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OXFORDIAN BRACHIOPODS FROM THE SAÏDA AND FRENDA MOUNTAINS (TLEMCENIAN DOMAIN, NORTH-WESTERN ALGERIA)

Adam T. HALAMSKI[1] & Amine CHERIF[2]

[1] *Institute of Paleobiology, Polish Academy of Sciences, Twarda 51/55, PL- 00-818 Warszawa, Poland; e-mail: ath@twarda.pan.pl;*
[2] *Laboratoire de Géologie du Sahara, Université Kasdi-Merbah, Route nationale de Ghardaïa, 30000 Ouargla, Algeria; e-mail: acherif11@gmail.com*

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Abstract: Five brachiopod species are reported from two middle to upper Oxfordian (Late Jurassic) outcrops, situated in the Saïda and Frenda mountains (Tlemcenian Domain, north-western Algeria) and belonging to the heterochronous (Callovian to Oxfordian, locally to the Kimmeridgian) Argiles de Saïda Formation (Saïda Clay Formation). The upper Oxfordian (probably Dichotomoceras bifurcatus Zone) outcrop A yielded *Dictyothyris kurri* and Loboidothyridoidea indet. The middle Oxfordian (Liosphinctes plicatilis Zone, Cardioceras vertebrale Subzone) outcrop B yielded *Monticlarella rollieri*, *Karadagithyris boullierae* sp. n., and *Zittelina* sp.; this is the first report of the last-mentioned genus from Africa. *Karadagithyris boullierae* sp. n. is a link between previously known Bajocian to Bathonian (Callovian?) *Karadagithyris* s.s. and Tithonian to Lower Cretaceous species, formerly segregated as *Svaljavithyris*; the latter is considered herein as synonym of *Karadagithyris*. It is characterised by a plano-uniplicate anterior commissure and a suberect beak. The adult loop of *Zittelina* is confirmed as bilacunar (kingeniform) and not diploform (campagiform). The bulk of the assemblages comprises small and either smooth or finely ornamented species and thus represents a low-energy environment. The lack of modern revisions of the reported species in their type areas is the reason why only *Dictyothyris kurri* may be used as an index species for the middle to late Oxfordian.

Key words: Brachiopoda, Jurassic, Algeria, Atlas Mountains, systematics, palaeoecology, stratigraphy.

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INTRODUCTION

Brachiopods first appeared in the Early Cambrian (Williams and Carlson, 2007 and references therein) and were the dominant group of sessile filter-feeders in the Palaeozoic. Despite their decline after the Permian-Triassic mass extinction (Curry and Brunton, 2007 and references therein), in the Jurassic they were still a major faunal group of the benthos, often present in great abundance, and their evolution was sufficiently rapid to allow the establishment of local stratigraphic schemes (e.g., Różycki, 1948; Tchoumatchenco, 1984; Alméras *et al.*, 1997, 2011; Hantzpergue *et al.*, 2004).

Upper Jurassic brachiopods from Algeria, besides short mentions in regional geology papers (e.g., Ficheur, 1889, 1891; Welsch, 1890; Ghali, 1984), were studied in detail only by Tchoumatchenco (1984, 1986a, b, 1987, 1994) on the basis of sections located in the Tiaret Mountains (the Tlemcenian Domain, eastwards from the sections studied herein) and in the Bou Reddou Massif and Djebel Bechtout (southern Tell). These faunas, however, are very different from those described here and none of the eight Oxfordian species reported by Tchoumatchenco (1994) occurs in the Saïda and Frenda mountains.

The aim of the present paper is therefore threefold: first, the systematic description of a small middle to late Oxfordian (Late Jurassic) brachiopod fauna from the Saïda and Frenda mountains in the Tlemcenian Domain; secondly, the palaeoecological comparison of it with coeval faunas from the Tlemcenian and Tellian domains; and last, assessment of the potential of the species described to serve as local stratigraphic markers in an area, in which ammonoids are often infrequent and a local brachiopod zoning has been proposed (Tchoumatchenco, 1984).

GEOLOGICAL SETTING

From a geographic point of view, the study area belongs to the Atlas Mountains, a large mountain system in

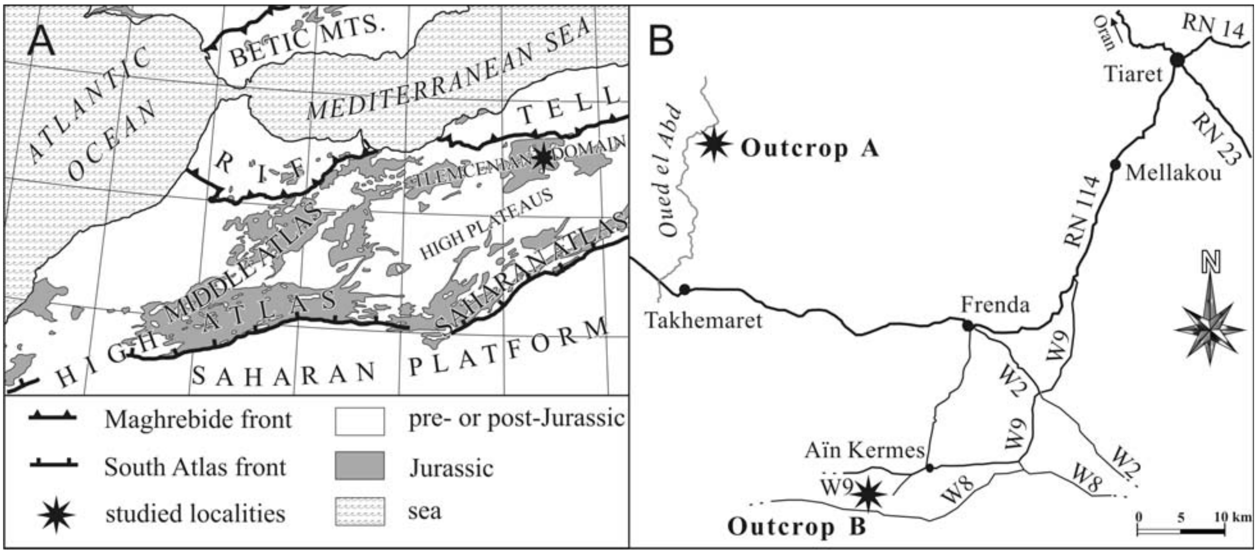

Fig. 1. Geological and geographical setting of the fauna studied. **A.** Geological sketch of north-western Africa, showing main tectonic zones and Jurassic outcrops, much simplified after Choubert and Faure-Muret (1988), Piqué *et al.* (1998), Frizon de Lamotte *et al.* (2009), and Melki *et al.* (2012). **B.** Topographical sketch of the study area showing the main wadis, roads, and the detailed positions of the localities studied. RN, national roads (routes nationales); W, provincial roads (routes wilayales).

north-western Africa, extending from Morocco in the west through Algeria into Tunisia in the east (Bridges, 1990; Paradise, 2005). The Algerian part of the Atlas is usually subdivided into three parts: two mountain ranges, the Tellian Atlas in the north, the Saharan Atlas in the south, and an area of elevated plateaus (High Plateaus or Hauts Plateaux *sensu lato*) encircled by the two above-mentioned branches (Ager, 1980; Paradise, 2005). The two localities that yielded the brachiopods studied are located in the northern part of the High Plateaus *s.l.* and, more exactly, in the Saïda and Frenda mountains (Saïda-Frenda Massif *sensu* Bernard, 1902 *pro parte*). Both outcrops are situated in the Tiaret wilaya (province).

