proceedings

Proceeding Paper

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

Fatiha Douas Bengoudira [1,*], Abdia Touahria [2] and Abbes Sebane [2]

1 Department of Biology, Faculty of Nature and life Sciences, Abdelhamid Ibn Badis University, Mostaganem 27000, Algeria
2 Department of Geology, Faculty of Geology and Universe Science, Benahmed Mohamed University, B.P 1015 El M'naouer, Oran 31000, Algeria; touahria_abdia@yahoo.fr (A.T.); sebane.abbes@yahoo.fr (A.S.)
* Correspondence: fatiha.douas@yahoo.fr; Tel.: +213-774-69-38-75

† Presented at the 4th International Electronic Conference on Geosciences, 1–15 December 2022; Available online: https://sciforum.net/event/IECG2022.

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 negative excursion of the isotope $\delta^{13}C$, $\delta^{18}O$ and an 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 a small size (swarf forms) collected in the marly levels and the well-identified specimens (ammonites) were attributed to the microshell forms.

Keywords: ammonites; anoxic event; Toarcian; Tiaret; hypoxia; foraminifera

Citation: Bengoudira, F.D.; Touahria, A.; Sebane, A. Micromorphs: Response of the Ammonite Fauna during the Toarcian Oceanic Anoxic Event (T-OAE) in the Es-Saffeh Mountains (Tiaret, Western Algeria). *Proceedings* **2023**, *87*, 18. https://doi.org/10.3390/IECG2022-13808

Academic Editor: Angelos G. Maravelis

Published: 2 December 2022

1. Introduction

The Early Toarcian Oceanic Anoxic Event (T-OAE) is recognized as one of the most important environmental perturbations during the Mesozoic Era, with a dramatic impact on marine biota revealed by a significant mass extinction event (MEE) in the 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., [6,8,22–49]).

The aim of this research is to analyze the ammonite's assemblages of the Pliensbachian–Toarcian limit of the Benia section (north western Algeria). The study of the ammonite's assemblages made it possible to analyze the morphological responses of adopted ammonites to paleoenvironmental 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.

