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THE OSTRACODAL RESPONSE TO THE CENOMANIAN-TURONIAN BOUNDARY EVENT AT WESTBURY (WILTSHIRE, UK)*

M. R. VAZIRI

Department of Geology, Faculty of Sciences, Shahid Bahonar University, Kerman, I. R. Iran
Email: Vazirimohammadreza@yahoo.com

Abstract – A detailed study of Ostracoda changes against the stable isotopes of carbon and oxygen across the Cenomanian-Turonian boundary mass extinction has been fully documented in one section, the South of England. This section comprises the uppermost Cenomanian to lowermost Turonian strata. The comparison between the results obtained in this research and two rival models for the Cenomanian-Turonian boundary mass extinction, famine and high productivity, have been carried out. Low oxygen level has been proposed as the main cause of the Cenomanian-Turonian boundary mass extinction.

Keywords – Extinction, ostracods, stable isotopes, Cenomanian-Turonian boundary

1. INTRODUCTION

The Cenomanian- Turonian boundary interval in shallow seas is characterized by worldwide deposition of sediments enriched in organic carbon [1-3], a major positive $\delta^{13}C$ spike [4-7] and a major extinction of marine taxa [8-11]. The faunal turnover of this interval is one of 10 post-Paleozoic marine mass extinctions [12]. The event is also known as Cretaceous oceanic anoxic event 2 (OAE2) or the Cenomanian-Turonian boundary event (CTBE).

The CTB is well outcropped in Britain in two depositional basins, the Anglo-Paris and Cleveland basins, each characterized by a different lithological succession. In the Anglo-Paris Basin (northern France and southern England) the Cenomanian-Turonian boundary is represented by a distinctive lithological unit, the Plenus Marls to the lower portion of the Ranscombe Chalk Member. In the Cleveland Basin and on the East Midland Shelf (northeast England from the Yorkshire Coast to Lincolnshire), the Cenomanian-Turonian boundary event is related to another distinctive lithology named the Black Band.

Paleogeographically, the studied section at Westbury, Wiltshire, in the south of England (Fig. 1) belongs to the Wessex Basin (a small sub-basin within the Anglo-Paris Basin). Although the section is not as expansive as Eastbourne [11], the latest Cenomanian and lowest Turonian strata are well outcropped, thus providing a good place to study the CTBE.

2. LITHOSTRATIGRAPHY

The studied section consists of three distinctive units: Grey Chalk Member, Plenus Marls Formation and the lower part of the White Chalk Formation (Fig. 2). The two former, besides the lowermost part of the White Chalk Formation, belong to the latest Cenomanian, while the upper part of the White Chalk Formation comprises the Turonian stage. It should be mentioned that the lithostratigraphic schemes introduced for the chalk of Sussex and Kent have been discussed by Mortimere and Robinson [13-18].

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Also, cyclostratigraphic schemes for the Cenomanian and Turonian stages introduced by Gale [19, 20] for sections in NW Europe are used here.

