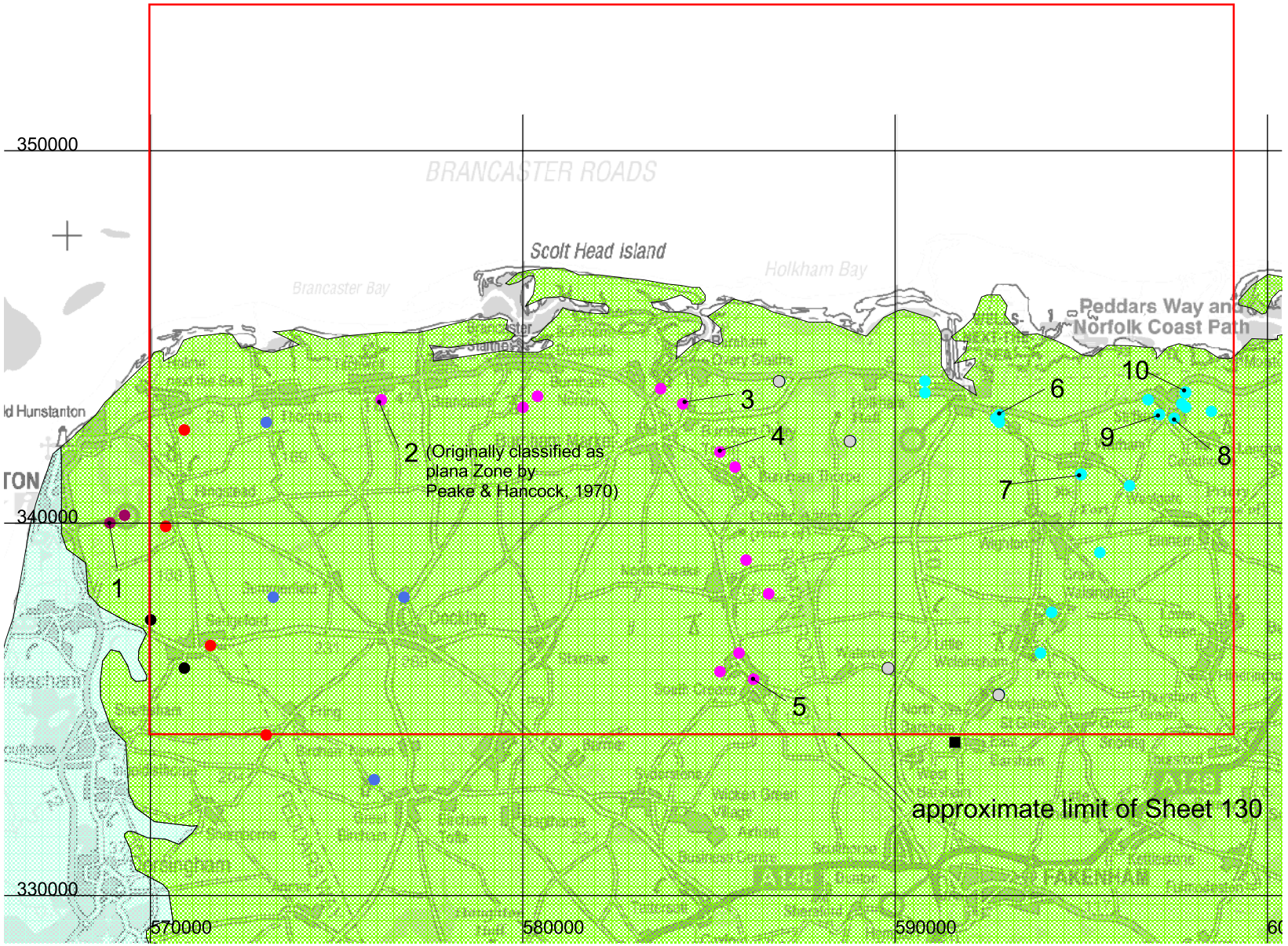

FIGURE 2. Occurrence of Chalk Group biozones in the Wells district. Based on data from N B Peake (BGS archives) and I P Wilkinson (see text).

KEY:

- 'Subglobosus Chalk' sensu Peake & Hancock (1970) (see Table 1)
- Mytiloides spp. Zone & T. lata Zone
- T. lata Zone
- P. (S.) plana Zone
- M. coranguinum Zone sensu Peake & Hancock (1970) (see Table 1)
- U. socialis & M. testudinarius Zone
- M. testudinarius Zone
- Gonioteuthis Zone sensu Peake & Hancock (1970) (see Table 1)
- 1 to 10 Localities shown on Table 1