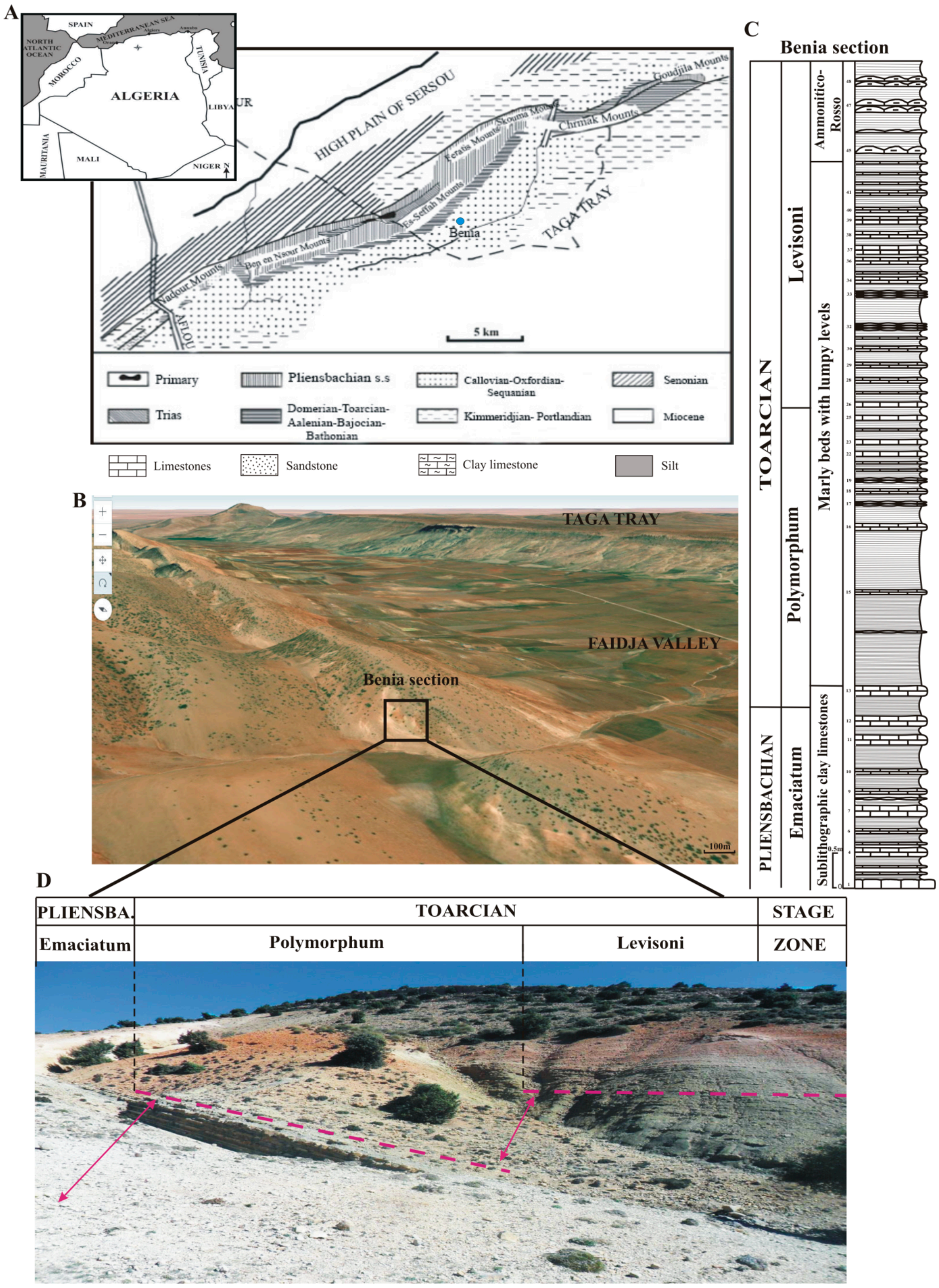

Figure 1. Geological setting and stratigraphical succession studied: (**A**) Situation and geological map of Nador mountains; (**B**) Satellite image of the locality studied; (**C**) Synthetic lower Jurassic lithostratigraphical column from Benia section; (**D**) Outcrop view of Benia section showing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

The 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 [50,51].
- The Faîdja Valley: It is occupied by marls from the Upper Jurassic period (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 period, 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 is 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 was exhaustively carried out to achieve a high-resolution record, resulting in 112 newly collected ammonites. Mean biometric parameters (length, width, thickness) were measured for complete specimens. Ammonites' associations allowed us to precisely characterize the upper Pliensbachian and lower Toarcian biozones.

4. Lithostratigraphic Framework

The section described in this work had already been the subject of several stratigraphic studies, which 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 could be summarized in two lithological units (Figure 1):

4.1. Lithological Unit I: (Sublithographic Marly Limestones)

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

The ammonites collected by Elmi et al. (1974) and Sebane (1984) within this limit constituted two groups (Figure 2):

- The first included *Arieticeras gr. Amaltheus* (*Oppel*), *Emaciaticeras type E. Villae* (*Gemm*), and *Amaltheus margaritatus* (*Month*). This association indicated an average Pliensbachian age;
- The second contained *Canavaria* (*Canavaria*) sp., *Emaciaticeras* sp., *Canavaria* (*Canavaria*) *gr.*, and *Zancliana* (*Fuc*). This association indicated the Upper Pliensbachian (Emaciatum Zone).

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

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

It grouped together the terms (c and d) of Caratini (1970); the term c corresponded to a greenish marl base, revealing small gray-greenish limestone levels, which passed towards the top to small discontinuous and lumpy banks; the term d corresponded to clayey "ammonitico-rosso". It began with nodular to lumpy levels and was greenish in color, becoming reddish at the top. The limestone levels were separated by lumpy reddish levels.

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

- The first contained *Dactylioceras* sp., *Dactyloceras delicatum* (*Bean-Simp*), *Dactyloceras tuberculatum* (*Guex*), *rare Hildaites gyralis* (*Buck*), and *Hildaites* sp. This fauna indicated the lower Toarcian (Polymorphum Zone);
- The second interval yielded *Hildaites cf., subserpentinus* (*Buck*), *Hildaiites cf. borialis* (*Seeback*), and rare *Harpoceratoides* sp. This association indicated the lower Toarcian (Levisoni Zone). In its top part, we noted the appearance of the first *Hildoceras gr. lusitanicum* (*Merst.*) indicating a middle Toarcian age (Bifron Zone).

