

Palaeoecological trends in Turonian-Coniacian (Late Cretaceous) calcareous nannofossils from Chalk Group sections, SE England

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Abstract Turonian-Coniacian calcareous nannofossils were documented from three sections in south-eastern England: Baldock Bypass, a temporary road-cut section in Hertfordshire; Kensworth Quarry, Berkshire; and New Pit Depot, Sussex. The sections were dated and correlated using nannofossil biostratigraphy and lithostratigraphy. Quantitative assemblage data reveal a synchronous acme event of *Braarudosphaera* and *Nannoconus* in the Baldock and Kensworth sections close to the Turonian/Coniacian boundary, which may have been caused by shallowing. Morphometric data highlight dwarfing trends in the species *Watznaueria barnesiae*, with smaller coccoliths occurring in volcanically-derived marls, suggesting a possible productivity control, related to increased nutrient input.

Keywords Turonian, Coniacian, *Braarudosphaera*, *Nannoconus*, *Watznaueria barnesiae*, dwarfing, England

1. Introduction

A number of Mesozoic calcareous nannofossil studies have suggested links between morphological and abundance trends and palaeoenvironmental change (e.g. Williams & Bralower, 1995; Erba, 1994, 2004; Mutterlose & Ruffell, 1999; Lees, 2002; Bornemann *et al.*, 2003; Mattioli *et al.*, 2004). Very few of these studies have focussed on Late Cretaceous time-intervals (e.g. Gale *et al.*, 2000; Lees, 2002; Elson & Bralower, 2005; Frank *et al.*, 2005), and none have specifically studied the Turonian-Coniacian interval.

Three Turonian-Coniacian Chalk Group sections have been studied from localities in SE England (Figure 1). Two trends, thought to be palaeoecologically significant, were found in these sections. Firstly, periodic dwarfing trends are seen within the species *Watznaueria barnesiae*, found in all three sections. Secondly, a *Braarudosphaera* and *Nannoconus* acme event is present in the Turonian/Coniacian boundary interval in the Baldock and Kensworth sections.

W. barnesiae is ubiquitous in marine Cretaceous sediments, often dominating nannofossil assemblages. This has led to palaeoecological comparisons with the extant *Emiliana huxleyi* (e.g. Street & Bown, 2000), which dominates many modern assemblages across a broad range of environments, and is widely accepted as being r-selected (*i.e.* capable of rapidly reproducing and of displaying opportunistic behaviour). However, such interpretations are never straightforward, and abundance variations in *Watznaueria* are most commonly considered to reflect either preservation (e.g. Roth & Krumbach, 1986) or complex productivity signals (e.g. Watkins, 1989; Mutterlose & Kessels, 2000; Lees *et al.*, 2004; Watkins *et*

al., 2005). One of our aims in this study was to establish whether morphometric trends observed through the sections were a preservational effect or a primary assemblage characteristic.

Braarudosphaera and *Nannoconus* are generally uncommon in Late Cretaceous sediments (e.g. Lees, 2002), although increased abundances are occasionally encountered (e.g. Cunha & Shimabukuru, 1997; Svábénická, 1999). Whilst *Braarudosphaera* is an extant taxon, *Nannoconus* became extinct in the Late Campanian, making palaeoecological inferences more

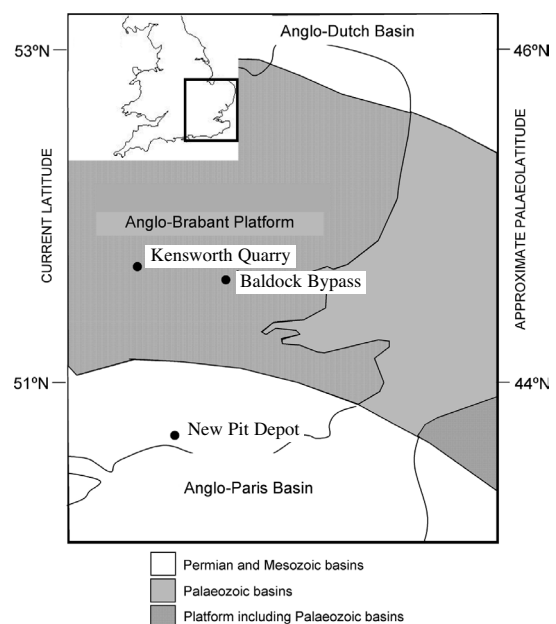


Figure 1: Location map showing sampled sites. Modified after Mortimore *et al.* (2001)

difficult for this latter genus.