Fig.1. Map showing location of section mentioned in the text

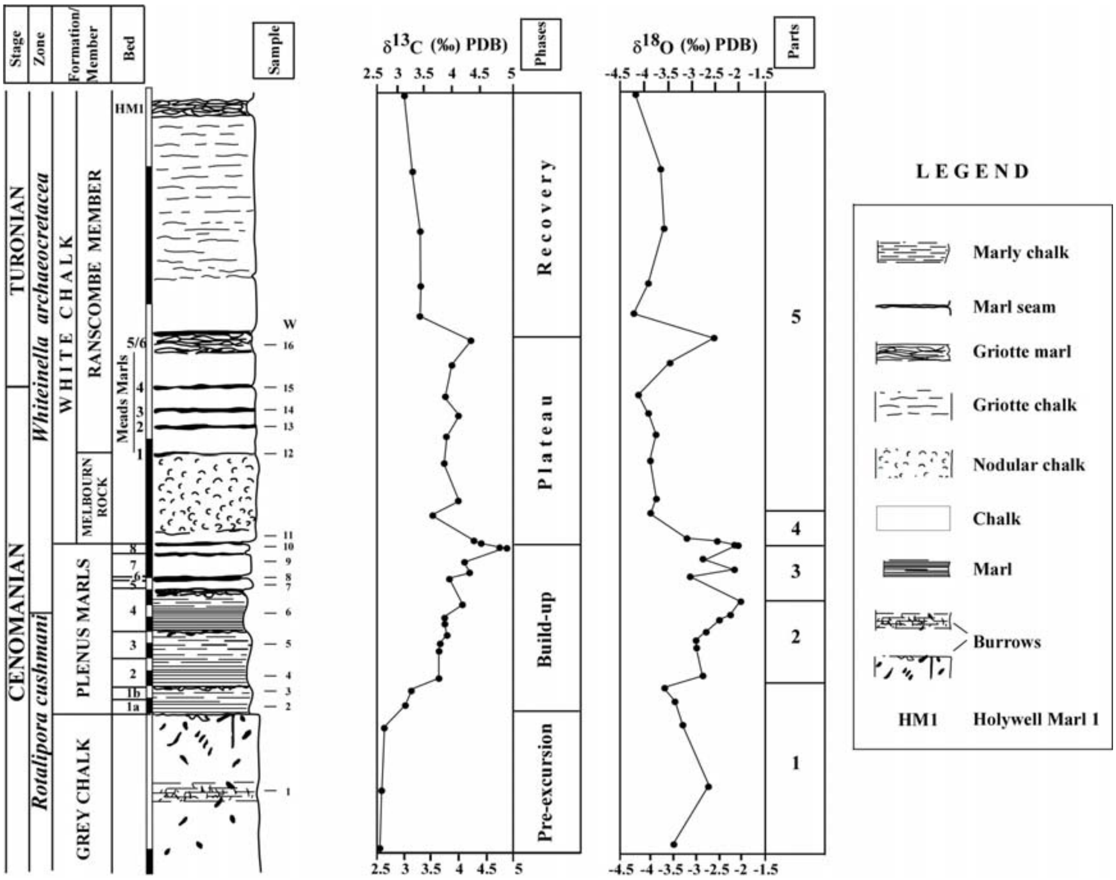

Fig. 2. Lithostratigraphy and stable isotope curves of the Upper Cenomanian-Lower Turonian at Westbury

a) Lower Chalk Formation (Grey Chalk Member)

Grey Chalk constitutes the upper part of the Lower Chalk, which consists mainly of marly chalk (vs. the lower part, Chalk Marl, which shows rhythmic alteration of marl and chalk). In the studied sections, *Chondrites* burrow systems are developed in the Grey Chalk. These traces are filled with poorly contrasting chalk.

b) Plenus Marls

The Plenus Marls Formation represents a clay-rich interval between the carbonate-rich Lower Chalk and White Chalk Formation [11]. Jefferies [8] divided the Plenus Marls into eight beds, each characterized by a distinctive fauna and demonstrated that they could be traced around the Anglo-Paris Basin. The thickness of the Plenus Marls Formation at Westbury is less than at Eastbourne. Also, the exposure of Grey Chalk is less prominent, but the Plenus Marls and post Plenus strata (Melbourne Rock and Ranscombe Chalk Member) are clearly visible.

c) White Chalk Formation

The Plenus Marls are overlain by Ranscombe Member of the Sussex White Chalk Formation [15, 21]. The Ranscombe Member contains the Meads Marls Beds, Holywell Beds and New Pit Beds, among which only Meads Marls Beds have been investigated.

3. MATERIAL AND METHODS

a) Field investigation

The fundamental approach has been to log the section in detail and to provide a lithostratigraphic framework against which paleontological and geochemical information can be plotted and compared. The samples were taken close to the Cenomanian-Turonian boundary and each was split into 2 parts for micropaleontological and geochemical examination. All together, 16 samples were collected from the top of the Grey Chalk to the top of the Meads Marls 5/6 (Griotte Marl 1), among which only 1 sample (W11) was not studied (due to difficulties in processing the hard chalk).

b) Laboratory

Samples were dried overnight in an oven. A hundred g of dried sediment was disaggregated by repeated freezing and thawing in a super saturated solution of sodium sulphate. When disaggregated, the samples were washed through a 63 μm sieve and the residues dried and dropped through a nest of sieves (63, 90, 125, 180, 250, 355, 500, 1000 μm). The 500-1000 μm split was picked completely and the 250-500 μm split was picked to provide at least 300 ostracods (where possible) from a known weight. This provides a 95% chance of not overlooking a taxon that represents more than 5% of the total fauna.

