



HAL
open science

Ordovician stratigraphy and benthic community replacements in the eastern Anti-Atlas, Morocco

J. Javier Alvaro, Mohammed Benharref, Jacques Destombes, Juan Carlos Gutiérrez-Marco, Aaron Hunter, Bertrand Lefebvre, Peter van Roy, Samuel Zamora

► **To cite this version:**

J. Javier Alvaro, Mohammed Benharref, Jacques Destombes, Juan Carlos Gutiérrez-Marco, Aaron Hunter, et al.. Ordovician stratigraphy and benthic community replacements in the eastern Anti-Atlas, Morocco. The Great Ordovician Biodiversification Event: Insights from the Tafilalt Biota, Morocco, 485, The Geological Society of London, pp.SP485.20, In press, Geological Society, London, Special Publication, 10.1144/SP485.20 . hal-02405970

HAL Id: hal-02405970

<https://hal.science/hal-02405970v1>

Submitted on 13 Nov 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

The Geological Society Special Publications

Ordovician stratigraphy and benthic community replacements in the eastern Anti-Atlas, Morocco --Manuscript Draft--

Manuscript Number:	GSLSpecPub2019-17R1
Article Type:	Research article
Full Title:	Ordovician stratigraphy and benthic community replacements in the eastern Anti-Atlas, Morocco
Short Title:	Ordovician stratigraphy of the Anti-Atlas
Corresponding Author:	Javier Alvaro Instituto de Geociencias SPAIN
Corresponding Author E-Mail:	jj.alvaro@csic.es
Other Authors:	MOHAMMED BENHARREF JACQUES DESTOMBES JUAN CARLOS GUTIÉRREZ-MARCO AARON W. HUNTER BERTRAND LEFEBVRE PETER VAN ROY SAMUEL ZAMORA
Order of Authors (with Contributor Roles):	Javier Alvaro (Methodology: Lead; Supervision: Lead; Writing – original draft: Lead; Writing – review & editing: Lead) MOHAMMED BENHARREF (Data curation: Supporting) JACQUES DESTOMBES (Data curation: Supporting; Formal analysis: Supporting; Methodology: Supporting; Project administration: Supporting) JUAN CARLOS GUTIÉRREZ-MARCO (Writing – review & editing: Supporting) AARON W. HUNTER (Visualization: Supporting) BERTRAND LEFEBVRE (Visualization: Supporting) PETER VAN ROY (Writing – review & editing: Supporting) SAMUEL ZAMORA (Visualization: Supporting)
Abstract:	The Anti-Atlas contains a thick, volcanic-free Ordovician succession, originally deposited in a passive-margin basin. Three main sedimentary packages are bounded by major unconformities: (i) the Tremadocian–Floian Lower Fezouata and Upper Fezouata formations, which unconformably overlie a palaeorelief of Cambrian rifting volcanosedimentary complexes, and is subsequently overlain by a Dapingian paraconformable gap; (ii) the Darriwilian–Katian Tachilla Formation and First Bani and Ktaoua groups, the latter unconformably overlain by a Hirnantian glaciogenic succession; (iii) subsequently infilled with deposits of the Second Bani Group. Due to the scarcity of carbonate interbeds for etching analyses, the global Ordovician chart is interpolated on the basis of microphytoplankton (acritarchs and chitinozoans), regional graptolites and brachiopods. The Ordovician counter-clockwise rotation of Gondwana led its Moroccan margin from mid- to high-latitude positions, leading to the onset of a siliciclastic, wave- and storm-dominated platform. Flooding surfaces are marked by shelly silty carbonate interbeds that reflect the episodic development of echinoderm-bryozoan meadows during Katian times; in areas protected from siliciclastic input, they reached massive and bedded bioaccumulations (Khabt-el-Hajar Formation). The Hirnantian glaciation controlled the incision of numerous tunnel channels, infilled with both alluvial-to-fluvial sediments and glaciomarine diacmictites. The Hirnantian

	palaeorelief was definitively sealed during Silurian times.
Section/Category:	The Great Ordovician Biodiversification Event: Insights from the Tafilalt Biota, Morocco
Additional Information:	
Question	Response
Are there any conflicting interests, financial or otherwise?	No
Samples used for data or illustrations in this article have been collected in a responsible manner	Confirmed

1 **Ordovician stratigraphy and benthic community replacements in the eastern Anti-Atlas,**
2 **Morocco**

3

4 J. JAVIER ÁLVARO^{1*}, MOHAMMED BENHARREF², JACQUES DESTOMBES[†], JUAN
5 CARLOS GUTIÉRREZ-MARCO¹, AARON W. HUNTER³, BERTRAND LEFEBVRE⁴,
6 PETER VAN ROY⁵ & SAMUEL ZAMORA⁶

7

8 ¹ *Instituto de Geociencias (CSIC-UCM), Dr. Severo Ochoa 7, 28040 Madrid, Spain*

9 ² *CAP Ressources, 56 El Fourat, Résidence Sanaa, bureau 18, 20330 Casablanca, Morocco*

10 ³ *Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge,*
11 *Cambridgeshire CB2 3EQ, United Kingdom*

12 ⁴ *UMR CNRS 5276 LGLTPE, Géode, Université Lyon 1, Villeurbanne Cedex, France*

13 ⁵ *Department of Geology and Soil Science, Ghent University, Krijgslaan 281 / S8, B-9000*
14 *Ghent, Belgium*

15 ⁶ *Instituto Geológico y Minero de España, Manuel Lasala 44–9^oB, 50006 Zaragoza, Spain*

16

17 *** Corresponding author:** *jj.alvaro@csic.es*

18

19 **Abstract**

20

21 The Anti-Atlas contains a thick, volcanic-free Ordovician succession, originally deposited in a
22 passive-margin basin. Three main sedimentary packages are bounded by major unconformities:
23 (i) the Tremadocian–Floian Lower Fezouata and Upper Fezouata formations, which
24 unconformably overlie a palaeorelief of Cambrian rifting volcanosedimentary complexes, and is
25 subsequently overlain by a Dapingian paraconformable gap; (ii) the Darriwilian–Katian Tachilla
26 Formation and First Bani and Ktaoua groups, the latter unconformably overlain by a Hirnantian
27 glaciogenic **succession**; (iii) subsequently infilled with deposits of the Second Bani Group. Due
28 to the scarcity of carbonate interbeds for etching analyses, leading to rare references of
29 conodonts, the global Ordovician chart is interpolated on the basis of microphytoplankton
30 (acritarchs and chitinozoans), regional graptolites and brachiopods. The Ordovician counter-
31 clockwise rotation of Gondwana led its Moroccan margin from mid- to high-latitude positions,
32 leading to the onset of a siliciclastic, wave- and storm-dominated platform. Flooding surfaces
33 are marked by shelly silty carbonate interbeds that reflect the episodic development of
34 echinoderm-bryozoan meadows during Katian times; in areas protected from siliciclastic input,
35 they reached massive and bedded bioaccumulations (Khabt-el-Hajar Formation). The Hirnantian
36 glaciation controlled the incision of numerous tunnel channels, infilled with both alluvial-to-

37 fluvial sediments and glaciomarine diamicrites. The Hirnantian palaeorelief was definitively
38 sealed during Silurian times.

39

40 **Introduction**

41

42 In the Anti-Atlas Ranges of Morocco, the Ordovician rocks occupy approximately 24,000 km²
43 of surface exposures (Fig. 1A–B) and host one of the most productive sedimentary metalliferous
44 deposits in NW Africa (Agard *et al.* 1952; Destombes 1954, 1958, 1959, 1985a; Destombes &
45 Jeanette 1962; Destombes 1970; Destombes *et al.* 1985; Raddi *et al.* 2011). Largely due to their
46 economic importance, these ironstones have ceaselessly been the focus of continuing mapping
47 programs and associated research projects.

48 About three decades ago, Destombes *et al.* (1985) summarized what was known at that
49 time about the Ordovician stratigraphy (Moroccan Program of Geological Mapping at
50 1/200,000 scale) and basin evolution history in the Anti-Atlas. Since then, the huge work
51 fostered by the Moroccan Geological Survey has been progressively improved by the
52 subsequent programs of geological mapping at 1/100,000 and 1/50,000 scales. Data acquired
53 during the last decades have provided important information about the Ordovician fossil record
54 and represent the basis for comparisons with neighbouring margins of Gondwana and other
55 continents based on chronostratigraphical, biogeographical, sedimentological and sequence-
56 stratigraphical correlations.

57 The Ordovician of the eastern Anti-Atlas contains three major gap-bounded, volcanic-
58 free sedimentary packages: (i) the Tremadocian–Floian Lower Fezouata and Upper Fezouata
59 formations, which unconformably overlie a palaeorelief of Cambrian rifting volcanosedimentary
60 complexes, and is subsequently overlain by a Dapingian paraconformable gap; (ii) the
61 Darriwilian–Katian Tachilla Formation and First Bani and Ktaoua groups, the latter
62 unconformably overlain by a Hirnantian glaciogenic succession; and (iii) the Second Bani
63 Group that infills the former glaciogenic palaeorelief.

64 Due to the virtual lack of igneous rocks and the scarcity of carbonate interbeds,
65 mapping and correlation of the Ordovician have traditionally relied on lithostratigraphical
66 comparisons along a 1,000 km-long transect from Tan-Tan (western edge of the Anti-Atlas) to
67 Erfoud (eastern edge). It seems timely to review the stratigraphical nomenclature established
68 over the past three decades in order to provide a convenient synthesis, from which to develop
69 local and basin-wide correlations. We provide below an overview of the Ordovician strata from
70 the eastern Anti-Atlas and adjacent areas. Major mappable lithostratigraphical units are
71 reviewed and placed in a regional geodynamical and sequence context.

72

73 **Geological setting and tectonostratigraphical units**

74

75 The Proterozoic basement of the Anti-Atlas lies along the northern margin of the West African
76 craton (Ennih & Liégeois 2008). The inliers of the High Atlas and the Anti-Atlas inliers are
77 crosscut by two major fault networks, the so-called South Atlas and Anti-Atlas Major Faults
78 (SAF and AAMF in Fig. 1B): the former crosscuts longitudinally the High Atlas, whereas the
79 latter exemplifies a Neoproterozoic ophiolite-bearing transect, representative of the Pan-African
80 orogenic suture (Michard *et al.* 2008). The end of the Pan-African orogeny was succeeded by
81 the onset of a latest Ediacaran–Cambrian rift, known as the Cambrian Atlas Rift (Álvaro *et al.*
82 2014a, b; Pouclet *et al.* 2018), which evolved during Ordovician times into a passive-margin
83 basin.

84 Geographically speaking, the Anti-Atlas is subdivided into the western, central and
85 eastern Anti-Atlas, the latter including the Jbel Saghro, the Jbel Ougnate and the Tafilalt district.
86 In contrast, from a geological point of view, several works suggest distinguishing the eastern
87 Anti-Atlas as westerly bounded by the Anti-Atlas Major Fault, as a result of which, a part of the
88 El Graara massif (including the Bou Azzer-El Graara inlier) would be included in the eastern
89 Anti-Atlas. In this work, we consider the eastern Anti-Atlas as including the Ordovician
90 exposures flanking the Jbel Saghro, the Jbel Ougnate and the scattered outcrops that punctuate
91 the Tafilalt district (1/200,000 maps of Destombes 1985b, d, 1987, 2006a; Raddi *et al.* 2006,
92 2012; Álvaro *et al.* 2014c, d; Benharref *et al.* 2014a, b, c) (Fig. 1B–C). In the eastern Anti-
93 Atlas, Ordovician rocks are well exposed, easily accessible, fossiliferous and relatively
94 undisturbed by tectonism. These advantageous attributes make this region a key area for the
95 study of the Ordovician stratigraphy and fossil record in Northwest Africa.

96

97 **A mid-latitude passive-margin basin**

98

99 After the end of the Pan-African Orogeny, a syn-rift megasequence comprises the Cambrian
100 Taroudant, Tata, Feijas Internes and Tabanite groups. These volcanosedimentary complexes
101 infilled the accommodation space generated during a ca. 55.6 m.y.-rifting episode, known as the
102 Cambrian Atlas Rift. A network of narrow, interconnected rifting branches was episodically
103 generated, bounded by disconnected shoulders that were locally tilted and uplifted during syn-
104 rifting pulses.

105 The beginning of rift geodynamics is diachronous throughout the Anti-Atlas but
106 extended across the Ediacaran–Cambrian boundary interval. During Cambrian times, the Atlas
107 Rift recorded the onset of (half-)grabens and horsts forming a linear SSW-NNE trending belt,
108 up to 400 km long and interrupted by a series of major en echelon extensional faults
109 (Soulaimani *et al.* 2003; Pouclet *et al.* 2007, 2018; Álvaro & Debrenne 2010). The resulting
110 accommodation space was controlled by extensional rift pulses that led to (i) sharp changes in

111 lithology and facies thickness; (ii) episodic deposition of conglomerates and breccias along rift
 112 flanks; (iii) local tilting and uplift along rift shoulders associated with subaerial exposure,
 113 development of hydrothermally induced metal ore deposits and local stratigraphic gaps; and (iv)
 114 deposition of deeper water facies along the axes of rift branches (Álvarez & Clausen 2007, 2008;
 115 Álvarez 2013, 2014; Álvarez *et al.* 2015). Several major unconformities punctuate the Cambrian
 116 volcanosedimentary complexes of the Atlas Rift, marking (i) a pre-rift unconformity at the base
 117 of the Adoudou Formation; (ii) a syn-rift unconformity marking the top of the Taguedit Bed
 118 (Tabia Member, Adoudou Formation), which represents a sharp change from extensive fault-
 119 controlled hydrothermal activity, carbonate production and phosphogenesis followed by sealing
 120 of the palaeorelief by microbial carbonate-dominated platforms (Tifnout Member, Adoudou
 121 Formation); (iii) the hiatal shell accumulations of the Brèche à Micmacca Member (Jbel
 122 Wawrmast Formation) overlying a low-angle unconformity locally affected by karstification;
 123 and (iv) a Furongian break-up unconformity that marks the rift/drift turnover (Álvarez 2013;
 124 Álvarez *et al.* 2014a, b; Álvarez & Vicaïno 2018) (Fig. 2). The Azlag Formation (Tabanite Group)
 125 marks the end of Cambrian sedimentation in the Anti-Atlas, excluding a tectonically depressed
 126 area of the central Anti-Atlas (El Graara massif), where lies the Jbel Lmgaysmat Formation
 127 (Tabanite Group). The latter comprises a 10 cm-thick shelly siltstone that has yielded Furongian
 128 trilobites and brachiopods (Destombes *et al.* 1985; Destombes & Feist 1987; Álvarez *et al.*
 129 2007a).

130 Throughout the Anti-Atlas, the Cambrian/Ordovician or Tabanite/Fezouata contact is
 131 represented by both paraconformities and angular discordances. The Tremadocian Lower
 132 Fezouata Formation occurs unconformably overlying either the Jbel Afraou, Bailiella, Azlag or
 133 Jbel Lmgaysmat formations of the Tabanite Group. As a result, the erosive gap involved at this
 134 break-up unconformity varies throughout the region from part of the Furongian to the Drumian–
 135 Guzhangian–Furongian time span. The rift/drift unconformity is marked in the Anti-Atlas by
 136 generalized uplift, tilting, subaerial exposure and erosion, which led to the sedimentation of the
 137 breccias and conglomerates that characterize the lower member of the Lower Fezouata
 138 Formation (Álvarez & Vicaïno 2018) (Fig. 2). The latter may represent a lag interval of latest
 139 Furongian alluvial-to-fluvial deposition (Destombes *et al.* 1985; Destombes 2006b) before final
 140 drowning of the entire Atlas Rift and the onset of the Anti-Atlas passive-margin basin.

141 The Cambrian evolution of the Atlas Rift recorded an episodic volcanism, which ranged
 142 from rift tholeiites to subsidiary sub-alkaline and alkaline magmatism that ended during
 143 Guzhangian times. The Atlas Rift was somewhat geodynamically connected to the Ossa-
 144 Morena Rift, which recorded a common (although diachronous) late Ediacaran–Terreneuvian
 145 arc-rift transition and a late Furongian rift-drift shift (Álvarez *et al.* 2014b; Pouclet *et al.* 2018).

146 During Ordovician times, a SW-NE-trending depositional trough developed in the Anti-
 147 Atlas that experienced enhanced axial subsidence in a depocentre located close to the Zagora-

148 Fom Zguid area (central Anti-Atlas). Although the Ordovician history of the Anti-Atlas is
 149 characterized by relative tectonic quiescence, by comparison with the Cambrian rifting history,
 150 the Ordovician succession is punctuated by two major, laterally extensive gaps, marking a
 151 Dapingian hiatus and a Hirnantian glaciogenic gap. The Ordovician represents over 41.2 m.y. of
 152 continuous sedimentation, (i) regionally preceded by major episodes of tilting and shoulder
 153 uplift of a graben-to-halfgraben framework recording the dynamic geological history from the
 154 initial (rift-to-drift) breakup unconformity; (ii) punctuated by the Dapingian hiatus related to
 155 non-deposition and/or erosion; and (iii) the final post-glacial Silurian sealing of an inherited
 156 glaciogenic palaeorelief (Fig. 2).

157 Palaeomagnetic (Smith 1997; Evans 2003) and palaeoenvironmental (e.g., Destombes
 158 1968a, b, 1981, 1987, 2006a, b; Destombes *et al.* 1985; Destombes & Willefert 1988; Ouanaimi
 159 1998; Hamoumi 1999; Álvaro *et al.* 2000, 2004, 2014c, d, 2016a; Sutcliffe *et al.* 2001; Ghienne
 160 *et al.* 2007a; Le Heron 2007; Le Heron *et al.* 2007, 2008; Le Heron & Craig 2008; Loi *et al.*
 161 2010; Videt *et al.* 2010; Clerc *et al.* 2013; Benharref *et al.* 2014a, b, c; Ravier *et al.* 2014)
 162 evidence indicates for the Anti-Atlas a counter-clockwise drift towards South Polar positions
 163 from a latest Ediacaran–Cambrian Epoch 2 arid subtropical (10–30°) setting to a Late
 164 Ordovician (50–70°) subpolar palaeolatitude.

165

166 **Lithostratigraphical chart**

167

168 The Ordovician lithostratigraphical units erected by Destombes (1962a, 1963a, b, 1971) and
 169 Destombes *et al.* (1985) in the vicinity of Zagora (Jbel Bani, central Anti-Atlas) are
 170 recognisable in the Tafilalt district. Some differences are remarkable, such as the relative
 171 thickness increase in the Middle–Upper Ordovician sandstone and quartzite interbeds, reflecting
 172 a palaeogeographical transect from deeper (depocentre in the Zagora-Fom Zguid area) to
 173 shallower (Ougnate and Tafilalt) settings of the passive-margin basin. Thus the Ordovician is
 174 comparable formation-by-formation from Zagora to Erfoud. The only significant (at formation
 175 scale) lateral facies change is the sudden increase in Katian carbonate production (Khabt-el-
 176 Hajar Formation) recorded in the vicinity of Erfoud, by comparison with the coeval shale-
 177 dominant Upper Ktaoua Formation (Destombes 1987; Álvaro *et al.* 2007; Jiménez-Sánchez *et*
 178 *al.*, 2015; Villas & Colmenar, *this vol.*).

179 Four major, laterally extensive, sandstone/quartzite packages can be traced for about
 180 400 km (Fig. 2). These are the **Darriwilian** Tachilla Formation (a major marker bed for mapping
 181 due to its dark reddish colour), the **Darriwilian-Sandbian** First Bani **Group** (subdivided in the
 182 central Anti-Atlas into five formations), the Upper Tiouririne Formation and the Amouktir
 183 Member (Upper Formation of the Second Bani Group). Between them, shale-dominated
 184 landscapes form the plains and jbel flanks of the Anti-Atlas orography. The absence of

185 Ordovician fan-shaped aprons and megadebris-flow deposits in the Anti-Atlas led to the
 186 identification of its exposures as representative of a marine platform with no significant break
 187 slopes and slope-related deposits, which are incompletely recognized in the High Atlas
 188 (Destombes *et al.* 1985; Ouanaimi *et al.* 2006).

189

190 *Feijas Externes Group* (Choubert & Termier 1947)

191

192 In the Anti-Atlas, a shale-dominated unit is sandwiched between the weathering-resistant,
 193 sandstone/quartzite packages of the Cambrian Tabanite and Middle–Ordovician First Bani
 194 groups. The Feijas Externes Group forms the plains and flanks of jbel between Akka and Alnif,
 195 and mainly consists of monotonous shales with sandy intercalations exhibiting locally
 196 glauconitic and ironstone interbeds. The total thickness ranges from a few tens of metres in the
 197 northern Jbel Ougate to about 1100 m in the Zagora-Foum Zguid depocentre. Destombes
 198 (1962a, b, 1963a, b, 1971) and Destombes *et al.* (1985) subdivided the group into four units,
 199 named Lower Fezouata and Upper Fezouata (grouped in a single formation by Gutiérrez Marco
 200 & Martín 2016 and Martín *et al.* 2016a, b in the depocentre, **due to their homogeneous**
 201 **lithological features**, but still used as distinct mappable formations in the geological maps of the
 202 Tafilalt district by Álvaro *et al.* 2014c, d and Benharref *et al.* 2014a, b, c), Zini (recognized in
 203 the surroundings of Zagora and in the vicinity of its homonymous jbel, southwestern Anti-
 204 Atlas) and Tachilla formations.

205

206 *Lower Fezouata Formation.* This unit is a shale-dominated succession, blue-green in colour,
 207 with sandy and glauconitic interbeds in its upper part. As stated above, it unconformably
 208 overlies either the Jbel Afraou, Bailiella, Azlag or Jbel Lmgaysmat formations, and ranges in
 209 thickness from zero (Jbels Tachilla and Ouarzemine in the northwestern Anti-Atlas, and
 210 northern Saghro, Maïder and northern Jbel Ougate in the eastern Anti-Atlas) to 400 m (Zagora-
 211 Foum Zguid depocentre). The base of the formation comprises lag deposits (marking a
 212 transgressive surface), rich in ferruginous breccia, conglomerate and sandstone, broadly up to 1
 213 m thick throughout the Anti-Atlas. In the vicinity of Foum Zguid, this unit can reach 10 m of
 214 thickness and has been mapped as an informal lower member (Destombes 1985c; Destombes &
 215 Feist 1987) representing the incision of alluvial-to-fluvial sedimentary systems (Álvaro &
 216 Vizcaïno 2018).

217

218 In the Jbel Ougate and the Tafilalt district, the Lower Fezouata Formation
 219 unconformably overlies the Azlag Formation (Destombes 1960a, b). Its contact is both
 220 paraconformable and discordant, the latter representing onlapping geometries of Ordovician
 221 shales sealing an inherited palaeorelief topped by Cambrian quartzites (Tazoult n'Ouzina and
 Jbel Zorg; Álvaro *et al.* 2014c). Throughout the Tafilalt district, two members can be

222 distinguished in the Lower Fezouata Formation, from bottom to top: (i) a set of conglomerates
 223 and sandstones, up to 1 m thick in Tazoult n'Ouzina; and (ii) a monotonous shaly succession, up
 224 to 400 m thick, locally glauconitic and comprising centimetre-to-decimetre sandstone interbeds.

225

226 *Upper Fezouata Formation.* The formation is subdivided into two members: (i) a
 227 cartographically significant greenish package, approximately 20 m thick, composed of
 228 glauconitic and ferruginous conglomerates and sandstones rich in glauconitic peloids, iron-rich
 229 ooids and hematite cement (Fig. 3A–B), and broadly cropping out in the southern Jbel Saghro,
 230 southern Maider and Tafilalt district; and (ii) a package of variegated alternations of shales and
 231 sandstones, 300–400 m thick (Destombes *et al.* 1985). The formation either conformably
 232 overlies the Lower Fezouata Formation (e.g., in the Tafilalt district) or unconformably overlies
 233 the Jbel Afraou and Bailiella formations (e.g., in the northern Jbel Ougnat; Destombes 1962b;
 234 Destombes *et al.* 1985; Choukri *et al.* 2004; Choukri & Hamoumi 2005). Both the Lower
 235 Fezouata and Upper Fezouata formations are absent in the southwestern area of the Anti-Atlas
 236 (Jbels Tachilla and Ouarzemine; Fig. 2), and the latter reaches a thickness maximum (600–700
 237 m) along the Akka-Tata transect.

238

239 *Tachilla Formation.* This unit, up to 1200 m thick in the Jbels Tachilla and Ouarzemine (south
 240 of Agadir), is a key cartographic marker throughout the Ordovician of the Anti-Atlas. It consists
 241 of ochre-to-blackish, ooidal sandstones rich in iron oxyhydroxides (Fig. 3C–D) with subsidiary
 242 green shale interbeds bearing centimetre-thick carbonate nodules. The base of the formation is
 243 represented by an erosive paraconformity, whereas its top is conformable. In the Jbels Tachilla
 244 and Ouarzemine, the Tachilla Formation is paraconformably overlying the Tabanite Group. In
 245 the eastern Anti-Atlas, the formation ranges from 20 m in the northern Tafilalt to 200 m in the
 246 southern Maider district and the Jbel Ougnat.

247

248 *First Bani Group* ('Bani Quartzites' by Choubert & Termier 1947; 'Quartzites of First Bani' by
 249 Choubert 1952)

250

251 The group forms the most extensive Ordovician sandstone package throughout the Anti-Atlas
 252 and accounts for the main relief of the 450 km-long Jbel Bani. It consists of an alternation of
 253 variegated sandstones and shales, with common iron ooidal interbeds in its lower part. The
 254 Tachilla/First Bani transition is gradual and marked by a progressive enrichment in the
 255 sandstone/shale ratio, whereas the top of the group is sharp and marked by the abrupt
 256 occurrence of decametre-thick shales. The formation exhibits a gradual increase in thickness
 257 from the northern Tafilalt district to the Zagora-Foum Zguid depocentre, ranging from 15 to 700
 258 m (Destombes 1987, 2006a, b). Although this group was originally subdivided in the central

259 Anti-Atlas into five formations (Destombes *et al.* 1985), its lithostratigraphical subdivision
 260 becomes ambiguous northeasternward. Destombes (1985b, 1987, 2006a, b) described it as a
 261 single unit in the 1/200,000 Tafilalt-Taouz sheet and the eastern margin of the 1/200,000
 262 Todhra-Ma' der sheet maps. Álvaro *et al.* (2014c) and Benharref *et al.* (2014c) have subdivided
 263 the group, in the Tafilalt district, into the Taddrist, Guezzart, Bou-Zeroual, Ouine-Inirne and
 264 Izegguirene formations based on the sandstone/shale ratio characterized by the presence/absence
 265 of distinct sedimentary structures.