The analysis of lithofacies and microfacies made it possible to define two types of environment: first, a deep environment, inhabited by small brachiopods (dwarf forms). The sedimentation showed significantly high levels of illite and pyrite. The combination of these characters indicated a narrow basin, having the shape of a deep gutter, poorly oxygenated on the bottom, where we noted 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) settled. The microfauna reappeared. These characters indicated a resumption of life due to the change in conditions that became more favorable. The transition between the first environment and the second was marked by the absence of benthic life (azoic episode) [56].

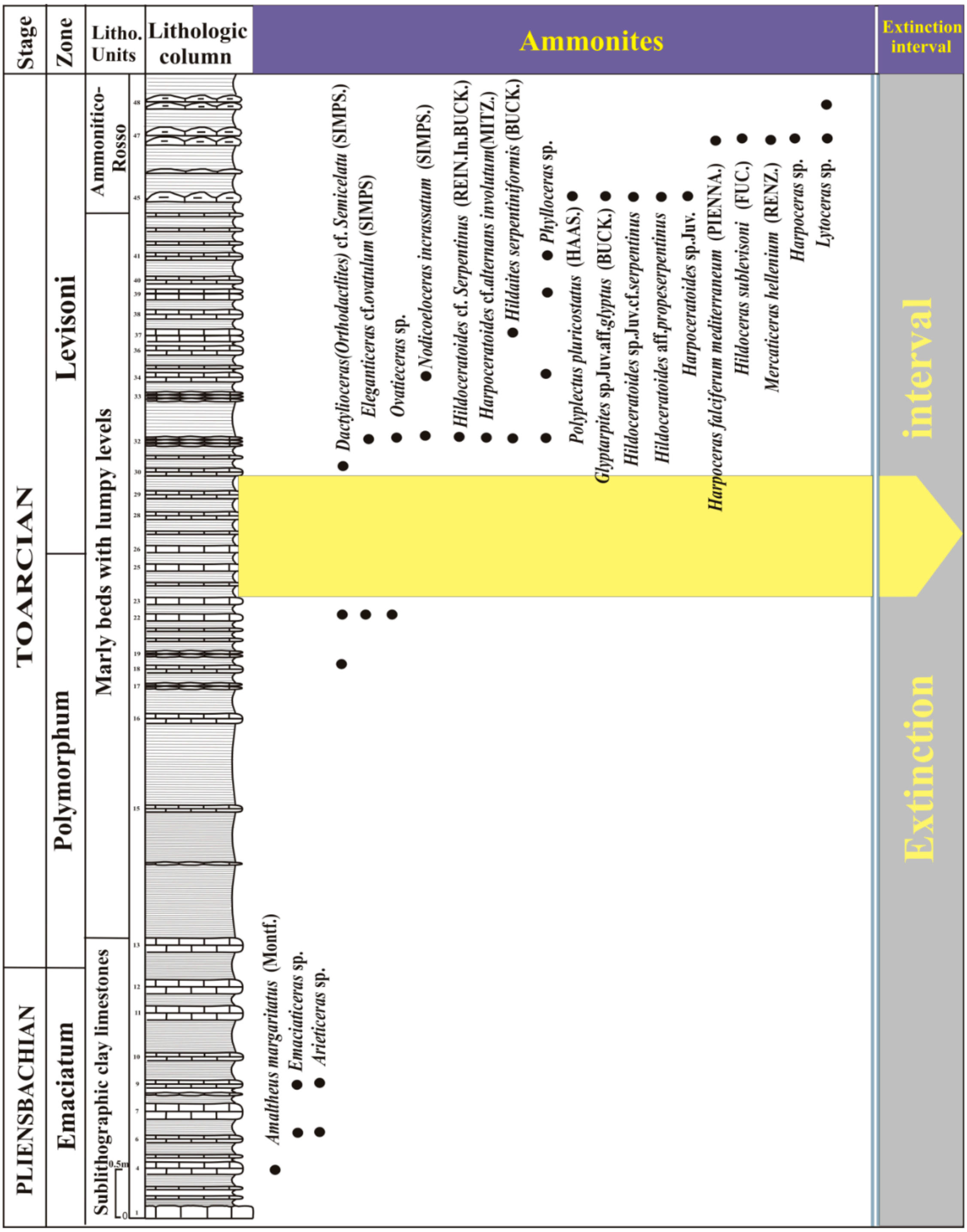

Figure 2. Stratigraphic distribution of ammonites from the Benia section.