c) Stable isotopes

Bulk sediments were used for stable isotope analyses. A small sample of powder, approximately 3 mg, was used to determine stable isotope ratio of carbon and oxygen in the Liverpool University Isotope Laboratory. All samples were roasted in a low pressure plasma oven for 4 hours to remove any organic matter. Gaseous CO2 for analysis was released by reacting the powder with 2 ml anhydrous 100% orthophosphoric acid in a constant temperature bath at 50º C for at least three hours or until the reaction was complete. Results were corrected using standard procedures [22] and are expressed as per mil (‰) deviation from the Pee Dee belemnite (PDB) international standard.

4. RESULTS

At Westbury four phases of $\delta^{13}C$ are recognizable including: pre-excursion phase, a single build up phase, plateau phase and recovery phase. Based on $\delta^{18}O$ values, oxygen stable curve can also be divided into five different parts. The geochemical curves against the lithostratigraphical column is shown in Fig. 2.

a) Correlation between δ^{13}C *values, diversity and ostracod assemblage*

The pre-excursion assemblage is diversified (Fig. 3) and podocopid ostracods constitute about 82% of the assemblage (Fig. 4).

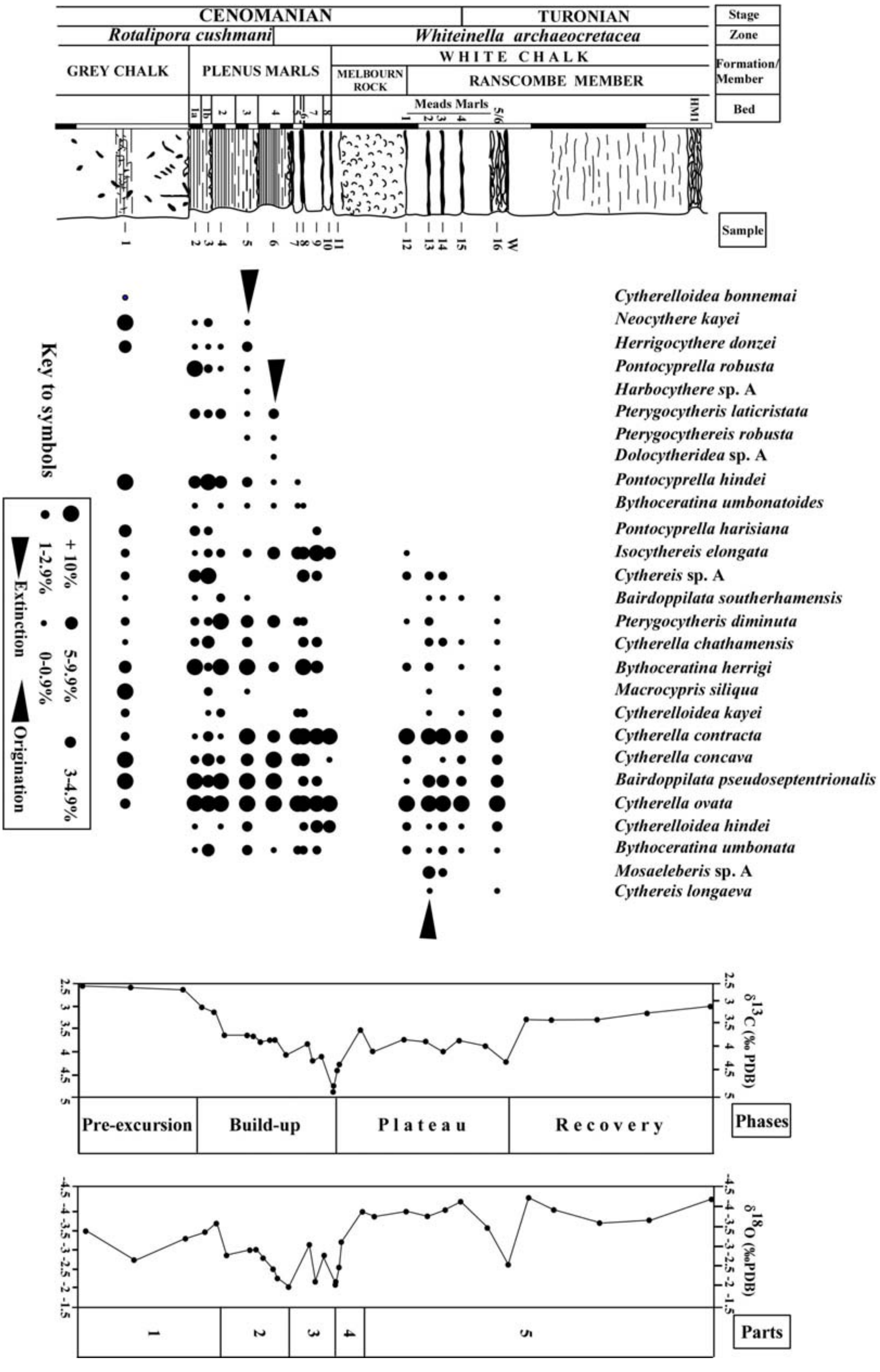

Fig. 3. Correlation between geochemical changes and distribution of ostracods across the Cenomanian-Turonian boundary at Westbury

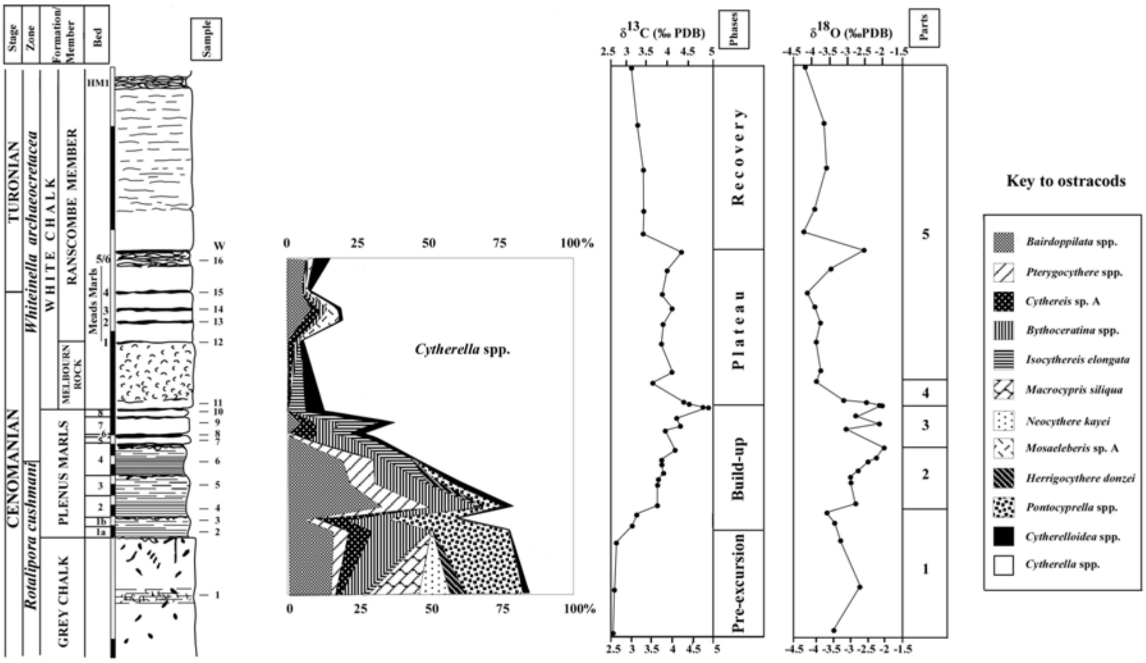

Fig. 4. Correlation between geochemical changes and cumulative percent
of ostracods across the Cenomanian-Turonian boundary at Westbury