266

267 *Ktaoua Group* (Choubert 1952)

268

269 The **toponymy** originally referred to the shaly plains and jbel flanks cropping out in the
 270 surroundings of Tagounite, central Anti-Atlas. It is sandwiched between the weathering-
 271 resistant sandstone-quartzite packages of the First and Second Bani groups. After several
 272 subdivisions, Destombes (1971) and Destombes *et al.* (1985) finally subdivided the group into
 273 three formations highlighting the presence of an intermediate sandstone-dominant package
 274 (Upper Tiouririne Formation) separating two shale-dominant units (Lower Ktaoua and Upper
 275 Ktaoua formations). Destombes *et al.* (1985) suggested a lateral change of the Upper Tiouririne
 276 Formation, to the east of Erfoud, into the 'Khabt-el-Hajar bryozoan limestones', which are
 277 distinguished below as a separate formation. The total thickness of the group attains its
 278 maximum close to the Ktaoua plain, with about 350 to 400 m.

279

280 *Lower Ktaoua Formation.* This unit is a shale-dominated succession with subsidiary sandstone
 281 interbeds and carbonate nodules and concretions parallel to stratification (Fig. 4A). In the
 282 Zagora-Foum Zguid depocentre, the base is marked by the occurrence of conglomeratic
 283 sandstones rich in ferruginous ooids. The members distinguished by Destombes *et al.* (1985) in
 284 the type area cannot be followed northeasternwards. In the Tafilalt district, Destombes (1987)
 285 distinguished three members, in ascending order: (i) the shale-dominated Jbel Bou-Isidane
 286 Member, (ii) the shale/sandstone alternations of the Jbel Tiberguent Member (Fig. 4B), and (iii)
 287 the heterolithic (sandstone-dominant) Jbel Tafersikt Member. However, the **latter** was
 288 exclusively recognized on jbel summits and, in some cases, will be reported below as the Alnif
 289 Member (Upper Formation of the Second Bani Group). A minor sandstone-dominant member,
 290 known as the "Middle Tiouririne sandstones" has been used in some maps of the depocentre due
 291 to its characteristic fossil content. Only the Jbel Bou-Isidane and Jbel Tiberguent members,
 292 reported as (informal) lower and upper subunits were mapped in the 1/50,000 maps of the
 293 Tafilalt district (Álvaro *et al.* 2014c, d; Benharref *et al.* 2014a, b, c).

294

295 *Upper Tiouririne Formation*. The presence of significant sandstone-dominated packages
296 marking the middle part of the Ktaoua Group is not clear in the Ktaoua plain and westwards. In
297 contrast, it is distinguishable in the Maider and Tafilalt districts and, to the west of Tagounite,
298 these sandstone packages served to Destombes (1985) to define the Rouïd Aïssa Formation.
299 There, this mappable sedimentary package is represented by a thick succession (150–300 m) of
300 sandstone beds and interbedded shales, calcareous siltites and carbonate nodules parallel to
301 stratification. Due to changes in the sandstone/shale ratio from Zagora to Tafilalt, the base is not
302 clearly distinguished northeasternwards. In the vicinity of Alnif, Álvaro *et al.* (2007b) suggested
303 the presence of a phosphatic limestone infested with the brachiopod *Rafinesquina pomoides* to
304 mark the base of the formation (Fig. 4C). This horizon can be followed in the Tafilalt district,
305 where the formation contains common cobble- to pebble-sized conglomeratic intervals rich in
306 shelly accumulations (Fig. 4D–G); its top is characterized by the presence of sandstone
307 packages with sigmoidal cross-stratified sets, episodically encrusted by ooidal hardgrounds rich
308 in iron oxyhydroxides (e.g., summit of Jbel Adrar; Álvaro *et al.* 2014b; Colmenar & Álvaro
309 2015: fig. 5a–b).

310
311 *Upper Ktaoua Formation*. This unit is incompletely preserved in the Tafilalt district due to its
312 upper erosive contact with the Second Bani Group. Where present, it can reach up to 80 m of
313 thickness and consists of monotonous shales episodically punctuated by decimetre-thick,
314 orthoceratid-rich calcareous siltstones (Fig. 4H) and sandstones, and scattered centimetre-thick
315 carbonate and phosphatic nodules, parallel to stratification and rich in orthoconic nautiloids.
316 One marker bed is recognizable close to the top of the formation, the so-called “Ouzregui bed”,
317 whose name is derived from the abundance of the trilobite species *Flexicalymene ouzregui*.

318
319 *Khabt-el-Hajar Formation*. To the North-East of Erfoud, some limestone/shale alternations
320 (Fig. 5A), informally named ‘Bryozoan Limestones’ and up to 40 m thick, were reported by
321 Termier & Termier (1950a, b) and Destombes (1962a). They were mapped and formally erected
322 by Destombes *et al.* (1985) as the Khabt-el-Hajar Formation. Several logs were reported by
323 Destombes (2006a) illustrating the presence of some angular discordances and ‘ravinement
324 surfaces’ representing, in fact, erosive surfaces (one of them marking the base of the formation)
325 and onlapping geometries of bryozoan- and echinoderm-rich limestone lenses (Fig. 5B–C). The
326 top of the formation is marked, in its northeasternmost outcrop (Destombes 2006a), by a barren
327 ironstone interval, 3 m thick, which may represent either the Second Bani Group or a Silurian
328 basal lag. Geometrically, the Khabt-el-Hajar Formation unconformably overlies a sandstone
329 package assigned to the Upper Tiouririne Formation by Destombes (2006a), and is
330 unconformably overlain by the above-reported, condensed ironstone level, which is
331 subsequently onlapped by Silurian shales (Destombes 1987, 2006a).

332

333 *Second Bani Group* ('Sandstones of the Second Bani' by Choubert & Termier 1947;

334 'Sandstones of the Second Bani or Beni Selmane' by Choubert 1952)

335

336 Although originally erected in the vicinity of Zagora, where a Lower Formation was
 337 distinguished, the Second Bani Group is only represented in the eastern Anti-Atlas by its upper
 338 formation (Destombes *et al.* 1985).

339

340 *Lower Formation.* In the Zagora-Foum Zguid depocentre, the heterolithic Lower Formation, up
 341 to 120 m thick, consists of conglomerates, sandstones and shales commonly separated by
 342 scouring surfaces. According to Destombes *et al.* (1985), its base is conformable and located at
 343 the occurrence of ooidal limestone nodules and centimetre-thick layers, whereas its top is
 344 marked by the glaciogenic unconformity that marks the base of the Upper Formation (Loi *et al.*
 345 2010).

346

347 *Upper Formation.* This formation was formally subdivided close to Alnif by Villas *et al.* (2006)
 348 and Álvaro *et al.* (2007b). Its three-fold subdivision (Alnif, Tamekhardt and Amouktir members)
 349 has been followed in the 1/50,000 geological sheets of the Tafilalt district (Álvaro *et al.* 2014c,
 350 d).

351 Several apparently diachronous unconformities had been traditionally recognized at the
 352 top of some jbel of the Ktaoua Group marking the base of variegated conglomerates.

353 According to their scouring position, these conglomerates received different lithostratigraphical
 354 names, such as 'Conglomérat d'Alnif' or 'Conglomérat d'Amessoui' (incising the Lower
 355 Ktaoua Formation in the vicinity of the eponymous village and jbel, respectively; Destombes
 356 1985b, c, d, 2006b; Hamoumi 1999; Choukri *et al.* 2004); 'Conglomérat d'Imzizoui' (incising
 357 the Upper Tiouririne Formation at the homonymous jbel; Destombes 2006a, b; El Maazouz &
 358 Hamoumi 2007); some conglomeratic beds forming the top of the Jbel Tafersikt Member
 359 (Lower Ktaoua Formation; Destombes 2006a), and the 'Argiles microconglomératiques'
 360 (Destombes *et al.* 1985) or glaciomarine diamictites (Villas *et al.* 2006). All these apparently
 361 diachronous unconformities represent indeed one single glaciogenic erosive unconformity that
 362 can be laterally correlated. After mapping in detail this unconformity and its stratigraphical
 363 contacts, the overlying Upper Formation (Second Bani Group) is clearly recognizable, on the
 364 basis of its deeply erosive lower boundary and the distinct glaciogenic features of its lower part
 365 (Álvaro *et al.* 2007b, 2014c, d; Benharref *et al.* 2014a, b, c).

366 The Alnif Member of the eastern Anti-Atlas represents a discontinuous unit, which
 367 comprises the Alnif Conglomerate *sensu* Destombes (1985b), up to 80 m thick, conformably
 368 overlain by an upper package of lenticular sandstones, up to 10 m thick (Fig. 5D–G). The Alnif

369 Member is overlain by a claystone-dominant diamictite, named ‘argiles microconglomératiques’
 370 by Destombes *et al.* (1985) owing to the presence of scattered quartz granules and pebbles
 371 ‘floating’ in a clayey matrix (Fig. 5H), and Tamekhtart Member by Villas *et al.* (2006); its
 372 thickness is highly variable (up to 100 m) and influenced by the bedrock palaeorelief inherited
 373 from the aforementioned erosive unconformity. Finally, the uppermost Amouktir Member, 30–
 374 60 m thick, is a stratigraphical unit resistant to weathering, composed of sandstone/shale
 375 alternations that pass upward into conglomerates (Fig. 5I), and ends at the occurrence of
 376 Silurian graptolite-bearing black shales.

377

378 **Biostratigraphical scale**

379

380 The global chronostratigraphical subdivisions defined by the *International Subcommission on*
 381 *Ordovician Stratigraphy* (ISOS) are mainly based on the first occurrence datum (FAD) of
 382 particular species of graptolites and conodonts. Due to the unsuitable environments for the **life**
 383 **and** preservation of key graptolites and the scarcity of carbonate interbeds for **dissolution to**
 384 **yield conodont elements**, leading to rare references of Ordovician conodonts in the Anti-Atlas
 385 (El Bourkhissi & Sarmiento 1997; Lehnert *et al.* 2016), the global chronostratigraphy of the
 386 Ordovician chart erected by the ISOS is interpolated in the Anti-Atlas on the basis of (i)
 387 microphytoplankton (acritarchs and chitinozoans; Elaouad-Debbaj 1984a, b, 1986, 1988a, b;
 388 Soufiane & Achab 1993; Paris 1990, 1996, 1999; Paris *et al.* 1995, 1999, 2007; Bourahrouh *et*
 389 *al.* 2004; Nowak *et al.* 2016; Tessitore 2016; Lefebvre *et al.* 2018), graptolites (Gutiérrez-Marco
 390 *et al.* 2003, Gutiérrez-Marco & Martin 2016; Lefebvre *et al.* 2018), brachiopods (Havlíček
 391 1970, 1971; Villas *et al.* 2006; Colmenar & Álvaro 2015) and, in its Katian part, by bryozoans
 392 (Jiménez-Sánchez *et al.* 2015a, b, 2016). The finest Ordovician zonation of the **N African-SW**
 393 **European margin of** Gondwana, based on chitinozoans, includes 26 biozones with an average
 394 duration close to 2 m.y. per zone. This biozonation can be tentatively correlated to the South
 395 Polar regional scale erected for the Ordovician, which includes several stages defined in
 396 Bohemia and Iberia (Gutiérrez-Marco *et al.* 2015, 2017b) (Fig. 6).

397

398 *Tremadocian–Floian*

399

400 The Lower Fezouata and Upper Fezouata formations are highly fossiliferous and have yielded
 401 acritarchs (Deunff 1968a, b), graptolites (Destombes & Willefert 1959), trilobites (Choubert *et*
 402 *al.* 1955; Destombes 1985b, c, d; Destombes *et al.* 1985) and echinoderms (Ubaghs 1963;
 403 Lefebvre & Fatka 2003). The scarcity of conodonts precluded any direct correlation with global
 404 Tremadocian horizons, but the presence of acritarchs and the graptolite *Rhabdinopora*
 405 *flabelliformis* has traditionally allowed the identification of the Tremadocian in the Anti-Atlas.

406 Destombes *et al.* (1985) and Destombes (2006a, b) reported an assemblage of
 407 graptolites sampled in the Upper Fezouata Formation cropping out in the Jbel Bou Legroun
 408 (NW Rissani), Taklimt, Aroudane and Zorg. Subsequently, based on graptolites, Gutiérrez-
 409 Marco & Martin (2016) recognized throughout the central and eastern Anti-Atlas the
 410 *Anisograptus matanensis*–*Rhabdinopora flabelliformis anglica*, ‘*Adelograptus*’ *tenellus*,
 411 *Aorograptus victoriae*, *Araneograptus murrayi*, *Hunnegraptus copiosus*, ?*Cymatograptus*
 412 *protobalticus*, ?*Baltograptus jacksoni* and *Baltograptus minutus* zones plus the ‘*Azygograptus*
 413 *interval*’, the succession of which represents the Tremadocian (Tr2–Tr3) and Floian (F11–F13)
 414 stage slices of Bergström *et al.* (2009). According to these authors, the base of the Lower
 415 Fezouata Formation does not coincide with the base of the Tremadocian, despite earlier studies
 416 reporting a Cambrian–Ordovician boundary age (Destombes 1971).

417 Recently, some strata of the Fezouata Konservat-Lagerstätte in the Tizig Zaouine
 418 section (north of Zagora) and the Adrar-Zouggar borehole (about 3 km SW of Zagora) have
 419 yielded a Tremadocian (Tr3 stage slice of Bergström *et al.* 2009) age, including the
 420 *messaoudensis*–*trifidum* acritarch assemblage of the upper Tremadocian–lower Floian (Cooper
 421 *et al.* 1995; Servais & Molyneux 1997), and the *paschaensis*–*symmetrica* and *brevis*
 422 chitinozoan-based zones (Nowak *et al.* 2015, 2016). Based on conodonts, Lehnert *et al.* (2016)
 423 recognized the Tremadocian (Tr3 stage slice) *Paraoistodus proteus* and the Floian (F11 slice)
 424 *Prioniodus oepiki* zones. A recent biostratigraphical reappraisal for the oldest Fezouata Biota by
 425 Lefebvre *et al.* (2018) clearly confirms the late Tremadocian age of the Lagerstätte strata, being
 426 mainly correlated with the *Paraoistodus proteus* biozone of conodonts, and with the 1–2 sub-
 427 assemblage of the *messaoudensis*–*trifidum* acritarch assemblage.

428

429 *Darriwilian*

430

431 Destombes *et al.* (1985) initially proposed four trilobite, two brachiopod and one echinoderm-
 432 based zones for the Tachilla Formation and the First Bani Group, which were subsequently
 433 assigned to the Fennian (*pars*), Oretanian and Drobotivian stages of the Mediterranean Province
 434 by Gutiérrez-Marco *et al.* (2003, 2017b). The regional stages represent the global Darriwilian
 435 Stage. These authors tentatively located the Middle–Upper Ordovician boundary below the
 436 FAD of the trilobite *Marrolithus cf. bureaui* Oehlert, about 20 m above the base of the
 437 Izegguirene Formation of the First Bani Group.

438 The chitinozoan *clavata (pars)*, *pissotensis* and *ponceti* zones have been recognized in
 439 the First Bani Group (Paris 1990), ranging as a whole from the early late Darriwilian to the
 440 earliest Sandbian (less than 3 m.y.; Videt *et al.* 2010).

441

442 *Sandbian–Katian*

443

444 In the central Anti-Atlas, the *deunffi* and *dalbyensis* chitinozoan zones were reported by
 445 Elaouad-Debbaj (1986) in the Assif bou Zeggarh Member of the Lower Ktaoua Formation,
 446 whereas, in the Amouguer Member of the same formation, the author recognized the
 447 *fistulosa/barbata* zones. As a result, the Lower Ktaoua Formation ranges in age from the early
 448 Sandbian to the mid Katian. The Upper Tiouririne Formation has yielded chitinozoans
 449 (Bourahrouh *et al.* 2004) of the *fistulosa/barbata* and *nigerica (pars)* zones, pointing to a mid-
 450 early late Katian age. The overlying Upper Ktaoua Formation has been assigned, based on
 451 chitinozoans, to the *nigerica (pars)* Zone (Elaouad-Debbaj 1984a; Destombes *et al.* 1985; Paris
 452 1990; Samuelsson *et al.* 2001; Bourahrouh *et al.* 2004), and correlated with the well J1-81A of
 453 NE **Lybia** (Molyneux & Paris 1985; Paris 1988).

454 In the vicinity of Alnif and in Tizi-n'Rsas (Al Atrous sheet, Tafilalt district), some
 455 calcareous siltstones marking the Lower Ktaoua/Upper Tiouririne transition are rich in
 456 brachiopods, which have allowed recognition of the *Tafilaltia destombesi*, *Drabovinella*,
 457 *Svobodaina feisti* and *Heterorthis alternata* brachiopod biostratigraphically significant
 458 associations (Villas *et al.* 2006; Álvaro *et al.* 2007b; Colmenar & Álvaro 2015).

459 Regarding the bryozoan-rich Khabt-el-Hajar Formation, Havlíček (1970, 1971),
 460 Termier & Termier (1970), Destombes (1985c, 2006a, b) and Le Menn & Spjeldnaes (1986)
 461 reported the presence of endemic trilobites, brachiopods and echinoderms, associated with
 462 undetermined conulariids, nautiloids, gastropods and bivalves. The **authors** claimed that the
 463 presence of some Telychian graptolites in marlstone interbeds, reported in older papers, should
 464 be ruled out. In addition, the record of the upper Katian brachiopods *Paucicrura catalanica*,
 465 *Drabovia* sp. and *Streptis?* sp. (Jiménez-Sánchez *et al.* 2015a; Villas & Colmenar this vol.), as
 466 well as of some **biostratigraphically significant** trilobites (such as *Brongniartella platynota*
 467 *marocana*, *Mucronaspis termieri*) and bryozoan species in the formation, have recently
 468 constrained the duration of episodes of carbonate productivity. Fenestrates (e.g., *Enallopora*
 469 *lineata*), cryptostomates (e.g., *Graptodictya meneghinii*, *Ptilodictya exilis*, *Stellatodictya*
 470 *valentinae* and *Ulrichostylus radiatus*) and trepostomates (e.g., *Anaphragma mirabile*,
 471 *Cyphotrypa magna*, *Dekayia minima*, *Diplotrypa languedociana*, *Homotrypa miqueli*,
 472 *Monotrypa jewensis*, *Prasopora falesi* and *Trematopora sardoa*) of the Khabt-el-Hajar
 473 Formation, also occur in the Glauzy and Gabian formations of the Montagne Noire, the
 474 Maciurru and Punta S'Argiola Members of the Domusnovas Formation and the units *c* and *e* of
 475 Sardinia, the La Peña Member (Cystoid Limestone **Formation**) of the Iberian Chains, and the
 476 Uggwa Formation of the Carnic Alps. Outside the Mediterranean margin, some of these species
 477 also occur in the Jövi and Oandu stages (D_{I-III}) and the Kegel Limestone of Estonia, the horizons
 478 B_I and B_{II} of the Volkhov and horizons B_I to B_{III} of the Lynna Formation in the Leningrad
 479 region (Russia); and in the Richmondian and Mohawkian Series of USA. This biostratigraphic

480 control and that provided by the Kralodvorian brachiopod and trilobite species listed above
 481 allowed Havlíček (1970, 1971), Destombes (1985c, 2006a, b), Jiménez-Sánchez *et al.* (2015a,
 482 b, 2016) and Villas & Colmenar (this vol.) to date the Khabt-el-Hajar Formation as late Katian.

483

484 *Hirnantian*

485

486 The Jbel Bou Ingarf section of east Zagora provides a complete Late Ordovician chitinozoan
 487 succession (Elaouad-Debbaj 1987; Paris *et al.* 1995) of the Katian–Hirnantian boundary interval
 488 and the Hirnantian. Some taxa, such as *Armoricochitina nigerica*, *Calpichitina lenticularis*,
 489 *Jenkinochitina leptota*, *Lagenochitina prussica* and *Ancyrochitina longispira*, occur both in the
 490 Upper Ktaoua and the Lower Second Bani formations, whereas other taxa (such as
 491 *Ancyrochitina merga*, *Plectochitina sylvanica*, *Spilachitina debbajae*) are restricted to the Upper
 492 Ktaoua Formation. The latter assemblage is characteristic of the *merga* Zone (Paris 1990).

493 Based on the presence of **an indeterminate species** of the brachiopod genus *Hirnantia* in the
 494 Lower Formation (Second Bani Group) of **the laterally equivalent Aït Issioul section, West of**
 495 **Tagounite**, Destombes (1985c, 2006b), Destombes *et al.* (1985), Loi *et al.* (2010) and Videt *et*
 496 *al.* (2010) placed **tentatively** the Katian–Hirnantian boundary within this formation. **However,**
 497 **Colmenar *et al.* (this vol.) has noted the presence of late Katian trilobites in the lower part of**
 498 **this formation at the Aït Issioul section, some metres below an undoubtedly Hirnantian**
 499 **brachiopod assemblage.**

500 The Tamekhtart and Amouktir members of the Upper Formation have yielded *A.*
 501 *nigerica*, *C. lenticularis*, *Spinachitina cf. fragilis* and *Tanuchitina elongata* (Elaouad-Debbaj
 502 1984), which Paris *et al.* (1995) referred to the *elongata* Zone. In addition, the *Eostropheodonta*
 503 *jebiletensis* brachiopod association has been reported in the Amouktir Member, which
 504 represents the *Aphanomena (=Eostropheodonta)-Hirnantia* Community (Rong 1986; Wang *et*
 505 *al.* 1987; Colmenar & Álvaro 2005).

506

507 **Control of sequence framework on the replacement of benthic communities**

508

509 The Ordovician of the Anti-Atlas comprises the sedimentation of a siliciclastic-dominant
 510 platform with subsidiary episodes of reefal-free carbonate productivity. The distal slope-apron
 511 and deep basinal deposits of this platform are absent in the Anti-Atlas, and may be placed
 512 throughout the northern High Atlas and Coastal meseta outcrops. The Ordovician exhibits the
 513 superposition of several orders of sea-level fluctuations. Changes in the rate of subsidence,
 514 driven by thermal cooling, global eustatism, sediment loading and/or local tilting were probably
 515 responsible for sequence and cyclic sedimentation. Tilting led to the record of low-angle
 516 discordances and onlapping features, which change laterally into paraconformities over larger

517 areas. The recorded sequence stratigraphic architecture exerted a primary control on the fossil
 518 record, mainly as a result of the onset of sharp environmental changes on flooding surfaces and
 519 the erosive role played by scouring surfaces capped by shoaling complexes.

520 In the Zagora-Foum Zguid depocentre, six Tremadocian–Floian third-order sequences
 521 were recognized by Loi *et al.* (2010) and Videt *et al.* (2010) (O1 to O6 in Fig. 7). Although a
 522 direct correlation of these six sequences with other Ordovician sequence frameworks is not
 523 available (for comparison, see e.g., Ross & Ross 1992, 1995 for Laurentia; Nielsen 2004 for
 524 Baltica; Ghienne *et al.* 2007b for the Ougarta Range of Algeria; Videt *et al.* 2010 for the
 525 Armorican Massif), some of them can be identified in the Anti-Atlas, such as the *Ceratopyge*
 526 Regressive Event of Baltica (*tenellus* graptolite Zone), identified in the Anti-Atlas by the O2
 527 sequence boundary. In the Tafilalt district, the Lower Fezouata/Upper Fezouata contact is well
 528 marked by the abundance of glauconitic ironstones, separating two successions of four-order
 529 shoaling-upward parasequences (O6 in Fig. 7) in a wave-dominant tide-modulated platform
 530 with predominance of offshore clayey substrates (Álvarez *et al.* 2014c, d; Vaucher *et al.* 2017;
 531 Saleh *et al.* 2018). About 200 taxa have been reported from these two formations, mainly
 532 controlled by the exceptional preservation conditions of the Fezouata Biota (Gaines *et al.* 2012;
 533 Lefebvre *et al.* 2016a, b, 2018; see list in Annex 1), the taphonomic conditions of which were
 534 virtually controlled by external climatic forcing (Saleh *et al.* 2019). The most representative
 535 benthic communities include non-reefal algae, bryozoans, cnidarians, echinoderms (Crinoidea,
 536 Diploporita, Edrioasteroidea, Eocrinoidea, Rhombifera, Soluta, Somasteroidea and Stylophora)
 537 and sponges, which are associated with brachiopods, molluscs (bivalves, rostroconchs,
 538 paragastropods, gastropods and tergomyans), hyoliths, annelids, cycloneuralia, lobopodians,
 539 arthropods (agnostoids, radiodonts, trilobites and other euarthropods) and problematica.

540 The Dapingian gap is marked by the absence of representative fossils in the Anti-Atlas.
 541 This paraconformity is sealed by the Darriwilian–Sandbian–Katian First Bani and Ktaoua
 542 groups. In some areas of the Anti-Atlas, such as in the Tachilla and Ouarzemine jbelles of the
 543 western Anti-Atlas, the Darriwilian sedimentation occurs directly sealing an inherited
 544 palaeorelief formed by Miaolingian strata; the corresponding Miaolingian–Dapingian gap
 545 should be associated with a Dapingian event responsible of uplift, tilting and erosion (Fig. 2).
 546 Although no geodynamic explanation has yet been advanced for this gap, a possible distal
 547 influence of the Mid–Late Ordovician Sardic Phase may be recorded in this margin of
 548 Gondwana. The Sardic Phase has been reported in the eastern branch of the Variscan Ibero-
 549 Armorican Arc (Sardinia, Pyrenees, Montagne Noire and Mouthoumet massif of Occitan
 550 Domain in South France, and Briançonnais in the Alps), but is virtually absent in the western
 551 branch or Iberian Massif (e.g., Stampfli *et al.* 2002; Casas 2010; Oggiano *et al.* 2010; Minzoni
 552 2011; Zubriggen 2015; Álvarez *et al.* 2016b).

553 The Darriwilian–Katian sedimentary package of the Anti-Atlas comprises the
 554 conformable Tachilla Formation and the First Bani and Ktaoua groups, which represent seven
 555 (O8 to O15 in Fig. 7) third-order sequences. They consist of interfingering sandstone- and
 556 shale-dominant rock packages, subdivisible into four-order parasequences dominated by
 557 shallowing-upward trends from deeper water (offshore) sediments shoaling, through
 558 aggradation and progradation, to shoreface/foreshore deposits. Some tops show evidence of
 559 fluvial point-bar migration and subaerial exposure and widespread precipitation of hematite
 560 crusts (Colmenar & Álvaro 2015). Carbonate production was not laterally persistent in the
 561 eastern Anti-Atlas (Álvaro *et al.* 2007b; El Maazouz & Hamoumi 2007), except in an area
 562 protected from **persistent** siliciclastic input. To the north of Erfoud, the Khabt-el-Hajar
 563 Formation consists of two successive marlstone-limestone units shallowing upward into mixed
 564 siliciclastic-limestone packages (Destombes *et al.* 1985).