5. Results

The systematic study identified and described fourteen (14) genera of ammonites belonging to six subfamilies (Figure 3): *Dactylioceratinae*, *Hildoceratinae*, *Harpoceratinae*, *Mercaticeratinae*, *Calliphylloceratinae*, and *Lytoceratinae*.

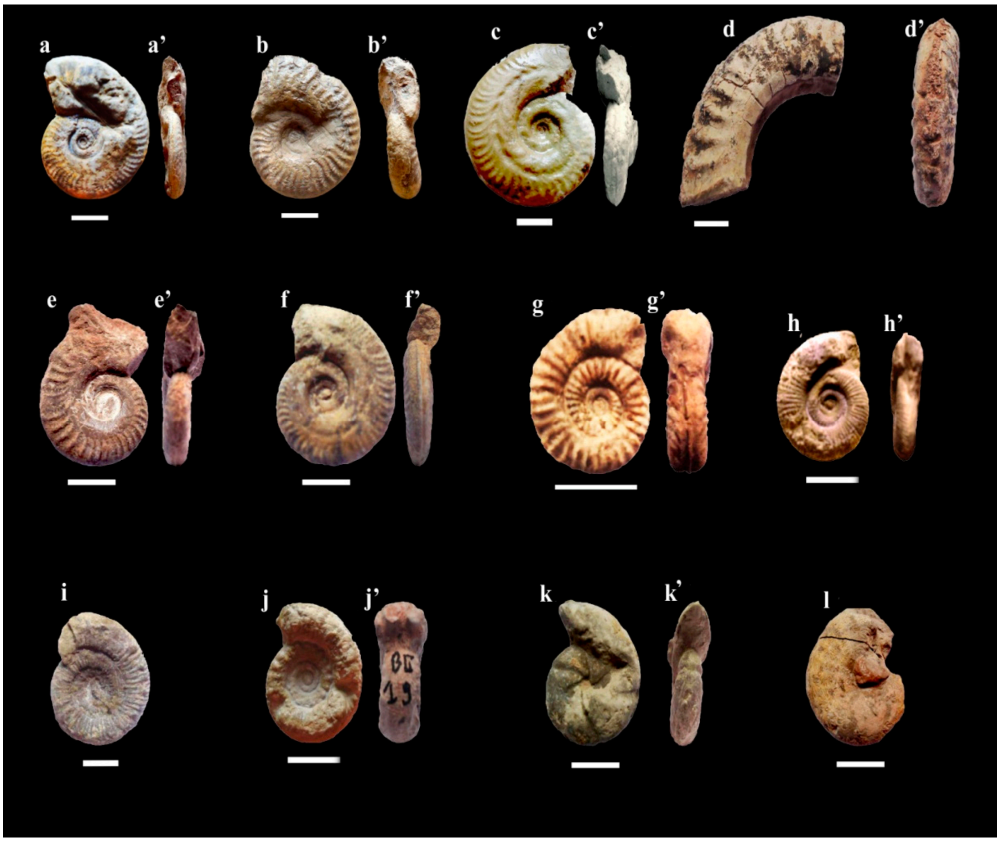

Figure 3. The ammonites collected: (**a**,**a′**) *Harpoceras falciferum SOWERBY*; (**b**,**b′**) *Maconieras vigoense BUCKMAN*; (**c**,**c′**,**f**,**f′**) *Hildoceras lusitanicum MEISTER*; (**d**,**d′**) *Hildoceras* sp.; (**e**,**e′**) *Hildoceras sublevisoni FUCINI*; (**g**,**g′**) *Mercaticeras*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

The faunas studied were identical to those known in Western Europe and occupied the same stratigraphic positions. The vertical extension showed two important horizontals: the first, at the base of horizon XIII, corresponded to the extinction of the *Hildoceratinae* and the appearance of *Hammatoceratidae* and *Grammoceratinae*; the second, at the base of horizon XXII, marked the disappearance of *Grammoceratinae* and the emergence of *Dumortiinae*.

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 was recognized by the presence of *Hildoceratidae*.

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 negative excursion of the isotope $\delta^{13}C$, $\delta^{18}O$ and an 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], it should, however, be pointed out that the few specimens of a small size (swarf forms) collected in the marly levels and the well-identified specimens (ammonites) are attributed to the microshell forms and 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. Conclusions

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 [60].