Only one species (*Cytherelloidea bonnemai*, Fig. 5a) is restricted to this phase. In beds 1 and 2, the total diversity increases, then the Grey Chalk and five more species appear (*Pterygocythere laticristata*, Fig. 5i; *Bythoceratina umbonatoides*, Fig. 5f; *Pontocyprella robusta*, Fig. 6a-b; *Cytherelloidea hindei*, Fig. 6l and *Bythoceratina umbonata*, Fig. 7j). In these beds podocopids are still dominant. In beds 3 and 4, δ^{13}C values continue to increase, correlating with the high numbers of previous occurrences. Three species (*Neocythere kayei*, Fig. 5e; *Herrigocythere donzei*, Fig. 5k and *Pontocyprella robusta*) were extinct in bed 3, although one species (*Habrocythere* sp. A) appears only in one sample restricted to bed 3. Two species (*Pterygocythere laticristata* and *Pterygocythere robusta*, Fig. 5j) occur in bed 4 for the last time, although one species (*Dolocytheridea* sp. A, Fig. 6c) appears only in one sample and is restricted to bed 4. The diversity in these beds does not change significantly compared to that of the previous interval, but the dominance of podocopids in these beds decreases rapidly to 45% in bed 4.

In the rest of the build up phase (beds 5-8), where δ^{13}C values are very high, only 3 species (*Pontocyprella hindei*, Fig. 6d; *Bythoceratina umbonatoides* and *Pontocyprella harrisiana*, Fig. 6e-f) occur for the last time. The diversity falls to its lowest values and podocopids percentage decreases steadily, falling to about 6.5% of the assemblage in bed 8. Throughout the plateau phase two species (*Isocythereis elongata*, Fig. 7c and *Cythereis* sp. A, Fig. 7d) occur for the last time, while the origination of two species (*Mosaeleberis* sp. A, Fig. 7g-h and *Cythereis longaeva*) occurs. During the plateau phase, diversity recovers and platycopid ostracods are significant.