565 Most of the sandstone/shale alternations and sandstone packages reported in the
 566 Tachilla Formation and the First Bani and Ktaoua groups form coarsening-upwards
 567 parasequences indicative of shoaling and/or upwards increase in energy level. They reflect the
 568 interplay and feedback between (i) changes in third-order accommodation potential, (ii) episodic
 569 progradation of terrigenous wedges, and (iii) distal production of temperate-water (bryonoderm)
 570 carbonate shelly factories rich in trepostomate and fenestrate bryozoans. The carbonate
 571 production during the HST was less resilient to terrigenous poisoning and was susceptible to
 572 localized nucleation of bryozoan–pelmatozoan meadows and thickets. Nearly all the silty and
 573 skeletal limestones that occur as decimetre-scale interbeds are inferred to represent stacking of
 574 mineralized hardgrounds and increased content of reworked phosphate nodules and crusts,
 575 indicating increased sediment starvation.

576 Darriwilian–Katian benthic communities comprise arthropods (aglaspidid and
 577 chelionellid euarthropods, ostracods and trilobites), brachiopods, echinoderms (Asteroidea,
 578 Coronata, Crinoidea, Diploporita, Edrioasteroidea, Eocrinoidea, Ophiuroidea, **Rhombifera**,
 579 Soluta and Stylophora), hyoliths, molluscs (bivalves, gastropods, rostroconchs and tergomyans),
 580 conulariids, paleoscolecidans, cornulitids, paropsonemid eldonioids, machaeridians and
 581 agglutinated problematic tubes (see list in Annex 1). Colmenar & Álvaro (2015) recognized in
 582 the Katian of the Tafilalt district, four types of brachiopod-dominant shell accumulations: (i) lag
 583 concentrations, interpreted as indicators of erosive surfaces; (ii) event concentrations
 584 representing either single or amalgamation of multiple reworking pulses; (iii) hydraulic simple
 585 and composite concentrations marking the top of shoal complexes; and (iv) hiatal or condensed
 586 concentrations on maximum flooding surfaces.

587 As stated above, major flooding surfaces reflect the episodic development of
 588 echinoderm-bryozoan meadows in outer-platform settings. In the eastern Atlas Basin, some
 589 bryozoan thickets flourished locally on Katian silty carbonates of the Ktaoua Group (Álvaro *et*

590 *al.* 2007b, 2014a, b; Benharref *et al.* 2014a, b, c). The onset of echinoderm-bryozoan meadows
 591 and mud-mounds had been previously reported in Libya (Buttler & Massa 1996; Buttler *et al.*
 592 2007), the Iberian Peninsula (Vennin *et al.* 1998; Jiménez-Sánchez 2009, 2010; Jiménez-
 593 Sánchez & Villas 2010; Jiménez-Sánchez *et al.* 2013) and Sardinia (Conti 1990). The bryozoan
 594 assemblages of the upper Katian Khabt-el-Hajar Formation display a diversity close to that
 595 documented in the Iberian Chains (Jiménez-Sánchez 2009, 2010; Jiménez-Sánchez & Villas
 596 2010) and Sardinia (Conti 1990), only surpassed in the southwestern Mediterranean region in
 597 the southern Montagne Noire (Ernst & Key 2007). Recent taxonomic studies on the bryozoans
 598 of the Khabt-el-Hajar Formation (Jiménez-Sánchez *et al.* 2015a, b) have identified 21 species of
 599 12 trepostomate genera and 15 species of 13 cryptostomate, fenestrate and trepostomate genera
 600 (Jiménez-Sánchez *et al.* 2016) adapted to offshore-dominated, marly substrates. Many of these
 601 species exhibit significantly larger body sizes than congeneric species from lower latitudes.
 602 Based on autozoocial sizes, many of them may be examples of subpolar gigantism (Jiménez-
 603 Sánchez *et al.* 2016). A complete biogeographical study of mid-high latitude bryozoans from
 604 the Mediterranean region (Carnic Alps, Iberian Chains, Libya, Montagne Noire, Morocco and
 605 Sardinia) was made by Jiménez-Sánchez & Villas (2010) and Jiménez-Sánchez *et al.* (2016),
 606 who concluded that the Moroccan-Libyan transect plot close to the remaining high-latitude
 607 Mediterranean assemblages. Bryozoans that invaded the Mediterranean margin of Gondwana,
 608 during the late Katian transgression, although preserving Baltic affinities, developed an
 609 independent faunal signal, denoting clear environmental differences from those in subtropical
 610 palaeocontinents, from which they came.

611 **A distinct Mediterranean biogeographic unit** (extending from what is now Syria to NW
 612 Argentina; **see original definition by Spjeldnaes 1961**), **postdating the Boda Event and**
 613 **characterized by Avalonian-Baltic affinities with low diversity and marked endemism**, emerged
 614 at subpolar latitudes. The extinction of several bryozoan genera in tropical seas, simultaneously
 615 with their immigration into the Mediterranean cool waters, is consistent with the onset of a late
 616 Katian global warming (Boda event) (Taylor & Ernst 2004; Fortey & Cocks 2005; Jiménez-
 617 Sánchez & Villas 2010).

618 The benthic communities that characterize the Katian-Hirnantian transition cannot be
 619 studied in the eastern Anti-Atlas due to the absence of the Lower Formation of the Second Bani
 620 Group. In the eastern Anti-Atlas, the Upper Ktaoua Formation is unconformably overlain by the
 621 Upper Formation of the Second Bani Group, locally forming distinct tunnel channels
 622 (Destombes 2006a, b; Álvaro *et al.* 2007b, 2014a, b; Loi *et al.* 2010; Videt *et al.* 2010;
 623 Benharref *et al.* 2014a, b, c; Colmenar & Álvaro 2015) (Fig. 2).

624 Finally, the Hirnantian glaciation has developed two incisions in the Anti-Atlas, (i) the
 625 onset of glacial channels from Alnif to the Tafilalt district, subsequently infilled by the alluvial-
 626 to-fluvial Alnif Conglomerate and the Tamekhtart glaciomarine diamictites, and (ii) a second

627 erosive (Amouktir Member) capped by marine, fossiliferous strata rich in brachiopods
628 (sequence O16 in Fig. 7). The subsequent palaeorelief was finally sealed by Silurian strata
629 (Álvaro *et al.* 2014c, d; Benharref *et al.* 2014a, b, c).

630

631 **Concluding Remarks**

632

633 The Ordovician sediments of the eastern Anti-Atlas are punctuated by three major
634 unconformities: (i) a Furongian break-up unconformity marking the end of the Cambrian Atlas
635 Rift and the development of a passive margin devoid of volcanism; (ii) a Dapingian
636 unconformity that separates a Tremadocian–Floian sedimentary package (Lower and Upper
637 Fezouata formations) from a Darriwilian–Katian sedimentary package (Tachilla Formation and
638 First Bani and Ktaoua groups); and (iii) the Hirnantian incision of tunnel channels and
639 glaciogenic (both continental and glaciomarine) imprint. The final sealing of the Hirnantian
640 palaeorelief was achieved during Silurian times.

641 Except the Katian Khabt-el-Hajar Formation, erected in the vicinity of Erfoud, the
642 Ordovician lithostratigraphy was originally defined in the Zagora-Foum Zguid depocenter. The
643 Ordovician is dominated by terrigenous deposits sedimented at mid- to high latitudes. Despite
644 the presence of scattered episodes of shelly carbonate production, only a proximal area close to
645 Erfoud has recorded the onset of bryozoan-echinoderm meadows and thickets (Khabt-el-Hajar
646 Formation) that allow identification of the Katian Boda event in this segment of the Gondwanan
647 margin.

648 Due to the palaeolatitudinal position of the Anti-Atlas Basin during Ordovician times,
649 carbonate production was scattered and mainly associated with the record of shelly pavements.
650 Key conodonts and graptolites have not been recovered to recognize the global
651 chronostratigraphic subdivision erected by the *International Subcommission on Ordovician*
652 *Stratigraphy*. The **thinnest** Ordovician zonation of the **N African-SW European margin of**
653 **Gondwana**, based on chitinozoans, includes 26 biozones with an average duration close to 2
654 m.y. per biozone. This chitinozoan scale is the standard in Morocco, to which the stratigraphic
655 ranges of graptolites, trilobites, brachiopods and other taxa are referred. The
656 chronostratigraphical regional South Polar scale, defined in Bohemia and Iberia, is applicable in
657 the Anti-Atlas.

658

659 **Acknowledgements**

660

661 **The authors thanks the useful and detailed revisions made by J. Colmenar, T. Servais and one**
662 **anonymous referee.** This work is dedicated to the memory of Jacques Destombes who left us
663 during the redaction of this synthesis. This paper is a contribution to Spanish project CGL2017-

664 87631-P from Spanish Ministry of Science, Innovation and Universities and IGCP 653 (IUGS-
665 UNESCO) project ‘The Onset of the Great Ordovician Biodiversification Event’.

666

667 **References**

668

669 AGARD, J., DESTOMBES, J. & VAN LECKWIJCK, W. 1952. Fer. Géologie des gîtes minéraux
670 marocains. *Notes et Mémoires du Service géologique du Maroc*, **87**, 103–112.

671 AKODAD, M., EL HARIRI, K., GUTIERREZ-MARCO, J. C., LEFEBVRE, B., LEHNERT, O., MARTIN,
672 E. L. O., NOWAK, H. & SERVAIS, T. 2018. The precise age of the Fezouata Lagerstätte,
673 Lower Ordovician, Morocco. *In: ZHANG, Y., ZHAN, R., FAN, J. & MUIR, L. (eds), Filling
674 the gap between Cambrian Explosion and the GOBE. Zhejiang University Press,
675 Zhejiang, 3-7. ISBN 978-7-308-17519-7.*

676 ALESSANDRELLO, A. & BRACCHI, G. 2003. *Eldonia berbera* n. sp., a new species of the
677 enigmatic genus *Eldonia* Walcott, 1911 from the Rawtheyan (Upper Ordovician) of Anti-
678 Atlas (Erfoud, Tafilalt, Morocco). *Atti della Società italiana di scienze naturali e del
679 Museo civico di storia naturale di Milano*, **144**, 337–358.

680 ALESSANDRELLO, A. & BRACCHI, G. 2006. Late Ordovician arachnomorph arthropods from the
681 Anti-Atlas (Morocco). *Atti della Società italiana di scienze naturali e del Museo civico di
682 storia naturale di Milano*, **147**, 305–315.

683 ALLAIRE, N., LEFEBVRE, B., MARTIN, E., NARDIN, E. & VAUCHER, R. 2015. Taphonomy of new
684 *Rhopalocystis* assemblages in the Lower Ordovician of the Zagora area (central Anti-
685 Atlas, Morocco). *In: ZAMORA, S. & RÁBANO, I. (eds). Progress in Echinoderm
686 Palaeobiology. Cuadernos del Museo Geominero*, **19**, 21–26.

687 ALLAIRE, N., LEFEBVRE, B., NARDIN, E., MARTIN, E. L. O., VAUCHER, R. & ESCARGUEL, G.
688 2017. Morphological disparity and systematic revision of the eocrinoid genus
689 *Rhopalocystis* (Echinodermata, Blastozoa) from the Lower Ordovician of the central
690 Anti- Atlas (Morocco). *Journal of Paleontology*, **91**, 685–714.

691 ÁLVARO, J. J. 2013. Late Ediacaran syn-rift/post-rift transition and related fault-driven
692 hydrothermal systems in the Anti-Atlas Mountains, Morocco. *Basin Research*, **25**, 348–
693 360.

694 ÁLVARO, J. J. 2014. Rift, pull-apart rift, and continental drift crossword puzzles across the
695 lower–middle Cambrian transition of Iberia and Morocco. *GFF*, **136**, 2–5.

696 ÁLVARO, J. J. & CLAUSEN, S. 2007. Botoman (Lower Cambrian) turbid- and clear-water reefs
697 and associated environments from the High Atlas, Morocco. *In: ÁLVARO, J. J., ARETZ,
698 M., BOULVAIN, F., MUNNECKE, A., VACHARD, D. & VENNIN, E. (eds). Palaeozoic Reefs
699 and Bioaccumulations: Climatic and Evolutionary Controls. Geological Society, London,
700 Special Publication*, **275**, 51–70.

- 701 ÁLVARO, J. J. & CLAUSEN, S. 2008. Paleoenvironmental significance of Cambrian hiatal shell
702 accumulations in an intra-cratonic aborted rift, Atlas Mountains, Morocco. *In*: PRATT, B.
703 R. & HOLMDEN, C. (eds). Dynamics of Epeiric Seas. *Geological Association of Canada,*
704 *Special Paper*, **48**, 39–54.
- 705 ÁLVARO, J. J. & DEBRENNE, F. 2010. The Great Atlasian Reef Complex: an early Cambrian
706 subtropical fringing belt that bordered West Gondwana. *Palaeogeography,*
707 *Palaeoclimatology, Palaeoecology*, **294**, 120–132.
- 708 ÁLVARO, J. J. & VIZCAÍNO, D. 2018. The Furongian break-up (rift-drift) transition in the Anti-
709 Atlas, Morocco. *Journal of Iberian Geology*, **44**, 567–587.
- 710 ÁLVARO, J. J., ROUCHY, J. M., BECHSTÄDT, T., BOUCOT, A., BOYER, F., DEBRENNE, F.,
711 MORENO-EIRIS, E., PEREJÓN, A. & VENNIN, E. 2000. Evaporitic constraints on the
712 southward drifting of the western Gondwana margin during Early Cambrian times.
713 *Palaeogeography, Palaeoclimatology, Palaeoecology*, **160**, 105–122.
- 714 ÁLVARO, J. J., VENNIN, E., VILLAS, E., DESTOMBES, J. & VIZCAÍNO, D. 2004. Hirnantian
715 valley-glacier sedimentation in the eastern Anti-Atlas, Morocco. *Erlanger Geologische*
716 *Abhandlungen*, **5**, 18–19.
- 717 ÁLVARO, J. J., FERRETTI, F., GONZÁLEZ-GÓMEZ, C., SERPAGLI, E., TORTELLO, M. F., VECOLI,
718 M. & VIZCAÍNO, D. 2007a. A review of the Late Cambrian (Furongian) palaeogeography
719 in the western Mediterranean region, NW Gondwana. *Earth-Science Reviews*, **85**, 47–81.
- 720 ÁLVARO, J. J., VENNIN, E., VILLAS, E., DESTOMBES, J. & VIZCAÍNO, D. 2007b. Pre–Hirnantian
721 (latest Ordovician) benthic community assemblages: controls and replacements in a
722 siliciclastic-dominated platform of the eastern Anti-Atlas, Morocco. *Palaeogeography,*
723 *Palaeoclimatology, Palaeoecology*, **245**, 20–36.
- 724 ÁLVARO, J. J., BENZIANE, F., THOMAS, R., WALSH, G. J. & YAZIDI, A. 2014a. Neoproterozoic–
725 Cambrian stratigraphic framework of the Anti-Atlas and Ouzellagh promontory (High
726 Atlas), Morocco. *Journal of African Earth Sciences*, **98**, 19–33.
- 727 ÁLVARO, J. J., BELLIDO, F., GASQUET, D., PEREIRA, F., QUESADA, C. & SÁNCHEZ-GARCÍA, T.
728 2014b. Diachronism of late Neoproterozoic–Cambrian arc-rift transition of North
729 Gondwana: a comparison of Morocco and the Iberian Ossa-Morena Zone. *Journal of*
730 *African Earth Sciences*, **98**, 113–132.
- 731 ÁLVARO, J. J., ARETZ, M., BENHARREF, M., HIBTI, M., POUCKET, A., EL HADI, H., KOUKAYA,
732 A., ETTACHFINI, E. M. & BOUDAD, L. 2014c. Carte géologique du Maroc au 1/50 000.
733 Feuille Tawz. Mémoire explicatif. *Notes et Mémoires du Service géologique*, **551bis**, 1–
734 127.
- 735 ÁLVARO, J. J., BENHARREF, M., HIBTI, M. & BOUDAD, L. 2014d. Carte géologique du Maroc au
736 1/50 000. Feuille Irara. Mémoire explicatif. *Notes et Mémoires du Service géologique du*
737 *Maroc*, **552bis**, 1–98.

- 738 ÁLVARO, J. J., EZZOUHAIRI, H., CLAUSEN, S., RIBEIRO, M. L. & SOLÁ, A. R. 2015. Syn-rift
739 unconformities punctuating the lower–middle Cambrian transition of the Atlas Rift,
740 Morocco. *International Journal of Earth Sciences*, **104**, 753–773.
- 741 ÁLVARO, J. J., SHIELDS, G. A., AHLBERG, P., JENSEN, S. & PALACIOS, T. 2016a. Ediacaran–
742 Cambrian phosphorites from the western margins of Gondwana and Baltica.
743 *Sedimentology*, **63**, 350–377.
- 744 ÁLVARO, J. J., COLMENAR, J., MONCERET, E., POUCKET, A. & VIZCAÏNO D. 2016b. Late
745 Ordovician (post–Sardic) rifting branches in the North Gondwanan Montagne Noire and
746 Mouthoumet massifs of southern France. *Tectonophysics*, **681**, 111–123.
- 747 AZIZI, A., VINN, O., EL HARIRI, K., HAFID, A. & KOURAISS, K. 2017. First description of
748 *Skolithos* burrows from the Cambrian–Ordovician boundary interval of the Central Anti-
749 Atlas, Morocco. *Estonian Journal of Earth Sciences*, **66**, 174–182.
- 750 BABIN, C. & DESTOMBES, J. 1990. Les Mollusques Bivalves et Rostroconches ordoviciens de
751 l’Anti-Atlas marocain: Intérêt paléogéographique de leur inventaire. *Géologie*
752 *Méditerranéenne*, **17**, 243–261.
- 753 BEISSWENGER, M. 1994. A calcichordate interpretation of the new mitrate *Eumitrocystella*
754 *savilli* from the Ordovician of Morocco. *Paläontologische Zeitschrift*, **68**, 443–462.
- 755 BENHARREF, M., ÁLVARO, J. J., HIBTI, M., POUCKET, A., EL HADI, H. & BOUDAD, L. 2014a.
756 Carte géologique du Maroc au 1/50 000. Feuille Marzouga. Mémoire explicatif. *Notes et*
757 *Mémoires du Service géologique du Maroc*, **553bis**, 1–119.
- 758 BENHARREF, M., HIBTI, M., POUCKET, A., EL HADI, H. & KOUKAYA, A. 2014b. Carte
759 géologique du Maroc au 1/50 000. Feuille MFis. Mémoire explicatif. *Notes et Mémoires*
760 *du Service géologique du Maroc*, **554bis**, 1–117.
- 761 BENHARREF, M., ÁLVARO, J. J., HIBTI, M., POUCKET, A., EL HADI, H., KOUKAYA, A. &
762 ETTACHFINI, E. 2014c. Carte géologique du Maroc au 1/50 000. Feuille Al Atrous.
763 Mémoire explicatif. *Notes et Mémoires du Service géologique du Maroc*, **555bis**, 1–146.
- 764 BERGSTRÖM, S. M., CHEN, X., GUTIÉRREZ-MARCO, J. C. & DRONOV, A. 2009. The new
765 chronostratigraphic classification of the Ordovician System and its relations to major
766 regional series and stages and to $\delta^{13}\text{C}$ chemostratigraphy. *Lethaia*, **42**, 97–107.
- 767 BOTTING, J. P. 2007. “Cambrian” demosponges in the Ordovician of Morocco: insights into the
768 early evolution of sponges. *Geobios*, **40**, 737–748.
- 769 BOTTING, J. P. 2016. Diversity and ecology of sponges in the Early Ordovician Fezouata Biota,
770 Morocco. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **460**, 75–86.
- 771 BOTTING, J. P. (this vol.). Late Ordovician crinoids from the Anti-Atlas region of Morocco. In:
772 HUNTER, A. W., ÁLVARO, J. J., LEFEBVRE, B., VAN ROY, P. & ZAMORA, S. (eds), *The*
773 *Great Ordovician Biodiversification Event: Insights from the Tafilalt Biota, Morocco*.
774 Geological Society, London, Special Publication, **485**, doi: 10.1144/SP485.4

- 775 BOURAHROUH, A., PARIS, F. & ELAOUAD-DEBBAJ, Z. 2004. Biostratigraphy, biodiversity and
 776 palaeoenvironments of the chitinozoans and associated palynomorphs from the Upper
 777 Ordovician of the Central Anti-Atlas, Morocco. *Review of Palaeobotany and Palynology*,
 778 **130**, 17–40.
- 779 BRUTON, D. 2008. A systematic revision of *Selenopeltis* (Trilobita: Odontopleuridae) with
 780 description of new material from the Ordovician of the Anti-Atlas region, Morocco.
 781 *Paläontologische Zeitschrift*, **82**, 1–16.
- 782 BUTTLER, C. J. & MASSA, D. 1996. Late Ordovician bryozoans from carbonate buildups,
 783 Tripolitania, Libya. In: GORDON, D. P., SMITH, A. M. & GRANT-MACKIE, J. E. (eds)
 784 *Bryozoans in Space and Time*. NIWA, Wellington, 63–68.
- 785 BUTTLER, C. J., CHERNS, L. & MASSA, D. 2007. Bryozoan mud-mounds from the Upper
 786 Ordovician Jifarah (Djeffara) formation of Tripolitania, north-west Libya.
 787 *Palaeontology*, **50**, 479–494.
- 788 CANDELA, Y. & HARPER, D. A. T. 2016. The brachiopod fauna of the Fezouata Shale (Lower
 789 Ordovician) of Morocco: preliminary results. *Programme, Abstracts and AGM papers*,
 790 *60th Annual Meeting of the Palaeontological Association, 14–17 December 2016, Lyon*,
 791 63–64.
- 792 CASAS, J. M. 2010. Ordovician deformations in the Pyrenees: new insights into the significance
 793 of pre-Variscan (“Sardic”) tectonics. *Geological Magazine*, **147**, 647–689.
- 794 CHAUVEL, J. 1966a. Echinodermes de l’Ordovicien du Maroc. *Cahiers de Paléontologie*, 120 p.
- 795 CHAUVEL, J. 1966b. Présence du genre *Anatifopsis* Barrande (Crustacés) dans l’Ordovicien du
 796 Maroc. *Comptes Rendus sommaires de la Société géologique de France*, **8**, 301–302.
- 797 CHAUVEL, J. 1966c. Sur quelques représentants du genre *Plumulites* Barrande (Machairidiés)
 798 provenant de l’Ordovicien du Maroc et du Massif armoricain. *Bulletin de la Société*
 799 *géologique et minéralogique de Bretagne* (nouvelle série), **1967**, 73–84.
- 800 CHAUVEL, J. 1969a. Données nouvelles sur le genre *Destombesia* Chauvel (Echinoderme,
 801 Cystoïde, Ordovicien de l’Anti-Atlas marocain). *Notes et Mémoires du Service*
 802 *géologique du Maroc*, **129** (213), 25–30.
- 803 CHAUVEL, J. 1969b. Les échinodermes macrocystellidés de l’Anti-Atlas marocain. *Bulletin de*
 804 *la Société géologique et minéralogique de Bretagne* (série C), **1**, 21–32.
- 805 CHAUVEL, J. 1971a. *Rhopalocystis ubaghsi*: un échinoderme du Trémadocien de l’Anti-Atlas
 806 marocain. Collection Ordovicien–Silurien, Brest. *Mémoires du BRGM*, **73**, 43–49.
- 807 CHAUVEL, J. 1971b. Les échinodermes carpoïdes du Paléozoïque inférieur marocain. *Notes et*
 808 *Mémoires du Service géologique du Maroc*, **237**, 49–60.
- 809 CHAUVEL, J. 1977. Note complémentaire sur les Cystoïdes Rhombifères (Echinodermes) de
 810 l’Ordovicien marocain. *Notes et Mémoires du Service géologique du Maroc*, **268**, 115–
 811 139.