Modern and fossil *Braarudosphaera* are typically restricted to shelf settings, and their distributions must be influenced by some aspect of the neritic environment, perhaps salinity and/or fertility (Bown, 2005). However, there are important fossil exceptions to this neritic biogeography, most notably the widespread oceanic Oligocene *Braarudosphaera* laminae reported from the South Atlantic Ocean (Kelly *et al.*, 2003). *Braarudosphaera* is also prominent in post-Cretaceous/Tertiary boundary extinction assemblages (*e.g.* Gartner, 1996). The origins of these anomalous acme occurrences are still uncertain, but appear to represent opportunistic behaviour.

Studies on *Nannoconus* have concentrated mainly on the Lower Cretaceous (*e.g.* Roth & Krumbach, 1986; Mutterlose, 1989; Busson & Noël, 1991; Erba, 1994). *Nannoconus* was abundantly present in the marginal basins of the circum-western Tethys, proto-Atlantic and Caribbean, and was periodically more widely distributed (Mutterlose, 1989, 1992; Street & Bown, 2000). This distribution pattern has led to a range of explanations concerning their biology and palaeoecology, but most have noted the link with tropical, sediment-starved shelves and the association with braarudosphaerids (Roth & Krumbach, 1986; Mutterlose, 1989; Bown, 2005). The relationship between nannoconids and surface-water fertility has been discussed by a number of authors, and many have suggested that they were adapted to oligotrophic environments. This interpretation is based largely on the inverse relationship between nannoconid and coccolith abundances, and the decline of nannoconid abundances through oceanic anoxic event successions (Busson & Noël, 1991; Coccioni *et al.*, 1992; Erba, 1994; Watkins *et al.*, 2005). However, Cunha & Shimabukuru (1997) reported alternating *Nannoconus*- and *Braarudosphaera*-rich horizons in laminated sediments from the Turonian South Atlantic (Santos Basin, Brazil) attributing these to eutrophic conditions. Also, the black shales of the Albian OAE1b in southern France are enriched in nannoconids (Kennedy *et al.*, 2000; Herrle, 2003; Nagai *et al.*, 2002), and so the relationship between organic-rich sediments, productivity and nannoconids may not be straightforward (Herrle, 2003).

2. Materials and methods

The Kensworth Quarry and Baldock Bypass samples were provided by H. Bailey (Network Stratigraphic Consulting, Ltd.), and the New Pit Depot samples were collected by R. Mortimore (University of Brighton). All three sections are dominated by moderately lithified chalk lithologies of the Lewes Nodular Chalk Formation, with flint-nodule levels and occasional clay-rich 'marl' horizons. All but one of the marl beds in the sections studied appear to have been derived from volcanic ash, based on the geochemical study of Wray & Wood (1998). Samples were studied from all the significant lithostratigraphic

horizons.

For light-microscope examination, the samples were prepared as simple smear-slides, by cleaning a surface of the sample by scraping and rinsing, then scraping a small amount of sediment onto a glass coverslip. The sediment was then mobilised with distilled water, spread over the coverslip using a flat-sided toothpick and placed on a hot-plate. To aid biostratigraphic counts, a striped effect was created, to ensure that each traverse included thick and thin areas of sediment, to include both small and large elements of the assemblage. When dry, the coverslip was attached to a glass slide using Norland Optical Adhesive and placed in a UV-box for one hour to cure the mounting medium. For the purpose of scanning electron microscope (SEM) illustration of the nannoconid and braarudosphaerid acme, one sample was filtered (by J.A. Lees), following the methodology of Minoletti *et al.* (2001), in order to concentrate the 8-10 μ m fraction that contained these taxa.

