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First record of trace fossils in the Ediacaran–Cambrian transition on the northern Gondwana platform (Anti-Atlas, Morocco)

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ABSTRACT

The Anti-Atlas Mountains of Morocco preserve one of the most complete latest Neoproterozoic to Cambrian stratigraphic successions worldwide, with high-resolution chemostratigraphic $\delta^{13}C_{carb}$ coverage. However, the exact stratigraphic position of the Ediacaran–Cambrian boundary remains unresolved. Until now, no trace fossils or body fossils have been recorded from the terminal Ediacaran strata in the Anti-Atlas Mountains. The only exception is a discoidal body fossil-like structure from the shallow-marine sandstones of the Ediacaran Tabia Member, Adoudou Formation, in the Taroudant Group in the Igherm inlier. For the first time, we document the occurrence of abundant trace fossils from the base of the Adoudou Formation, including Treptichnids, *Monomorphichnus* isp., *Helminthoidichnites* isp., *Gordia* isp., *Palaeophycus* isp., *Planolites* isp., and *Conichnus* isp. The integration of both trace fossils and carbon isotope $\delta^{13}C_{carb}$ records suggests that the Ediacaran–Cambrian transition in the Sous Basin can be placed at the contact between the Tifnout and Tabia Members, which chemostratigraphically coincides with the large negative $\delta^{13}C_{carb}$ excursion that had been previously suggested for the Ediacaran–Cambrian boundary (BACE) in the western Anti-Atlas Mountains.

1. Introduction

The Ediacaran–Cambrian boundary is one of the most interesting transitions in the history of life, characterized by the first mass extinction of the Ediacaran biota in the fossil record (Darroch et al., 2015, 2018; Smith et al., 2017; Nance et al., 2022), the first appearance of diverse metazoans with biomineralized skeletons (Germs, 1995), and an exceptional development of metazoan complexity and behaviour (Erwin, 1999; Knoll and Carroll, 1999; Narbonne, 2004, 2005). However, the exact timing of this bioevent and the stratigraphic position of the Ediacaran–Cambrian boundary remain poorly resolved. Reaching this goal is complicated due to an approximately 20-million-year gap between the youngest preservation of Ediacaran body fossil assemblages and that of Cambrian Stage 3 (Buatois et al., 2014). In contrast, the trace fossil record across the Ediacaran–Cambrian transition is far more diverse and continuous than that of the body fossils, providing valuable information about this critical biological transition. One of the ecological manifestations of the Cambrian Explosion was a rapid spread and diversification of complex animals capable of burrowing and penetrating the sediment, thereby producing a dramatic increase in the depth and intensity of bioturbation, known as the 'Agronomic Revolution' (e.g., Seilacher, 1999; Bottjer et al., 2000; Seilacher et al., 2005; Buatois et al., 2014, 2020). This bioturbation event was marked by a sudden shift in the trace fossil style from horizontal surficial traces in the late Ediacaran to vertically penetrative ichnofabrics in the Cambrian. The Ediacaran–Cambrian boundary is defined by the first appearance of the trace fossil *Treptichnus pedum* (Brasier et al., 1994). Secondary markers include the last occurrences of Ediacaran-type body fossils and the first appearance of small shelly fossils (SSFs), as well as a large negative carbon isotope excursion, termed the BACE (BAsal Cambrian carbon isotope Excursion) (e.g., Kimura and Watanabe, 2001; Amthor et al., 2003; Smith et al., 2016; Nelson et al., 2022, 2023).

In Morocco, the Ediacaran–Cambrian Adoudou Formation of the Taroudant Group is well exposed across the Anti-Atlas Mountains and serves as a standard for the global chemostratigraphic carbonate $\delta^{13}C$ curve of the Ediacaran–Cambrian boundary interval (Maloof et al.,

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