- 812 CHAUVEL, J. 1978. Compléments sur les Echinodermes du Paléozoïque marocain (Diploporites,
813 Eocrinoïdes, Edrioastéroïdes). *Notes et Mémoires du Service géologique du Maroc*, **272**,
814 27–78.
- 815 CHAUVEL, J. & REGNAULT, S. 1986. Variabilité du genre *Rhopalocystis* Ubaghs, éocrinoïde du
816 Trémadocien de l'Anti-Atlas marocain. *Geobios*, **19**, 863–870.
- 817 CHOUBERT, G. 1952. Histoire géologique du domaine de l'Anti-Atlas (Géologie du Maroc,
818 fascicule 1, 2^e partie). *Notes et Mémoires du Service géologique du Maroc*, **100**, 75–194.
- 819 CHOUBERT, G. & TERMIER, H. 1947. Sur la stratigraphie de l'Ordovicien marocain. *Comptes*
820 *Rendus sommaires des Séances de la Société géologique de France*, **1947** (16), 335–337.
- 821 CHOUBERT, G., TERMIER, H. & TERMIER, G. 1953. Présence du genre *Mimocystites* Barrande
822 dans l'Ordovicien du Maroc. *Notes et Mémoires du Service géologique du Maroc*, **117**,
823 137–143.
- 824 CHOUBERT, G., HINDERMEYER, J. & HUPE, P. 1955. Découverte du Trémadoc dans l'Anti-
825 Atlas (Maroc). *Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences*
826 *de Paris*, **241**, 1592–1594.
- 827 CHOUKRI, C. & HAMOUMI, N. 2005. L'Arénig–Llanvirn du Haut Atlas occidental et central
828 (Maroc). Environnements sédimentaires, paléogéographie et contrôle de la sédimentation.
829 *Comptes Rendus Géoscience*, **337**, 1026–1034.
- 830 CHOUKRI, C., HAMOUMI, N. & ATTOU, A. 2004. Climatic and tectonic control of Ordovician
831 sedimentation in the western and central High Atlas (Morocco). *Journal of African Earth*
832 *Sciences*, **39**, 329–336.
- 833 CLERC, S., BOUCRISTIANI, J. F., GUIRAUD, M., VENNIN, E., DESAUBLIAUX, G. & PORTIER, E.
834 2013. Subglacial to proglacial depositional environments in an Ordovician glacial tunnel
835 valley, Alnif, Morocco. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **370**, 127–
836 144.
- 837 COLMENAR, J. 2016. Ordovician rafinesquinine brachiopods from peri-Gondwana. *Acta*
838 *Palaeontologica Polonica*, **61** (2), 293–326.
- 839 COLMENAR, J. & ÁLVARO, J. J. 2015. Integrated brachiopod-based bioevents and sequence-
840 stratigraphy framework for a Late Ordovician subpolar platform, eastern Anti-Atlas,
841 Morocco. *Geological Magazine*, **152** (4), 603–620.
- 842 COLMENAR, J., PEREIRA, S., PIRES, M., SILVA, C. M., SÁ, A. A. & YOUNG, T. P. 2017. A
843 Kralodvorian (upper Katian, Upper Ordovician) benthic association from the Ferradosa
844 Formation (central Portugal) and its significance for the redefinition and subdivision of
845 the Kralodvorian Stage. *Bulletin of Geosciences*, **92**, 443–464.
- 846 COLMENAR, J., VILLAS, E. & RASMUSSEN, C. M. Ø. (this vol.). A synopsis of Late Ordovician
847 brachiopod diversity in the Anti-Atlas, Morocco. *In*: HUNTER, A. W., ÁLVARO, J. J.,
848 LEFEBVRE, B., VAN ROY, P. & ZAMORA, S. (eds), *The Great Ordovician*

- 849 *Biodiversification Event: Insights from the Tafilalt Biota, Morocco*. Geological Society,
850 London, Special Publication, **485**, doi: 10.1144/SP485.3
- 851 CONTI, S. 1990. Upper Ordovician bryozoans from Sardinia. *Palaeontographia Italica*, **77**, 85–
852 165.
- 853 COOPER, A. H., RUSHTON, A. W. A., MOLYNEUX, S. G., HUGHES, R. A., MOORE, R. M. &
854 WEBB, B. C. 1995. The stratigraphy, correlation, provenance and palaeogeography of the
855 Skiddaw Group (Ordovician) in the English Lake District. *Geological Magazine*, **132**,
856 185–211.
- 857 CRIPPS, A. P. 1990. A new stem craniate from the Ordovician of Morocco and the search for the
858 sister group of craniate. *Zoological Journal of the Linnean Society*, **100**, 27–71.
- 859 DESTOMBES, J. 1954. Sur la présence du Llanvirn à minerai de fer oolithique dans l'anticlinal de
860 Tiflet (Maroc). *Comptes Rendus sommaires de la Société géologique de France*, **13**, 294–
861 296.
- 862 DESTOMBES, J. 1958. Les gisements de minerai de fer sédimentaire oolithique de la bordure S
863 de l'Ougnat et du Maïder. *Mines et Géologie, Rabat*, **4**, 32–35.
- 864 DESTOMBES, J. 1959. Les minerais de fer oolithiques: idées actuelles sur leur structure et leur
865 genèse. *Mines et Géologie, Rabat*, **6**, 43–52.
- 866 DESTOMBES, J. 1960a. Stratigraphie de l'Ordovicien de la partie occidentale du Jbel Bani et du
867 Jbel Zini (Anti-Atlas occidental), Maroc. *Bulletin de la Société géologique de France* (7^e
868 série), **2**, 747–751.
- 869 DESTOMBES, J. 1960b. Sur l'extension du Trémadoc dans le Sud marocain. *Comptes Rendus des*
870 *Séances mensuelles de la Société des Sciences Naturelles et Physiques du Maroc*, **3**, 45–
871 47
- 872 DESTOMBES, J. 1962a. Stratigraphie et paléogéographie de l'Ordovicien de l'Anti-Atlas
873 (Maroc): un essai de synthèse. *Bulletin de la Société géologique de France*, **4**, 453–460.
- 874 DESTOMBES, J. 1962b. Sur le caractère transgressif de l'Arénig supérieur dans l'Anti-Atlas
875 nord-occidental (Maroc). *Comptes Rendus sommaires de la Société géologique de*
876 *France*, **1**, 14–15.
- 877 DESTOMBES, J. 1963a. Le Cambrien et la base de l'Ordovicien dans la partie orientale et
878 méridionale du Tafilalt (Maroc). *Bulletin de la Société géologique de France*, **5**, 938–945.
- 879 DESTOMBES, J. 1963b. Données stratigraphiques sur l'Ordovicien de l'Anti-Atlas. *Rapport de*
880 *l'IFP, Paris*, **18**, 1464–1471.
- 881 DESTOMBES, J. 1963c. Quelques nouveaux Phacopina (Trilobites) de l'Ordovicien supérieur de
882 l'Anti-Atlas (Maroc). *Notes et Mémoires du Service géologique du Maroc*, **23** (172), 47–
883 65.

- 884 DESTOMBES, J. 1966. Quelques *Calymenina* (Trilobita) de l'Ordovicien moyen et supérieur de
885 l'Anti-Atlas (Maroc). *Notes et Mémoires du Service géologique du Maroc*, **26** (188), 33–
886 53.
- 887 DESTOMBES, J. 1967a. Distribution et affinités des genres de trilobites de l'Ordovicien de
888 l'Anti-Atlas (Maroc). *Comptes Rendus sommaires de la Société géologique de France*, **4**,
889 133–134.
- 890 DESTOMBES, J. 1967b. Quelques trilobites rares (*Lichas*, *Amphitryon*, *Dionide*) de l'Ashgill
891 (Ordovicien supérieur) de l'Anti-Atlas, Maroc. *Annales de la Société géologique du*
892 *Nord*, **87**, 123–126.
- 893 DESTOMBES, J. 1968a. Sur la présence d'une discordance générale de ravinement d'âge Ashgill
894 supérieur dans l'Ordovicien terminal de l'Anti-Atlas (Maroc). *Comptes Rendus de*
895 *l'Académie des Sciences, Paris* (série D), **267**, 565–567.
- 896 DESTOMBES, J. 1968b. Sur la nature glaciaire des sédiments du groupe du 2^e Bani, Ashgill
897 supérieur de l'Anti-Atlas, Maroc. *Comptes Rendus de l'Académie des Sciences, Paris*
898 (série D), **267**, 684–686.
- 899 DESTOMBES, J. 1970. Cambrien et Ordovicien. *Notes et Mémoires du Service géologique du*
900 *Maroc*, **229**, 161–170.
- 901 DESTOMBES, J. 1971. L'Ordovicien au Maroc. Essai de synthèse stratigraphique. *Mémoires du*
902 *BRGM*, **73**, 237–263.
- 903 DESTOMBES, J. 1972. Les Trilobites du sous-ordre des Phacopina de l'Ordovicien de l'Anti-
904 Atlas (Maroc). *Notes et Mémoires du Service géologique du Maroc*, **240**, 1–114.
- 905 DESTOMBES, J. 1981. Hirnantian (Upper Ordovician) tillites on the north flank of the Tindouf
906 Basin, Anti-Atlas, Morocco. In: HAMBREY, M. & HARLAND, W. (eds) *Earth's Pre-*
907 *Pleistocene Glacial Record*. Cambridge University Press, Cambridge, 84–88.
- 908 DESTOMBES, J. 1985a. Mineralization and non-metallic materials. In: HOLLAND, C. H. (ed.)
909 *Lower Palaeozoic Rocks of the World: Lower Palaeozoic Rocks of Northwestern and*
910 *West-Central Africa*. John Wiley and Sons, Chichester, 321–325.
- 911 DESTOMBES, J. 1985b. Notice explicative de la carte géologique du Maroc au 200.000e
912 "Todhra-Maïder" (Anti-Atlas oriental). Cambrien moyen, Ordovicien, base du Silurien.
913 Rapport inédit du Service de la Carte géologique du Maroc (2nd ed. in 2003), 80 pp.
- 914 DESTOMBES, J. 1985c. Notice explicative de la carte géologique du Maroc au 200.000e
915 "Zagora-Coude du Dra" (Anti-Atlas oriental). Cambrien moyen, Ordovicien, base du
916 Silurien. Rapport inédit du Service de la Carte géologique du Maroc (2nd ed. in 2003), 48
917 pp.
- 918 DESTOMBES, J. 1985d. Notice explicative de la carte géologique du Maroc au 200.000e
919 "Saghro-Dadès" (Anti-Atlas oriental). Cambrien moyen, Ordovicien, base du Silurien.
920 Rapport inédit du Service de la Carte géologique du Maroc, 36 pp.

- 921 DESTOMBES, J. 1987. Notice explicative de la carte géologique du Maroc au 200.000e “Tafilalt-
 922 Taouz” (Anti-Atlas oriental). Cambrien moyen, Ordovicien, base du Silurien. Rapport
 923 inédit du Service de la Carte géologique du Maroc, 87 pp.
- 924 DESTOMBES, J. 2000. Carte géologique du Maroc au 1/200 000 de l’Anti-Atlas marocain.
 925 Ordovicien, base du Silurien de la Feuille Akka-Tafagount-Tata. Mémoire explicatif,
 926 Chapitre G. Unpublished Report of the Service de la Carte géologique du Maroc, Rabat, 40
 927 p.
- 928 DESTOMBES, J. 2006a. Carte géologique au 1 : 200 000 de l’Anti- Atlas marocain. Paléozoïque
 929 inférieur: Cambrien moyen et supérieur – Ordovicien – base du Silurien. Sommaire
 930 général sur les mémoires explicatifs des cartes géologiques au 1/200 000 de l’Anti- Atlas
 931 marocain. *Notes et Mémoires du Service Géologique du Maroc*, **515**, 1–150.
- 932 DESTOMBES, J. 2006b. Carte géologique au 1/200 000 de l’Anti-Atlas marocain. Paléozoïque
 933 inférieur: Cambrien moyen-Ordovicien-base du Silurien. Feuille Goulimine-Dra inférieur
 934 au 1/200 000, feuille Fask au 1/100 000 (Anti-Atlas occidental, Maroc). Mémoire
 935 explicatif, Chapitre I [written in 2002]. *Notes et Mémoires du Service géologique du Maroc*,
 936 **90 bis A**, 34 p.
- 937 DESTOMBES, J. 2006c. Carte géologique au 1/200 000 de l’Anti-Atlas marocain. Paléozoïque
 938 inférieur : Cambrien moyen-Ordovicien-base du Silurien. Feuille régions de Tan-Tan–
 939 Jbel Zini (Province de Tarfaya). Mémoire explicatif, Chapitre J (Anti-Atlas sud-occidental
 940 au sud de l’oued Dra) [written in 2003]. *Notes et Mémoires du Service géologique du*
 941 *Maroc*, **90 bis B**, 29 p.
- 942 DESTOMBES, J. 2006d. Carte géologique au 1/200 000 de l’Anti-Atlas marocain. Paléozoïque
 943 inférieur: Cambrien moyen et supérieur-Ordovicien-base du Silurien. Feuille Telouet Sud,
 944 Ouarzazate, Alougoum, Agadir-Tissintt. Mémoire explicatif, Chapitre F [writtren in
 945 1988]. *Notes et Mémoires du Service géologique du Maroc*, **138 bis**, 43 p.
- 946 DESTOMBES, J. 2006e. Carte géologique au 1/200 000 de l’Anti-Atlas marocain. Paléozoïque
 947 inférieur (Cambrien moyen et supérieur-Ordovicien-base du Silurien). Feuille Foun el
 948 Hassane-Assa. Mémoire explicatif, Chapitre H (Flanc sud de l’Anti-Atlas occidental et des
 949 plaines du Dra) [written in 2001]. *Notes et Mémoires du Service géologique du Maroc*, **159**
 950 **bis**, 35 p.
- 951 DESTOMBES, J. 2006f. Carte géologique au 1/200 000 de l’Anti-Atlas marocain. Paléozoïque
 952 inférieur. Cambrien moyen et supérieur-Ordovicien-base du Silurien. Feuille Jbel Saghro-
 953 Dadès. Mémoire explicatif, Chapitre C [written in 1983]. *Notes et Mémoires du Service*
 954 *géologique du Maroc*, **161 bis**, 41 p.
- 955 DESTOMBES, J. 2006g. Carte géologique au 1/200 000 de l’Anti-Atlas marocain. Notice
 956 explicative. Paléozoïque inférieur. Cambrien moyen et supérieur-Ordovicien-base du

- 957 Silurien. Feuille Todrha- Maïder. Mémoire explicatif, Chapitre D [written in 1985]. *Notes*
 958 *et Mémoires du Service géologique du Maroc*, **243 bis**, 58 p.
- 959 DESTOMBES, J. 2006h. Carte géologique au 200 000 de l'Anti-Atlas marocain. Paléozoïque
 960 inférieur (Cambrien moyen et supérieur-Ordovicien-base du Silurien). Feuille Tafilalt-
 961 Taouz. Mémoire explicatif, Chapitre E (Anti-Atlas oriental) [written in 1987]. *Notes et*
 962 *Mémoires du Service géologique du Maroc*, **244 bis**, 69 p.
- 963 DESTOMBES J. 2006i. Carte géologique au 1/200 000 de l'Anti-Atlas marocain. Paléozoïque
 964 inférieur. Cambrien moyen et supérieur-Ordovicien-base du Silurien. Feuille Bou Haiara-
 965 Zegdou. Mémoire explicatif, Chapitre B [written in 1983]. *Notes et Mémoires du Service*
 966 *géologique du Maroc*, **259 bis**, 30 p.
- 967 DESTOMBES, J. 2006j. Carte géologique au 1/200 000 de l'Anti-Atlas marocain. Paléozoïque
 968 inférieur. Cambrien moyen et supérieur-Ordovicien-base du Silurien. Feuille Zagora-
 969 Coude du Dra. Mémoire explicatif, Chapitre A [written in 1983]. *Notes et Mémoires du*
 970 *Service géologique du Maroc*, **273 bis**, 36 p.
- 971 DESTOMBES, J. 2006k. Carte géologique au 200 000 de l'Anti- Atlas marocain. Paléozoïque
 972 inférieur: Cambrien moyen et supérieur – Ordovicien – base du Silurien. Feuille Zagora
 973 - Coude du Dra. Chapitre A. *Notes et Mémoires du Service Géologique du Maroc*, **273**,
 974 1–54.
- 975 DESTOMBES, J. 2006l. Carte géologique au 200 000 de l'Anti-Atlas marocain. Paléozoïque
 976 inférieur. Cambrien moyen et supérieur-Ordovicien-base du Silurien. Sommaire général
 977 sur les Mémoires explicatifs des cartes géologiques au 1/200 000 de l'Anti-Atlas
 978 marocain. *Notes et Mémoires du Service géologique du Maroc*, **515 bis**, 149 p.
- 979 DESTOMBES, J. & FEIST, R. 1987. Découverte du Cambrien supérieur en Afrique (Anti-Atlas
 980 central, Maroc). *Comptes Rendus de l'Académie des Sciences, Paris*, **304**, 719–724.
- 981 DESTOMBES, J. & HENRY, J. L. 1987. Trilobites *Calmoniidae* de l'Ordovicien supérieur du
 982 Maroc et les origines de la Province Malvino-Cafre. *Lethaia*, **20**, 129–139.
- 983 DESTOMBES, J. & JEANETTE, A. 1962. Carte métallogénique du Maroc. Carte des gîtes
 984 sédimentaires au 1/2.000.000. *Notes et Mémoires du Service géologique du Maroc*, **169**.
- 985 DESTOMBES, J. & WILLEFERT, S. 1959. Sur la présence de *Dictyonema* dans le Trémadoc de
 986 l'Anti-Atlas (Maroc). *Comptes Rendus de l'Académie des Sciences, Paris*, **249**, 1246–
 987 1247.
- 988 DESTOMBES, J. & WILLEFERT, S. 1988. The Ordovician–Silurian boundary in Morocco. *Bulletin*
 989 *of the British Museum of Natural History (Geological Series)*, **43**, 165–170.
- 990 DESTOMBES, J., TERMIER, H. & TERMIER, G. 1971. Sur quelques bryozoaires ectoproctes de
 991 l'Ordovicien supérieur du Sud marocain. *Notes et Mémoires du Service géologique du*
 992 *Maroc*, **237**, 61–64.

- 993 DESTOMBES, J., HOLLARD, H. & WILLEFERT, S. 1985. Lower Palaeozoic rocks of Morocco. *In:*
 994 HOLLAND, C. H. (ed.) *Lower Palaeozoic Rocks of the World: Lower Palaeozoic Rocks of*
 995 *Northwestern and West-Central Africa*. John Wiley & Sons, Chichester, **4**, 91–136.
- 996 DEUNFF, J. 1968a. *Arbusculidium*, genre nouveau d'Acritarche du Trémadoc marocain.
 997 *Comptes Rendus sommaires de la Société géologique de France*, **3**, 101–102.
- 998 DEUNFF, J. 1968b. Sur une forme nouvelle d'acritarche possédant une ouverture polaire
 999 (*Veryhachium miloni* n. sp.) et sur la présence d'une colonie de *Veryhachium* dans le
 1000 Trémadocien marocain. *Comptes Rendus de l'Académie des Sciences, Paris*, **267**, 46–49.
- 1001 DEUNFF, J. 1977. Un microplancton à Acritarches dans les schistes llanvirniens de l'Anti-Atlas
 1002 (Zagora, Maroc). *Notes et Mémoires du Service géologique du Maroc*, **268**, 141–151.
- 1003 DONOVAN, S. K. & SAVILL, J. J. 1988. *Ramseyocrinus* (Crinoidea) from the Arenig of Morocco.
 1004 *Journal of Paleontology*, **62**, 283–285.
- 1005 DRAGE, H. B., VANDENBROUCKE, T. R. A., VAN ROY, P. & DALEY, A. C. 2019. Sequence of
 1006 post-moult exoskeleton hardening preserved in a trilobite mass moult assemblage from
 1007 the Lower Ordovician Fezouata Konservat-Lagerstätte, Morocco. *Acta Palaeontologica*
 1008 *Polonica*, **64**, 261–273.
- 1009 EBBESTAD, J. O. R. 2016. Gastropoda, Tergomya and Paragastropoda (Mollusca) from the
 1010 Lower Ordovician Fezouata Formation, Morocco. *Palaeogeography, Palaeoclimatology,*
 1011 *Palaeoecology*, **460**, 87–96.
- 1012 EBBESTAD, J. O. R. & LEFEBVRE, B. 2015. An unusual onychochilid mollusc from the
 1013 Ordovician (Tremadocian) Fezouata Formation, Morocco. *Geobios*, **48**, 427–438.
- 1014 EBBESTAD, J. O. R., POLECHOVÁ, M., KRÖGER, B. & GUTIÉRREZ-MARCO, J. C. (this vol.). Late
 1015 Ordovician molluscs of eastern Anti-Atlas, Morocco. *In:* HUNTER, A. W., ÁLVARO, J. J.,
 1016 LEFEBVRE, B., VAN ROY, P. & ZAMORA, S. (eds), *The Great Ordovician*
 1017 *Biodiversification Event: Insights from the Tafilalt Biota, Morocco*. Geological Society,
 1018 London, Special Publications, **485**, doi: 10.1144/SP485.9.
- 1019 EL BOURKHISSI, M. & SARMIENTO, G. N. 1997. Primeros conodontos ordovícicos del Anti-Atlas
 1020 (Marruecos). *In:* GRANDAL D'ANGLADE, A., GUTIÉRREZ-MARCO, J. C. & SANTOS
 1021 FIDALGO, L. (eds). *Comunicaciones de las XIII Jornadas de Paleontología. V Reunión*
 1022 *Internacional PIGC 351*, 56–59.
- 1023 EL MAAZOUZ, B. & HAMOUMI, N. 2007. Différentiation paléogéographique à l'Ordovicien
 1024 supérieur dans le Tafilalt (Anti-Atlas oriental, Maroc) sous l'interaction de la glaciation et
 1025 de la tectonique. *Comptes Rendus Geoscience*, **339**, 562–571.
- 1026 ELAOUAD-DEBBAJ, Z. 1984a. Acritarches et Chitinozoaires de l'Arenig-Llanvirm de l'Anti-
 1027 Atlas (Maroc). *Review of Palaeobotany and Palynology*, **43**, 67–88.
- 1028 ELAOUAD-DEBBAJ, Z. 1984b. Chitinozoaires ashgilliens de l'Anti-Atlas (Maroc). *Geobios*, **17**,
 1029 45–68.

- 1030 ELAOUAD-DEBBAJ, Z. 1986. Chitinozoaires de la Formation du Ktaoua Inférieur, Ordovicien
1031 Supérieur de l'Anti-Atlas (Maroc). *Hercynica* (série 2), **1**, 35–55.
- 1032 ELAOUAD-DEBBAJ, Z. 1988a. Acritarches et Chitinozoaires du Trémadoc de l'Anti-Atlas central
1033 (Maroc). *Revue de Micropaléontologie*, **31**, 85–128.
- 1034 ELAOUAD-DEBBAJ, Z. 1988b. Acritarches de l'Ordovicien supérieur (Caradoc, Ashgill) de
1035 l'Anti-Atlas, Maroc. *Revue de Micropaleontologie*, **30**, 232–248.
- 1036 ENNIH, N. & LIÉGEOIS, J. P. 2008. The boundaries of the West African craton, with special
1037 reference to the basement of the Moroccan metacratonic Anti-Atlas belt. In: ENNIH, N. &
1038 LIÉGEOIS, J. P. (eds) *The Boundaries of the West African Craton. Geological Society,*
1039 *London, Special Volume*, **297**, 1–17.
- 1040 ERNST, A. & KEY, M. 2007. Upper Ordovician bryozoans from the Montagne Noire, Southern
1041 France. *Journal of Systematic Palaeontology*, **5**, 359–428.
- 1042 ERNST, A., JIMENEZ-SANCHEZ, A. & BAIDDER, L. 2015. Bryozoan fauna of the Upper
1043 Ordovician (Katian) of Alnif, Morocco. *Palaeobiodiversity and Palaeoenvironments*, **95**,
1044 537–553.
- 1045 EVANS, D. A. D. 2003. True polar wander and supercontinents. *Tectonophysics*, **362**, 303–320.
- 1046 FORTEY, R. A. 2009. A new giant asaphid trilobite from the Lower Ordovician of Morocco.
1047 *Memoirs of the Association of Australasian Palaeontologists*, **37**, 9–16.
- 1048 FORTEY, R. A. 2011a. Trilobites of the genus *Dikelokephalina* from Ordovician Gondwana and
1049 Avalonia. *Geological Journal*, **46**, 405–415.
- 1050 FORTEY, R. A. 2011b. The first known complete lichakephalid trilobite. *Memoirs of the*
1051 *Association of Australasian Palaeontologists*, **42**, 1–7.
- 1052 FORTEY, R. & COCKS, L. R. M. 2005. Late Ordovician global warming - the Boda event.
1053 *Geology*, **35**, 405–408.
- 1054 FORTEY, R. A. & EDGECOMBE, G. D. 2017. An Upper Ordovician (Katian) trilobite fauna from
1055 the Lower Ktaoua Formation, Morocco. *Bulletin of Geosciences*, **92**, 311–322.
- 1056 GAINES, R. R., BRIGGS, D. E. G., ORR, P. J. & VAN ROY, P. 2012. Preservation of giant
1057 anomalocaridids in silica- chlorite concretions from the Early Ordovician of Morocco.
1058 *Palaios*, **27**, 317–325.
- 1059 GHYENNE, J. F., LE HERON, D., MOREAU, J., DENIS, M. & DEYNOUX, M. 2007a. The Late
1060 Ordovician glacial sedimentary system of the North Gondwana platform. In: HAMBREY,
1061 M., CHRISTOFFERSEN, P., GLASSER, N., JANSSEN, P., HUBBARD, B. & SIEGERT, M. (eds)
1062 *Glacial Sedimentary Processes and Products. International Association of*
1063 *Sedimentologists, Special Publication*, **39**, 295–319.
- 1064 GHYENNE, J. F., BOUMENDJEL, K., PARIS, F., VIDET, B., RACHEBOEUF, P. & AÏT SALEM, H.
1065 2007b. The Cambrian–Ordovician succession in the Ougarta Range (Algeria, North
1066 Africa) and interference of the Late Ordovician glaciation on the development of the

- 1067 Lower Palaeozoic transgression on northern Gondwana. *Bulletin of Geosciences*, **82**,
 1068 183–214.
- 1069 GIBB, S., CHATTERTON, B. D. E. & GINGRAS, M. K. 2010. *Rusophycus carleyi* (James, 1885),
 1070 trace fossils from the Lower Ordovician of Southern Morocco, and the trilobites that
 1071 made them. *Ichnos*, **17**, 271–283.
- 1072 GUTIÉRREZ-MARCO, J. C. & GARCÍA-BELLIDO, D. C. 2015. Micrometric detail in
 1073 palaeoscolecid worms from Late Ordovician sandstones of the Tafilalt Konservat-
 1074 Lagerstätte, Morocco. *Gondwana Research*, **28**, 875–881.
- 1075 GUTIÉRREZ-MARCO, J. C. & MARTIN, E. L. O. 2016. Biostratigraphy and palaeoecology of
 1076 Lower Ordovician graptolites from the Fezouata Shale (Moroccan Anti-Atlas).
 1077 *Palaeogeography, Palaeoclimatology, Palaeoecology*, **460**, 35–49.
- 1078 GUTIÉRREZ-MARCO, J. C. & VINN, O. 2018. Cornulitids (tubeworms) from the Late Ordovician
 1079 *Hirnantia* fauna of Morocco. *Journal of African Earth Sciences*, **137**, 61–68.
- 1080 GUTIÉRREZ-MARCO, J. C., DESTOMBES, J., RÁBANO, I., ACEÑOLAZA, G. F., SARMIENTO, G. N.
 1081 & SAN JOSÉ, M. A. 2003. El Ordovícico Medio del Anti-Atlas marroquí: paleodiversidad,
 1082 actualización bioestratigráfica y correlación. *Geobios*, **36**, 151–177.
- 1083 GUTIÉRREZ-MARCO, J.C., SÁ, A.A., RÁBANO, I., SARMIENTO, G.N., GARCÍA-BELLIDO, D.C.,
 1084 BERNÁRDEZ, E., LORENZO, S., VILLAS, E., JIMÉNEZ-SÁNCHEZ, A., COLMENAR, J. &
 1085 ZAMORA, S. 2015. Iberian Ordovician and its international correlation. *Stratigraphy*, **12**
 1086 (3-4), 257–263.
- 1087 GUTIÉRREZ-MARCO, J. C., GARCÍA-BELLIDO, D. C., RÁBANO, I. & SÁ, A. A. 2017a. Digestive
 1088 and appendicular soft-parts, with behavioural implications, in a large Ordovician trilobite
 1089 from the Fezouata Lagerstätte, Morocco. *Scientific Reports*, **7**: 39728, 7 p.
- 1090 GUTIÉRREZ-MARCO, J. C., SÁ, A. A., GARCÍA-BELLIDO, D. C. & RÁBANO, I. 2017b. The
 1091 Bohemo-Iberian regional chronostratigraphic scale for the Ordovician System and
 1092 palaeontological correlations within South Gondwana. *Lethaia*, **50** (2), 258–295.
- 1093 GUTIÉRREZ-MARCO, J. C., PEREIRA, S., GARCÍA-BELLIDO, D. C. & RÁBANO, I. (this vol. a).
 1094 Ordovician trilobites from the Tafilalt Lagerstätte: new data and reappraisal of the Bou
 1095 Nemrou assemblage. In: HUNTER, A. W., ÁLVARO, J. J., LEFEBVRE, B., VAN ROY, P. &
 1096 ZAMORA, S. (eds), *The Great Ordovician Biodiversification Event: Insights from the*
 1097 *Tafilalt Biota, Morocco*. Geological Society, London, Special Publication, **485**.
- 1098 GUTIÉRREZ-MARCO, J. C., MUIR, L. A. & MITCHELL, C. E. (this vol. b). Upper Ordovician
 1099 graptolites and other benthic colonial organisms from the Tafilalt Biota, southeastern
 1100 Morocco. In: HUNTER, A. W., ÁLVARO, J. J., LEFEBVRE, B., VAN ROY, P. & ZAMORA, S.
 1101 (eds), *The Great Ordovician Biodiversification Event: Insights from the Tafilalt Biota,*
 1102 *Morocco*. Geological Society, London, Special Publication, **485**.