From a geological point of view, the Mesozoic structures of north-western Africa represent two different domains (Michard *et al.*, 2008), the Atlas *sensu stricto*, an autochthonous intracontinental belt (Frizon de Lamotte *et al.*, 2008), and the Maghrebides (Betic-Rif-Tell orogen), composed of parautochthonous to allochthonous units (Chalouan *et al.*, 2008). The Atlas *s.s.* thus corresponds to a series of basins (now inverted aborted rifts), associated with the opening of the central Atlantic and Neo-Tethys oceans (Brede *et al.*, 1992; Gomez *et al.*, 2000). The outcrops studied belong to the northernmost unit of the Atlas *s.s.*, the east-west trending Tlemcenian (Tlemcen) Domain (Benest *et al.*, 1999), situated between the overthrusted Tellian Atlas in the north and the pre-Atlas zone (High Plateaus *s.s.*) further south (Fig. 1A).

The brachiopod-bearing beds belong to the "Argiles de Saïda" Formation, consisting of an alternation of claystone-dominated and sandstone beds, with subordinate yet locally important carbonate beds (for details, see Benest *et al.*, 1999). The "Argiles de Saïda" Formation belongs to the Hauts Plateaux Detritic Group (Groupe détritique des Hauts Plateaux; Augier, 1967), corresponding overall to prodelta sediments (Tchoumatchenco and Khrischev 1992b). More precisely, the depositional environment of the Argiles de Saïda was a shallow, detrital or carbonate platform, as evidenced by frequent tidal and tempestite structures (Bendella *et al*., 2011; Cherif *et al*. 2015). In the equivalent of the same fossiliferous level at Dj. Chraïf (Takhemaret, west of the study area), many hydrodynamic structures indicating a shallow marine environment have been detected (nested channels, ripple wave laminations and unidirectional oblique laminations; Cherif, 2017).

The "Argiles de Saïda" Formation is dated as Callovian–Oxfordian (and outside the area studied up to the lower Kimmeridgian according to Benest *et al.*, 1999 or even to the lower Tithonian according to Tchoumatchenco and Khrischev, 1992a) interval and is heterochronous across the whole of the Tlemcenian Domain, older in its western part (Ghar Roubane Mountains) and younger in its eastern part (Frenda Mountains) (Elmi and Benest, 1978). This formation was defined for the first time by Auclair and Biehler (1967) in Sidi Kada locality (south-eastern part of Mascara province). It was also the subject of several studies, especially dealing with biostratigraphy and palaeoenvironment (e.g., Augier, 1967; Sapunov, 1973; Mangold *et al.*, 1979; Elmi, 1976; Elmi and Benest, 1978; Ciszak, 1993; Benest *et al.*, 1998; Bendella *et al.*, 2011; Cherif *et al.*, 2015). More precisely, the brachiopod-bearing part of the Formation is the biodetritic-calcareous beds, called "Niveau fossilifère d'Auclair et Biehler" in Takhemaret and "Calcaires de Tounkira" (Ganev *et al.*, 1980) in Frenda. They belong to the uppermost of the three units, distinguished within the Argiles de Saïda Formation by Cherif *et al.* (2015).

In the Late Jurassic, the area studied was situated on the southern shelf of the western extremity of the Tethys Ocean (Dercourt *et al.*, 1993; Berra and Angiolini, 2014 and references therein), i.e., on the northern shore of Gondwana (Africa). The Tlemcenian Domain corresponds to a platform margin (Tchoumatchenco and Khrischev, 1992b). The local topography was quite complicated and included a number of small, emergent areas (Ouardas, 1983), often resulting in limited communication with the open sea (Ghali, 1984). In the Saïda Mountains, the middle and late Oxfordian represent the maximum transgression interval (Benest *et al.*, 1999).

MATERIAL AND METHODS

The material studied here comes from two outcrops (Fig. 1B). In both cases, the brachiopod-bearing beds are channelized biodetritic limestones with sedimentary structures, ranging from storm-generated to tide-generated structures and channel systems. Biostratigraphic dating of both outcrops is given below according to unpublished results from A. Cherif.

Outcrop A is situated at Djebel Oum el Alou, near Takhemaret in the Tiaret province (25 km north-east from Takhemaret village), and its base is dated as middle–late Oxfordian limit (between Dichotomoceras rotoides and Dichotomoceras stenocycloides subzones). Some 3 km further west, at Djebel Brame, analogous beds are dated as late Oxfordian (bifurcatus Zone, Dichotomoceras grossouvrei Subzone) (Cherif *et al.*, 2015). Outcrop A has yielded two brachiopod species (*Dictyothyris kurri* and Loboidothyridoidea? indet.), associated with abundant benthic fossils (solitary corals, bivalves, bryozoans, sea urchins).

Outcrop B is situated in the Oued Tounkira, near (southern) Frenda in the Tiaret province (Lambert coordinates X1=343, Y1=180, X2=343, Y2=180.9; Ganev *et al.*, 1980). Preliminary identifications of ammonites seem to indicate a middle Oxfordian age (plicatilis Zone, vertebrale Subzone), thus confirming the dating given by Sapunov (1973). Outcrop B has yielded three brachiopod species (*Monticlarella rollieri*, *Karadagithyris boullierae* sp. n., and *Zittelina* sp.), associated with abundant benthic (as in Outcrop A) and pelagic fossils (ammonites and belemnites).

