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Micromorphs: Response of the Ammonite Fauna during the Toarcian Oceanic Anoxic Event (T-OAE) in the Es-Saffeh Mountains (Tiaret, Western Algeria) †

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Abstract: The paleontological analysis of the fauna of ammonites collected in the marl-limestone series of the Pliensbachian and The Toarcian of the Es-Saffeh Mountains (Tiaret, western Algeria) brings new data to the Oceanic Anoxic Event of the lower Toarcian (T-OAE). During this time interval, hypoxia is characterized by a significant disturbance of the global carbon cycle marked by a negatve excursion of the isotope $\delta^{13}C$, $\delta^{18}O$ and a increase in organic carbon content (TOC). Benthic life almost completely disappears and microfauna (foraminifera) is absent, it should however be pointed out that the few specimens of small size (swarf forms) collected in the marly levels and well identified (ammonites), attributed to the microshell forms; can be interpreted as a response to the conditions of the reducing environment during the Lower Toarcian, particularly at the end of the Polymorphum Zone and the beginning of the Levisoni Zone.

Keywords: Ammonites; Anoxic event; Toarcian; Tiaret; hypoxia; foraminifera

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1. Introduction

The Early Toarcian Oceanic Anoxic Event (T-OAE) is recognized as one of the most important environmental perturbations during the Mesozoic, with a dramatic impact on marine biota revealed by a significant mass extinction event (MEE) in benthic and pelagic groups ([1–9]). It has been recognized for many principal groups of fossil organisms: ostracods, foraminifers, bivalves, brachiopods and ammonoids ([3,4,7,10–21]).

The sedimentary record of the T-OAE is characterized by organic-rich sediments "black shales" associated with a distinctive negative excursion in the δ 13C recorded in organic matter, biomarkers, marine carbonates, and fossil wood from marine and continental sections (e.g., [6,8,22–34]).

Several environmental changes may have been involved in the mass extinction event, mainly affecting benthic organisms, such as generalized anoxia, the enhancement of greenhouse conditions and a warming trend, or the incidence of sea-level changes (e.g., [2,35–49,51).

The aim of this research is to analyse the ammonite's assemblages of the Pliensbachian–Toarcian limit of the Benia section (Northwestern Algeria). The study of the ammonite's assemblages made it possible to analyze the morphological response of adopted ammonites to palaeoenvironmental changes.

2. Location and Geological Setting

The study region is located at the Es Seffah Mountain (Figure 1), part of the Nador Mountains; it is located approximately 45 km SE of Tiaret city. The Nador Mountains are part of the pre-Atlas domain which is bordered to the north by the external zone of the Tellian Domain, to the South–East by the Atlas Domain, to the south by the Oran High Plains and to the west by the Tlemcenian Domain.

The Nador Chain is organized into three topographic units arranged from North to South as follows:

- The Nador Zérange: It corresponds to an anticline with a liasic core spilled towards the North West; the southern flank is clearly less disturbed and shows good development of the Jurassic series [52];
- The Faîdja Valley: It is occupied by marls from the Upper Jurassic (Oxfordian). These deposits are sometimes covered by Miocene and Plio-Quaternary sediments.
- The Taga Plateau: It occupies the southern flank of the anticlinal structure of Nador. It corresponds to the dolomitico-limestone formations of the Upper Jurassic which show a slight dip and a great extension towards the South.

The ammonites studied in this work come from the Benia section, which is located on the southern flank of the Es Saffeh Mountain (Figure 1). The studied outcrop was raised near the old "Lime kiln" which is located 2 km North Western of the village of Bénia.

3. Materials and Methods

New bed- by bed sampling in the Benia section located on the southern flank of the Es Seffah Mountain has been exhaustively carried out to achieve a high-resolution record, resulting 112 newly collected ammonites. Mean biometric parameters (length, width, thickness) were measured for complete specimens. Ammonites associations allow to precisely characterise the upper Pliensbachian and lower Toarcian biozones.

4. Lithostratigraphic *Framework*

The section described in this work has already b een the subject of several stratigraphic studies which have made it possible to subdivide the formation of the “Benia Marno-limestone” into several terms (a–f), ([52–55]). In this work we will retain the last subdivision of established by Sebane [56], which can be summarized in two lithological units (Figure 1):

4.1. Lithological Unit I: (Sublithographic Marly Limestones)

It is a close alternation of marl and limestone grouping together the "a & b" terms of Caratini (1970). The limestone beds are thick, more or less clayey, sometimes compact or crumbling. In the upper part, the limestone banks are better defined and their upper surfaces are highlighted by accumulations of ammonites, belemnites, and trace fossils of benthic organisms. The marly levels are greenish gray in color, are not very thin and contain abundant microfauna (foraminifera, ostacods).