- 1103 GUTIÉRREZ-MARCO, J. C., RÁBANO, I. & GARCÍA-BELLIDO, D. C. . 2019. The nileid trilobite
 1104 *Symphysurus* from upper Tremadocian strata of the Moroccan Anti-Atlas: taxonomic
 1105 reappraisal and palaeoenvironmental implications. *Fossils & Strata*, **64**, 155–171.
- 1106 HAMOUMI, N. 1999. Upper Ordovician glaciation spreading and its sedimentary record in
 1107 Moroccan north Gondwanan margin. *Acta Universitatis Carolinae, Geologica*, **43**, 111–
 1108 114.
- 1109 HAVLÍČEK, V. 1970. Heterorthidae (Brachiopoda) in the Mediterranean Province. *Sborník*
 1110 *Geologických Věd, Paleontologie*, **12**, 7–39.
- 1111 HAVLÍČEK, V. 1971. Brachiopodes de l'Ordovicien du Maroc. *Notes et Mémoires du Service*
 1112 *géologique du Maroc*, **230**, 1–135.
- 1113 HENRY, J. L. 1991. Clasificación de quelques Calymenina (Trilobita) ordoviciens: Calymenidae
 1114 ou Homalonotidae? *Geobios*, **29**, 331–340.
- 1115 HENRY, J. L. & DESTOMBES, J. 1991. Un biofaciès à Trilobites Homalonotidae dans
 1116 l'Ordovicien de la marge nord-gondwanienne: implications paléobiologiques et
 1117 paléogéographiques. *Lethaia*, **24**, 249–253.
- 1118 HENRY, J. L., VIZCAÏNO, D. & DESTOMBES, J. 1992. Evolution de l'œil et hétérochronie chez les
 1119 Trilobites ordoviciens *Ormathops* Delo 1935 et *Toletanaspis* Rábano 1989
 1120 (Dalmanitidae, Zeliszkeellinae). *Paläontologische Zeitschrift*, **66**, 277–290.
- 1121 HORNÝ, R. D. 1997a. Ordovician Tergomya and Gastropoda (Mollusca) of the Anti-Atlas
 1122 (Morocco). *Acta Musei Nationalis Pragae, Series B - Historia Naturalis*, **53** (3–4), 37–
 1123 78.
- 1124 HORNÝ, R. D. 1997b. *Quasisinuities rapax* gen. et sp. n., a new sinuate cyrtoneid mollusc
 1125 (Class Tergomya) with involute shell from the Ordovician of Morocco. *Věstník Českého*
 1126 *geologického ústavu*, **72**, 345–350.
- 1127 HORNÝ, R. D. 1997c. Circumbilical retractor muscle attachment area in the Ordovician trilobed
 1128 bellerophontoidean gastropod *Tritonophon peeli* (Mollusca). *Věstník Českého*
 1129 *geologického ústavu*, **72**, 333–338.
- 1130 HUNTER, A. W. & ORTEGA-HERNÁNDEZ, J. 2017. A primitive starfish ancestor from the Early
 1131 Ordovician of Morocco reveals the origin of crown group Echinodermata. *bioRxiv*.
 1132 Publisher's Version, doi: 10.1101/216101.
- 1133 JIMÉNEZ-SÁNCHEZ, A. 2009. The upper Katian (Ordovician) bryozoans from the Eastern
 1134 Iberian Chains (NE Spain). *Bulletin of Geosciences*, **84**, 687–738.
- 1135 JIMÉNEZ-SÁNCHEZ, A. 2010. New monticuliporidae (Trepotomata) from the Cystoid
 1136 Limestone Formation (Upper Ordovician) of the Iberian Chains (NE Spain).
 1137 *Geodiversitas*, **32**, 177–199.

- 1138 JIMÉNEZ-SÁNCHEZ, A. & VILLAS, E. 2010. The bryozoan dispersion into the Mediterranean
1139 margin of Gondwana during the pre-glacial Late Ordovician. *Palaeogeography,*
1140 *Palaeoclimatology, Palaeoecology*, **294**, 220–231.
- 1141 JIMÉNEZ-SÁNCHEZ, A., TAYLOR, P. D. & GÓMEZ, J. B. 2013. Palaeogeographical patterns in
1142 Late Ordovician bryozoan morphology as proxies for temperature. *Bulletin of*
1143 *Geosciences*, **88**, 417–426.
- 1144 JIMÉNEZ-SÁNCHEZ, A., VENNIN, E. & VILLAS, E. 2015a. Trepostomate bryozoans from the
1145 upper Katian (Upper Ordovician) of Morocco: gigantism in the high latitude Gondwana
1146 platforms. *Journal of Paleontology*, **89** (2), 195–221.
- 1147 JIMÉNEZ-SÁNCHEZ, A., VILLAS, E. & VENNIN, E. 2015b. New trepostomate bryozoans from
1148 the Upper Ordovician of Morocco and the temperature influence on zooid size. *Journal*
1149 *of Paleontology*, **89** (3), 385–404.
- 1150 JIMENEZ-SANCHEZ, A., ERNST, A., VENNIN, E. & VILLAS, E. 2016. New bryozoans from the
1151 Upper Ordovician of Morocco and their place in the temperate-to-cool water
1152 Mediterranean Province. *Bulletin of Geosciences*, **91**, 23–50.
- 1153 KOURAISS, K., EL HARIRI, K., EL ALBANI, A., AZIZI, A., MAZURIER, A. & VANNIER, J. 2018. X-
1154 ray microtomography applied to fossils preserved in compression: palaeoscolecid worms
1155 from the Lower Ordovician Fezouata Shale. *Palaeogeography, Palaeoclimatology,*
1156 *Palaeoecology*, **508**, 48–58.
- 1157 KRÖGER, B. & LEFEBVRE, B. 2012. Palaeogeography and palaeoecology of early Floian (Early
1158 Ordovician) cephalopods from the Upper Fezouata Formation, Anti-Atlas, Morocco.
1159 *Fossil Record*, **15**, 61–75.
- 1160 LE HERON, D. P. 2007. Late Ordovician glacial record of the Anti-Atlas, Morocco. *Sedimentary*
1161 *Geology*, **201**, 93–110.
- 1162 LE HERON, D. P. & CRAIG, K. 2008. First-order reconstructions of a Late Ordovician Saharan
1163 ice sheet. *Journal of the Geological Society*, **165**, 19–29.
- 1164 LE HERON, D. P., GHIENNE, J. F., EL HOUICHA, M., KHOUKHI, Y. & RUBINO, J. L. 2007.
1165 Maximum extent of ice sheets in Morocco during the Late Ordovician glaciation.
1166 *Palaeogeography, Palaeoclimatology, Palaeoecology*, **245**, 200–226.
- 1167 LE HERON, D. P., KHOUKHI, Y., PARIS, F., GHIENNE, J. F. & LE HERISSE, A. 2008. Black shale,
1168 grey shale, fossils and glaciers: Anatomy of the Upper Ordovician–Silurian succession in
1169 the Tazzeqa Massif of eastern Morocco. *Gondwana Research*, **14**, 483–496.
- 1170 LE MENN, J. & SPJELDNAES, N. 1996. Un nouveau crinoïde Dimerocrinitidae (Camerata,
1171 Diplobathrida) de l'Ordovicien supérieur du Maroc: *Rosfacrinus robustus* nov. gen., nov.
1172 sp. *Geobios*, **29**, 341–351.
- 1173 LEFEBVRE, B. 2007. Early Palaeozoic palaeobiogeography and palaeoecology of stylophoran
1174 echinoderms. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **245**, 156–199.

- 1175 LEFEBVRE, B. & BOTTING, J. P. 2007. First report of the mitrate *Peltocystis cornuta* Thoral
 1176 (Echinodermata, Stylophora) in the Lower Ordovician of central Anti- Atlas (Morocco).
 1177 *Annales de Paléontologie*, **93**, 183–198.
- 1178 LEFEBVRE, B. & FATKA, O. 2003. Palaeogeographical and palaeoecological aspects of the
 1179 Cambrian–Ordovician radiation of echinoderms in Gondwanan Africa and peri-
 1180 Gondwanan Europe. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **195**, 73–97.
- 1181 LEFEBVRE, B. & ROCH, R. 2009. A la poursuite d’une chimère: reconstitution de la morphologie
 1182 de *Plasiacystis mobilis*, un solute (Echinodermata, Blastozoa) atypique de l’Ordovicien
 1183 péri-gondwanien. *Journal de l’Association Paléontologique Française*, **56**, 44–45.
- 1184 LEFEBVRE, B., NARDIN, E., HUNTER, A. W. & REGNAULT, S. 2007. Les échinodermes de
 1185 l’Ordovicien supérieur de l’Anti-Atlas (Maroc): biostratigraphie et paléobiodiversité.
 1186 *Africa Geoscience Review*, **14**, 123–148.
- 1187 LEFEBVRE, B., NOAILLES, F., HUNTER, A. W., NARDIN, E., REGNAULT, S., FRANZIN, B., VAN
 1188 ROY P. & EL HARIRI, K. 2008. Les niveaux à échinodermes de Bou Nemrou, un gisement
 1189 à préservation exceptionnelle de l’Ordovicien supérieur du Tafilalt occidental (Maroc).
 1190 *Mésogée*, **64**, 7–25.
- 1191 LEFEBVRE, B., NOUAILLES, F., FRANZIN, B., REGNAULT, S., NARDIN, E., HUNTER, A. W.,
 1192 ZAMORA, S., VAN ROY, P., EL HARIRI, K. & LAZREQ, N. 2010. Les gisements à
 1193 échinodermes de l’Ordovicien supérieur de l’Anti-Atlas oriental (Maroc): un patrimoine
 1194 scientifique exceptionnel à préserver. *Bulletin de l’Institut Scientifique, Rabat*, 1–17.
- 1195 LEFEBVRE, B., LEROSEY- AUBRIL, R., SERVAIS, T. & VAN ROY, P. 2016a. The Fezouata Biota:
 1196 an exceptional window on the Cambro–Ordovician faunal transition. *Palaeogeography,*
 1197 *Palaeoclimatology, Palaeoecology*, **460**, 1–6.
- 1198 LEFEBVRE, B., EL HARIRI, K., LEROSEY- AUBRIL, R., SERVAIS, T. & VAN ROY, P. 2016b. The
 1199 Fezouata Shale (Lower Ordovician, Anti- Atlas, Morocco): a historical review.
 1200 *Palaeogeography, Palaeoclimatology, Palaeoecology*, **460**, 7–23
- 1201 LEFEBVRE, B., ALLAIRE, N., GUENSBURG, T. E., HUNTER, A. W., KOURAÏSS, K., MARTIN, E. L.
 1202 O., NARDIN, E., NOAILLES, F., PITTET, B., SUMRALL, C. D. & ZAMORA, S. 2016c.
 1203 Palaeoecological aspects of the diversification of echinoderms in the Lower Ordovician
 1204 of central Anti- Atlas, Morocco. *Palaeogeography, Palaeoclimatology, Palaeoecology*,
 1205 **460**, 97–121
- 1206 LEFEBVRE, B., GUTIÉRREZ-MARCO, J. C., LEHNERT, O., MARTIN, E. L. O., NOWAK, H.,
 1207 AKODAD, M., EL HARIRI, K. & SERVAIS, T. 2018. Age calibration of the Lower
 1208 Ordovician Fezouata Lagerstätte, Morocco. *Lethaia*, **51** (2), 296–311.
- 1209 LEFEBVRE, B., GUENSBURG, T. E., MARTIN, E. L. O., MOOI, R., NARDIN, E., NOHEJLOVÁ, M.,
 1210 SALEH, F., KOURAÏSS, K., EL HARIRI, K. & DAVID, B. 2019. Exceptionally preserved soft

- 1211 parts in fossils from the Lower Ordovician of Morocco clarify stylophoran affinities
 1212 within basal deuterostomes. *Geobios*, **52**, 27–36.
- 1213 LEFEBVRE, B., NOHEJLOVA, M., KASICKA, L. & ZICHA, O. (this vol. a). New Peri-Gondwanan
 1214 occurrences of the Ordovician genus *Diamphidiocystis* (Echinodermata, Stylophora) -
 1215 Implications for mitrocystitid palaeobiogeography and diversity. *In*: HUNTER, A. W.,
 1216 ÁLVARO, J. J., LEFEBVRE, B., VAN ROY, P. & ZAMORA, S. (eds), *The Great Ordovician*
 1217 *Biodiversification Event: Insights from the Tafilalt Biota, Morocco*. Geological Society,
 1218 London, Special Publication, **485**.
- 1219 LEFEBVRE, B., NOHEJLOVA, M., MARTIN, E. L. O., KASICKA, L. & ZICHA, O. & GUTIÉRREZ-
 1220 MARCO, J. C. (this vol. b). New Middle and Late Ordovician cornute stylophorans
 1221 (Echinodermata) from Morocco and other peri-Gondwanan areas. *In*: HUNTER, A. W.,
 1222 ÁLVARO, J. J., LEFEBVRE, B., VAN ROY, P. & ZAMORA, S. (eds), *The Great Ordovician*
 1223 *Biodiversification Event: Insights from the Tafilalt Biota, Morocco*. Geological Society,
 1224 London, Special Publication, **485**.
- 1225 LEHNERT, H., NOWAK, H., SARMIENTO, G. N., GUTIÉRREZ-MARCO, J. C., AKODAD, M. &
 1226 SERVAIS, T. 2016. Conodonts from the Lower Ordovician of Morocco -contributions to
 1227 age and faunal diversity of the Fezouata Lagerstätte and peri-Gondwana biogeography.
 1228 *Palaeogeography, Palaeoclimatology, Palaeoecology*, **460**, 50–61.
- 1229 LOI, A., GHIENNE, J. F., DABARD, M. P., PARIS, F., BOTQUELEN, A., CHRIST, N., ELAOUAD-
 1230 DEBBAJ, Z., GORINI, A., VIDAL, M., VIDET, B. & DESTOMBES, J. 2010. The Late
 1231 Ordovician glacio-eustatic record from a high-latitude storm-dominated shelf succession:
 1232 the Bou Ingarf section (Anti-Atlas, Southern Morocco). *Palaeogeography,*
 1233 *Palaeoclimatology, Palaeoecology*, **296**, 332–358.
- 1234 MACGABHANN, B.A. 2012. *A solution to Darwin's dilemma: Differential taphonomy of*
 1235 *Palaeozoic and Ediacaran non-mineralised discoidal fossils*. Earth and Ocean Sciences,
 1236 National University of Ireland, Galway, Ireland, 657 pp.
- 1237 MACGABHANN, B.A., SCHIFFBAUER, J.D., HAGADORN, J.W., VAN ROY, P., LYNCH, E.P.,
 1238 MORRISON, L. & MURRAY, J. 2019. Resolution of the earliest metazoan record:
 1239 Differential taphonomy of Ediacaran and Paleozoic fossils molds and casts.
 1240 *Palaeogeography, Palaeoclimatology, Palaeoecology*, **513**, 146–165.
- 1241 MAREK, L. 1983. The Ordovician hyoliths of Anti-Atlas (Morocco). *Sborník Národního Muzea*
 1242 *v Praze [B]*, **39**, 1–36.
- 1243 MARTÍ MUS, M. 2016. A hyolithid with preserved soft parts from the Ordovician Fezouata
 1244 Konservat-Lagerstätte of Morocco. *Palaeogeography, Palaeoclimatology,*
 1245 *Palaeoecology*, **460**, 122–129
- 1246 MARTIN, E., LEFEBVRE, B. & VAUCHER, R. 2015. Taphonomy of a stylophoran- dominated
 1247 assemblage in the Lower Ordovician of Zagora area (central Anti- Atlas, Morocco). *In*:

- 1248 ZAMORA, S. & RÁBANO, I. (eds). Progress in Echinoderm Palaeobiology. *Cuadernos del*
 1249 *Museo Geominero*, **19**, 95–100.
- 1250 MARTIN, E. L. O., PITTET, B., GUTIÉRREZ- MARCO, J. C., VANNIER, J., EL HARIRI, K.,
 1251 LEROSEY- AUBRIL, R., MASROUR, M., NOWAK, H., SERVAIS, T., VANDENBROUCKE, T.
 1252 R. A., VAN ROY, P., VAUCHER, R. & LEFEBVRE, B. 2016a. The Lower Ordovician
 1253 Fezouata Konservat- Lagerstätte: age, environment and evolutionary perspectives.
 1254 *Gondwana Research*, **34**, 274–283.
- 1255 MARTIN, E. L. O., VIDAL, M., VIZCAÍNO, D., VAUCHER, R., SANJOFRE, P., LEFEBVRE, B. &
 1256 DESTOMBES, J. 2016b. Biostratigraphic and palaeoenvironmental controls on the trilobite
 1257 associations from the Lower Ordovician Fezouata Shale of the central Anti- Atlas,
 1258 Morocco. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **460**, 142–154.
- 1259 MARTIN, E. L. O., LEROSEY-AUBRIL, R. & VANNIER, J. 2016c. Palaeoscolecid worms from the
 1260 Lower Ordovician Fezouata Lagerstätte, Morocco: Palaeoecological and
 1261 palaeogeographical implications. *Palaeogeography, Palaeoclimatology, Palaeoecology*,
 1262 **460**, 130–141.
- 1263 MERGL, M. 1981. The genus *Orbithele* (Brachiopoda, Inarticulata) from the Lower Ordovician
 1264 of Bohemia and Morocco. *Věstník Ustředního ústavu geologického*, **56**, 287–292.
- 1265 MERGL, M. 1983. New brachiopods (Cambrian–Ordovician) from Algeria and Morocco
 1266 (Mediterranean Province). *Casopis pro Mineralogii a Geologii*, **28** (4), 337–348.
- 1267 MICHARD, A., HOEPPFNER, C., SOULAIMANI, A. & BAIDDER, L. 2008. The Variscan belt. *In*:
 1268 MICHARD, A., SADDIQLI, O., CHALOUAN, A. & FRIZON DE LAMOTTE, D. (eds)
 1269 *Continental Evolution: The Geology of Morocco*. Springer, Berlin, 65–131.
- 1270 MINZONI, N. 2011. Transtensional tectonics played a key role during the Variscan cycle in the
 1271 Sardinia-Corsica massif. *In*: SCHATTNER, U. (ed.) *New Frontiers in Tectonic Research-*
 1272 *At the Midst of Plate Convergence*. In Tech, Rijeka, Croatia.
- 1273 MOLYNEUX, S. M. & PARIS, F. 1985. Late Ordovician Palynomorphs. *Journal of*
 1274 *Micropalaeontology*, **4**, 11–26.
- 1275 MUIR, L. A., BOTTING, J. P., WALKER, S. N. A., SCHIFFBAUER, J. D. & MACGABHANN, B. A.
 1276 (this vol.). *Onuphionella corusca* sp. nov.: and early Cambrian-type agglutinated tube
 1277 from Upper Ordovician strata of Morocco. *In*: HUNTER, A. W., ÁLVARO, J. J., LEFEBVRE,
 1278 B., VAN ROY, P. & ZAMORA, S. (eds), *The Great Ordovician Biodiversification Event:*
 1279 *Insights from the Tafilalt Biota, Morocco*. Geological Society, London, Special
 1280 Publication, **485**, doi: 10.1144/SP485.7
- 1281 NARDIN, E. 2007. New occurrence of the Ordovician eocrinoid *Cardiocystites*:
 1282 Palaeogeographical and palaeoecological implications. *Acta Palaeontologica Polonica*,
 1283 **52**, 17–26.

- 1284 NARDIN, E. & RÉGNAULT, S. 2015. Palaeoecology of *Ascocystites*-dominated assemblages
1285 (Echinoderata, Blastozoa, Eocrinoidea) from the Moroccan Anti-Atlas. In: ZAMORA, S.
1286 & RÁBANO, I. (eds). *Progress in Echinoderm Palaeobiology. Cuadernos del Museo*
1287 *Geominero*, **19**, 109–114.
- 1288 NIELSEN, A. T. 2004. Ordovician sea level changes: a Baltoscandian perspective. In: WEBBY, B.
1289 D., PARIS, F., DROSER, M. L. & PERCIVAL, I. G. (eds) *The Great Ordovician*
1290 *Biodiversification Event*. Columbia University Press, New York, 84–93.
- 1291 NOAILLES, F., LEFEBVRE, B., GUENSBURG, T. E., HUNTER, A. W., NARDIN, E., SUMRALL, C. D.
1292 & ZAMORA, S. 2010. New echinoderm- Lagerstätten from the Lower Ordovician of
1293 central Anti- Atlas (Zagora area, Morocco): a Gondwanan perspective of the Great
1294 Ordovician Biodiversification Event. In: REICH, M., REITNER, J., RODEN, V. & THUY, B.
1295 (eds). *Echinoderm Research* (Universitätsverlag Göttingen, Göttingen), **2010**, 77–78.
- 1296 NOWAK, H., AKODAK, M., LEFEBVRE, B. & SERVAIS, T. 2015. Discovery of the
1297 *messaoudensis-trifidum* acritarch assemblage (upper Tremadocian–lower Floian, Lower
1298 Ordovician) in the subsurface of Morocco. *Estonian Journal of Earth Sciences*, **64**, 80–
1299 83.
- 1300 NOWAK, H., SERVAIS, T., PITTET, B., VAUCHER, R., AKODAD, M., GAINES, R. R. &
1301 VANDENBROUCKE, T. R. A. 2016. Palynomorphs of the Fezouata Shale (Lower
1302 Ordovician, Morocco): Age and environmental constraints of the Fezouata Biota.
1303 *Palaeogeography, Palaeoclimatology, Palaeoecology*, **460**, 62–74.
- 1304 OGGIANO, C., GAGGERO, I., FUNNEDA, A., BUZZI, L. & TIEPOLO, M. 2010. Multiple early
1305 Paleozoic volcanic events at the northern Gondwana margin: U–Pb age evidence from
1306 the Southern Variscan branch (Sardinia, Italy). *Gondwana Research*, **17**, 44–58.
- 1307 ORTEGA- HERNÁNDEZ, J., VAN ROY, P. & LEROSEY- AUBRIL, R. 2016. A new aglaspidid
1308 euarthropod with a six- segmented trunk from the Lower Ordovician Fezouata
1309 Konservat- Lagerstätte, Morocco. *Geological Magazine*, **153**, 524–536.
- 1310 OUANAÏMI, H. 1998. Le passage Ordovicien–Silurien à Tizi n’Tichka (Haut Atlas, Maroc):
1311 variations du niveau marin. *Comptes Rendus de l’Académie des Sciences, Paris*, **326**, 65–
1312 70.
- 1313 OUANAÏMI, H., SOULAIMANI, A., HOEPFFNER, C. & MICHARD, A. 2006. The Atlas-Meseta Red
1314 Beds basin (Morocco) and the Lower Ordovician rifting of NW-Gondwana. *Bulletin de la*
1315 *Société géologique de France*, **187**, 155–168.
- 1316 PARIS, F. 1988. Late Ordovician and Early Silurian chitinozoans from central and southern
1317 Cyrenaica. In: EL-ARNAUTI, A., OWENS, B. & THUSU, B. (eds) *Subsurface*
1318 *Palynostratigraphy of Northeast Libya*. Garyounis University Publications, Benghazi,
1319 Libya, 77–87.