Brachiopods (20 specimens in total) were collected as loose specimens from the scree. It is thus possible to refer them to informal subdivisions of the "Argiles de Saïda" Formation (see above), but not to individual beds. No mechanical preparation was necessary. Photographed specimens were coated with ammonium chloride. Internal structures were examined through the standard technique of serial sections and acetate peels. The preservation of interiors was very good in two cases (*Zittelina* sp., Figs 10–12; *Karadagithyris boullierae* sp. n., Fig. 5, 7A–D) and moderate in one case (*Karadagithyris boullierae* sp. n., Figs 6, 7E.–F). Serial sections are illustrated by camera lucida drawings (Figs 5–6, 10–11). Given the degree of complication of internal structures of the brachiopods studied, selected sections are also illustrated as photographs of acetate peels (Figs 7, 12).

The collection studied is housed in the Laboratoire de Géologie du Sahara, Université Kasdi-Merbah, Ouargla, Algeria, under the collection number UKM-LGS Bp 1.

SYSTEMATIC PALAEONTOLOGY

Phylum BRACHIOPODA Duméril, 1805
Class RHYNCHONELLATA Williams, Carlson, Brunton, Holmer & Popov, 1996
Order RHYNCHONELLIDA Kuhn, 1949
Family NORELLIDAE Ager, 1959
Genus *Monticlarella* Wiśniewska, 1932

Type species: *Rhynchonella czenstochaviensis* Roemer, 1870; Częstochowa, southern Poland; lower Oxfordian, Jurassic.
Remarks: The name of the type species has caused some orthographic confusion. The original spelling *czenstochaviensis* (Roemer, 1870) was modified to *czenstochowiensis* by Wiśniewska (1932), putatively as an emendation of a presumed printing error. As a matter of fact, this is not a printing error, but a difference caused by using either the German (Czenstochau) or the Polish (Częstochowa) name of the type locality; such a modification is not permissible under the ICZN (1999). Barczyk (1980, 1988) and Grădinaru and Bărbulescu (1994) followed Wiśniewska's emendation, whereas Smirnova spelt either *czenstochowiensis* (Smirnova 1965, p. 41) or *czenstochoviensis* (Smirnova 1965, fig. 3; 1973, p. 68). As pointed out already by Childs (1969, p. 21) and by Manceñido *et al.* (2002, p. 1316), the original spelling must be retained.

Monticlarella rollieri Wiśniewska, 1932
Fig. 2

* 1932 *Monticlarella Rollieri* sp. n. – Wiśniewska, pp. 59–60, pl. 6, figs 10–11.

Material: A single incomplete and partly exfoliated articulated shell from outcrop B; collection number UKM-LGS Bp 1/1.
Description: The single available shell is lacking the anterior region; it is 8.5 mm wide, ca. 10 mm long (estimated; preserved length 8.9 mm), and 5.9 mm thick. The shell is elliptic in shape, moderately ventribiconvex, with fine, markedly incurved ventral beak and small triangular foramen (Fig. 2E). The dorsal valve is medially flattened. The ornamentation consists of radial striae, 2–3 per mm (at 7 mm from the beak on the ventral valve; Fig. 2F). Interior not studied.
Discussion: This incomplete specimen can be identified confidently with *Monticlarella rollieri* on account of characteristic shape and ornamentation density. Up to now, *M. rollieri* has been found only in the middle Oxfordian (Peltoceras transversarium Zone) of southern Poland, where it was reported as rare (Wiśniewska, 1932). It is absent both in western Europe (Childs, 1969) and on the Russian Platform (Makridin, 1964). The report from the Callovian of the Pieniny Klippen Belt in Slovakia by Schlögl *et al.* (2009) is unsubstantiated (neither description nor figure), but stratigraphic ranges of some *Monticlarella* species are rather long (Childs, 1969, p. 14), so the presence in the Callovian of the species discussed cannot be excluded *a priori*.

Tchoumatchenco (1994) and Courville and Boullier (2014) suggest *M. rollieri* might be synonymous with *M. striocincta* (Quenstedt, 1871), known in Europe from the Oxfordian to the Kimmeridgian (transversarium to Aulacostephanoides mutabilis zones; Childs, 1969). According to Tchoumatchenco (1994), in Algeria *M. striocincta* is known from the Kimmeridgian to the lower Tithonian (Hybonoticeras hybonotum Zone).

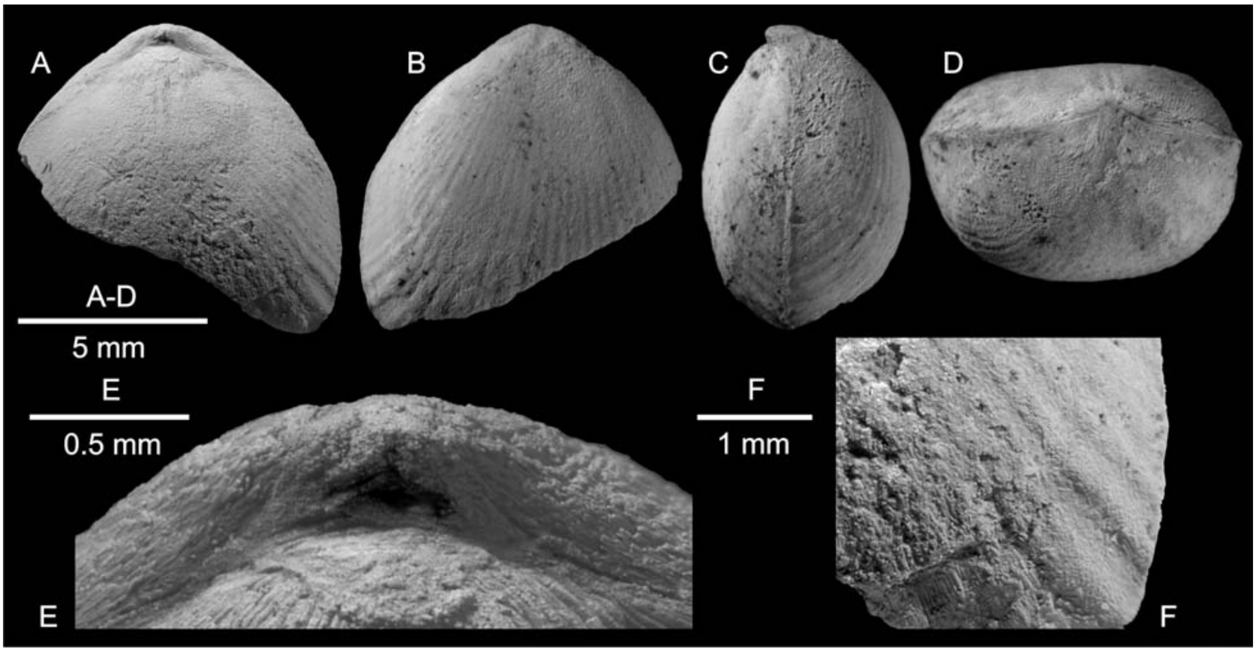

Fig. 2. *Monticlarella rollieri* Wiśniewska, 1932. Incomplete shell UKM-LGS Bp 1/1 from outcrop B (middle Oxfordian) in dorsal (**A**), ventral (**B**), lateral (**C**), and posterior (**D**) views and enlargements of the dorsal umbo in ventral view and of the ornamentation of the dorsal valve in antero-lateral region.