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 was recognized by the presence of *Hildoceratidae* [52]. During this time interval, hypoxia, favorable to the accumulation and preservation of organic matter, was characterized by a significant disturbance of the global carbon cycle, marked by an increase in organic carbon content (TOC). Benthic life almost completely disappeared, and microfauna (foraminifera) were absent ([56,59]). It should, however, be pointed out that the few specimens of a small size (swarf forms) collected in the marly levels and the well-identified specimens (ammonites) were attributed to the microshell forms and could 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 were correlated to those described in the North West Tethyan basins, where this global anoxic event (Oceanic Anoxic Event: OAE) was recorded [50]. During this period, the environmental conditions were also related to the Liasic tectonic event (eustatism), which played a key role in the paleogeographic evolution in North Africa and Europe.

Author Contributions: Conceptualization, F.D.B. and A.T.; methodology, F.D.B.; validation, F.D.B. and A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors thank all the people who contributed to the completion of this work, in particular the authorities of the Wilaya of Tiaret who facilitated and helped access cuts in the various sectors studied. We warmly thank them.

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

References

1. Hallam, A. Recovery of the marine fauna in Europe after the end-Triassic and early Toarcian mass extinctions. *Geol. Soc. Lond. Spec. Publ.* **1997**, *102*, 231–236. [CrossRef]
2. Wignall, P.B.; Newton, R.J.; Little, C.T.S. The timing of paleoenvironmental change and cause-and-effect relationships during the Early Jurassic mass extinction in Europe. *Am. J. Sci.* **2005**, *305*, 1014–1032. [CrossRef]
3. Arias, C. Extinction pattern of marine Ostracoda across the Pliensbachian Toarcian boundary in the Cordillera Ibérica, NE Spain: Causes and consequences. *Geobios* **2009**, *42*, 1–15. [CrossRef]
4. Arias, C. The Early Toarcian (Early Jurassic) ostracod extinction events in the Iberian Range: The effect of temperature changes and prolonged exposure to low dissolved oxygen concentrations. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2013**, *387*, 40–55. [CrossRef]
5. Reolid, M.; Nieto, L.M.; Sánchez-Almazo, I.M. Caracterización geoquímica de facies pobremente oxigenadas en el Toarciense inferior (Jurásico inferior) del Subbético Externo. *Rev. Soc. Geológica España* **2013**, *26*, 69–84.

