Ediacaran-Cambrian Boundary in the Anti-Atlas belt (Morocco): A review of biostratigraphy, chemostratigraphy and geochronology

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Abstract

Reassessment of biostratigraphic, chemostratigraphic, and geochronological data from the Ediacaran–Cambrian transition in the Anti-Atlas (Morocco) indicates that the previously assumed boundary—based solely on the BACE—may lie lower, within the upper Tabia Member (Adoudou Formation) of the Western Anti-Atlas, where the lower Cambrian ichnotaxon *Monomorphichnus* and *Treptichnus bifurcus* are recorded. Correlations show that the Tabia and Tifnout Members are diachronous, with a ~10 Myr stratigraphic gap in the Central-Eastern Anti-Atlas, suggesting the boundary likely lies within the regional unconformity between the Ouarzazate and Taroudant Groups.

Introduction & Geological setting

The Ediacaran–Cambrian transition has attracted significant attention from geoscientists due to its coincidence with the decline of Ediacaran biota and the emergence of Cambrian fauna. Investigating this interval relies on multidisciplinary approaches—including paleontology, ecology, and geobiochemistry—using dispersed stratigraphic sections across different continents. The Anti-Atlas belt of Morocco (Fig. 1), with its thick carbonate–siliciclastic successions of the Ouarzazate and Taroudant Groups (Fig. 2), represents one of the best-sampled regions for carbonate carbon isotopes ($\delta^{13}C$), alongside records of depauperate Ediacaran biota.

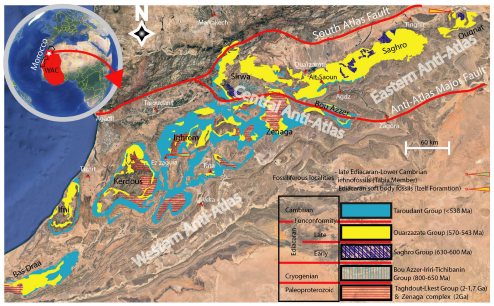


Fig. 1. Simplified geological map showing the geographical distribution of the late Ediacaran Ouarzazate Group and Cambrian Taroudant Group throughout the Anti-Atlas belt (adapted from Saadi et al., 1985; Maloof et al., 2005). WAC: West African Craton.

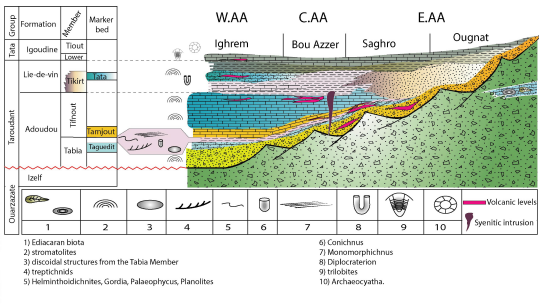


Fig. 2. SW-NE schematic stratigraphic cross-section showing the distribution of the geological formations of the Taroudant Group in the Anti-Atlas (from Álvaro et al., 2008 and references herein). Paleontological data are from Latham and Riding, 1990, El Kabouri et al. (2023a), Azizi et al. (2023).

However, in the absence of *Treptichnus pedum*, the exact position of the Ediacaran–Cambrian boundary in the Anti-Atlas remains uncertain. This uncertainty complicates the integration of the available $\delta^{13}C$ data from the region into a global stratigraphic framework.
In this study, we reassess the Ediacaran–Cambrian boundary in the Anti-Atlas belt in light of newly available biostratigraphic, chemostratigraphic, and geochronological data.

Methodology

We reassessed the available biostratigraphic, chemostratigraphic, and geochronological data from the Anti-Atlas belt. The paleontological data considered are limited to the Late Ediacaran Ouarzazate Group and the Late Ediacaran to Lower Cambrian Adoudou Formation (Taroudant Group, Fig. 2). These data were reevaluated in terms of their biogenicity and taxonomic identification. Additionally, we reexamined the stratigraphic correlations across the Western, Central, and Eastern Anti-Atlas using $\delta^{13}C$ chemostratigraphy and U–Pb geochronology.

Results & Discussion

The reassessed paleontological data indicate that an Ediacaran fossil assemblage occurs within the ca. 567–550 Ma Late Ediacaran Ouarzazate Group. In addition, paleontological evidence near the Ediacaran–Cambrian boundary consists of trace fossils preserved in the upper part of the Tabia Member (Fig. 2). Discoidal structures, previously interpreted as *Aspidella* and also found in the upper Tabia Member, are here reinterpreted as abiogenic in origin, based on their occurrence on mud crack-bearing beds. These structures likely result from the preferential weathering of concretions.
The ichnological assemblage of the upper Tabia Member includes *Monomorphichnus* and treptichnid traces, which we reinterpret as *Treptichnus bifurcus* (Miller, 1889), resembling those characteristic of the Lower Cambrian Treptichnus ichnozone (Fig. 3).