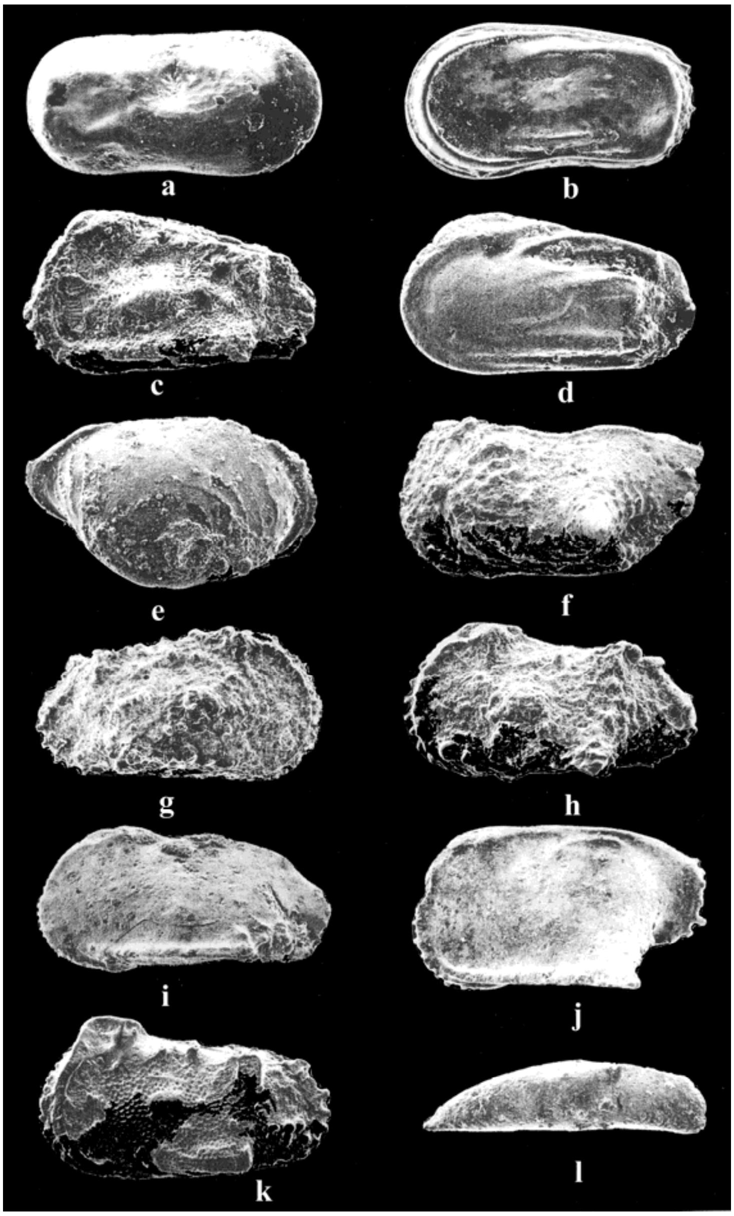

Fig. 5. Ostracoda recovered from the Cenomanian-Turonian boundary at Westbury.
a: *Cytherelloidea bonnemai* (Weaver). Right valve. Grey Chalk Formation, × 82.- b: *Cytherelloidea stricta* (Jones and Hindle). Left valve. Grey Chalk Formation, × 79.- c: *Curfsina derooi* Weaver. Left valve. Grey Chalk Formation, × 57.- d: *Imhotepia euglyphea* Weaver. Left valve. Grey Chalk Formation, × 85.- e: *Neocythere kayei* Weaver. Right valve. Grey Chalk Formation, × 104.- f: *Bythoceratina umbonatoides* (Kaye). Left valve. Grey Chalk Formation, × 89.- g: *Oertliella donzei* Weaver. Right valve. Plenus Marls Formation, × 87.- h: *Oertliella alata* Weaver. Left valve. Plenus Marls Formation, × 88.- i: *Pterygocythereis laticristata* (Bosquet). Left valve. Plenus Marls Formation, × 52.- j: *Pterygocythereis robusta* Weaver. Left valve. Plenus Marls Formation, × 65.- k: *Herrigocythere donzei* (Weaver). Left valve. Plenus Marls Formation, × 91.- l: *Macrocypris siliqua* (Jones). Right valve. Plenus Marls Formation, × 39.