Analysis of the nannofossils was conducted using an oil-immersion-objective Olympus BH-2 light-microscope at 1000x magnification. Each slide was viewed for approximately one hour in order to biostratigraphically date the samples using the UC biozonation of Burnett (1998). Each sample was then quantitatively analysed, counting the first 300 specimens in fields of view of comparable densities. Morphometric analysis of *Watznaueria barnesiae* was achieved by measuring 50 specimens per sample from fields of view chosen at random using an eye-piece graticule. Specimens were viewed in cross-polarised and transmitted light in order to determine maximum length, and 2950 specimens were measured in total.

3. Results

3.1 Biostratigraphy

The 60 samples studied from the three sections (Figure 2) yielded a total of 60 Turonian and Coniacian taxa (Wyton, 2006). The majority of samples showed moderate preservation, with only the occasional poorly-preserved sample, which is typical for a Mesozoic chalk (J.A. Lees, pers. comm., 2006). Coccolith abundance was moderately high, with low recovery only seen in the poorly-preserved samples. The first occurrence of *Broinsonia parca expansa*, and absence of *Micula staurophora*, in samples BB26 and KQ7 from the Baldock and Kensworth sections, respectively, allowed the Turonian/Coniacian boundary interval (UC9c; Lees, accepted) to be located in these sections, and a biostratigraphic correlation was established, using nannofossils, between all three sections (the nannofossil and foraminiferal biostratigraphies are to be published elsewhere).

3.2 *Watznaueria barnesiae*

The morphometric data for *Watznaueria barnesiae* is presented in Figure 3. *W. barnesiae* was abundant to dominant (>50 specimens in a count of 300) in all samples studied, commonly comprising over 30% of the assem-

