



Perspective

Evidence for an important extensional event during the Latest Proterozoic and Earliest Paleozoic in Morocco

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1. Introduction

By the end of Proterozoic times and during the Paleozoic, Morocco was connected to the West African shield. With the so-called Avalonian and Cadomian zones [8], it constituted the margin of the large Paleo-Gondwana continent (Fig. 1). The Proterozoic Panafrican orogeny left traces in many parts of the Paleo-Gondwana. In Morocco, this orogenic event is clearly displayed in the *Anti Atlas*, southern part of the country, where Proterozoic continental margin rocks and ophiolites are imbricated and covered in angular discordance by subsequent various continental, mainly detrital, sedimentary sequences and volcanic flows, pre-Cambrian in age. Their tectonic significance is still discussed; they represent either a late-orogenic molassic stage or a post-orogenic new cycle [14].

Lying above these redbeds, the Lower Cambrian carbonates contain some magmatic rocks. In the *Anti Atlas*, where they are well exposed and dated, some are effusive and intercalated into the sedimentary beds; others are intrusive into these carbonates. The *jbel Boho* syenite, for instance, in the central *Anti Atlas*, is dated at 534 ± 10 Ma [5]. All of them yield geochemical trends, tholeiitic or alkaline, compatible with an intracontinental extensional setting.

In *central Morocco*, the so-called *Meseta* domain is distinguished from the *Anti Atlas* by a more pronounced influence of the Hercynian shortening that

occurred, according to the area, from the end of the Devonian to the end of the Carboniferous [12]. In the less deformed areas, such as the western *Meseta*, the Cambrian sedimentary sequences are paleontologically dated and the intercalated volcanic flows can be characterized. All of these rocks, dated from Mid-Cambrian, present strong similarities with those of the *Anti Atlas*.

Elsewhere in the *Meseta*, the precise dating and geochemical characterization of the Cambrian magmatic series are difficult to realize due to the Hercynian deformation, and, moreover, the strong influence of the regional metamorphism responsible for the development of secondary parageneses. However, study of trace elements allows us to determine the geochemical trend of the initial rocks. In the eastern *Meseta* *Midelt* zone, for instance, the amphibolites thought to represent Cambrian metabasalts or dolerites yield, here too, an alkaline affinity, suggesting an intraplate setting [9]. Recently, a thorough study of the *Bou Acila* volcanic complex [10] in central *Meseta* has given the same results, concluding from their composition that these rocks witness an intra-continental extensional tectonic setting.

2. Structural and sedimentological evidence for an extensional regime during the Early Cambrian

In the *Anti Atlas* recent observations show that the Latest Proterozoic rocks, classically known as the *PIII* 'group', were deposited in faulted basins devel-

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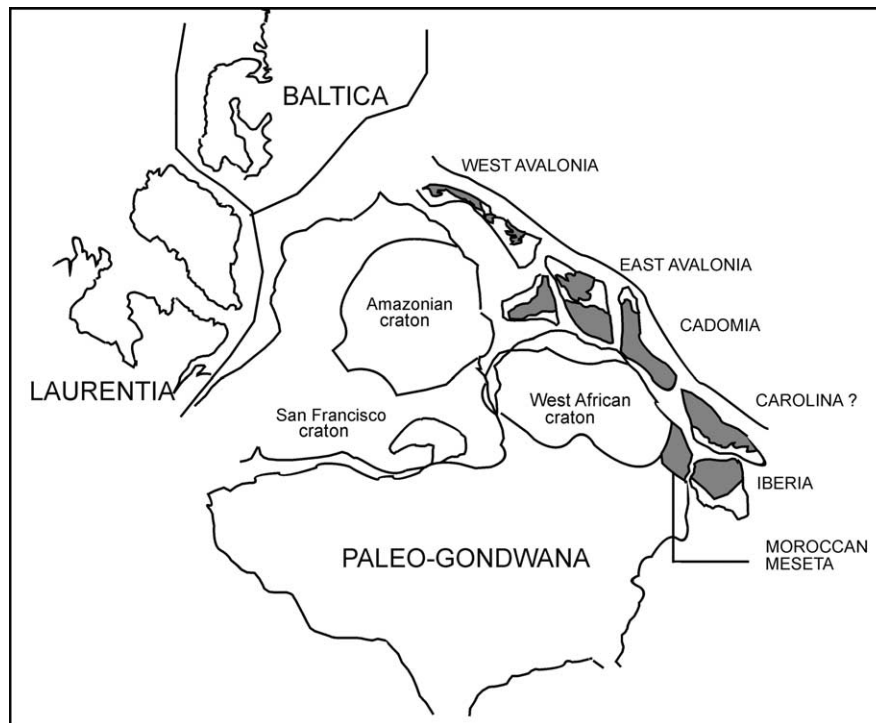