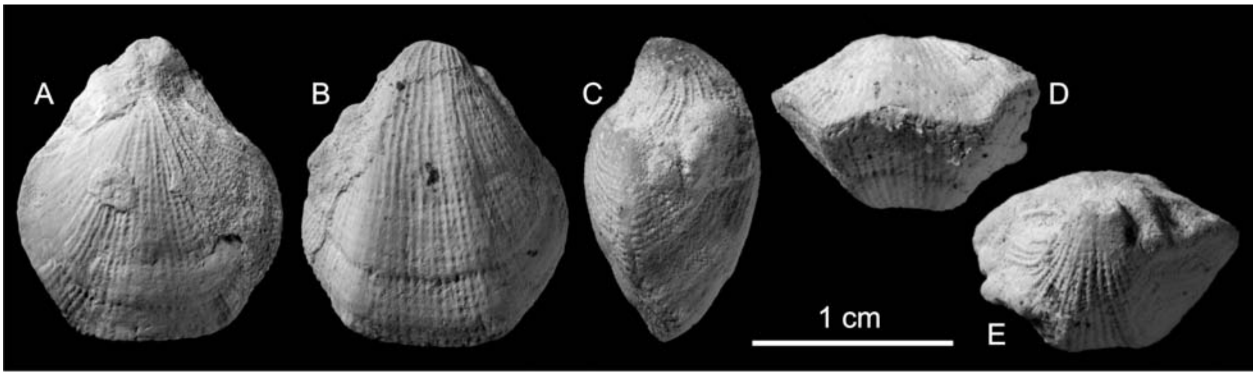

Fig. 3. *Dictyothyris kurri* (Oppel, 1857). Articulated shell UKM-LGS Bp 1/2 from outcrop A (upper Oxfordian) in dorsal (**A**), ventral (**B**), lateral (**C**), anterior (**D**), and posterior (**E**) views.

Order TEREBRATULIDA Waagen, 1883
Suborder TEREBRATULIDINA Waagen, 1883
Superfamily LOBOIDOTHYRIDOIDEA Makridin, 1964
Family DICTYOTHYRIDIDAE Makridin, 1964
Genus *Dictyothyris* Douvillé, 1879

Type species: *Terebratulites coarctatus* Parkinson, 1811; England; Bathonian, Jurassic.

Dictyothyris kurri (Oppel, 1857)
Fig. 3

*1857 *Terebratula Kurri* – Oppel, p. 688.
1965 *Dictyothyris kurri* (Oppel, 1857) – Delance & Tintant, p. 24–26, text-fig. 5, pl. 2, figs 11–18 [*ubi syn.*].
1981 *Dictyothyris kurri* (Oppel) – Boullier, p. 26, pl. 2, figs 13–14.
2014 *Dictyothyris kurri* (Oppel 1857) – Courville & Boullier, p. 51, fig. 4.1–4.3.

Material: Four subcomplete articulated shells from outcrop A; collection numbers UKM-LGS Bp 1/2–5.

Description: Shell elongate pentagonal in shape, about 14–17 mm long, 12–13 mm wide, and up to 10 mm thick, moderately to strongly ventribiconvex, maximal width about midlength or slightly anteriorly, anterior commissure plicosulcate. Dorsal valve subtriangular in anterior view. Ventral valve subtrapezoidal in anterior view, with two strong costae separating the flattened to weakly concave median region and lateral flanks, beginning at umbo and continuing to anterior commissure; umbo very large, incurved; foramen large, mesothyrid. Ornamentation covering the entire shell, consisting of radial costellae, 4–5(–6) per 2 mm at anterior commissure, intersecting with growth lines, with small nodes at intersections, thus forming a reticulate pattern. Interior not studied.

Discussion: These brachiopods are included in *Dictyothyris kurri* on account of characteristic ornamentation and external form, in particular that of the commissure and of the beak.

Occurrence: *Dictyothyris kurri* is known from the middle to late Oxfordian of Western Europe (Delance and Tintant, 1965, p. 26).

Courville and Boullier (2014, p. 51) suggest that the species may have been treated too widely by Delance and Tintant (1965) and its restricted stratigraphic distribution might be limited to the lower part of the transversarium Zone (end Perisphinctes parandieri and Perisphinctes luciaeformis subzones). The brachiopods described herein agree with *D. kurri* sensu Courville and Boullier (2014), as opposed to *Dictyothyris* sp. *sensu* Courville and Boullier (2014, fig. 4.4), which is larger, has finer ornamentation and is younger in age (rotoides Subzone).

Family MUIRWOODELLIDAE Tchorszhevsky, 1974
Genus *Karadagithyris* Tchorszhevsky, 1974

Type species: *Karadagithyris babanovae* Tchorszhevsky, 1974; Karadag Mountains, Crimea; Middle Jurassic (upper Bathonian).

Synonym: *Svaljavithyris* Tchorszhevsky, 1989 (type species: *Terebratula carpathica* Zittel, 1870; Rogoźnik, Pieniny, southern Poland; upper Tithonian to Berriasian, Upper Jurassic to Lower Cretaceous; see Barczyk, 1989 for detailed age).

Species assigned: See Alméras *et al.* (2014, p. 94; species assigned to *Karadagithyris* s.s.; see also Vörös and Dulai 2007, p. 57); Tchorszhevsky (1989, p. 77; species assigned to *Svaljavithyris*); *Karadagithyris boullierae* sp. n., as below.

Remarks: *Svaljavithyris* Tchorszhevsky, 1989 was introduced for a group of Tithonian to Berriasian terebratulides, said to differ from *Karadagithyris* in having straight commissure, thin, wide, and short hinge plates, well developed crural plates, and thick prismatic pedicle collar (Tchorszhevsky, 1989, p. 77). As a matter of fact, the genus had already been proposed by Tchorszhevsky (1974), but the formal description was not provided, so *Svaljavithyris* Tchorszhevsky, 1974 is a *nomen nudum* (Barczyk, 1979, p. 211). Nonetheless, Barczyk (1979, p. 211) and Cooper (1983, p. 95) discussed the proposal of distinguishing between *Karadagithyris* and *Svaljavithyris* and both concluded that the differences between the two presumed genera are insufficient for a distinction at the genus level, on account of which *Svaljavithyris* is to be considered as a junior subjective synonym of *Karadagithyris*. Their opinion is followed in the present paper.