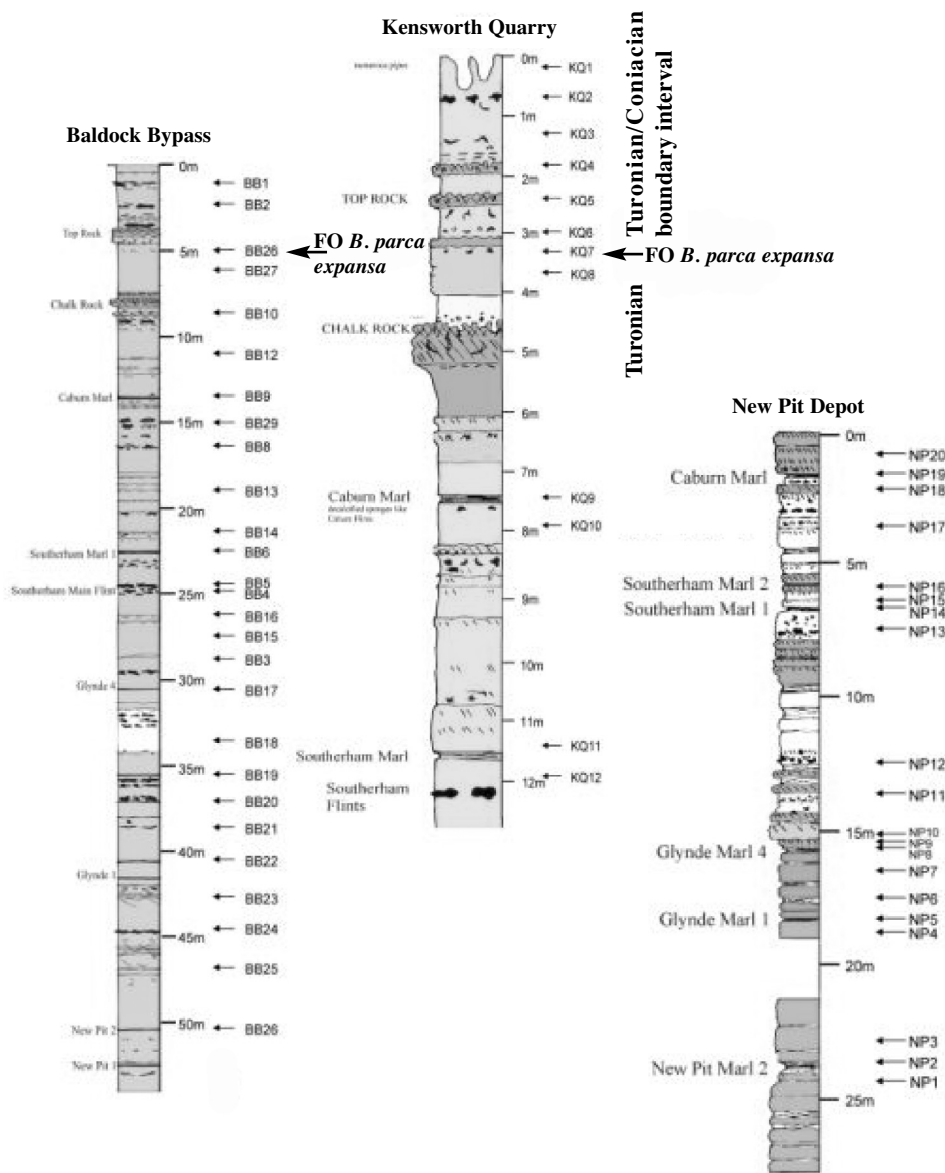


Figure 2: Lithological logs, lithostratigraphy and sampled levels for studied sections in the Lewes Nodular Chalk Formation - note different scales. Baldock Bypass log provided by H. Bailey (2006); Kensworth Quarry and New Pit Depot logs adapted from Mortimore *et al.* (2001)

blage. The morphometric data shows high abundances of smaller *W. barnesiae* in the marls, and specifically those which derived from volcanic ash (oldest to youngest, these are the Glynde Marls, Southerham Marls and Caburn Marl; Figure 3). Mean length values typically fall by around $2\mu\text{m}$ in each of these marls. *Eiffellithus* and *Zeughrabdotos* also display dwarfing at these marl horizons, but these were not quantified. The only significant, non-volcanogenic marl in the stratigraphy, New Pit Marl 2, does not show any evidence of this dwarfing.

3.3 *Braarudosphaera* and *Nannoconus*

The samples in which relatively high abundances of *Braarudosphaera* and *Nannoconus* were observed (BB1 and BB2 from Baldock Bypass; KQ3-KQ5 from Kensworth Quarry) lie immediately above the Top Rock

Bed in the Turonian/Coniacian boundary interval (UC9c, following Lees, accepted). Samples examined from below this level contain only rare and sporadic occurrences of braarudosphaerids and nannoconids. Accurate data on the abundance of these taxa was difficult to attain, as these nannofossils are large and tended to accumulate together in the thicker parts of the smear-slides, where individual specimens were somewhat obscured. The biostratigraphic counts did highlight the event to some extent, however, with an average of 13 specimens of *Nannoconus* (in a count of 300) in the samples mentioned above, and an average of seven specimens in the remaining samples (for both sections). This abundance increase was especially conspicuous in the thicker parts of the slide, which were not traversed as part of the biostratigraphic counts. However, an SEM image of a concentrated portion of Sample BB2 is shown in Figure 4, illustrating the abundance of nannoconids in that sample. This acme event con-

tains increased occurrences of several nannoconid species (*N. truittii frequens*, *N. truittii rectangularis*, *N. truittii truittii* and *Nannoconus* spp. indet. cross-sections), along with *Braarudosphaera bigelowii*. There is no significant change in abundance of other taxa in the associated nannofossil assemblages during this interval, although it is interesting to note that *Micrantholithus quasihoschulzii* occurs around this level, in UC9c.

4. Discussion

4.1 *Watznaueria barnesiae*

Watznaueria barnesiae is robust and relatively solution-resistant, and it is possible that its dominance in these assemblages, in part, reflects preservational bias. However, the moderate preservation of all taxa, and the little-to-no correlation between species diversity and the