Fig. 1. Morocco and related areas at the limit Proterozoic-Paleozoic, from [8], modified.

oped under an extensive regime that lasted during the beginning of the Cambrian, favouring the eastward progression of the Early Paleozoic marine transgression within the 'Adoudounian' (i.e. Lowermost Cambrian) gulf [4]. In the western Anti Atlas, a NE-SW to NNE-SSW trending graben, initiated during the Early Cambrian between carbonate platforms, was filled up by argillaceous and siliciclastic sediments, before the deposition of the disconformable Mid-Cambrian deposits [1]. In the central Anti Atlas, an Early Cambrian tectonic activity is indicated by synsedimentary folds and in the central-eastern Anti Atlas, the deposition of the Latest Proterozoic and Lower Cambrian sequences was controlled by N70°E faults, en échelon between sinistral N110°E trending faults [15]. The tectonic regime that is determined for the whole Anti Atlas implies a pure extension in the western part of the domain, with, to a NW-SE direction, a north-south direction for the central Anti Atlas and a transtensive opening in the central-eastern Anti Atlas (Fig. 2).

North of the Anti Atlas, the Late Proterozoic and Early Cambrian sequences of the High Atlas present

important variations in their thickness from west to east [15]. Further to the north, the Mid Cambrian greywackes of the western Meseta were deposited in a NNE-SSW trending subsident trough (Fig. 2), bordered to the west and the east by more stable areas [2]. There, the synsedimentary tectonic activity was achieved by the end of Mid-Cambrian, when quartzitic sandstones of uniform thickness were deposited over the whole domain.

Finally, from south to north, the whole of Morocco was submitted to an extensive regime during the end of the Proterozoic and the beginning of the Paleozoic. Although the exact direction of the horizontal extension may vary from one area to another, the main extensive direction was, almost everywhere, subvertical. This regional extension, that began during the Late Proterozoic in the Anti Atlas, ended in this area at the end of the Early Cambrian. In the western Meseta it lasted during the Mid-Cambrian. In the central and eastern parts of the Meseta our knowledge of the Cambrian sequences is not sufficient to allow precise dating of the end of the extension.