6. Reolid, M.; Mattioli, E.; Nieto, L.M.; Rodríguez-Tovar, F.J. The Early Toarcian Ocanic Anoxic Event in the External Subbetic (Southiberian Palaeomargin, Westernmost Tethys): Geochemistry, nannofossils and ichnology. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2014**, *411*, 79–94. [CrossRef]
7. Reolid, M.; Rivas, P.; Rodríguez-Tovar, F.J. Toarcian ammonitico rosso facies from the South Iberian Paleomargin (Betic Cordillera, southern Spain): Paleoenvironmental reconstruction. *Facies* **2015**, *61*, 22. [CrossRef]
8. Rodríguez-Tovar, F.J.; Uchman, A. Ichnofabric evi- dence for the lack of bottom anoxia during the Lower Toarcian Oceanic Anoxic Event (T-OAE) in the Fuente de la Vidriera section, Betic Cordillera, Spain. *Palaios* **2010**, *25*, 576–587. [CrossRef]
9. Rita, P.; Reolid, M.; Duarte, L.V. The incidence of the Late Pliensbachian –Early Toarcian biotic crisis from ecostratigraphy of benthic foraminiferal assemblages: New insights from the Peniche reference section, Portugal. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2016**, *454*, 267–281. [CrossRef]
10. Hallam, A.; Wignall, P.B. *Mass Extinctions and their Aftermath*; Oxford University Press: Oxford, UK, 1997; 320p.
11. Baeza-Carratalá, J.F. Diversity patterns of Early Jurassic brachiopod assemblages from the westernmost Tethys (Eastern Subbetic). *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2013**, *381–382*, 76–91. [CrossRef]
12. Baeza-Carratalá, J.F.; García Joral, F.; Giannetti, A.; Tent-Manclús, J.E. Evolution of the last koninckinids (Athyridida, Koninckinidae), a precursor signal of the Early Toarcian mass extinction event in the Western Tethys. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2015**, *429*, 41–56. [CrossRef]
13. Vörös, A. Victims of the Early Toarcian anoxic event: The radiation and extinction of Jurassic Koninckinidae (Brachiopoda). *Lethaia* **2002**, *35*, 345–357. [CrossRef]
14. Lathuilière, B.; Marchal, D. Extinction, survival and recovery of corals from the Triassic to Middle Jurassic time. *Terra Nova* **2009**, *21*, 57–66. [CrossRef]
15. Reolid, M.; Chakiri, S.; Bejjaji, Z. Adaptative strategies of the Toarcian benthic foraminiferal assemblages from the Middle Atlas (Morocco): Palaeoecological implications. *J. Afr. Earth Sci.* **2013**, *84*, 1–12. [CrossRef]
16. Reolid, M.; Marok, A.; Sebane, A. Foraminiferal assemblages and geochemistry for interpreting the incidence of Early Toarcian environmental changes in North Gondwana palaeomargin (Traras Mountains, Algeria). *J. Afr. Earth Sci.* **2014**, *95*, 105–122. [CrossRef]
17. Reolid, M.; Sánchez-Quiñónez, C.A.; Alegret, L.; Molina, E. The biotic crisis across the Oceanic Anoxic Event 2: Palaeoenvironmental inferences based on foraminifera and geochemical proxies from the South Iberian Palaeomargin. *Cretac. Res.* **2016**, *60*, 1–27. [CrossRef]
18. Reolid, M.; Duarte, L.V.; Rita, P. Changes in foraminiferal assemblages and environmental conditions during the T-OAE (Early Jurassic) in the northern Lusitanian Basin, Portugal. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2019**, *520*, 30–43. [CrossRef]