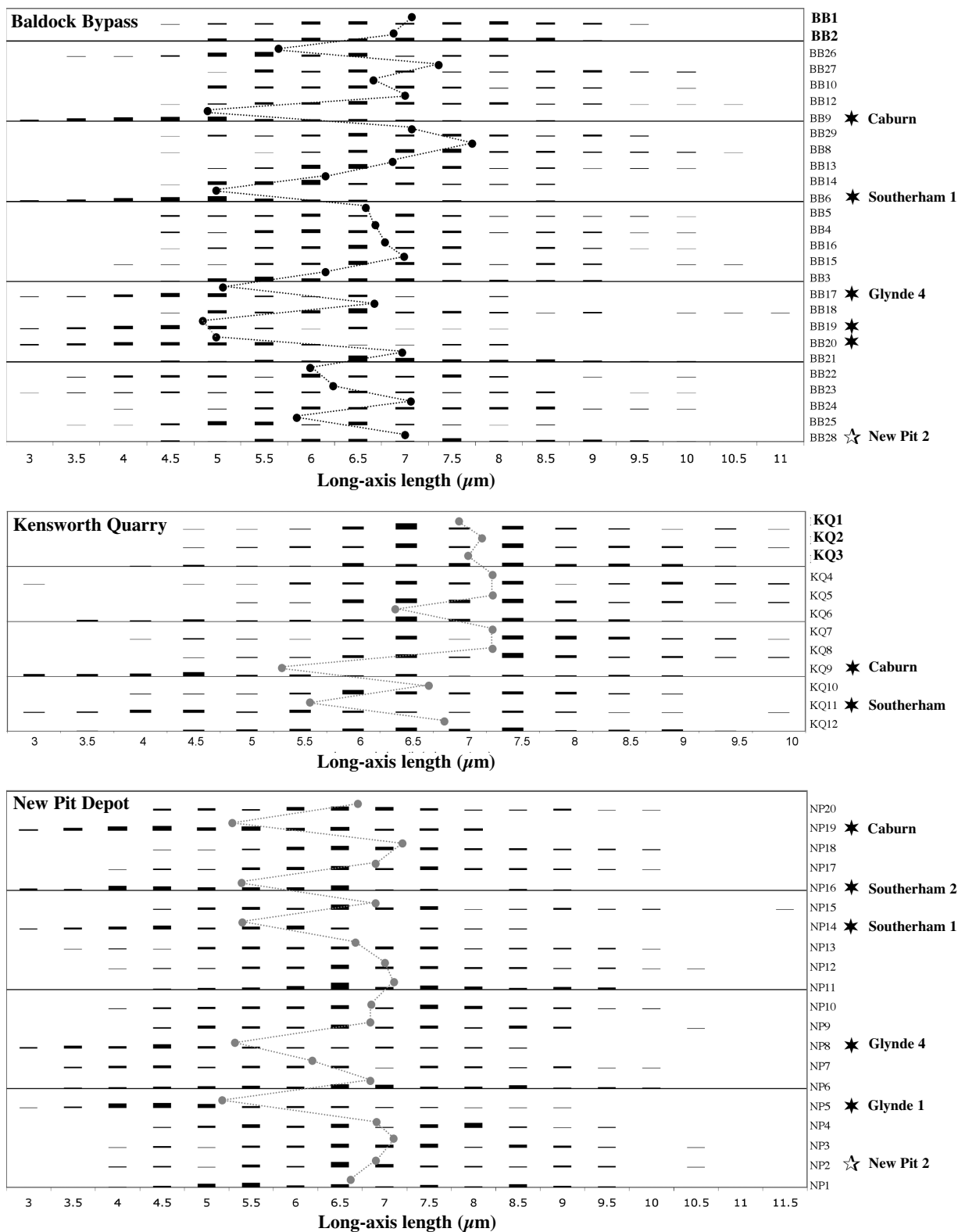


Figure 3: Histograms showing morphometric variation in *W. barnesiae*. Sample numbers on right. Dots represent mean length values for each sample. Filled stars denote volcanically-derived marls; unfilled stars denote non-volcanic marls. Emboldened sample numbers correspond to nannoconid/braarudosphaerid acme samples

relative abundance of *W. barnesiae* (Wyton, 2006), indicates that this dominance may reflect original assemblage composition. Lees *et al.* (2004) have shown that *Watznaueria* dominance can be seen in well-preserved

Jurassic assemblages and, therefore, can reflect primary proportions. The dominance of *W. barnesiae* in such assemblages lends weight to comparisons drawn between this taxon and the extant *Emiliania huxleyi* (e.g. Street &