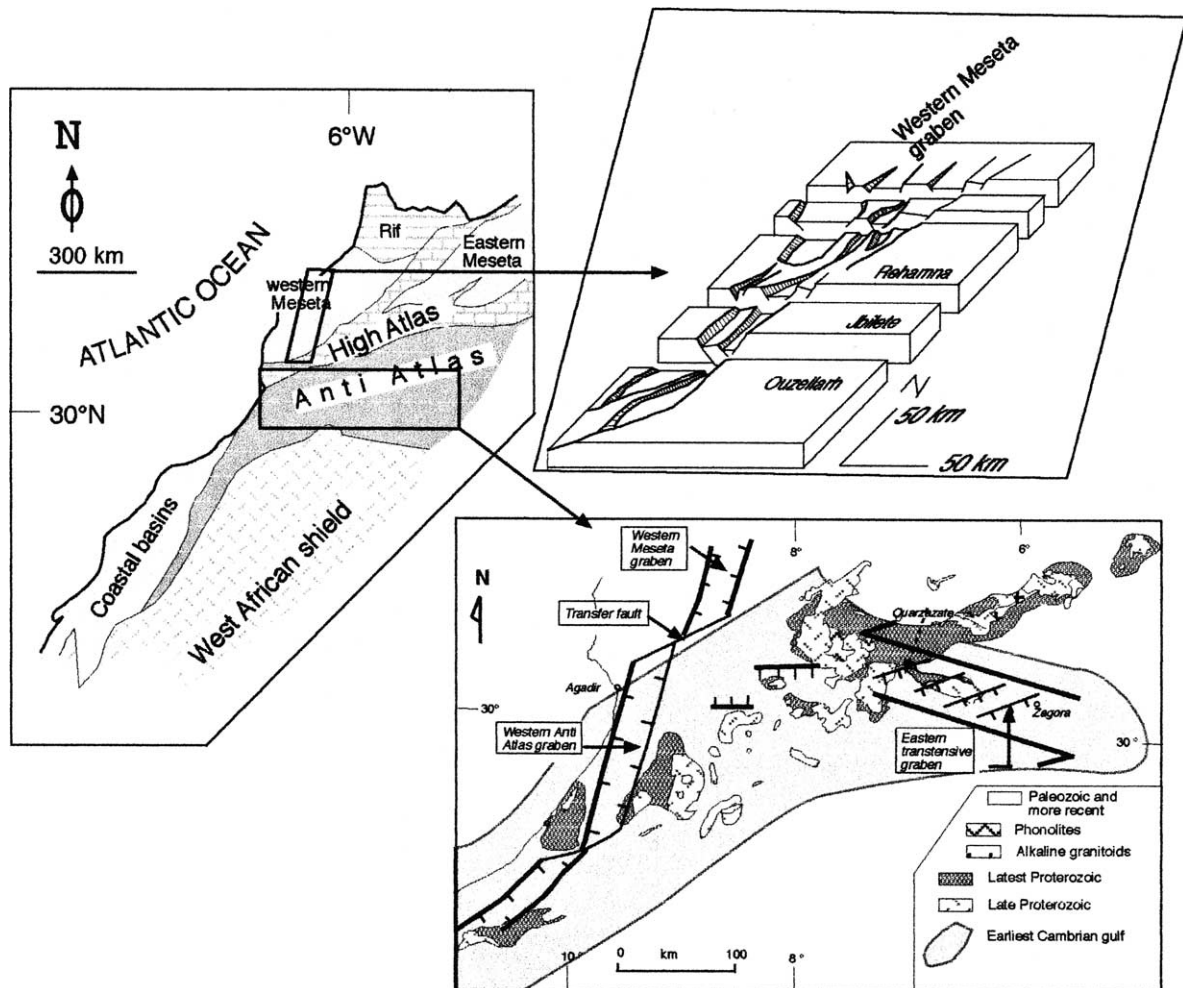


Fig. 2. The Late Proterozoic–Early Paleozoic rift on Morocco, from [2] and [11].

3. Tectonic significance of this extension

Throughout Morocco an important tectonic event occurred from the Latest Proterozoic to the beginning of the Paleozoic. It vanished during the Early Cambrian in the Anti Atlas and at the end of the Mid-Cambrian in the western Meseta. Its development is indicated by several markers that acted simultaneously:

- a structural extension, responsible for the development of fault-limited basins;
- the initiation of a marine transgression within these grabens, particularly evident in the Anti At-

las, giving way to the deposition of the Early Cambrian carbonates;

- the emplacement of effusive and intrusive magmas, most of them alkaline;
- a hydrothermal activity, known in the Precambrian basement of the Anti Atlas and its sedimentary cover as well, which accompanied the faulting and the magma emplacement and resulted in metallogenic concentrations [15].

All of these markers result from a same geotectonic event: the stretching of the continental crust and the partial melting of the underlying mantle. The crustal extension was shown by the development of

grabens where the marine transgression progressed. Meanwhile, mantelic magmas rose and emplaced in the sedimentary sequences. Developed at the scale of Morocco, this lithospheric thinning is therefore described in terms of a continental rifting. The rifting was initiated during the end of Proterozoic times, principally in the Anti Atlas. By the very beginning of the Cambrian, the Meseta was also affected. The rift aborted diachronously, later and later toward the north: in the Earliest Cambrian in the Anti Atlas, in the Mid-Cambrian in the western Meseta.

4. Conclusion: the Latest Precambrian-Early Paleozoic North-Gondwanan rifting

Traces of the rifting described above in Morocco exist in many regions, which are presently far from Morocco but share the same Gondwanian origin. In western Europe, the Armorican massif Cambrian graben is comparable to the western Morocco graben, although its end occurred later, during the Tremadocian [13]. Elsewhere, in Algeria [3], a Late Proterozoic (and Cambrian?) extension is associated with the emplacement of intraplate magmas [7]. A similar setting is known, also, further east, for instance in Egypt [6].

It is highly probable that, from the end of the Proterozoic to the beginning of the Paleozoic, the entire northern margin of the Gondwana suffered an intracontinental extension displayed by structural, magmatic, etc. markers.

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