The ammonites collected by Elmi et al, (1974) & Sebane, (1984) within this limit constitute two groups (Figure 2):

- The first includes *Arieticeras* gr. *Amaltheus* (Oppel), *Emaciaticeras* type *E. Villae* (Gemm) and *Amaltheus margaritatus* (Month). This association indicates an average Pliensbachian age;

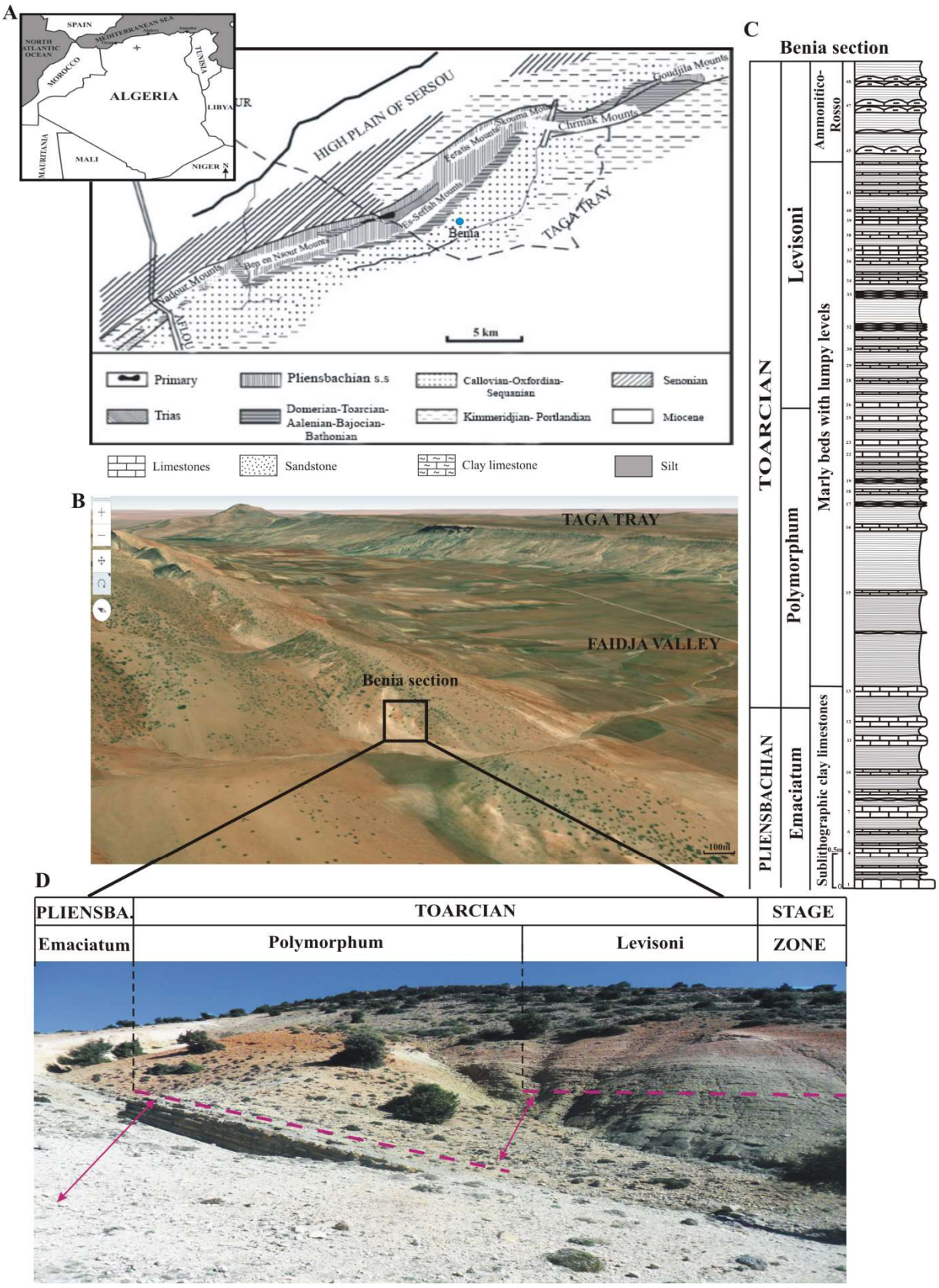

Figure 1. Geological setting and stratigraphical succession studied: (**A**) Situation and geological map of Nador mountains; (**B**) Satellite image of the locality studied; (**C**) Synthetic lower Jurassic lithostratigraphical column from Benia section; (**D**) Outcrop view of Benia section showing the distribution of the ammonites chronozones.