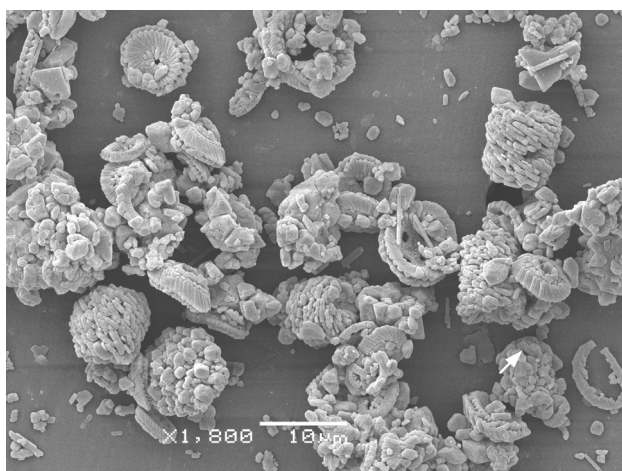


Figure 4: SEM micrograph of Sample BB2, 8-10 μ m fraction, illustrating relatively high abundance of nannoconids

Bown, 2000).

It is possible that the morphometric trends in *W. barnesiae* documented here also in part reflect the higher preservation potential of coccoliths in marl horizons (due to increased clay content), allowing preservation of smaller coccoliths. However, *Watznaueria* coccoliths of 5 μ m and 7 μ m should have relatively similar preservation potential, and so the variation shown seems too great to be a result of preservation alone. It is postulated, therefore, that the dwarfing observed in *W. barnesiae* is a direct consequence of increased nutrient input into the water-column, associated with the volcanic ash from which these marls were derived. In addition, associated water-column transparency and temperature changes may have played a role. As *W. barnesiae* is likely to have been ecologically r-selected for rapid reproduction in certain heightened-nutrient conditions, this period of increased nutrient-input could have increased the reproduction rates of *W. barnesiae*, causing smaller coccoliths to be shed. The only other example of dwarfing in Late Cretaceous coccoliths is that of Erba *et al.* (1995), who documented Campanian dwarfed assemblages, including *W. barnesiae*, from lagoonal sediments at Wodejebato Guyot (central Pacific Ocean). They observed a comparable decrease in coccolith length, when compared with nearby open-ocean sites, and attributed the dwarfing to the restricted lagoonal environment and high surface-water fertility.

4.2 *Braarudosphaera* and *Nannoconus*

The acme of *Braarudosphaera* and *Nannoconus* is recorded above the Top Rock and Chalk Rock hardground horizons (Figure 2), which are thought to have formed due to slow deposition in shallow-water environments, with significant winnowing of sediment (Hopson *et al.*, 1996). As the abundance increase of these large nannofossils lies above the winnowed horizons, and as there is no obvious change in assemblage diversity, we argue that these signals may reflect primary trends.

There is no obvious change in the background assem-

blage composition through this interval, so the acme is unlikely to have resulted from a sudden change in the palaeoenvironment (*i.e.* lower salinity/nutrient availability). However, the sediments immediately above the Top Rock were deposited during a period of sea-level fall (Grant *et al.*, 1999), and the increase in both taxa may be a response to this shallowing, driven by any one of the environmental changes which accompanied it. Svábennická (1999) has previously reported *Braarudosphaera*-rich sediments of Turonian age (in UC9a) from the Czech Republic, and suggested that this was the result of increased terrigenous sediment and associated nutrient input. Our nannoconid acme at the Turonian/Coniacian level has not been recorded previously.

5. Conclusions

The calcareous nannofossil assemblages from the three studied Turonian-Coniacian chalk sections contain two palaeoecologically significant trends. A morphometric trend within *Watznaueria barnesiae* suggests that this species underwent dwarfing during periods of increased nutrient input, related to volcanic ash deposition into the water-column. Palaeoecological comparisons of this species to *Emiliania huxleyi* seem justified, with this trend identifying *W. barnesiae* as an r-selected species. A simultaneous acme event of *Braarudosphaera* and *Nannoconus* has also been recorded, and may represent a response to shallowing during the Turonian/Coniacian boundary interval.

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