19. Reolid, M.; Copestake, P.; Johnson, B. Foraminiferal assemblages, extinctions and appearances associated with the Early Toarcian Oceanic Anoxic Event in the Llanbedr (Mochras Farm) Borehole, Cardigan Bay Basin, United Kingdom. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2019**, *532*, 109–277. [CrossRef]
20. Vörös, A. The Pliensbachian brachiopods of the Bakony Mountains (*Hungary*). *Geol. Hung.* **2009**, *58*, 1–300.
21. Vörös, A. Early Jurassic (Pliensbachian) brachiopod biogeography in the Western Tethys: The Euro-Boreal and Mediterranean faunal provinces revised. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2016**, *457*, 170–185. [CrossRef]
22. Jenkyns, H.C.; Clayton, C.K. Lower Jurassic epicontinental carbonates and mudstones from England and Wales: Chemostratigraphic signals and the early Toarcian anoxic event. *Sedimentology* **1997**, *44*, 687–706. [CrossRef]
23. Jenkyns, H.C.; Jones, C.E.; Gröcke, D.R.; Hesselbo, S.P.; Parkinson, D.N. Chemostratigraphy of the Jurassic System: Applications, limitations and implications for palaeoceanography. *J. Geol. Soc.* **2002**, *159*, 351–378. [CrossRef]
24. Cohen, A.S.; Coe, A.L.; Harding, S.M.; Scwark, L. Osmium isotope evidence for the regulation of atmospheric CO_2 by continental weathering. *Geology* **2004**, *32*, 157–160. [CrossRef]
25. Hesselbo, S.P.; Jenkyns, H.C.; Duarte, L.V.; Oliveira, L.C.V. Carbon isotope record of the Early Jurassic (Toarcian) Oceanic Anoxic Event from fossil word and marine carbonate (Lusitanian Basin, Portugal). *Earth Planet. Sci. Lett.* **2007**, *253*, 455–470. [CrossRef]
26. Suan, G.; Pittet, B.; Bour, I.; Mattioli, E.; Duarte, L.V.; Mailliot, S. Duration of the Early Toarcian carbon isotope excursion deduced from spectral analysis: Consequence for its possible causes. *Earth Planet. Sci. Lett.* **2008**, *267*, 666–679. [CrossRef]
27. Hermoso, M.; Le callonnec, L.; Minoletti, F.; Renard, M.; Hesselbo, S.P. Expression of the Early Toarcian negative carbon-isotope excursion in separated carbonate microfractions (Jurassic, Paris Basin). *Earth Planet. Sci. Lett.* **2009**, *277*, 194–203. [CrossRef]
28. Sabatino, N.; Neri, R.; Bellanca, A.; Jenkyns, H.C.; Baudin, F.; Parisi, G.; Masetti, D. Carbon-isotope records of the Early Jurassic (Toarcian) oceanic anoxic event from the Valdorbia (Umbria-Marche Apennines) and Monte Mangart (Julian Alps) sections: Palaeoceanographic and stratigraphic implications. *Sedimentology* **2009**, *56*, 1307–1328. [CrossRef]
29. Bodin, S.; Mattioli, E.; Frölich, S.; Marshall, J.D.; Boutib, L.; Lahsini, S.; Redfern, J. Toarcian carbon isotope shifts and nutrient changes from the Northern margin of Gondwana (High Atlas, Morocco, Jurassic): Palaeoenvironmental implications. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2010**, *297*, 377–390. [CrossRef]
30. Gómez, J.J.; Arias, C. Rapid warming and ostracods mass extinction at the Lower Toarcian (Jurassic) of central Spain. *Mar. Micropaleontol.* **2010**, *74*, 119–135. [CrossRef]
31. Littler, K.; Hesselbo, S.; Jenkyns, H.C. A carbon-isotope perturbation at the Pliensbachian–Toarcian boundary: Evidence from the Lias Group, NE England. *Geol. Mag.* **2010**, *147*, 181–192. [CrossRef]
32. Baghli, H.; Mattioli, E.; Spangenberg, J.E.; Bensalah, M.; Arnaud- Godet, F.; Pittet, B.; Suan, G. Early Jurassic climatic trends in the south-Tethyan margin. *Gondwana Res.* **2020**, *77*, 67–81. [CrossRef]