However, it should be pointed out that *Karadagithyris* s.s., as known heretofore, was an exclusively Middle Jurassic group of species (Bajocian to middle Bathonian, according to Alméras *et al.*, 2014; Bajocian to lower Callovian, according to Tchorszhevsky, 1989, but without further details), whereas *Svaljavithyris* is Tithonian to Berriasian in age. Lee *et al.* (2006, p. 2106) accept both genera, but give a Middle to Late Jurassic age for *Karadagithyris* s.s.; this is apparently a misunderstanding, resulting from taking into account the species of "*Svaljavithyris*" included in *Karadagithyris* by Barczyk (1979). *Karadagithyris boullierae* sp. n. described below is an Oxfordian species, linking the Middle Jurassic *Karadagithyris* s.s. and the latest Jurassic to Cretaceous "*Svaljavithyris*" and thus providing another argument for lumping both genera.

Karadagithyris boullierae sp. n.
Figs 4–7

Type material: Holotype, articulated shell UKM-LGS Bp 1/6 (shown in Fig. 4K–O); paratypes, seven articulated shells UKM-LGS Bp 1/7–13, two of them (UKM-LGS Bp 1/11, 13) serially sectioned (Figs 5–7).

Type locality: Outcrop B, as described above, Oued Tounkira near Frenda, Tiaret Province, Algeria (Lambert coordinates X1=343, Y1=180, X2=343, Y2=180.9).

Type stratum: Argiles de Saïda; middle Oxfordian (plicatilis Zone, vertebrale Subzone).

Etymology: In honour of Annick Boullier (*née* Rollet), student of Jurassic terebratulide brachiopods (Rollet, 1972; Boullier, 1976, 1981; Hantzpergue *et al.*, 2004; Courville and Boullier, 2014).

Diagnosis: *Karadagithyris* moderate in size for the genus; shell elongate in smaller individuals, about as wide as long in larger ones; beak suberect; pedicle foramen relatively large.

Description: Shell teardrop-shaped, up to 21.8 mm in length, markedly longer than wide in smaller individuals to about as long as wide in larger ones (length-to-width ratio spanning from 0.99 to 1.5), maximum width anteriorly to midlength, markedly ventribiconvex. Dorsal valve rounded to weakly flattened in anterior view. Ventral valve rounded to parabolic in anterior view, beak suberect, foramen permesothyrid, relatively large. Anterior commissure lowly and broadly uniplicate (plano-uniplicate). Shell smooth.

Dimensions of selected specimens (holotype in boldface)

Coll. number UKM-LGS Bp	1/12	1/10	**1/6**	1/7	1/9
Length (in mm)	21.8	16.9	**14.7**	15.5	13.3
Width (in mm)	21.9	15.3	**12.4**	10.4	10.6
Thickness (in mm)	13.9	8.4	**8.9**	8.6	7.5
Length-to-width ratio	0.99	1.10	**1.19**	1.49	1.25

Dorsal interior: hinge plates horizontal, connected to the crural bases. The latter supported by subparallel crural plates reaching the valve floor; the length of this connection is apparently variable, as the crural bases cease to be supported relatively earlier in the larger sectioned shell (Fig. 6, section at 5.5 mm) than in the smaller one (Fig. 5, between sections at 3.5 at 4.0 mm), unless imperfect preservation of the former specimen is to be invoked. Loop with transverse band and long flanges, 6.1 mm long in the specimen 13.9 mm long (0.44 of the total length) and over 10.2 mm long in the specimen ca. 20 mm long (>0.51 of the total length). Ventral interior: pedicle collar present; deltidial plates thin (Fig. 5, section at 1.8 mm); no septum.

Remarks: The available material consists of six smaller (less than 17 mm long) and more elongate shells (Figs 4A–T, 5) and two larger (over 20 mm long) shells about as long as wide (Figs 4U–Y, 6). Their internal structures are much alike, so they are interpreted as representing the same taxon.

The species discussed is included in *Karadagithyris* Tchorszhevsky, 1974 on account of the presence of crural plates, which reach the floor of the dorsal valve and thus separate lateral cavities ("crural props", "mantle plates"; see Cooper, 1983, p. 198). Similar brachidium-supporting structures (Vörös, 1974; Baeza-Carratalá *et al.*, 2011) appeared convergently in other unrelated terebratulides, such as, for example, Early Jurassic *Viallithyris* Vörös, 1974, Late Jurassic *Rouillieria* Makridin in Licharew, Makridin and Rzhonsnitskaya, 1960 (see Makridin, 1964 for serial sections correcting his partly incorrect original description repeated recently by Lee *et al.*, 2006; *Rouillieria sensu* Sandy *et al.*, 2014 is lacking such structures, so the attribution to the genus should be confirmed) or Recent *Erymnia* Cooper, 1977 (see Cooper, 1983, p. 198).

Species of *Karadagithyris* are all relatively similar. However, the following differences distinguish *K. boullierae* sp. n. from the remaining taxa. Tithonian to Berriasian *Karadagithyris carpathica* (Zittel, 1870) and *K. bilimeki* (Suess, 1858) have rectimarginate anterior commissures (Barczyk, 1979). Bajocian to Bathonian *Karadagithyris gerda* (Oppel, 1863) and Bajocian *Karadagithyris eduardi* Vörös, 1995 have more incurved beaks; the former species is also larger (up to 38 mm in length) (Baeza-Carratalá *et al.*, 2011, 2014)

Occurrence: Type locality and stratum only.