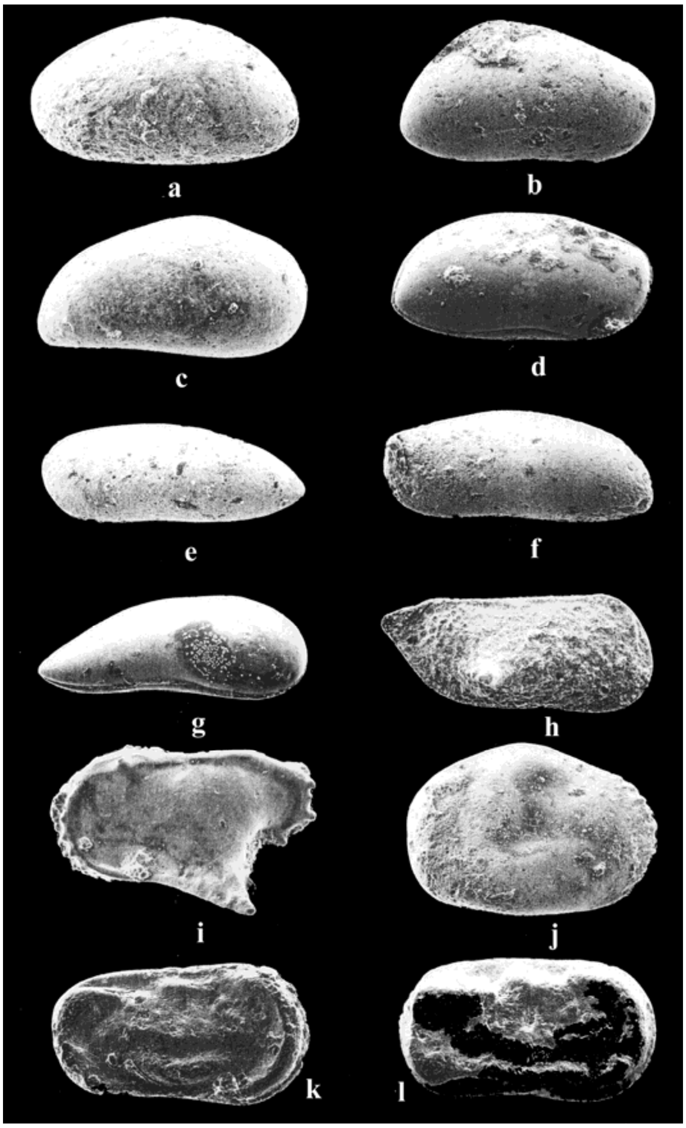

Fig. 6. Ostracoda recovered from the Cenomanian-Turonian boundary at Westbury.
a, b: *Pontocyprella robusta* Weaver. a; left valve, b; right valve. Plenus Marls Formation,.a × 75 and. b × 71.- c: *Dolocytheridea* sp. A. Right valve, Plenus Marls Formation, × 76.- d: *Pontocyprella hindei* Weaver. Right valve, Grey Chalk Formation, × 75.- e-f: *Pontocyprella harrisiana* (Jones). Both e and f show left valve. Grey Chalk Formation, e × 64 and f × 82.- g: *Paracypris wrothamensis* Kaye. Right valve. Grey Chalk Formation, × 69- h: *Bythoceratina herrigi* Weaver. Right valve. Plenus Mmarls Formation, × 75.- i: *Pterygocythereis diminuta* Weaver. Left valve, Grey Chalk Formation, × 74.- j: *Cytherella chathamensis* Weaver. Right valve. Grey Chalk Formation, × 84.- k: *Cytherelloidea kayei* Weaver. Right valve. Plenus Marls Formation, × 97.- l: *Cytherelloidea hindei* Kaye. Right valve. Ranscombe Chalk Formation, × 68.

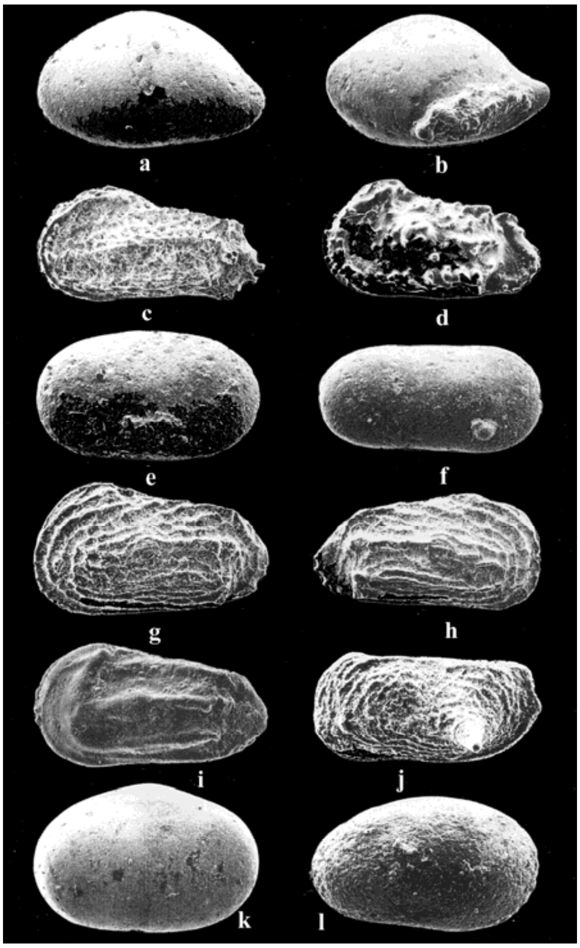

Fig. 7. Ostracoda recovered from the Cenomanian-Turonian boundary at Westbury.
a: *Bairdoppilata pseudoseptentrionalis* Mertens. Left valve. Plenus Marls Formation, × 67.- b: *Bairdoppilata southerhamensis* Weaver. Left valve. Grey Chalk Formation, × 67.- c: *Isocythereis elongata* Weaver. Left valve. Plenus Marls Formation, × 57.d: *Cythere*is sp. A. Left valve. Plenus Marls Formation, × 61.- e: *Cytherella concava* Weaver. Right valve. Plenus Marls Formation, × 80.- f: *Cytherella contracta* van Veen. Right valve. Plenus Marls Formation, × 78.- g-h: *Mosaeleberis* sp. A. g, left valve; h, right valve. Ranscombe Chalk Member, g × 78 and h × 75.- i: *Cornicythereis* sp. A. Left valve. Plenus Marls Formation, × 85.- j: *Bythoceratina umbonata* (Williamson). Left valve. Grey Chalk Formation, × 98.- k-l: *Cytherella ovata* Roemer. k, female right valve; l, male right valve. Plenus Marls Formation. k × 61 and l × 76.