- The second contains *Canavaria* (*Canavaria*) sp., *Emaciaticeras* sp., *Canavaria* (*Canavaria*) gr., *Zancliana* (Fuc). This association indicates the Upper Pliensbachian (Emaciatum Zone).

The lithological nature of the sediments (marl and limestones), as well as the abundance of cephalopods and radiolarians indiate an open marine enironment.

4.2. Lithological Unit II (Marly Beds with Lumpy Levels)

It groups together the terms (c & d) of Caratini (1970); The term c corresponds to a greenish marl base revealing small gray-greenish limestone levels which pass towards the top to small discontinuous and lumpy banks; The term d corresponds to clayey "ammonitico-rosso". It begins with nodular to lumpy levels, greenish in color, becoming reddish at the top. The limestone levels are separated by lumpy reddish levels.

The ammonites collected in this unit make it possible to distinguish two successive intervals (Figure 2):

- The first contains *Dactylioceras* sp., *Dactyloceras delicatum* (Bean-Simp), *Dactyloceras tuberculatum* (Guex), rare *Hildaites gyralis* (Buck) and *Hildaites* sp. This fauna indicates the lower Toarcian (Polymorphum Zone);

- The second interval yielded *Hildaites* cf., *subserpentinus* (Buck), *Hildaiites* cf. *borialis* (Seeback) and rare *Harpoceratoiides* sp. This association indicates the lower Toarcian (Levisoni Zone). In its top part, we note the appearance of the first *Hildoceras* gr. *lusitanicum* (Merst.) indicating a middle Toarcian age (Bifron Zone).

The analysis of lithofacies and microfacies makes it possible to define two types of environment: First, a deep environment, inhabited by small brachiopods (dwarf forms. The sedimentation shows significantly high levels of illite and pyrite. The conbination of this characters indicates a narrow basin, having the shape of a deep gutter, poorly oxygenated on the bottom, where we note the presence of a certain degree of confinement ([56–58]). Then a relatively deep environment where a clayey sedimentation rich in lumpy facies (Ammonitico-rosso facies) settles. The microfauna reappears. These characters indicate a resumption of life due to the change of conditions which become more favorable. The transition between the first environment and the second is marked by the absence of benthic life (azoic episode) [56].

5. Results

The systematic study identified and described fourteen (14) genera of ammonites belonging to six subfamilies: Dactylioceratinae, Hildoceratinae, Harpoceratinae, Mercaticeratinae, Calliphylloceratinae and Lytoceratinae.

The faunas studied are identical to those known in Western Europe and occupy the same stratigraphic positions, their The vertical extension shows two important horizontals: The first, at the base of horizon XIII, corresponds to the extinction of the Hildoceratinae and the appearance of Hammatoceratidae and Grammoceratinae; ; the second, at the base of horizon XXII, marks the disappearance of Grammoceratinae and the emergence of Dumortiinae.