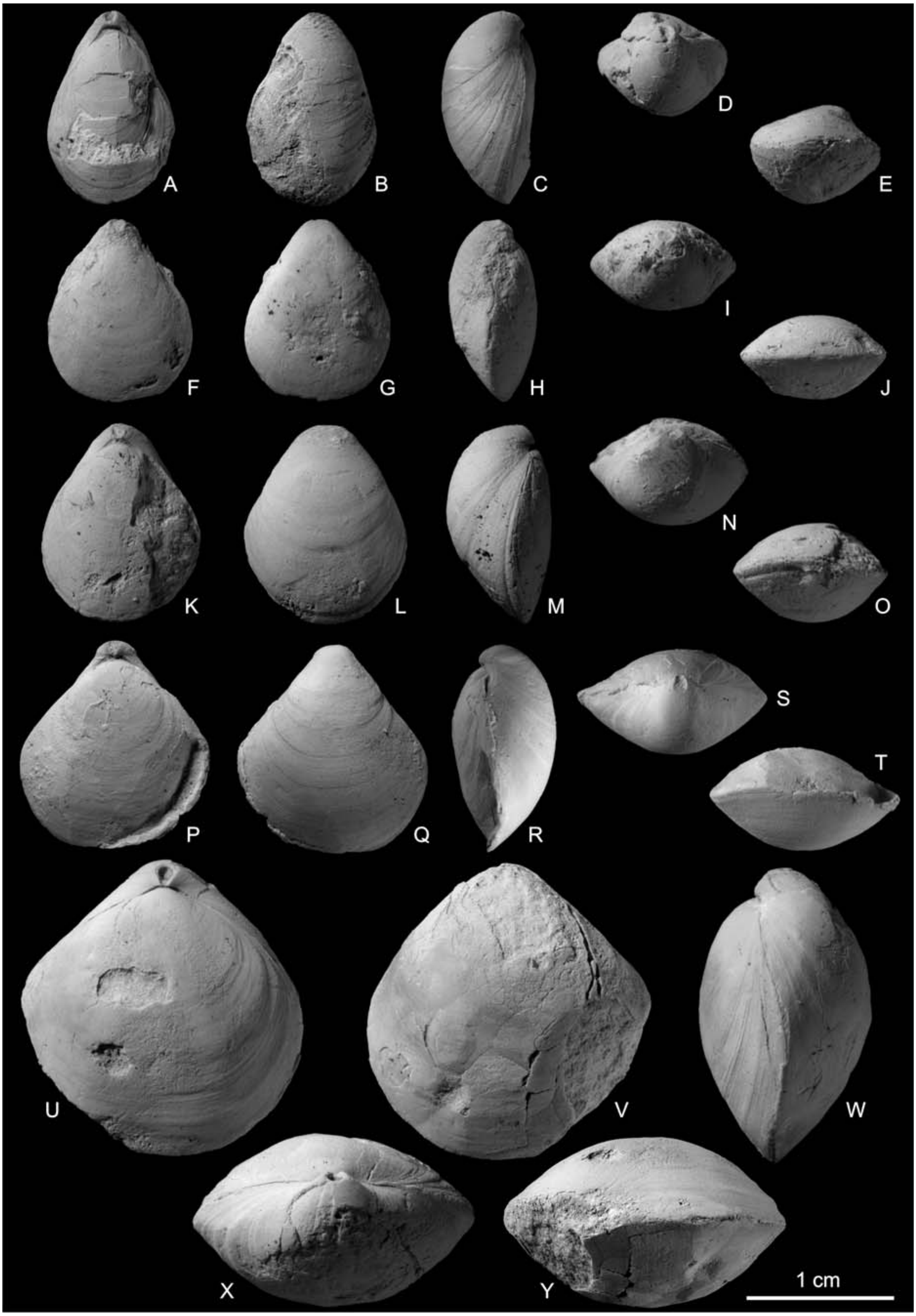

Fig. 4. *Karadagithyris boullierae* sp. n. Articulated shells UKM-LGS Bp 1/7, 6, 11, 10, 12 from outcrop B (middle Oxfordian) in dorsal (**A, F**, **K**, **P**, **U**), ventral (**B, G**, **L**, **Q**, **V**), lateral (**C**, **H**, **M**, **R**, **W**), posterior (**D**, **I**, **N**, **S**, **X**), and anterior (**E**, **J**, **O**, **T**, **Y**) views. The shell UKM-LGS Bp 1/6 represented in K–O is the holotype. The shell UKM-LGS Bp 1/11 represented in F–J has been serially sectioned (sections given in Fig. 5).