- 1320 PARIS, F. 1990. The Ordovician chitinozoan biozones of the Northern Gondwana Domain.
 1321 *Review of Palaeobotany and Palynology*, **66**, 181–209.
- 1322 PARIS, F. 1996. Chitinozoan biostratigraphy and palaeogeography. In: Jansonius, J. &
 1323 McGregor, D. C. (eds) *Palynology: Principles and Applications*. American Association
 1324 of Stratigraphic Palynologist Foundation, Volume 2, Chapter 17, 531–532.
- 1325 PARIS, F. 1999. Palaeobiodiversification of Ordovician chitinozoans from northern Gondwana.
 1326 *Acta Universitatis Carolinae, Geologica*, **43**, 283–286.
- 1327 PARIS, F., ELAOUAD-DEBBAJ, Z., JAGLIN, J. C., MASSA, D. & OULEBSIR, L. 1995. Chitinozoans
 1328 and Late Ordovician glacial events on Gondwana. In: COOPER, J. D., DROSER, M. L. &
 1329 FINNEY, S. C. (eds) *Ordovician Odyssey: Short Papers for the 7th International*
 1330 *Symposium on the Ordovician System, Las Vegas Nevada*. Fullerton, California: Pacific
 1331 Section Society for Sedimentary Geology (SEPM), 171–176.
- 1332 PARIS, F., VERNIERS, J., ACHAB, A., ALBANI, R., ANCILLETTA, A., ASSELIN, E., CHEN, X. H.,
 1333 FATKA, O., GRAHN, Y., MOLYNEUX, S., NOLVAK, J., SAMUELSSON, J., SENNIKOV, N. V.,
 1334 SOUFIANE, A., WANG, X. F. & WINCHESTER SEETO, T. 1999. Correlation of Ordovician
 1335 regional chitinozoan biozonations. *Acta Universitatis Carolinae, Geologica*, **43**, 291–294.
- 1336 PARIS, F., BOUMENDJEL, K., DABARD, M. P., GHIENNE, J. F., LOI, A., TANG, P., VIDET, B. &
 1337 ACHAB, A. 2007. Chitinozoan-based calibration of Early–Mid Ordovician transgression
 1338 events on northern Gondwana. *Acta Paleontologica Sinica*, **46**, 370–375.
- 1339 PARSLEY R. L. & GUTIÉRREZ-MARCO J. C. 2005. Stylophorans in middle Arenig shallow water
 1340 siliciclastics: *Vizcainocarpus* from the Imfout Syncline in Morocco's western Meseta.
 1341 *Bulletin of Geosciences*, **80**, 185–192.
- 1342 PAUL, C. R. C. 1968. *Macrocytella* Callaway, the earliest glyptocystitid cystoid.
 1343 *Palaeontology*, **11**, 580–600
- 1344 PEREIRA, S., SILVA, C. M., SA, A. A., PIRES, M., MARQUES GUEDES, A., BUDIL, P., LAIBL, L. &
 1345 RÁBANO, I. 2017. The illaenid trilobites *Vysocania* (Vanek & Vokác, 1997) and
 1346 *Octillaenus* (Barrande, 1846) from the Upper Ordovician of the Czech Republic,
 1347 Portugal, Spain and Morocco. *Bulletin of Geosciences*, **92** (4), 465–490.
- 1348 POLECHOVÁ, M. 2016. The bivalve fauna from the Fezouata Formation (Lower Ordovician) of
 1349 Morocco and its significance for palaeobiogeography, palaeoecology and early
 1350 diversification of bivalves. *Palaeogeography, Palaeoecology, Palaeoclimatology*, **460**,
 1351 155–169.
- 1352 POUCKET, A., AARAB, A., FEKKAK, A. & BENHARREF, M. 2007. Geodynamic evolution of the
 1353 northwestern Paleo-Gondwanan margin in the Moroccan Atlas at the Precambrian–
 1354 Cambrian boundary. In: LINNEMANN, U., NANCE, R. D., KRAFT, P. & ZULAUF, G. (eds)
 1355 *The Evolution of the Rheic Ocean: From Avalonian–Cadomian Active Margin to*

- 1356 Alleghenian–Variscan Collision. *Geological Society of America, Special Paper*, **423**,
1357 27–60.
- 1358 POUCKET, A., EL HADI, H., ÁLVARO, J. J., BARDINTZEFF, J. M., BENHARREF, M. & FEKKAK, A.
1359 2018. Review of the Cambrian volcanic activity in Morocco: geochemical fingerprints
1360 and geotectonic implications for the rifting of West Gondwana. *International Journal of*
1361 *Earth Sciences*, **107**, 2101–2123.
- 1362 RÁBANO, I. 1990. Trilobites del Museo GeoMinero. I. *Platypeltoides magrebiensis* n. sp.
1363 (Asaphina, Nileidae), del Ordovícico inferior del Anti- Atlas central (Marruecos). *Boletín*
1364 *Geológico y Minero*, **101**, 21–27.
- 1365 RÁBANO, I., SÁ, A. A., GUTIÉRREZ-MARCO, J. C. & GARCÍA BELLIDO, D. 2010. Two more
1366 Bohemian trilobites from the Ordovician of Portugal and Morocco. *Bulletin of*
1367 *Geosciences*, **85**, 415–424.
- 1368 RÁBANO, I., GUTIÉRREZ-MARCO, J. C. & GARCÍA-BELLIDO, D. C. 2014. A remarkable illaenid
1369 trilobite from the Middle Ordovician of Morocco. *Bulletin of Geosciences*, **89**, 365–374.
- 1370 RADDI, Y., BAIDDER, L., RJIMATI, E. C. & AIT BRAHIM, L. 2011. Le fer oolithique d’Imi
1371 n’Tourza au sud du J. Saghro. *In*: MICHARD, A., SADDIQI, O., CHALOUAN, A., RJIMATI,
1372 E. C. & MOUTTAQI, A. (eds) Nouveaux guides géologiques et miniers du Maroc. *Notes*
1373 *et Mémoires du Service géologique du Maroc*, **564**, 41–44.
- 1374 RADDI, Y., TAHIRI, M., DERRE, C., LECOLLE, M., BAIDDER, L. 2006. Carte géologique du
1375 Maroc au 1/50 000. Feuille Oukhit. *Notes et Mémoires du Service géologique du Maroc*,
1376 **475**. Notice explicative 475 bis.
- 1377 RADDI, Y., DERRE, C., LECOLLE, M., MICHARD, A., BAIDDER, L., TAHIRI, M. 2012. Carte
1378 géologique du Maroc au 1/50 000. Feuille Bou Adil. *Notes et Mémoires du Service*
1379 *géologique du Maroc*, **477**. Notice explicative 477 bis
- 1380 RAVIER, E., BOUNCRISTIANI, J. F., GUIRAUD, M., MENZIES, J., CLERC, S., GOUPY, B., &
1381 PORTIER, E. 2014. Porewater pressure control on subglacial soft sediment remobilization
1382 and tunnel valley formation: a case study from the Alnif tunnel valley (Morocco).
1383 *Sedimentary Geology*, **304**, 71–95.
- 1384 REGNAULT, S. 2007. Présence de l’éocrinoïde *Ascocystites* Barrande (Echinodermata,
1385 Blastozoa) dans l’Ordovicien supérieur (Caradoc) de l’Anti-Atlas (Maroc): premières
1386 données. *Annales de Paléontologie*, **93**, 215–227.
- 1387 REICH, M., SPRINKLE, J., LEFEBVRE, B., RÖSSNER, G.E. & ZAMORA, S. 2017. The first
1388 Ordovician cyclocystoid (Echinodermata) from Gondwana and its morphology,
1389 paleoecology, taphonomy, and paleogeography. *Journal of Paleontology*, **91**, 735–754.
- 1390 RONG, J. Y. 1984. Distribution of the Hirnantia fauna and its meaning. *In*: BRUTON, D. L. (ed.)
1391 Aspects of the Ordovician System. *Paleontological Contributions from the University of*
1392 *Oslo*, **295**, 101–112.

- 1393 RONG, J. Y. 1986. Ecostratigraphy and community analysis of Late Ordovician and Silurian in
1394 southern China. *In: Palaeontological Society of China (ed.) Selected Papers of the 13th*
1395 *and 14th Annual Convention of the Palaeontological Society of China*. Anhui Science and
1396 Technology Publishing House, Hefei, 1–24 [in Chinese with English summary].
- 1397 ROSS, J. R. P. & ROSS, C. A. 1992. Ordovician sea-level fluctuations. *In: WEBBY, B. D. &*
1398 *LAURIE, J. R. (eds) Global Perspectives on Ordovician Geology*. Proceedings of the 6th
1399 International Symposium on the Ordovician System. Balkema, Rotterdam, 327–335.
- 1400 ROSS, C. A. & ROSS, J. R. P. 1995. North American Ordovician depositional sequences and
1401 correlations. *In: COOPER, J., DROSER, M. L. & FINNEY, S. (eds) Ordovician Odyssey*. 7th
1402 International Symposium of the Ordovician System. Las Vegas, The Pacific Section
1403 Society of Sedimentary Geology (SEPM), Fullerton, 309–313.
- 1404 RUTA, M. 1999. A new stylophoran echinoderm, *Juliaecarpus milnerorum*, from the late
1405 Ordovician Upper Ktaoua Formation of Morocco. *Bulletin of Natural History Museum of*
1406 *London (Geology)*, **55**, 47–79.
- 1407 SALEH, F., CANDELA, Y., HARPER, D. A. T., POLECHOVÁ, M., LEFEBVRE, B. & PITTET, B. 2018.
1408 Storm-induced community dynamics in the Fezouata Biota (Lower Ordovician,
1409 Morocco). *Palaios*, **33**, 1–7.
- 1410 SALEH, F., PITTET, B., PERRILLAT, J. P. & LEFEBVRE, B. 2019. Orbital control on exceptional
1411 fossil preservation. *Geology*, **47**, 103–106.
- 1412 SAMUELSSON, J., VAN ROY, P. & VECOLI, M. 2001. Micropalaeontology of a Moroccan
1413 Ordovician deposit yielding soft-bodied organisms showing Ediacara-like preservation.
1414 *Geobios*, **34**, 365–373.
- 1415 SÁNCHEZ-GARCÍA, T., CHICHORRO, M., SOLÁ, R., ÁLVARO, J. J., DÍEZ, A., BELLIDO, F.,
1416 RIBEIRO, M. L., QUESADA, C. & CARRILHO LOPES, J. 2019. Rifting Stage. *In: QUESADA,*
1417 *C. & OLIVEIRA, J. T. (eds) The Geology of Iberia: A Geodynamic Approach*. Regional
1418 Geology Reviews Series, Springer, Heidelberg.
- 1419 SERVAIS, T. & MOLYNEUX, S. G. 1997. The messaoudensis-trifidum acritarch assemblage
1420 (Ordovician: late Tremadoc-early Arenig) from the subsurface of Rügen (Baltic Sea, NE
1421 Germany). *Palaeontographia Italiana*, **84**, 113–161.
- 1422 SMITH, A. G. 1997. Estimates of the Earth's spin (geographic) axis relative to Gondwana from
1423 glacial sediments and palaeomagnetism. *Earth-Science Reviews*, **42**, 161–169.
- 1424 SOUFIANE, A. & ACHAB, A. 1993. Quelques assemblages de Chitinozoaires de l'Ordovicien du
1425 Maroc, Bassin de Tadla. *Geobios*, **26**, 535–553.
- 1426 SOULAIMANI, A., BOUABDELLI, M. & PIQUE, A. L. 2003. L'extension continentale au
1427 Néoprotérozoïque supérieur–Cambrien inférieur dans l'Anti-Atlas (Maroc). *Bulletin de la*
1428 *Société géologique de France*, **174**, 83–92.

- 1429 STAMPFLI, G. M., VON RAUMER, J. F. & BOREL, G. D. 2002. Paleozoic evolution of pre-
 1430 Variscan terranes: from Gondwana to the Variscan collision. *In*: MARTÍNEZ CATALÁN, J.
 1431 R., HATCHER, R. D., ARENAS, R. & DÍAZ GARCÍA, F. (eds) Variscan-Appalachian
 1432 dynamics: the Building of the Late Paleozoic Basement. *Geological Society of America,*
 1433 *Special Paper*, **364**, 263–280.
- 1434 SUMRALL, C. D. & ZAMORA, S. 2011. Ordovician edrioasteroids from Morocco: faunal
 1435 exchanges across the Rheic Ocean. *Journal of Systematic Palaeontology*, **9**, 425–454.
- 1436 SUMRALL, C. D. & ZAMORA, S. (this vol.). New Upper Ordovician edrioasteroids from
 1437 Morocco. *In*: HUNTER, A. W., ÁLVARO, J. J., LEFEBVRE, B., VAN ROY, P. & ZAMORA, S.
 1438 (eds), *The Great Ordovician Biodiversification Event: Insights from the Tafilalt Biota,*
 1439 *Morocco*. Geological Society, London, Special Publication, **485**, doi: 10.1144/SP485.6
- 1440 SUTCLIFFE, O. E., HARPER, D. A. T., AÏT SALEM, A., WHITTINGTON, R. J. & CRAIG, J. 2001.
 1441 The development of an atypical *Hirnantia*-brachiopod Fauna and the onset of the
 1442 glaciation in the Late Ordovician of Gondwana. *Transactions of the Royal Society of*
 1443 *Edinburgh: Earth Sciences*, **92**, 1–14.
- 1444 TAYLOR, P. D. & ERNST, A. 2004. Bryozoan diversification during the Ordovician. *In*: WEBBY,
 1445 B. D., DROSER, M. L. & PARIS, F. (eds) *The Great Ordovician Biodiversification Event*.
 1446 Columbia University Press, New York, 147–156.
- 1447 TERMIER, G. & TERMIER, H. 1950a. *Paléontologie marocaine*. II: Invertébrés de l'Ère Primaire,
 1448 fascicule 2. Bryozoaires et brachiopodes, 1–20. Hermann & Cie, Paris.
- 1449 TERMIER, G. & TERMIER, H. 1950b. *Paléontologie marocaine*. II. Invertébrés de l'Ere Primaire,
 1450 fascicule 4. Annélides, arthropodes, échinodermes, conularides et graptolithes. *Notes et*
 1451 *Mémoires du Service géologique du Maroc*, **79**, 1–281.
- 1452 TERMIER, H. & TERMIER, G. 1970. Un échinoderme encroûtant de l'Ashgill (Ordovicien
 1453 supérieur) du Tafilalt (Sud marocain): *Herpetocystis destombesi* nov. gen. nov. sp.
 1454 *Comptes Rendus de l'Académie des Sciences, Paris*, **271**, 1260–1263.
- 1455 **TESSITORE, L. 2016. La biostratigraphie des chitinozoaires dans le décryptage de la glaciation**
 1456 **fini-ordovicienne sur les marges gondwaniennes. Ph.D., Université de Lille 1, 192 pp.**
- 1457 UBAGHS, G. 1963. *Rhopalocystis destombesi* n.g., n.sp. Eocrinoïde de l'Ordovicien inférieur
 1458 (Trémadocien supérieur) du Sud marocain. *Notes et Mémoires du Service géologique du*
 1459 *Maroc*, **23** (172), 25–39.
- 1460 UBAGHS, G. 1968. Eocrinoids. *In*: MOORE, R.C. (ed.) *Treatise on Invertebrate Paleontology Pt.*
 1461 *S, Echinodermata*, 1 (2), S455–S495.
- 1462 UBAGHS, G. 1969. *Aethocrinus moorei* Ubaghs, nov. gen., nov. sp., le plus ancien crinoïde
 1463 dicyclique connu. *University of Kansas Paleontological Contributions*, **38**, 1–25.
- 1464 VALENT, M. & CORBACHO, J. 2015. *Pauxillites thaddei* a new Lower Ordovician hyolith from
 1465 Morocco. *Sborník Národního Muzea v Praze [B]*, **71**, 51–54.

- 1466 VAN ITEN, H., MUIR, L., SIMÕES, M. G., MARQUES, A. C. & YODER, N. 2016.
1467 Palaeobiogeography, palaeoecology and evolution of Lower Ordovician conulariids and
1468 *Sphenothallus* (Medusozoa, Cnidaria), with emphasis on the Fezouata Shale of
1469 southeastern Morocco. *Palaeogeography, Palaeoecology, Palaeoclimatology*, **460**, 170–
1470 178.
- 1471 VAN ITEN, H., GUTIÉRREZ-MARCO, J. C., MUIR, L. A., SIMOES, M. G. & LEME, J. M. (this vol.).
1472 Ordovician conulariids from the Upper Tiouririne Formation (Katian), Eastern Anti-Atlas
1473 mountains, southern Morocco. In: HUNTER, A. W., ÁLVARO, J. J., LEFEBVRE, B., VAN
1474 ROY, P. & ZAMORA, S. (eds), *The Great Ordovician Biodiversification Event: Insights
1475 from the Tafilalt Biota, Morocco*. Geological Society, London, Special Publications, **485**,
1476 doi: 10.1144/SP485.5.
- 1477 VAN ROY, P. 2006a. Non-trilobite arthropods from the Ordovician of Morocco. Universiteit
1478 Gent, unpublished Ph.D dissertation.
- 1479 VAN ROY, P. 2006b. An aglaspidid arthropod from the Late Ordovician of Morocco with
1480 remarks on the affinities and limitations of Aglaspidida. *Transactions of the Royal Society
1481 of Edinburgh, Earth Sciences*, **96**, 327–350.
- 1482 VAN ROY, P. & BRIGGS, D. E. G. 2011. A giant Ordovician anomalocaridid. *Nature*, **473**, 510–
1483 513.
- 1484 VAN ROY, P. & TETLIE, O. E. 2006. A spinose appendage of a problematic arthropod from the
1485 Early Ordovician of Morocco. *Acta Palaeontologica Polonica*, **51**, 239–246.
- 1486 VAN ROY, P., ORR, P. J., BOTTING, J. P., MUIR, L. A., VINTHER, J., LEFEBVRE, B., EL HARIRI, K.
1487 & BRIGGS, D. E. G. 2010. Ordovician faunas of Burgess Shale type. *Nature*, **465**, 215–
1488 218.
- 1489 VAN ROY, P., DALEY, A. C. & BRIGGS, D. E. G. 2015a. Anomalocaridid trunk limb homology
1490 revealed by a giant filter- feeder with paired flaps. *Nature*, **522**, 77–80.
- 1491 VAN ROY, P., BRIGGS, D. E. G. & GAINES, R. R. 2015b. The Fezouata fossils of Morocco; an
1492 extraordinary record of marine life in the Early Ordovician. *Journal of the Geological
1493 Society*, **172**, 541–549.
- 1494 VAUCHER, R., MARTIN, E. L. O., HORMIÈRE, H. & PITTET, B. 2016. A genetic link between
1495 *Konzentrat-* and *Konservat-* Lagerstätten in the Fezouata Shale (Lower Ordovician,
1496 Morocco). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **460**, 24–34.
- 1497 VAUCHER, R., PITTET, B., HORMIÈRE, H., MARTIN, E. L. O. & LEFEBVRE, B. 2017. A wave-
1498 dominated, tide- modulated model for the Lower Ordovician of the Anti- Atlas,
1499 Morocco. *Sedimentology*, **64**, 777–807.
- 1500 VENNIN, E., ÁLVARO, J. J. & VILLAS, E. 1998. High-latitude pelmatozoan-bryozoan mud-
1501 mounds from the Late Ordovician northern Gondwana platform. *Geological Journal*, **3**,
1502 121–140.

- 1503 VIDAL, M. 1998a. Le modèle des biofaciès à trilobites: un test dans l'Ordovicien inférieur de
1504 l'Anti-Atlas, Maroc. *Comptes Rendus de l'Académie des Sciences, Paris*, **327**, 327–333.
- 1505 VIDAL, M. 1998b. Trilobites (Asaphidae et Raphiophoridae) de l'Ordovicien inférieur de l'Anti-
1506 Atlas, Maroc. *Palaeontographica Abteilung A*, **251**, 39–77.
- 1507 VIDET, B., PARIS, F., RUBINO, J. L., BOUMENDJEL, K., DABARD, M. P., LOI, A., GHIENNE, J. F.,
1508 MARANTE, A. & GORINO, A. 2010. Biostratigraphical calibration of third order
1509 Ordovician sequences on the northern Gondwana platform. *Palaeogeography*,
1510 *Palaeoclimatology, Palaeoecology*, **296**, 359–375.
- 1511 VILLAS, E. & COLMENAR, J. (this vol.). Brachiopods from the Upper Ordovician of Erfoud
1512 (eastern Anti-Atlas, Morocco) and the stratigraphic correlation of the bryozoan-rich
1513 Khabt-el Hajar Formation. In: HUNTER, A. W., ÁLVARO, J. J., LEFEBVRE, B., VAN ROY, P.
1514 & ZAMORA, S. (eds), *The Great Ordovician Biodiversification Event: Insights from the*
1515 *Tafilalt Biota, Morocco*. Geological Society, London, Special Publication, **485**, doi
1516 10.1144/SP485.2
- 1517 VILLAS, E., VIZCAÍNO, D., ÁLVARO, J. J., DESTOMBES, J. & VENNIN, E. 2006. Biostratigraphic
1518 control based on brachiopods of the latest Ordovician glaciogenic unconformity in Alnif,
1519 eastern Anti-Atlas, Morocco. *Geobios*, **39** (5), 727–737.
- 1520 VINTHER, J., VAN ROY, P. & BRIGGS, D. E. G. 2007. Machaeridians are Palaeozoic armoured
1521 annelids. *Nature*, **451**, 185–188.
- 1522 VINTHER, J., PARRY, L., BRIGGS, D. E. G. & VAN ROY, P. 2017. Ancestral morphology of
1523 crown- group molluscs revealed by a new Ordovician stem aculiferan. *Nature*, **542**, 471–
1524 474.
- 1525 WANG, Y., BOUCOT, A. J., RONG, J. Y. & YANG, X. C. 1987. Community paleoecology as a
1526 geologic tool: the Chinese Ashgillian–Eifelian (latest Ordovician through Devonian) as
1527 an example. *Geological Society of America, Special Papers*, **211**, 1–100.
- 1528 WARE, D. & LEFEBVRE, B. 2007. Abnormalities in the Lower Ordovician cornute *Phyllocystis*
1529 *Thoral* (Echinodermata: Stylophora) of Montagne Noire (southern France): implications
1530 for plate homology and phylogeny. *Journal of Paleontology*, **81**, 779–787.
- 1531 ZALASIEWICZ, J., TAYLOR, L. S., RUSHTON, A. W. A., LOYDELL, D. K., RICKARDS, R. B. &
1532 WILLIAMS, M. 2009. Graptolites in British stratigraphy. *Geological Magazine*, **146** (6),
1533 785–850.
- 1534 ZAMORA, S. & SUMRALL, C. D. (this vol. a). *Hexedriocystis*, an aberrant eocrinoid convergent
1535 with edriasteroids from the Upper Ordovician of Morocco. In: HUNTER, A. W.,
1536 ÁLVARO, J. J., LEFEBVRE, B., VAN ROY, P. & ZAMORA, S. (eds), *The Great Ordovician*
1537 *Biodiversification Event: Insights from the Tafilalt Biota, Morocco*. Geological Society,
1538 London, Special Publication, **485**, doi: 10.1144/SP485.

- 1539 ZAMORA, S. & SUMRALL, C. D. (this vol. b). The first report of coronates (Echinodermata) from
1540 Africa. *In*: HUNTER, A. W., ÁLVARO, J. J., LEFEBVRE, B., VAN ROY, P. & ZAMORA, S.
1541 (eds), *The Great Ordovician Biodiversification Event: Insights from the Tafilalt Biota,*
1542 *Morocco*. Geological Society, London, Special Publication, **485**.
- 1543 ZAMORA, S., RAHMAN, I. A. & AUSICH, W. I. 2015. Palaeogeographic implications of a new
1544 iocrinid (Disparida) from the Ordovician (Darriwilian) of Morocco. *Peer Journal*, **3**,
1545 e1540, doi: 10.7717/peerj.1450.
- 1546 ZAMORA, S., NARDIN, E., ESTEVE, J. & GUTIÉRREZ-MARCO, J. C. (this vol.). New rhombiferan
1547 blastozoans (Echinodermata) from the Late Ordovician of Morocco. *In*: HUNTER, A. W.,
1548 ÁLVARO, J. J., LEFEBVRE, B., VAN ROY, P. & ZAMORA, S. (eds), *The Great Ordovician*
1549 *Biodiversification Event: Insights from the Tafilalt Biota, Morocco*. Geological Society,
1550 London, Special Publication, **485**, doi: [10.1144/SP485.10](https://doi.org/10.1144/SP485.10).
- 1551 ZURBRIGGEN, R. 2015. Ordovician orogeny in the Alps: a reappraisal. *International Journal of*
1552 *Earth Sciences*, **104**, 335–350.
- 1553

1554 **FIGURE CAPTIONS**

1555

1556 Figure 1. A. Sketch of main geographical units in NW Africa. B. Geological sketch showing the
 1557 geographical distribution of Ordovician exposures throughout the Anti-Atlas, High Atlas and
 1558 Ouagarta massif; modified from Destombes *et al.* (1985); abbreviations: Ar- Aroudane jbel, BI-
 1559 Bou Ingarf jbel, BK- Bou el-Khoualb, BR- Bou Rdim, OU- Ouzina jbel, Ti- Timzizouit jbel and
 1560 TR- Tizi n'Rsas.

1561

1562 Figure 2. Stratigraphical chart of the Miaolingian-Hirnantian in the Anti-Atlas with setting of
 1563 main gaps; abbreviations of Hirnantian glacial tunnels: Ad- Adrar (Merzouga sheet), Am-
 1564 Amessoui, Ar- Aroudane, Im-Ti- Imzizoui-Timzizouit, Ti- Taouirt n'Irjdelen, TR: Tizi n'Rsas;
 1565 modified from Álvaro *et al.* (2014c, d), Benharref *et al.* (2014a, b, c) and Álvaro & Vizcaíno
 1566 (2018).

1567

1568 Figure 3. Field aspect of the Feijas Externes Group in the Tafilalt district. A. Centimetre-scale
 1569 glauconitic sandstone/siltstone alternations rich in hematite cement, forming the basal part of
 1570 the Upper Fezouata Formation, South of Jbel Ouzina. B. Thin-section photomicrograph (parallel
 1571 light) of clast-supported glauconitic-quartz sandstone cemented with hematite; detail of
 1572 previous picture; scale = 1 mm. C. Three shallowing-upward cycles (tops arrowed) forming the
 1573 Tachilla Formation, North of Jbel Ouzina. D. Thin-section photomicrograph of a clast- to
 1574 cement-supported ironstone with scattered ooids from the Tachilla Formation; detail of previous
 1575 image; scale = 1 mm.

1576

1577 Figure 4. Field aspect of the Ktaoua Group in the Maider-Tafilalt district. A. Claystone-
 1578 dominated succession with scattered metre-scale carbonate concretions of the Lower Ktaoua
 1579 Formation, close to Alnif; scale = 1 m. B. Channels interbedded in the shales of the Lower
 1580 Ktaoua Formation showing angular cobble clasts embedded in a brachiopod shell matrix,
 1581 reflecting high-energy episodes, close to Alnif. C. Phosphatic layer marking the Lower
 1582 Ktaoua/Upper Tiouririne contact at Alnif. D. Coquina on a silty carbonate surface with
 1583 branching bryozoans (b), orthoceratids (o), tentaculitids (te) and trilobites (tr), from the Upper
 1584 Tiouririne Formation at Jbel Aroudane; scale = 4 cm. E. Channel interbeds of the Upper
 1585 Tiouririne Formation with superposed scouring surfaces and granule-to-boulder clasts, close to
 1586 Alnif. F. Thin-section photomicrograph (parallel light) of a bryozoan floatstone with
 1587 disarticulated echinodermossicles and brachiopods, embedded in a silty carbonate matrix; Upper
 1588 Tiouririne Formation at Jbel Aroudane; scale = 1 mm. G. Coquina of disarticulated echinoderm
 1589 plates from the top of the Upper Tiouririne Formation at Tizi n'Rsas. H. Thin-section
 1590 photomicrograph (parallel light) illustrating the traditional orthoceratid-rich carbonate siltstone

1591 that punctuate the monotonous shales of the Upper Ktaoua Formation, Jbel Aroudane; scale = 1
1592 mm.