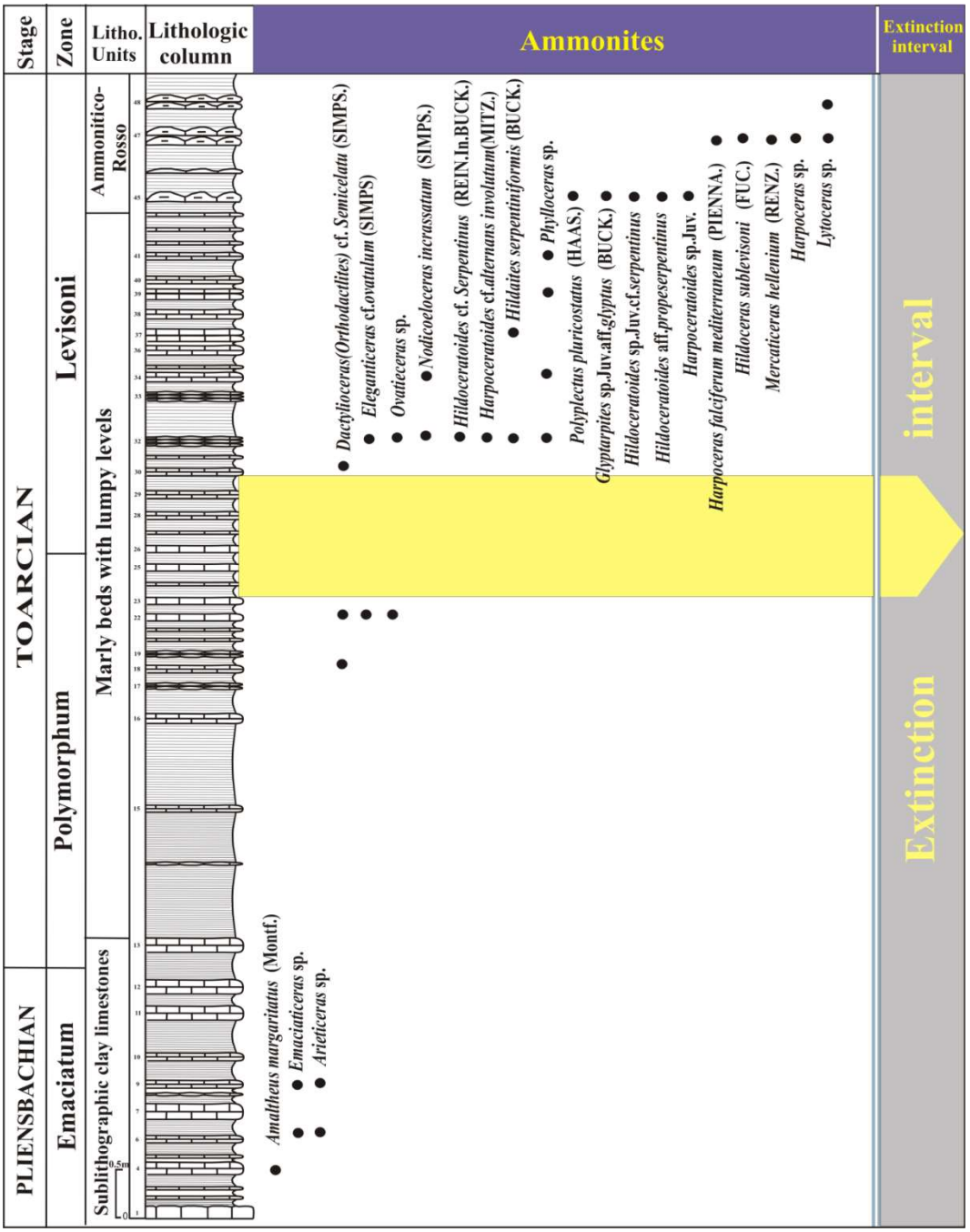

Figure 2. Stratigraphic distribution of ammonites from the Benia section.

The Dactylioceratidae, Harpoceratidae and Arieticeratidae collected in the Es-Saffeh Mountains section made it possible to recognize all the passage terms from the Emaciatum Zone to the end of the Polymorphum Zone. The Levisoni Zone is recongnize by the presence of Hildoceratidae [52].

It should however be pointed out that the few specimens of small size (swarf forms) collected in the marly levels and well identified (ammonites), attributed to the microshell forms (Figure 3).