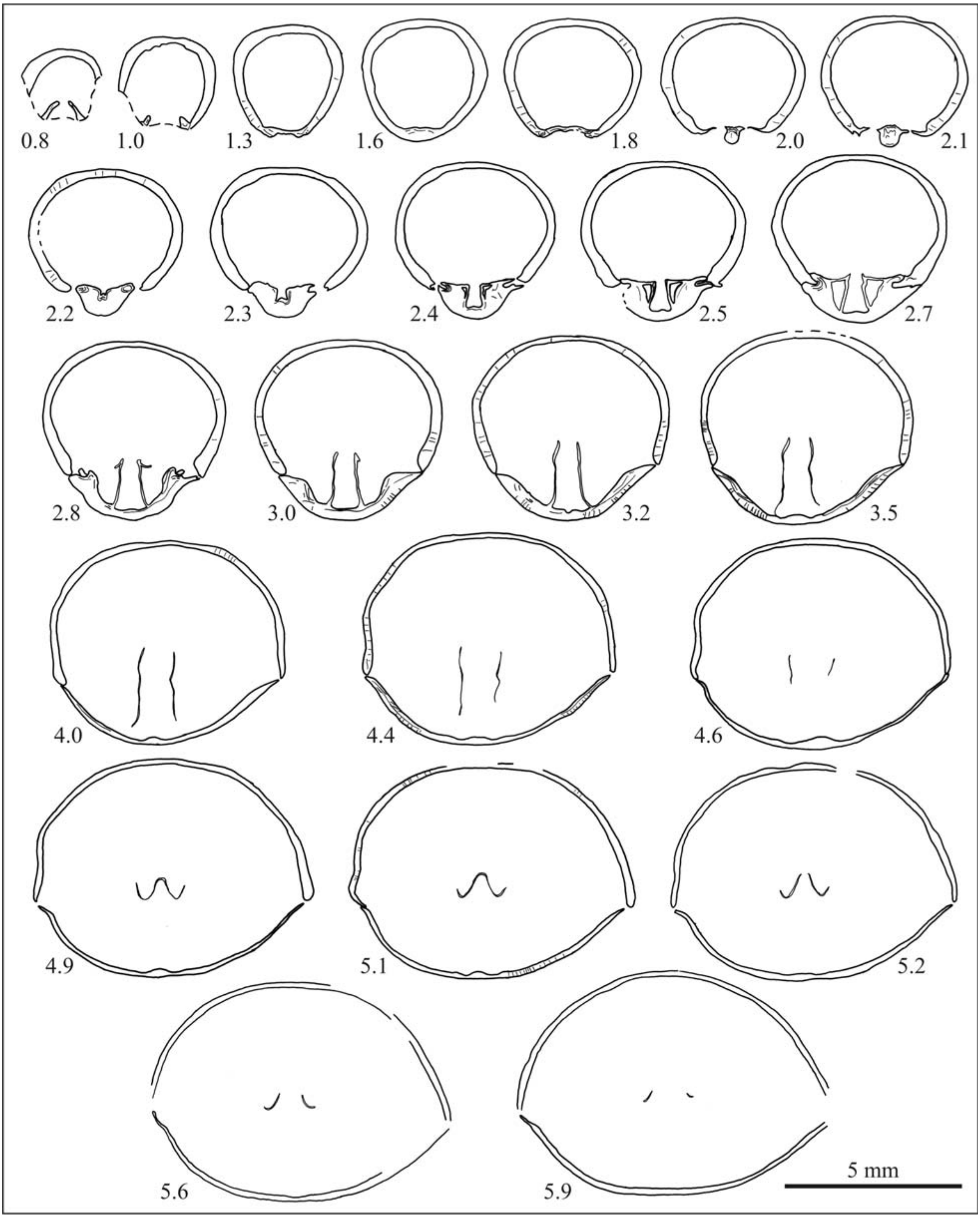

Fig. 5. Transverse serial sections of *Karadagithyris boullierae* sp. n. (camera lucida drawings) through the shell UKM-LGS Bp 1/11 (total length 13.9 mm) from outcrop B (middle Oxfordian). Distances measured in millimetres from the tip of the ventral umbo.

Family unknown

Loboithyridoidea? fam., gen. et sp. indet.
Fig. 8

Material: A single shell from outcrop A (nearly complete but slightly crushed), collection number UKM-LGS Bp 1/14.

Description: Shell 38.3 mm long, 32.5 mm wide, and ca. 21 mm thick, elliptical in shape, ventribiconvex; maximum width about midlength. Dorsal valve weakly convex in anterior view. Ventral

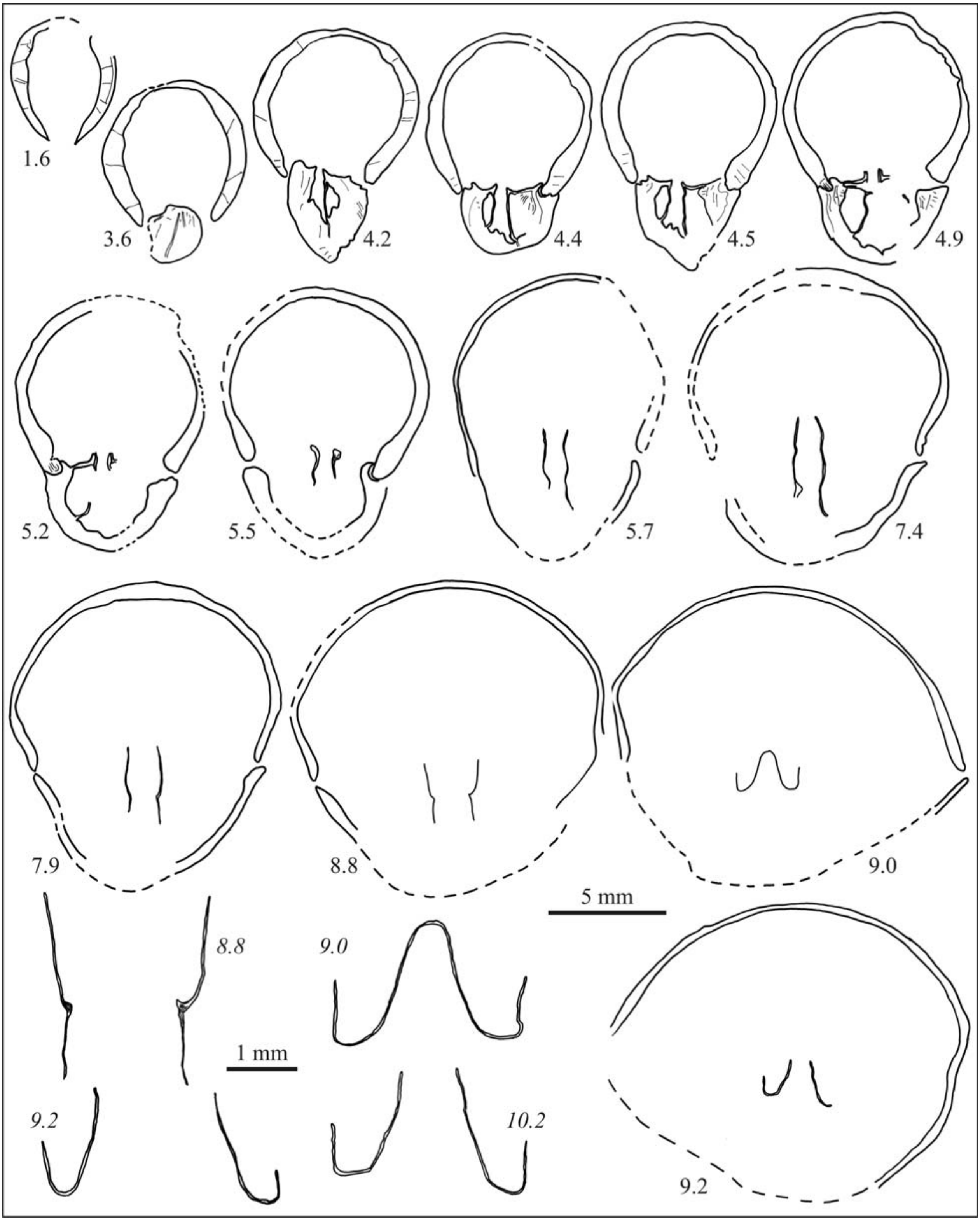

Fig. 6. Transverse serial sections of *Karadagithyris boullierae* sp. n. (camera lucida drawings) through the shell UKM-LGS Bp 1/13 (total length ca. 20 mm) from outcrop B (middle Oxfordian); global views and four enlargements of the loop. Distances measured in millimetres from the tip of the ventral umbo.

valve strongly convex; umbo thick, redressed; pedicle foramen elliptical, 3.0 mm long and 2.4 mm wide, mesothyrid? Anterior commissure uniplicate, tongue broad, trapezoidal. Interior unknown.