1593

1594 Figure 5. Field aspect of the Khabt-el-Hajar Formation and the Upper Formation of the Second
1595 Bani Group in the Maider-Tafilalt district. A. Second shallowing-upward trend of marlstone-to-
1596 limestone rich in echinoderm-bryozoan debris from the northwestern edge exposure of the
1597 formation, north of Erfoud. B. Destombes' (1987) "ravinement surface" (arrowed) separating
1598 two packages of echinoderm-bryozoan limestones, reinterpreted as an onlapping geometry of a
1599 palaeorelief formed by skeletal shoals, north of Erfoud. C. Aspect of bryozoan meadows from
1600 the upper part of the Khabt-el-Hajar Formation exhibiting parautochthonous robust and fragile
1601 branching and dendroid bryozoans, north of Erfoud. D. Alluvial channel (scouring base
1602 arrowed) infilled with clast-supported conglomerates of the Alnif Member, subsequently capped
1603 by fluvial sandstone bars at the base of Jbel Boulakoualeb. E. Western contact (arrowed) of the
1604 Hirnantian Alnif tunnel channel, incised in the Upper Tiouririne Formation (subhorizontal beds
1605 on the left). F. Alternating conglomerate and sandstone beds with subparallel and low-angle
1606 laminae reflecting pulsations in the infill of the Hirnantian Alnif tunnel channel. G. Clast-
1607 supported conglomerate highlighted by the orange colour of the silty carbonate clasts eroded
1608 from the Lower Ktaoua and Upper Tiouririne formations; Alnif Member at Tizi n'Rsas tunnel
1609 channel. H. Outsized sandstone clasts embedded in a homogeneous claystone of the Tamekhar
1610 Member; glaciogenic diamictite at Jbel Imzizoui. I. Overlying cross-stratified sandstones of the
1611 Amouktir Member at Jbel Imzizoui.

1612

1613 Figure 6. Updated litho-and chronostratigraphical charts of the Ordovician in the Anti-Atlas,
1614 Morocco. [Global chronostratigraphic scale subdivisions according to Bergström *et al.* \(2009\);](#)
1615 [regional scale updated by Gutiérrez-Marco *et al.* \(2017\) and Colmenar *et al.* \(2017\).](#)
1616 [Lithostratigraphy after Destombes \(in Destombes *et al.* 1985\). Chitinozoan zonation updated](#)
1617 [from Paris *et al.* \(1990, 1999\) in Gutiérrez-Marco *et al.* \(2015, 2017b\). Graptolite zones after](#)
1618 [Gutiérrez-Marco & Martin \(2016\) and Gutiérrez Marco *et al.* \(2017b\).](#)

1619

1620 Figure 7. Chronostratigraphical distribution of third-order sequences described in the Zagora-
1621 Fom Zguid depocentre and the Maider-Tafilalt districts, central and eastern Anti-Atlas; based
1622 on Destombes *et al.* (1985), Álvaro *et al.* (2007b, 2014c, d), Ghienne *et al.* (2007a), Loi *et al.*
1623 (2010), Benharref *et al.* (2014a, b, c), Colmenar & Álvaro (2015), and Álvaro & Vizcaïno
1624 (2018).

1625

1626 **ANNEX 1. Updated Ordovician fossil record**

1627

1628 In the Anti-Atlas, taxonomic works have been focusing on trilobites (Choubert *et al.* 1955;
1629 Destombes 1963c, 1966, 1967a, b, 1972, 1985a, b, c, d, 1987, 2000, 2006a-j; Destombes &
1630 Henry 1987; Rábano 1990; Henry 1991; Henry & Destombes 1991; Henry *et al.* 1992; Vidal
1631 1998a, b; Bruton 2008; Fortey 2009, 2011a, b; Rábano *et al.* 2010, 2014; Martin *et al.* 2016b;
1632 Fortey & Edgecombe 2017; Pereira *et al.* 2017; Gutiérrez-Marco *et al.* 2017, 2019; Drage *et al.*
1633 2019), radiodonts (Van Roy & Tetlie 2006; Van Roy & Briggs 2011; Van Roy *et al.* 2015a),
1634 aglaspids (Van Roy 2006a, b; Ortega-Hernández *et al.* 2016), cheloniellid arthropods
1635 (Alessandrello & Bracchi 2006, Van Roy 2006a), echinoderms (Termier & Termier 1950a, b,
1636 1970; Ubaghs 1963, 1968, 1969; Choubert *et al.* 1953; Chauvel 1966a, b, 1969a, b, 1971a, b,
1637 1977, 1978; Paul 1968; Chauvel & Régnault 1986; Donovan & Savill 1988; Cripps 1990;
1638 Beisswenger 1994; Le Menn & Spjeldnaes 1996; Ruta 1999; Lefebvre & Fatka 2003; Parsley &
1639 Gutiérrez Marco 2005; Lefebvre 2007; Lefebvre & Botting 2007; Lefebvre *et al.* 2007, 2008,
1640 2010, 2016c, 2019; Nardin 2007; Régnault 2007; Ware & Lefebvre 2007; Lefebvre & Roch
1641 2009; Noailles *et al.* 2010; Sumrall & Zamora 2011; Allaire *et al.* 2015, 2017; Martin *et al.*
1642 2015; Nardin & Régnault 2015; Zamora *et al.* 2015; Reich *et al.* 2017; Hunter & Ortega-
1643 Hernández 2017), brachiopods (Havliček 1970, 1971; Mergl 1981, 1983; Villas *et al.* 2006;
1644 Colmenar & Álvaro 2015; Candela & Harper 2016; Colmenar 2016), hyoliths (Marek 1983;
1645 Valent & Corbacho 2015; Martí Mus 2016), sachtids (Vinther *et al.* 2017), bivalves and
1646 rostroconchs (Termier & Termier 1950b; Babin & Destombes 1990; Polechová 2016),
1647 gastropods, paragastropods and tergomiids (Horný 1997a, b, c; Ebbestad & Lefebvre 2015;
1648 Ebbestad 2016), graptolites (Destombes & Willefert 1959; Martin *et al.* 2016a; Gutiérrez-Marco
1649 & Martin 2016), conodonts (El Bourkhissi & Sarmiento 1997; Lehnert *et al.* 2016), ostracods
1650 (Gutiérrez-Marco *et al.* 1997), sponges (Botting 2007, 2016), conulariids (Van Iten *et al.* 2016),
1651 cephalopods (Kröger & Lefebvre 2012), machaeridians (Chauvel 1966c; Vinther *et al.* 2007),
1652 palaeoscolecid and soft-bodied metazoans (Samuelsson *et al.* 2001; Alessandrello & Bracchi
1653 2003; Van Roy 2006a; Gaines *et al.* 2012; McGabhan 2012; Gutiérrez-Marco & García-Bellido
1654 2015; Martin *et al.* 2016c; Gutiérrez Marco *et al.* 2017a; Kouraiss *et al.* 2018; McGabhan *et al.*
1655 2019), cornulitids (Gutiérrez-Marco & Vinn 2018), bryozoans (Destombes *et al.* 1971; Ernst *et al.*
1656 2015; Jiménez-Sánchez *et al.* 2015a, b, 2016), organic-walled microfossils (Deunff 1968a, b,
1657 1977; Elaouad-Debbaj, 1984a, b, 1986, 1988a, b; Paris 1990; Nowak *et al.* 2015, 2016) and
1658 some ichnofossils (Gibb *et al.* 2010; Azizi *et al.* 2017). To these fossil associations are added
1659 the palaeontological contributions reported in this special volume, which include conulariids
1660 (Van Iten *et al.*), brachiopods (Colmenar *et al.*; Villas & Colmenar), echinoderms (crinoids by
1661 Botting *this vol.*; stylophorans by Lefebvre *et al.*; edrioasteroids by Sumrall & Zamora;
1662 coronates and *Hexedriocystis* by Zamora & Sumrall; and rhombiferans by Zamora *et al.*),

1663 graptolites (Gutiérrez-Marco *et al.*), molluscs (Ebbestad *et al.*), trilobites (Gutiérrez-Marco *et al.*
 1664 this vol.), and problematica (agglutinated tubes by Muir *et al.*).

1665 The Lower Fezouata and Upper Fezouata formations contain about 200 taxa that have
 1666 been reported in the so-called Fezouata Biota (Van Roy *et al.* 2010, 2015b; Lefebvre *et al.*
 1667 2016b, c; Vaucher *et al.* 2016, 2017; Saleh *et al.* 2018, 2019), many of which still remain
 1668 undescribed. The biota includes algae (such as chaetocladids); sponges (*Choia*, *Choiaella*,
 1669 *Hamptonia*, *Pirania*, *Valospongia* and other demosponges, hexactinellids, leptomitids and
 1670 wapkiiids); cnidarians (*Archaeoconularia*, *Eoconularia* and *Sphenothallus*); brachiopods
 1671 (*Angusticardinia*, *Celdobolus*, *Elliptoglossa*, *Monobolina*, *Orbithele*, *Paurorhis*, *Plectorthis*,
 1672 *Ranorthis*, *Tarfaya* and *Wosekella*); undetermined bryozoans; molluscs such as bivalves
 1673 (*Alococoncha?*, *Babinka*, *Cardiolaria?*, *Cienagomya?*, *Coxiconchia*, *Ekaterodonta*, *Glyptarca*,
 1674 *Praenucula?* and *Redonia*), rostroconchs (*Ribeiria*, *Tolmachovia?*), paragastropods
 1675 (*Pelecogyra*), gastropods (*Lesueurilla* and *Sinuities*), tergomians (*Carcassonnella* and
 1676 *Thoralispira*), cephalopods (a.o. *Bactroceras*, *Bathmoceras*, *Destombesiceras*, *Polymeres*,
 1677 *Protocryptendoceras* and *Rioceras*) and other stem mollusc groups (sachitids such as
 1678 *Calvapilosa*, halkieriids, helcionellids and wiwaxiids); hyoliths (*Cavernolites*, *Gompholites*,
 1679 *Elegantilites*, *Gamalites?*, *Nephrotheca?* and *Pauxilites*); annelids (*Plumulites*, different
 1680 polychaetes and isolated scolecodonts), cycloneuralia (*Palaeoscolex?* and priapulids),
 1681 lobopodians, radiodonts (*Aegirocassis* and other hurdiids, and amplexobeluids), euarthropods
 1682 (*Brachyaglaspis*, *Mollisonia*, *Pseudoangustidontus*, *Thelxiope*, *Tremaglaspis*, canadaspidids,
 1683 leanchoiliids, aglaspidids, cheloniellids, basal chelicerates, xiphosurids, chasmataspidids,
 1684 eurypterids, liwiids, naraoiids, marrellid and acercostracan marrellomorphs, and possible
 1685 helmetiids, pycnogonids and retifaciids); trilobites (*Agerina*, *Ampyx*, *Anacheirurus*,
 1686 *Apatokephalus*, *Asaphellus*, *Asaphopsis*, *Basilicus*, *Bathycheilus*, *Bavarilla*, *Cnemidopyge*,
 1687 *Colpocoryphe*, *Dikelokephalina*, *Eoharpes*, *Euloma*, *Harpides*, *Foulonia*, *Kierarges*,
 1688 *Lichakephalus*, *Megistaspis*, *Neseuretus*, *Nileus*, *Orometopus*, *Ogyginus*, *Parabathycheilus*,
 1689 *Platycoryphe*, *Platypeltoides*, *Pharostomina*, *Pradoella*, *Prionocheilus*, *Selenopeltis*,
 1690 *Symphysurus*, *Toletanaspis* and *Uralichas*) and agnostoids (*Geragnostus*), phyllocarids,
 1691 ostracods, angustidontids and lepadomorph barnacles; echinoderms such as Crinoidea (*Iocrinus*
 1692 and *Ramseyocrinus*), Diploporita (*Aristocystites* and *Palaeosphaerites*), Edrioasteroidea
 1693 (*Anedriophus*, *Argodiscus* and *Rhenopyrgidae*), Eocrinoidea (*Balantiocystis*, *Lingulocystis*,
 1694 *Pareocrinus?* and *Rhopalocystis*), Rhombifera (*Macrocystella*), Soluta (*Plasiacystis*),
 1695 Somasteroidea (*Cantabrigiaster*, a.o.), Stylophora (*Ampelocarpus*, *Amygdalotheca*, *Anatifopsis*,
 1696 *Aspidocarpus*, *Balanocystites*, *Bohemiaecystis*, *Chauvelicystis*, *Chinianocarpus*, *Flabellucarpus*,
 1697 *Galliaecystis*, *Hanusia*, *Lagynocystis*, *Nanocarpus*, *Peltocystis*, *Phyllocystis*, *Procothurnocystis*,
 1698 *Prokopicystis* and *Vizcainocarpus*); graptolites (*Adelograptus?*, *Ancoragraptus*, *Araneograptus*,
 1699 *Azygograptus*, *Baltograptus*, *Choristograptus*, *Clonograptus*, *Cymatograptus?*, *Dictyonema*,

1700 ‘*Didymograptus*’, *Hunnegraptus*, ‘*Kiaerograptus*’, *Koremagraptus*, *Paradelograptus*,
 1701 *Paratemnograptus*, *Rhabdinopora*, *Schizograptus*?, ‘*Tetragraptus*’ and ?tuboids); conodonts
 1702 (*Acodus*, *Cornuodus*, *Drepanodus*, *Drepanoistodus*, *Paltodus*, *Parapaltodus*, *Paroistodus*,
 1703 *Periodon*, *Prioniodus*, *Scalpellodus*, *Scolopodus*, *Semiacontiodus*, *Stolodus*, *Tripodus* and
 1704 *Tropodus*); chordates (dermal plates) and problematica (e.g., Van Roy *et al.* 2010, 2015b;
 1705 Martin *et al.* 2016a, b).

1706 The Tachilla Formation has yielded trilobites (*Bathycheilus*, *Colpocoryphe*, *Dionide*,
 1707 *Ectillaenus*, *Eohomalonotus*, *Morgatia*, *Neseuretus*, *Ormathops*, *Placoparia*, *Plaesiacomia*,
 1708 *Selenopeltis* and ‘*Zeliszella*’), brachiopods (*Euorthisina* and ‘*Orthambonites*’), ostracods
 1709 (*Brephocharieis*), echinoderms [Diploporita (*Calix*), Stylophora (*Bohemiaecystis*)], hyoliths
 1710 (*Elegantilites*, *Gompholites* and *Pauxillites*), bivalves (*Praenucula* and *Redonia*), tergomyans
 1711 (*Cyrtodiscus*, *Tachillanella* and *Thoralispira*?), gastropods (*Lesueurilla*, *Ptychonema*, *Sinuities*,
 1712 *Selesinuities* and *Tropidodiscus*), graptolites (*Aulograptus*?, *Corymbograptus*, *Didymograptus*,
 1713 *Hustedograptus*?, *Jenkinsograptus* and *Xiphograptus*?) and undetermined lingulaceans,
 1714 orthoconic nautiloids and conulariids.

1715 The First Bani Group contains trilobites (such as *Basilicus*, *Bathycheilus*, *Caudillaenus*,
 1716 *Cekovia*, *Colpocoryphe*, *Crozonaspis*, *Degamella*, *Eccoptochile*, *Ectillaenus*, *Eoharpes*,
 1717 *Eohomalonotus*, *Iberocoryphe*, *Isabelinia*, *Kerfornella*, *Marrolithus*, *Morgatia*, *Mytocephala*,
 1718 *Neseuretus*, *Nobiliasaphus*, *Parabarrandia*, *Phacopidina*, *Placoparia*, *Plaesiacomia*,
 1719 *Selenopeltis* and *Uralichas*), cheloniellid euarthropods (*Duslia* and possibly *Triopus*),
 1720 brachiopods (*Atlantida*, *Euorthisina*, *Mimella*, ‘*Orthambonites*’, *Paterorthis*, *Tafilaltia* and
 1721 *Tissintia*); echinoderms including Crinoidea (*Iocrinus* and *Trichinocrinus*?), Diploporita
 1722 (*Aristocystites*, *Calix*, *Oretanocalix*, *Isidalocystis*, *Phlyctocystis* and *Sphaeronites*?),
 1723 Edrioasteroidea (*Belochthus*?, *Isorophus* and *Moroccodiscus*), Eocrinoidea (*Ascocystites*),
 1724 Ophiuroidea, Stylophora (*Anatifopsis*, *Aspidocarpus*, *Bohemiaecystis*, *Destombesicarpus*,
 1725 *Diamphidiocystis*, *Eumitrocystella*, *Milonicystis*, *Nanocarpus*, *Procothurnocystis* and
 1726 *Scotiaecystis*) and incertae sedis (*Hexedriocystis*); molluscs such as tergomyans (*Quasisinuities*),
 1727 bivalves (*Cardiolaria*, *Coxiconchia*, *Cyrtodontula*?, *Hemiprionodonta* and *Redonia*) and
 1728 rostroconchs (*Ribeiria*); hyoliths (*Elegantilites* and *Gompholites*), graptolites (*Didymograptus*,
 1729 *Dendrograptus* and *Ptilograptus*), conulariids (*Archaeoconularia*), paleoscolecids
 1730 (*Gamascolex*), conodonts (*Coleocerodontus*?, *Distomodus*?, *Drepanoistodus*?,
 1731 *Paraprioniodus*?, *Phragmodus*?, *Plectodina* and ‘*Scandodus*’), ostracods (‘*Dilobella*’,
 1732 ‘*Piretopsis*’, *Quadrijugator*?, *Reuentalina* and *Sigmoopsis*?), paropsonemid eldonioids
 1733 (*Discophyllum*), agglutinated problematic tubes (*Onuphionella*) and undetermined lingulaceans,
 1734 asterozoans, nautiloids, and bryozoans.

1735 The Lower Ktaoua Formation has yielded trilobites (*Actinopeltis*, *Calymenella*,
 1736 *Colpocoryphe*, *Crozonaspis*, *Dalmanitina*, *Deanaspis*, *Eccoptochile*, *Eohomalonotus*,

1737 *Eudolatites*, *Flexicalymene*, *Kloucekia*, *Mucronaspis*, ‘*Ogmasaphus*’, *Onnia*, *Ormathops*,
 1738 *Placoparia*, *Plaesiacomia*, *Primaspis*, *Prionocheilus*, ‘*Scotiella*’, *Selenopeltis*, *Sokhretia* and
 1739 *Stenopareia*), brachiopods (*Aegiromena*, *Bicuspina*, *Dalmanella*, *Drabovia*, *Drabovinella*,
 1740 *Eostropheodonta*, *Gelidorthis*, *Heterorthis*, *Howellites*, *Irhirea*, *Mimella*, *Onniella*,
 1741 *Protomendacella*, *Rafinesquina*, *Rostricellula*, *Schizocrania*, *Svobodaina*, *Tafilaltia*, *Tazzarina*
 1742 *Triplesia*), echinoderms such as Diploporita (*Calix*, *Codiacystis*, *Destombesia*, *Maghrebocystis*
 1743 and *Phlyctocystis*), Edrioasteroidea (*Isorophusella*, *Spinadiscus* and *Streptaster*), Eocrinoidea
 1744 (*Cardiocystites*), Ophiuroidea, Rhombifera (*Arachnocystites*, *Deutocystites*, *Echinosphaerites*,
 1745 *Heliocrinites* and *Homocystites*), Soluta (*Dendrocystites*) and Stylophora (*Anatifopsis*,
 1746 *Aspidocarpus*, *Barrandeocarpus* and *Eumitrocystella*?); molluscs such as tergomyans
 1747 (*Sinuitopsis*), gastropods (*Atlantophon*, *Bucanopsina*, *Deaechospira*, *Nonorios*, *Radvanospira*
 1748 and *Tritonophon*) and bivalves (*Myoplusia*, *Phestia*?, *Pseudarca*? and *Praenucula*); hyoliths
 1749 (*Elegantilites*, *Joachimilites*?, *Leolites*, *Nephroteca*, *Panitheca* and *Sololites*?), machaeridians
 1750 (*Plumulites*), graptolites (*Climacograptus*, *Dictyonema* and *Ptilograptus*), paropsonemid
 1751 eldonioids (*Discophyllum* and *Praeclarus*), agglutinated problematic tubes (*Onuphionella*) and
 1752 undetermined conulariids, bivalves, ostracods, asterozoans, and bryozoans.

1753 The Upper Tiouririne Formation contains trilobites (*Actinopeltis*, *Baniaspis*,
 1754 *Calymenella*, *Cyclopyge*, *Declivolithus*, *Delgadoa*, *Eudolatites*, *Flexicalymene*,
 1755 *Heterocyclopyge*, *Kloucekia*, *Mucronaspis*, *Nobiliasaphus*, *Onnia*, *Pricyclopyge*, *Prionocheilus*,
 1756 *Selenopeltis* and *Sokhretia*), agnostoids (*Corrugatagnostus*), aglaspimid and chelionellid
 1757 arthropods (*Chlupacaris* and *Triopus*), brachiopods (*Aegiromena*, *Cliftonia*, *Destombesium*,
 1758 *Drabovia*, *Drabovinella*, *Eostropheodonta*, *Hirnantia*, *Heterorthis*, *Eostropheodonta*,
 1759 *Heterorthis*, *Kiaeromena*?, *Orbiculoidea*, *Rafinesquina*, *Rostricellula*, *Svobodaina*,
 1760 *Schizocrania* and *Tafilaltia*), echinoderms such as Asteroidea, Coronata (*Mespilocystites*),
 1761 Crinoidea (*Euptychocrinus*?, *Isthlocrinus* and *Rosfacrinus*), Diploporita (*Codiacystis*,
 1762 *Destombesia* and *Maghrebocystis*), Edrioasteroidea (*Euryeschatia*, *Hemicystites*,
 1763 *Moroccopyrgus*, *Panidiscus* and *Streptaster*), Ophiuroidea, Rhombifera (*Echinosphaerites*),
 1764 Stylophora (*Aspidocarpus*, *Barrandeocarpus*? and *Eumitrocystella*?), and incertae sedis
 1765 (*Hexedriocystis*); molluscs such as tergomyans (*Sinuitopsis*), gastropods (*Sinuites*,
 1766 *Deaechospira* and *Radvanospira*), bivalves (*Praenucula*) and cephalopods (*Tafadnatoceras*),
 1767 conulariids (*Archaeoconularia* and *Pseudoconularia*), cornulitids, paropsonemid eldonioids
 1768 (*Discophyllum*), biserial graptolites (*Neodiplograptus*? and *Normalograptus*?) and agglutinated
 1769 problematic tubes (*Onuphionella*).

1770 The Upper Ktaoua Formation has yielded trilobites (*Actinopeltis*, *Amphitryon*,
 1771 *Baniaspis*, *Brogniartella*, *Calymenella*, *Chlustinia*, *Dionide*, *Dreyfussina*, *Eccoptochile*,
 1772 *Eudolatites*, *Flexicalymene*, *Kloucekia*, *Lichas*, *Mucronaspis*, *Octillaenus*, *Onnia* and
 1773 *Selenopeltis*), brachiopods (*Chonetoidea*, *Comatopoma*, *Eochonetes* and *Eostropheodonta*),

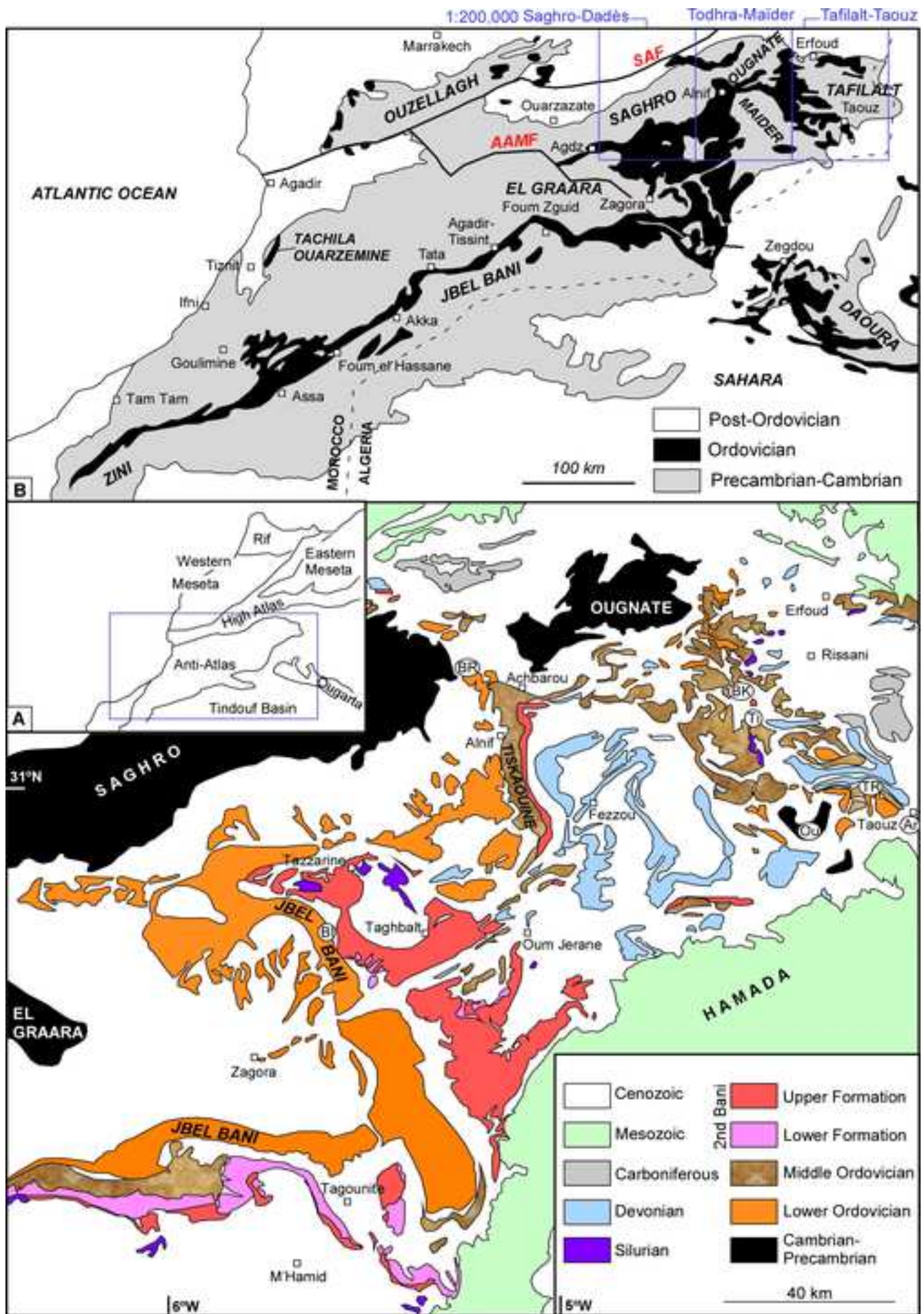
1774 echinoderms such as Diploporita (*Destombesia* and *Maghreboecystis*), Rhombifera
 1775 (*Arachnocystites*, *Echinosphaerites* and *Heliocrinites*) and Stylophora (*Barrandeocarpus?*);
 1776 molluscs, including cephalopods (*Armenoceras*, *Wadema* and ormoceratids), gastropods
 1777 (*Allossospira*, *Lophospira* and *Sinuites*) and bivalves (*Sluha*, *Cleionychia* and *Praenucula*);
 1778 hyoliths (*Elegantilites*), conularids (*Archaeoconularia*, *Pseudoconularia*), machaeridians
 1779 (*Plumulites*) and undetermined ostracods, rostroconch molluscs, and biserial graptolites
 1780 (*Normalograptus?*).