33. Ruebsam, W.; Müller, T.; Kovacs, J.; Palfy, J.; Schwark, L. Environmental response to the early Toarcian carbon cycle and climate perturbation in the northeastern part of the West Tethys shelf. *Gondwana Res.* **2018**, *59*, 144–158. [CrossRef]
34. Ruebsam, W.; Reolid, M.; Schwark, L. δ13C of terrestrial vegetation records Toarcian CO2 and climate gradients. *Sci. Rep. UK* **2020**, *10*, 117. [CrossRef]
35. Hallam, A. The Pliensbachian and Tithonian extinction events. *Nature* **1986**, *319*, 765–768. [CrossRef]
36. Hallam, A. Radiations and extinctions in relation to environmental change in the marine Lower Jurassic of northwest Europe. *Paleobiology* **1987**, *13*, 152–168. [CrossRef]
37. Elmi, S. Stratigraphic correlations of the main Jurassic events in the Western Mediterranean Tethys (western Algeria and eastern Morocco). *Georesearch Forum* **1996**, *1–2*, 343–357.
38. Elmi, S.; Marok, A.; Sebane, A.; Almeras, Y. Intérêt de la coupe de Mellala (Monts des Traras, Algérie occidentale pour les corrélations de la limite Pliensbachien-Toarcien. 12eme Séminaire national des Sciences de la Terre, Oran. *Mars* **2006**, *2006*, 29–30.
39. Elmi, S. Pliensbachien/Toarcian boundary; the proposed GSSP of Peniche (Portugal). *Ciências Terra (UNL)* **2007**, *16*, 7–16.
40. Elmi, S.; Mouterde, R.; Rocha, R.B.; Ruget, C. Toarcian GSSP candidate: The Peniche section at Ponta do Trovão. Ciências Terra (UNL). *Lisboa* **2007**, *16*, 25–35.
41. Elmi, S.; Marok, A.; Sebane, A.; Almeras, Y. Importance of the Mellala section (Traras Mountains, northwestern Algeria) for the correlation of the Pliensbachian-Toarcian boundary. *Vol. Jurass.* **2009**, *7*, 37–45.
42. Mcarthur, J.M.; Donovan, D.T.; Thirvall, M.F.; Fouke, B.W.; Mattey, D. Strontium isotope of the Early Toarcian (Jurassic) oceanic anoxic event, the duration of ammonite biozones and belemnite palaeotemperatures. *Earth Planet. Sci. Lett.* **2000**, *179*, 269–285. [CrossRef]
43. Bailey, T.R.; Rosenthal, Y.; Mcarthur, J.M.; Van de schootbrugge, B.; Thirlwall, M.F. Paleoceanographic changes of the Late Pliensbachian-Early Toarcian interval: A possible link to the genesis of an oceanic anoxic event. *Earth Planet. Sci. Lett.* **2003**, *212*, 307–320. [CrossRef]
44. Ruban, D.A.; Tyszka, J. Diversity dynamics and mass extinctions of the Early-Middle Jurassic foraminifers: A record from the Northwestern Caucasus. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2005**, *222*, 329–343. [CrossRef]
45. Ghadeer, S.G.; Macquaker, J.H.S. Sediment transport processes in an ancient mud-dominated succession: A comparison of processes operating in marine offshore settings and anoxic basinal environments. *J. Geol. Soc.* **2011**, *168*, 1121–1132. [CrossRef]
46. Gómez, J.J.; Goy, A. Warming-driven mass extinction in the Early Toarcian (Early Jurassic) of northen and central Spain. Correlation with other time-equivalent European sections. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2011**, *306*, 176–195. [CrossRef]
47. Reolid, M.; Rodríguez-Tovar, F.J.; Marok, A.; Sebane, A. The Toarcian Oceanic Anoxic Event in the Western Saharan Atlas, Algeria (North African Paleomargin): Role of anoxia and productivity. *GSA Bull.* **2012**, *124*, 1646–1664. [CrossRef]
48. Trabucho-Alexandre, J.; Dirkx, R.; Veld, H.; Klaver, G.; De Boer, P.L. Toarcian black shales in the Dutch Central Graben: Record of energetic, variable depositional condition during an Oceanic Anoxic Event. *J. Sediment. Res.* **2012**, *82*, 104–120. [CrossRef]
49. Reolid, M.; Molina, J.M.; Nieto, L.M.; Rodríguez-Tovar, F.J. *The Toarcian Oceanic Anoxic Event in the South Iberian Palaeo-Margin*; Springer: London, UK, 2018; 122p.
50. Jenkyns, H.C. The early Toarcian (Jurassic) Oceanic Anoxic Event: Stratigraphic, sedimentary, and geochemical evidence. *Am. J. Sci.* **1988**, *288*, 101–151. [CrossRef]
51. Mcarthur, J.M.; Algeo, T.J.; Van de schootbrugge, B.; Li, Q.; Howarth, R.J. Basinal restriction, black shales, Re-Os dating, and the Early Toarcian (Jurassic) oceanic anoxic event. *Paleoceanography* **2008**, *23*, PA4217. [CrossRef]
52. Elmi, S.; Atrops, F.; Mangold, C. Les zones d'ammonites du Domérien-Callovien de l'Algérie occidentale—Première partie: Domérien-Toarcien. *Doc. Lab. Géologique Sci.* **1974**, *61*, 1–84.
53. Deleau, P. Le Djebel Nador. Etude stratigraphique et paléontologique. Bulletin du Service de la Carte Géologique d'Algérie. *2e série Stratigraphique* **1948**, *17*, 68.
54. Caratini, C. Etude géologique de la région de Chellala-Reibel. *Publ. Serv. Géologique L'algérie* **1970**, *40*, 1–2.
55. Lucas, G. Bordure Nord des Hautes Plaines dans l'Algérie occidentale. Primaire, Jurassique. Analyse structurale. In Proceedings of the XIX ème Congrès Géologique International, Aigiers, Algeria, 8–15 September 1952; 39p.
56. Sebane, A. Etude Systématique et Paléoécologique de la Microfaune du Lias Moyen et Supérieur du Djebel Nador (Tiaret -Algérie). Ph.D. Thesis, Université Claude Bernard, Lyon, France, 1984; 136p.
57. Elmi, S.; Almeras, Y.; Ameur, M.; Atrops, F.; Benhamou, M.; Moulin, G. La dislocation des plates-formes carbonatées liasique en Méditerranée occidental et ses implications sur les échanges fauniques. *Bull. Soc. Géol. Fr.* **1982**, *5–6*, 1007–1016. [CrossRef]
58. Sebane, A. Les Foraminifères du Jurassique des Monts des Ksour. Etude Biostratigraphique et Paléoécologique. Ph.D. Thesis, Université d' Oran, Oran, Algérie, 2007; 211p.
59. Mahdjoub, A.H. Les Foraminifères Benthiques du Passage Pliensbachien-Toarcien du Djebel Es- saffeh (Tiaret, Algérie Occidentale). Master's Thesis, Université Oran2, Oran, Algérie, 2018; 53p.
60. Guex, J. Sur la classification des *Dactylioceratidae* (*Ammonoidea*) du Toarcien. *Bull. Lab. Géol* **1971**, *64*, 225–243.