b) Correlation between δ^{18}O values, diversity and ostracod assemblages

At Westbury, part 1 of the δ^{18}O curve correlates with a diversified assemblage, in which only one platycopid (*Cytherelloidea bonnemai*) occurs in one sample (Fig. 3) and the assemblage is strongly dominated by podocopids, Fig. 4. In part 2, five species (*Neocythere kaye*i, *Herrigocythere donzei*, *Pontocyprella robusta*, *Pterygocythere laticristata* and *Pterygocythere robusta*) are recorded for the last time, while two species (*Habrocythere* sp. A and *Dolocytheridea* sp. A) occur only in one sample. During this section diversity is high, but the percentage of podocopids decreases rapidly. Parts 3 and 4 are characterized by last occurrences of three species (*Pontocyprella hindei*, *Bythoceratina umbonatoides* and *Pontocyprella harrisiana*). Diversity falls and the percentage of podocopids continues to decrease rapidly. In part 5, two other species (*Isocythereis elongata* and *Cythereis* sp. A) occur for the last time, while the origination of two new species (*Mosaeleberis* sp. A and *Cythereis longaeva*) is recorded. Diversity increases and platycopids are dominant in the assemblage.

5. DISCUSSION

Two models have been proposed for the possible causes of the Cenomanian-Turonian boundary mass extinction. Jarvis et al. [6] argued for a massive increase in oceanic productivity, which caused an expansion of the oxygen minimum zone in the water column. This in turn caused the turnover of the benthic foraminifera and ostracods and then as the oxygen minimum zone migrated upward in the water column, a successive extinction of the planktic foraminifera took place. Therefore, they considered the Cenomanian-Turonian boundary event as an oceanic anoxic event. However, Paul and Mitchell [23] argued for a reduction in oceanic primary productivity during the Cenomanian-Turonian boundary. They assumed that positive $\delta^{13}C$ excursion during the build-up phase is caused by the burial of organic materials. This process removed nutrients and reduced coccolith production, led to famine among ostrcods and foraminifera, and consequently the extinction of many taxa.

At Westbury, in the normal conditions of the Grey Chalk (low $\delta^{13}C$ and less negative $\delta^{18}O$ value), seventeen species occur and assemblage is dominated by podocopids. During the build-up phase, accompanied by increasing $\delta^{18}O$ values, eight species have their last occurrences, while two species occur only in one sample. During this part, the percentage of platycopids increases rapidly. In the post-build up phase, which coincides with decreasing $\delta^{18}O$ values, the number of last occurrences decreases and two species are replaced by two others and the percentage of platycopids continue to increase slowly. Therefore, at Westbury the dominance of platycopids correlates with $\delta^{13}C$ values, so that from bed 2 to the top of bed 8, which correlates with the build-up phase, the percentage of platycopids increases steadily. In other words, at Westbury the situation is in marked contrast to the famine model, because at times of food shortage (build-up phase), platycopid ostracods which filtered food from the water column would succumb earlier than did detrivour podocopids, which used alternative food sources.

On the other hand, there is a correlation between the abundance of platycopids and increasing $\delta^{13}C$ values, which in the productivity model [6] has been regarded as the main factor to induce oxygen depletion in the environment. Platycopid ostrcods are naturally adapted to low oxygen conditions and their dominance suggests lowered oxygenation levels in bottom water. Due to the filter feeding system, these ostracods have a lot of branchial plates that circulate water over the ventral surface, and because of the high rate of respiration are relatively immune to oxygen deficiency [24]. Therefore, variation in the platycopid % reflects the changes in the $\delta^{13}C$ signature and is compatible with the productivity model.

6. CONCLUSIONS

a) Late Cenomanian ostracod assemblages indicate stressed conditions leading to species turnover through the boundary. It starts with more diverse assemblage, dominated by podocopids, and ends with less diverse assemblage dominated by platycopids.

b) The $\delta^{13}C$ curve shows a positive excursion in the studied section. The curve consists of: a pre-excursion background, a build-up of rapid increase in $\delta^{13}C$ values, a plateau phase, and a recovery phase.

c) The relationship between $\delta^{18}O$ values and the dominance of podocopids or platycopids is not clear and assemblage is essentially correlated with $\delta^{13}C$ values.

d) Low oxygen in the environment might have been the main cause for the extinction of ostracodal assemblages through the Cenomanian-Turonian boundary in the study area.

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