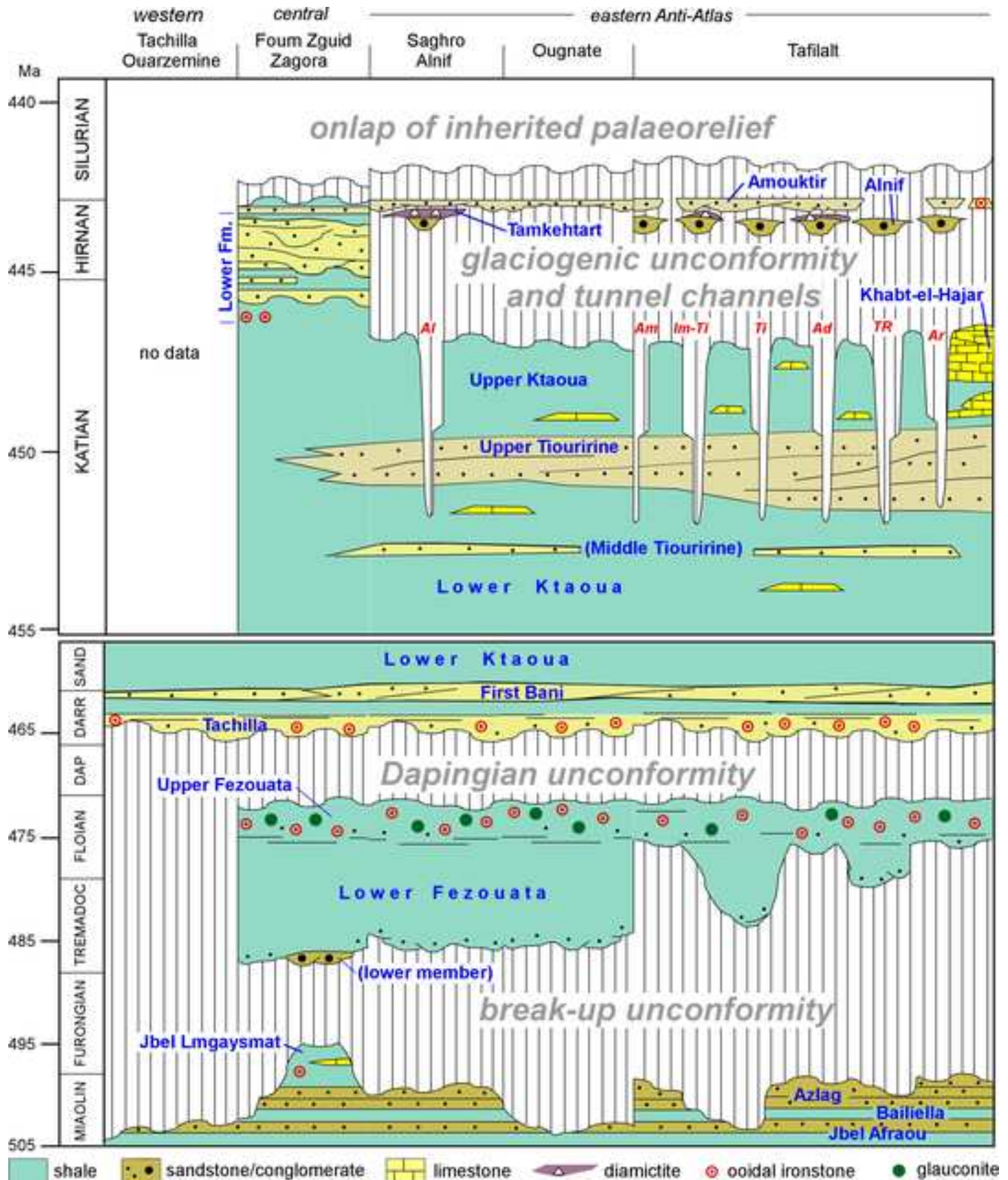
1781 In the Khabt-el-Hajar Formation, a complete assemblage of bryozoans has been
 1782 described by Jiménez-Sánchez *et al.* (2015a, b, 2016), including cryptostomates (*Graptodictya*,
 1783 *Ptilodictya*, *Staliodictya* and *Ulrichostylus*), fenestrates (*Enallopora*) and trepostomates
 1784 (*Anaphragma*, *Aostipora*, *Atactoporella*, *Calloporella*, *Cyphotrypa*, *Decayia*, *Diplotrypa*,
 1785 *Eridotrypa*, *Heterotrypa*, *Homotrypa*, *Monotrypa*, *Monticulipora*, *Parvohallopora*, *Prasopora*,
 1786 *Radiotrypa* and *Trematopora*); associated with trilobites (*Brogniartella* and *Mucronaspis*;
 1787 Destombes 1985c, 2006a, b; Le Menn & Spjeldnaes 1986) and brachiopods (*Drabovia* and
 1788 *Paucicrura*; Havlíček 1970, 1971; Villas & Colmenar this vol.)

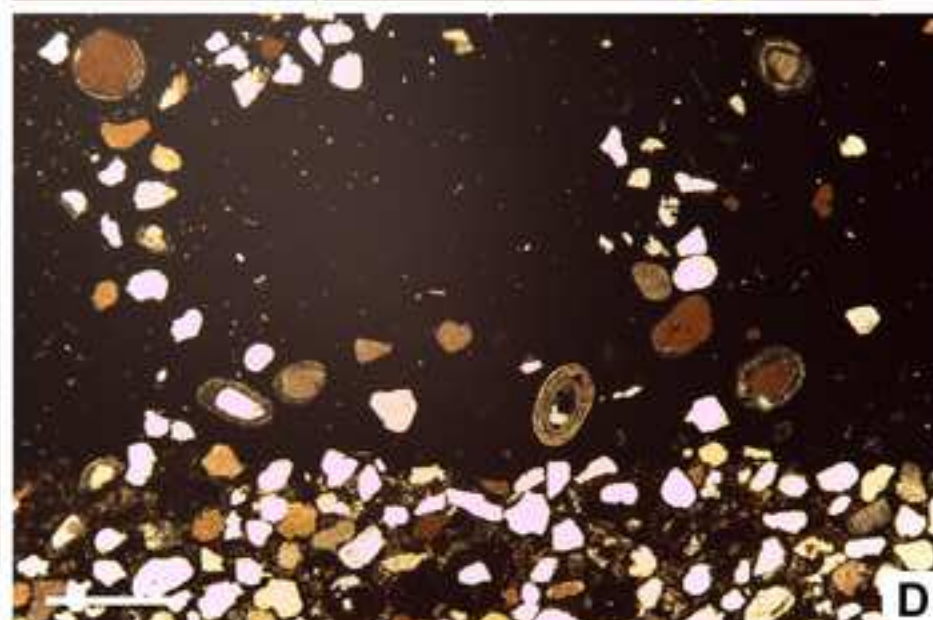
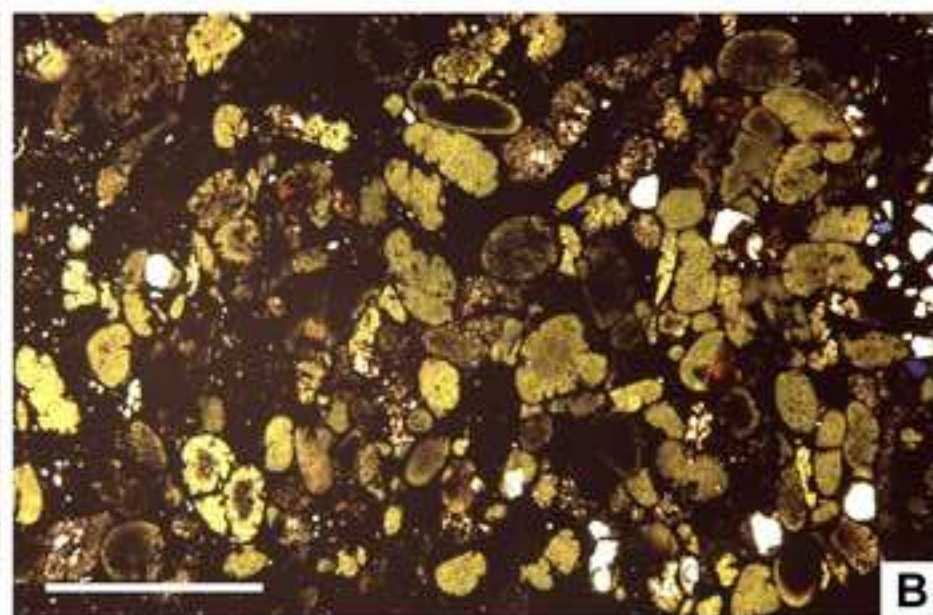
1789 The Katian-Hirnantian boundary lies within the Lower Formation of the Second Bani
 1790 Formation. Its latest Katian part has yielded brachiopods (*Dalejina*, *Destombesium*,
 1791 *Eostropheodonta* and *Hirnantia*), trilobites (*Actinopeltis*, *Cekovia*, *Dreyfussina*, *Mucronaspis*
 1792 and *Onnia*) and diploporite echinoderms (*Herpetocystis* and *Magreboecystis*). In contrast, the
 1793 Hirnantian part contains a diversified Hirnantia fauna including brachiopods (*Arenorthis*,
 1794 *Clarkeia*, *Dalejina*, *Destombesium*, *Eostropheodonta*, *Fehamya*, *Hirnantia*, *Holderleyella*,
 1795 *Kinnella*, *Plectothyrella* and ‘*Resserella*’), trilobites (*Calymenella* and *Mucronaspis*),
 1796 gastropods (*Tritonophon*, *Radvanospira* and *Sinuites*), bivalves (*Ambonychia*, *Cleionychia*,
 1797 *Cyrtodonta*, *Dzeruska*, *Modiolopsis* and *Nuculites*); echinoderms including Diploporita
 1798 (*Magreboecystis*), Stylophora (*Anatifopsis*, *Barrandeocarpus?*, *Enoploura?* and *Nanocarpus*) and
 1799 undetermined asterozoans and crinoids; cornulitids (*Cornulites*) and some bryozoans
 1800 (Destombes 2006a, b; Álvaro *et al.* 2014a, b; Colmenar & Álvaro 2015; Gutiérrez-Marco &
 1801 Vinn 2018; Ebbestad *et al.* this vol.; Colmenar *et al.* this vol.).

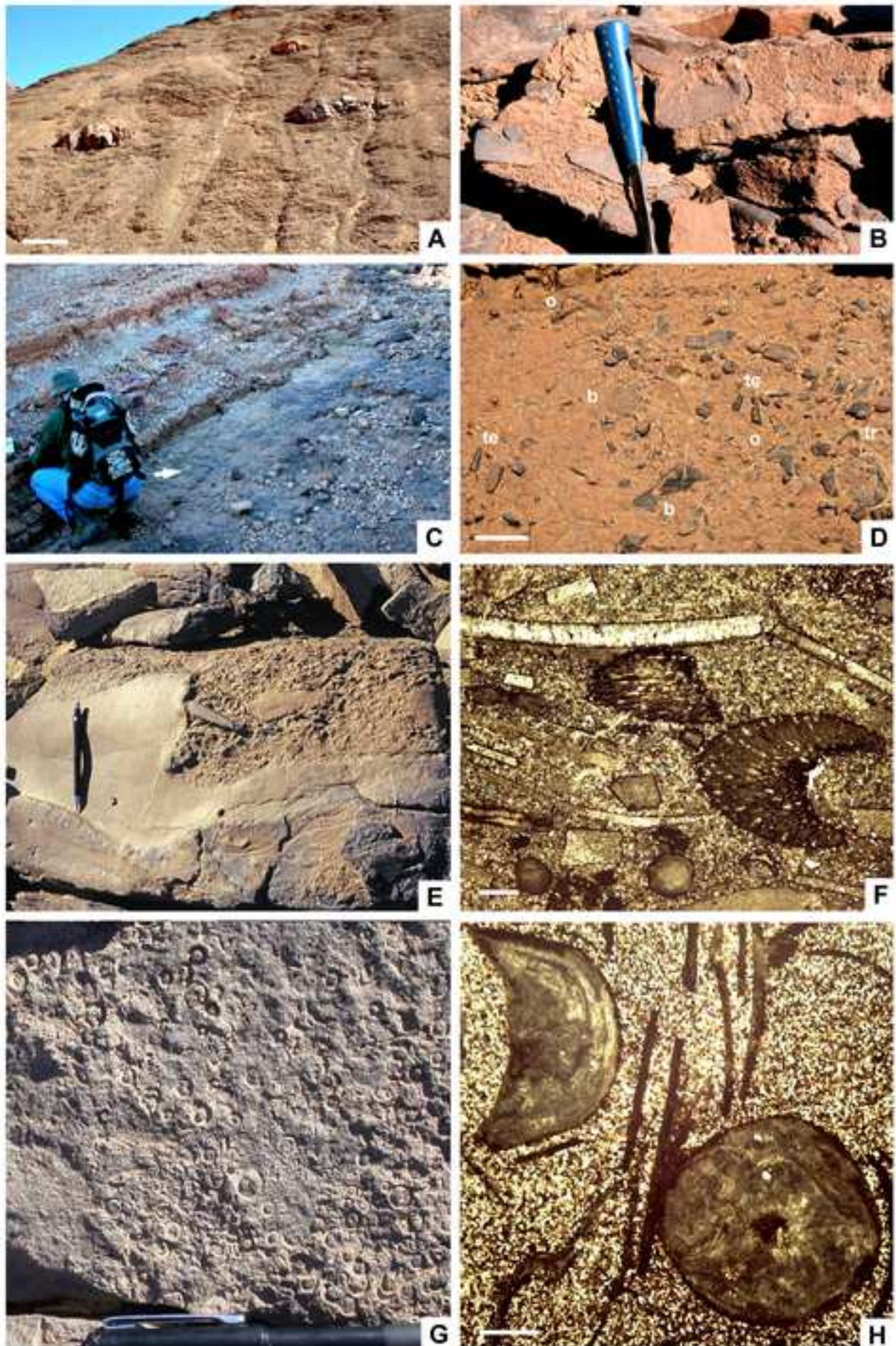
1802 Boulders included in the glaciogenic sediments of the Alnif Member have yielded a
 1803 redeposited fauna from the underlying Ktaoua Group, including allochthonous esthonioporene,
 1804 trepostome and rhabdosemine bryozoans (Ernst *et al.* 2015), brachiopods (e.g., *Destombesium*
 1805 *akkaensis* and *Eostropheodonta? tafilaltensis*; Colmenar & Álvaro 2015), bivalves, gastropods,
 1806 echinoderms, cornulitids and orthoconic nautiloids mainly sourced from the Upper Tiouririne
 1807 Formation. Finally, the Tamekhtart Member of the Upper Second Bani Formation has yielded
 1808 brachiopods (*Arenorthis*, *Destombesium* and *Eostropheodonta*) and undetermined bryozoans,
 1809 bivalves and trilobites. Sandstone interbeds of the Amouktir Member are locally rich in the
 1810 brachiopods *Eostropheodonta*, *Hirnantia*, *Kinnella* and *Plectothyrella*; the latter represents the

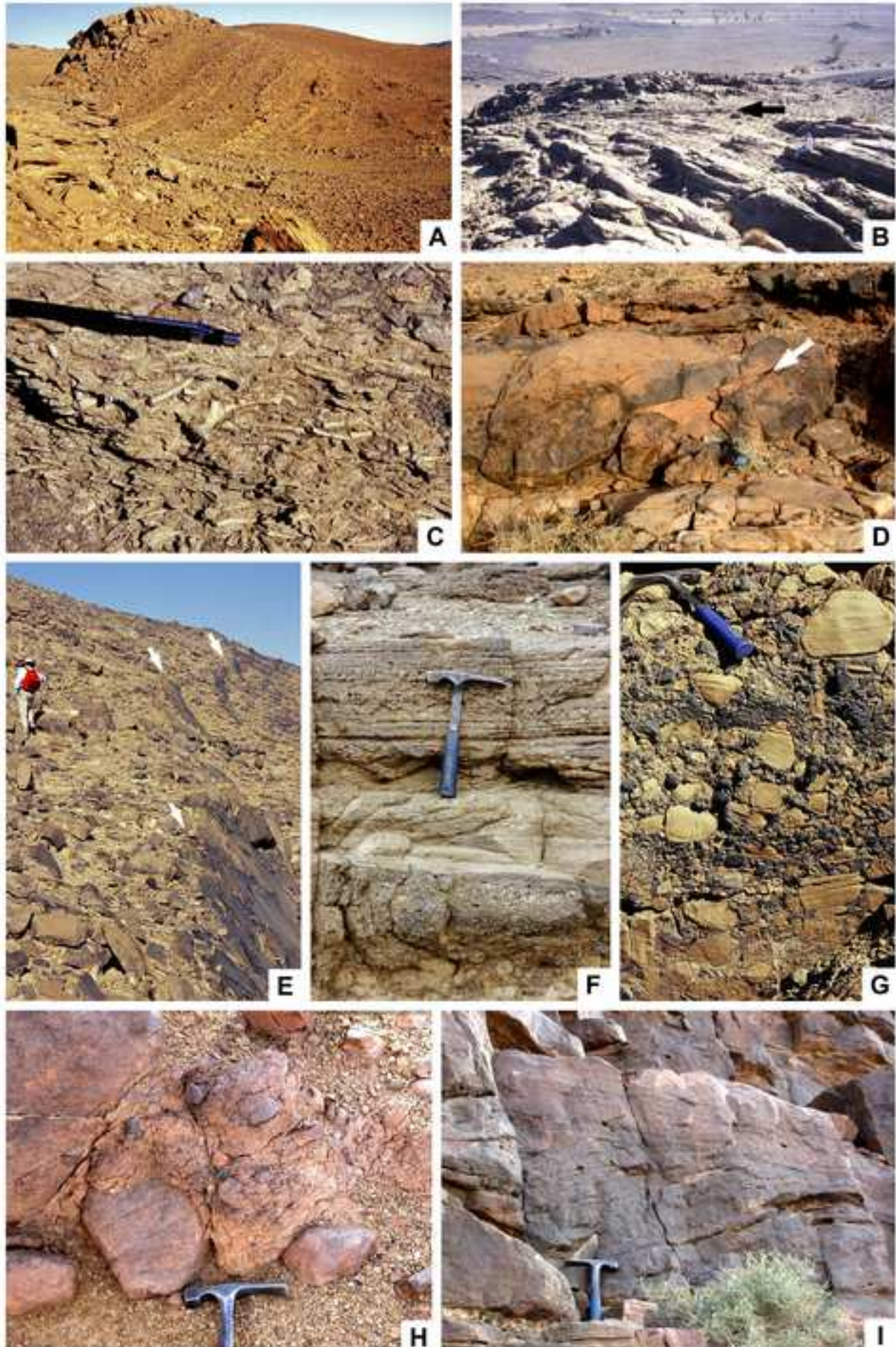
1811 so-called *E. jebiletensis* association (Colmenar & Álvaro 2015), typical of the *Aphanomena*
1812 (= *Eostropheodonta*)-*Hirnantia* Community (Rong 1984, 1986; Wang *et al.* 1987).
1813
1814



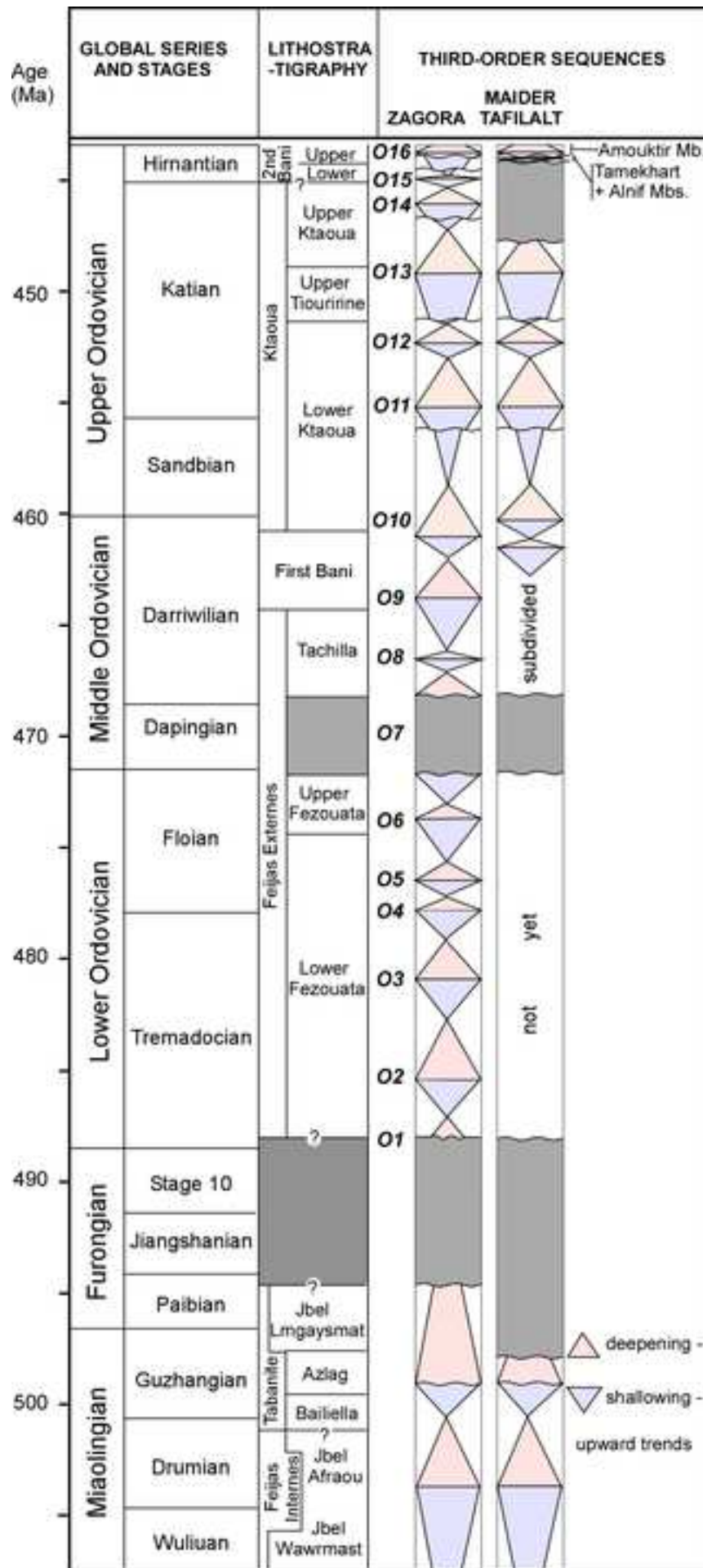








GLOBAL		REGIONAL		ANTI-ATLAS	REGIONAL	REGIONAL			
CHRONOSTRATIGRAPHIC		CHRONOSTRATIGRAPHIC		FORMATIONS	CHITINOZOAN	GRAPTOLITE			
SCALES		SCALES		AND GROUPS	ZONES	ZONES			
UPPER ORDOVICIAN	Hirnantian	Hi2	HIRNANTIAN	Upper Second Bani	2nd Bani	<i>oulebsiri</i>	<i>persculptus</i>		
		-?		Lower Second Bani		<i>elongata</i>	<i>ojsuensis</i> - <i>extraord.</i> <i>charis</i>		
	Katian	Ka4	KRALODVORIAN	Upper Ktaoua	Ktaoua	<i>merga</i>	<i>laticeps</i> <i>complanatus</i>		
		Ka3		Upper Tiouririne		<i>nigerica</i>	<i>teres / lobatus</i>		
		Ka2	BEROUNIAN	Lower		<i>barbata</i>	<i>bohdalecensis</i>		
		Ka1		middle Tiouririne		<i>fistulosa</i> <i>robusta</i>			
	Sandbian	Sa2		Ktaoua	<i>tanvillensis</i>	<i>trubinensis</i>			
		Sa1			<i>dalbyensis</i> <i>deunffi</i>	<i>bekkeri</i>			
	MIDDLE ORDOVICIAN	Darnwilian	Dw3	DOBROTIVIAN	Izeggourene	First Bani	<i>ponceti</i>		
					Ouine-Inirne		<i>pissotensis</i>	<i>'eretiusculus' -</i> <i>Proclimacograptus</i> <i>n. sp.</i>	
Guezzart					<i>clavata</i>		<i>distichus</i>		
Bou-Zeroual					<i>jenkinsi</i> <i>armoricana</i>		<i>murchisoni</i>		
Daping.		Dw2	ORETANIAN	Taddrist	<i>formosa</i>	<i>artus</i>			
				Tachilla	<i>calix</i> <i>protocalix</i> <i>bulla</i> <i>lebrayi</i>	<i>retroflexus</i> <i>austrodentatus</i>			
Daping.		Dw1	'ARENIGIAN'	Zini	Feijas Externes (pars)	<i>omensis</i>	<i>hirundo</i>		
		Dp3				<i>brevis</i>	<i>minutus</i>		
		Dp2					<i>jacksoni</i>		
Lower Ordovician		Floian	F11	Upper Fezouata	Feijas Externes (pars)	<i>paschaensis -</i> <i>symmetrica</i>	<i>protobalticus</i> <i>phyllograptoides</i> <i>copiosus</i>		
	Tremadocian					Tr3	Lower Fezouata	<i>destombesi</i>	<i>murrayi</i>
								Tr2	<i>paschaensis -</i> <i>symmetrica</i> <i>?</i>
	Tremadocian	Tr1				<i>destombesi</i>	<i>malanensis</i> <i>praepar./parabola</i>		
							<i>?</i>		





Click here to access/download
supplementary material (not datasets)
APPENDIX.docx