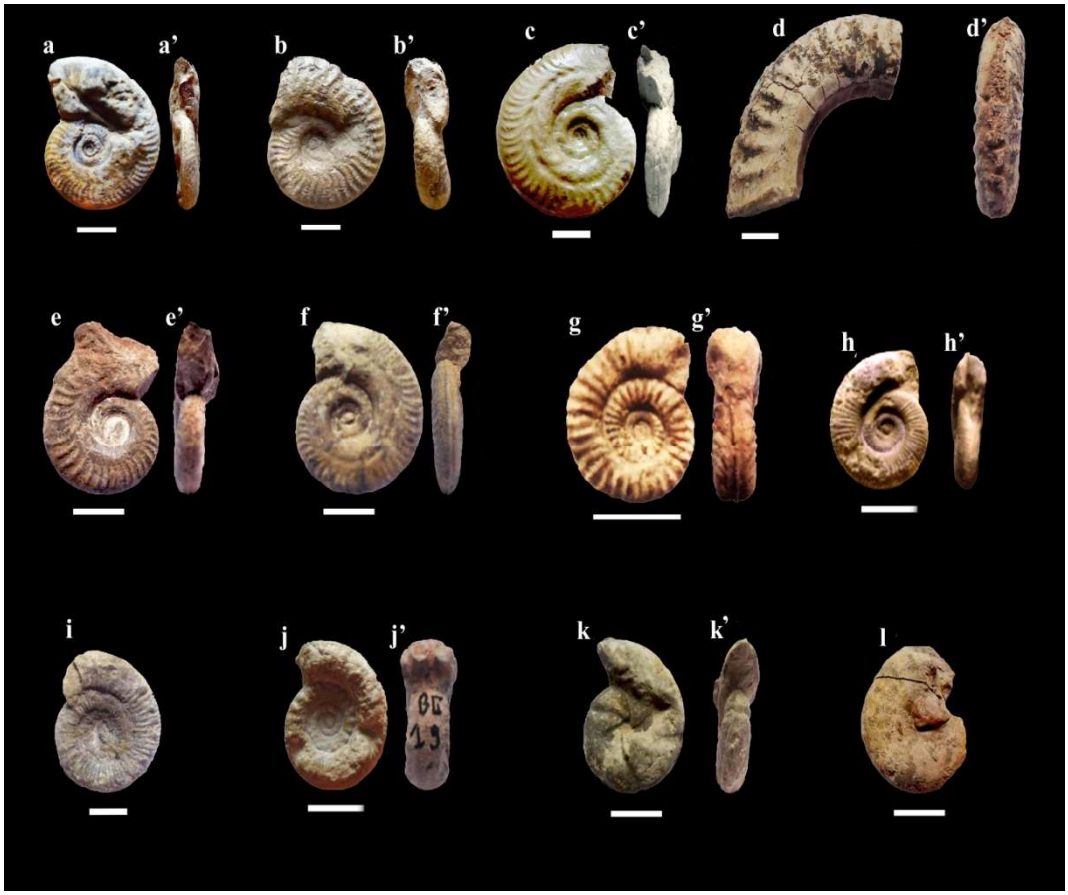

Figure 3. The ammonites collected: (a) Harpoceras falciferum SOWERBY; (b) Maconieras vigoense BUCKMAN; (c&f) Hildoceras lusitanicum MEISTER; (d) Hildoceras sp; (e) Hildoceras sublevisoni FUCINI; (g) Mercaticeras sp; (h) Dactylioceras sp; (i) Peronoceras fibulatum SOWERBY; (j) Cataco-eloceras sp; (k) Callyphyloceras sp; (l) Partshiceras sp, Scale: 1cm.

6. Discussion

In the Nador Mountains during this time interval, hypoxia, favorable to the accumulation and preservation of organic matter, is characterized by a significant disturbance of the global carbon cycle marked by a negatve excursion of the isotope $\delta^{13}C$, $\delta^{18}O$ and a increase in organic carbon content (TOC).

Benthic life almost completely disappears, and microfauna (foraminifera) is absent ([56], [59]). Although the existence of a sexual dimorphism of the Dactylioceratidae is often discussed by certain authors ([60], [18]), it should however be pointed out that the few specimens of small size (swarf forms) collected in the marly levels and well identified (ammonites), attributed to the microshell forms; can be interpreted as a response to the conditions of the reducing environment during the Lower Toarcian, particularly at the end of the Polymorphum Zone and the beginning of the Levisoni Zone.

7. Conclusion

The paleontological analysis of the fauna of ammonites collected in the marl-limestone series of the Pliensbachian and The Toarcian of the Es-Saffeh Mountains (Nador Mountais, western Algeria) brings new data to the Oceanic Anoxic Event of the lower Toarcian (T-OAE) well known over a significant part of the North West Europe and West Tethys shelves and basins [50].

The Dactylioceratidae, Harpoceratidae and Arieticeratidae collected in the Es-Saffeh Mountains section made it possible to recognize all the passage terms from the Emaciatum Zone to the end of the Polymorphum Zone. The Levisoni Zone is recongnize by the

presence of Hildoceratidae [52]. During this time interval, hypoxia, favorable to the accumulation and preservation of organic matter, is characterized by a significant disturbance of the global carbon cycle marked by a negatve excursion of the isotope $\delta^{13}C$, $\delta^{18}O$ and a increase in organic carbon content (TOC). Benthic life almost completely disappears, and microfauna (foraminifera) is absent ([56], [59]). It should however be pointed out that the few specimens of small size (swarf forms) collected in the marly levels and well identified (ammonites), attributed to the microshell forms; can be interpreted as a response to the conditions of the reducing environment during the Lower Toarcian, particularly at the end of the Polymorphum Zone and the beginning of the Levisoni Zone.

These levels are correlated to those described in the Northwest Tethyan basins where this global anoxic event (Oceanic Anoxic Event:OAE) is recordes [50]. During this period, the environmental conditions are also related to the Liasic tectonic event (eustatism) which palyed a key role in the paleogeographic evolution in North Africa and Europe.

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Conflicts of Interest: The authors declare no conflict of interest.

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