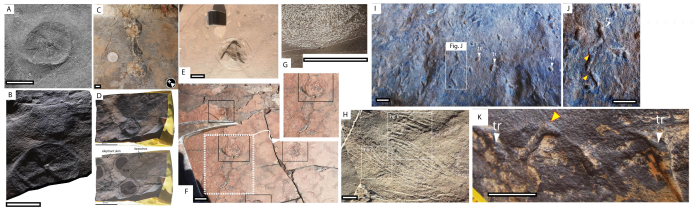
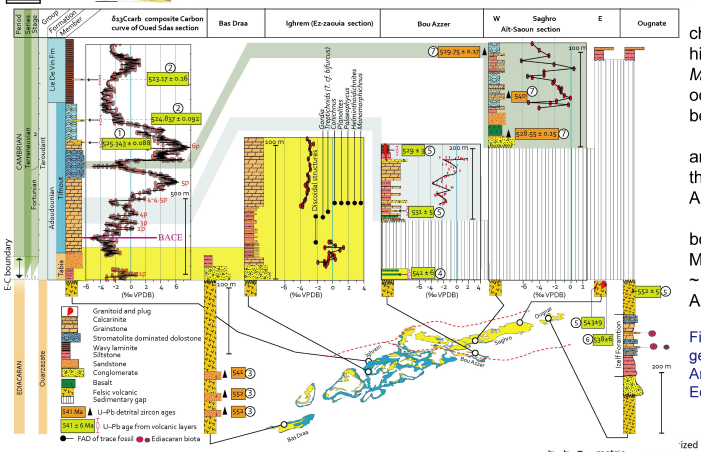


Fig. 3. Some Ediacaran–Lower Cambrian fossils and ichnofossils from the Izelf Formation (Ouarzazate Group) and the Tamria Member (Adoudou Formation), revised in this study. A, B: *cf. Arkarua*. C, D: frondose organisms. E, F, G: discoidal structures from the Tabia Member; note the association of these discoidal structures with mud cracks in F. H: *Monomorphichnus*. I, J: Trepichnid ichnofossils from the Tabia Member. K: *Treptichnus bifurcus*. Scale bar is 1 cm for all images.



Correlations of different sections based on chemostratigraphy and U-Pb geochronology highlight that, in the Western Anti-Atlas, *Monomorphichnus* and *Treptichnus bifurcus* occur in the upper part of the Tabia Member, below the BACE (Fig. 4).

In the Central-Eastern Anti-Atlas, the Tabia and Tifnout formations are, in fact, equivalent to the middle Tifnout Member in the Western Anti-Atlas (Fig. 4).

These data place the Ediacaran–Cambrian boundary below the upper part of the Tabia Member in the Western Anti-Atlas and within a ~10 Myr stratigraphic gap in the Central-Eastern Anti-Atlas (Fig. 4).

Fig. 4. Synthetic diagram of available paleontological, geochronological and chemostratigraphic data of the Anti-Atlas, and the probable position of the Ediacaran-Cambrian Boundary.

The integration of ichnological data from Morocco into the refined chemostratigraphy highlights that *Monomorphichnus* and *Treptichnus bifurcus* occur below the BACE in the Anti-Atlas (Fig. 5). This stratigraphic relationship suggests that, in the Anti-Atlas, the BACE is located within the Lower Cambrian (Fig. 5), contrary to the most recent global chemostratigraphic age models.

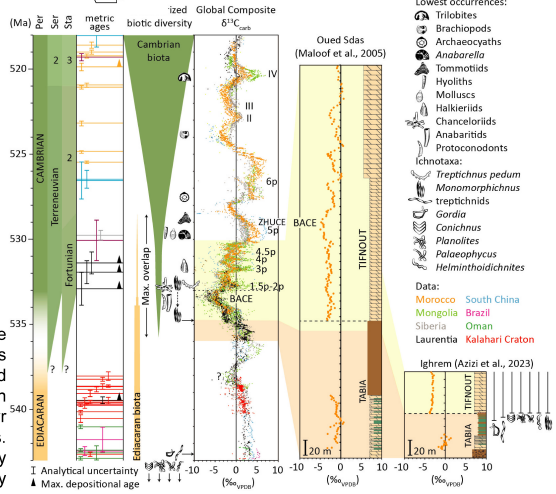


Fig. 5. Integration of new ichnological data (Azizi et al., 2023) in the global chronostratigraphic database after Bowyer et al., 2023b and references therein, showing available high precision radiometric ages with internal/analytical uncertainty, global chemostratigraphic data coloured by source region, and lowest occurrences of selected fossils.

Conclusion

The position of the Ediacaran–Cambrian (E–C) boundary in the Anti-Atlas belt is reassessed. In the current framework, this boundary is older than the upper part of the Tabia Member, located approximately 150 meters below the previously proposed level. In the Eastern–Central Anti-Atlas, the boundary lies within a ~10 Myr stratigraphic gap between the Ouarzazate and Taroudant groups. Some discoidal structures from the Tabia Member, previously interpreted as Aspidella, are likely abiogenic in origin and formed by preferential weathering of concretions.