Remarks: The described specimen resembles the middle Oxfordian species *Moeschia alata* (Rollet, 1972), the most common terebratulide brachiopod in the middle (to lowermost upper) Oxfordian of Burgundy (Courville and Boullier, 2014, p. 50). In particular, it is nearly identical with the shell from Mont-Rivel, figured by Boullier (1976, pl. 11, fig. 2). However, some representatives of *Loboidothyris* or even *Rouilleria* can be externally simi-

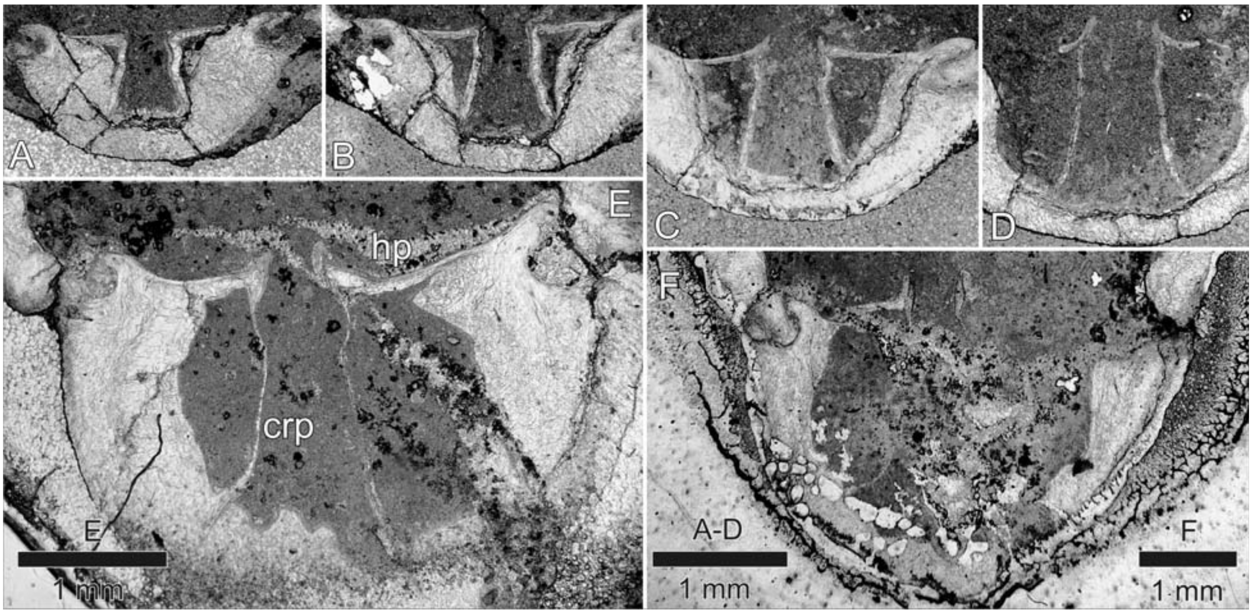

Fig. 7. Selected transverse serial sections of *Karadagithyris boullierae* sp. n. (photographs of acetate peels) through the shells UKM-LGS Bp 1/11 (**A–D**; total length 13.9 mm) and UKM-LGS Bp 1/13 (**E, F**; total length ca. 20 mm) from outcrop B (middle Oxfordian) showing brachidium-supporting structures. Sections at 2.4 (**A**), 2.5 (**B**), 2.7 (**C**) and 2.8 (**D**) from the tip of the ventral umbo of the smaller shell and at 4.5 (**E**) and 5.2 (**F**) from the tip of the ventral umbo of the larger shell. Abbreviations: *crp*, crural plate; *hp*, hinge plate.

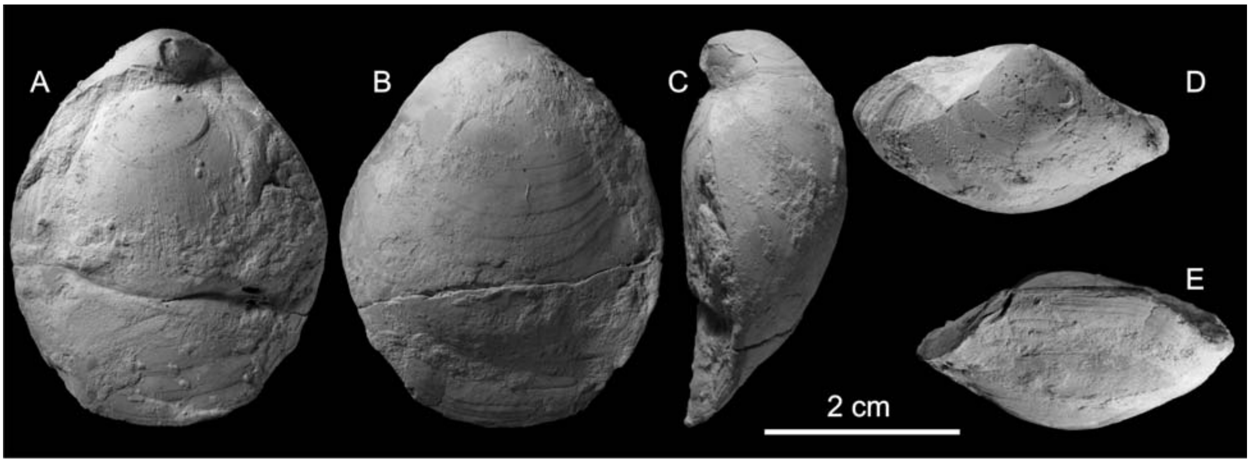

Fig. 8. A representative of Loboithyridoidea? fam., gen. et sp. indet.; articulated shell UKM-LGS Bp 1/14 from outcrop A (upper Oxfordian) in dorsal (**A**), ventral (**B**), lateral (**C**), anterior (**D**), and posterior (**E**) views.

lar and very difficult to distinguish in the absence of interiors, so open nomenclature has been used.

Suborder TEREBRATELLIDINA Muir-Wood, 1955
Superfamily KINGENOIDEA Elliott, 1948
Family KINGENIIDAE Elliott, 1948
Genus *Zittelina* Rollier, 1919

Type species: *Terebratula orbis* Quenstedt, 1858; Germany; Upper Jurassic.

Remarks: The present authors can only agree with the observation by Courville and Boullier (2014, p. 54) that the genus *Zittelina* had been oversplit. However, its revision should be conducted on the basis of European material and is thus outside the scope of the present paper; open nomenclature is used accordingly.

The anatomy of *Zittelina* is insufficiently known; only a single series of serial section has been published (Owen, 1970, fig. 14; re-figured by MacKinnon *et al.*, 2006, fig. 1455f–u). The ontogeny of the loop is quite complex, including resorption of earlier formed elements, the three main stages being the cucullate (precampagiform), diploform (campagiform), and bilacunar (kingeniform) phases (Owen, 1970, fig. 2). The differences between internal features of *Zittelina orbis* sectioned by Owen (1970) and *Zittelina* sp. sectioned herein (Figs 10–12) are ascribed mainly to ontogenetic variation.

As evidenced by the section at 3.2 mm (Fig. 12C), the adult loop in *Zittelina* is bilacunar (kingeniform), as interpreted by Owen (1970) and not diploform (campagiform) as stated by MacKinnon *et al.* (2006, p. 2192; see also MacKinnon and Lee, 2006).

This is the first report of *Zittelina* from Africa.

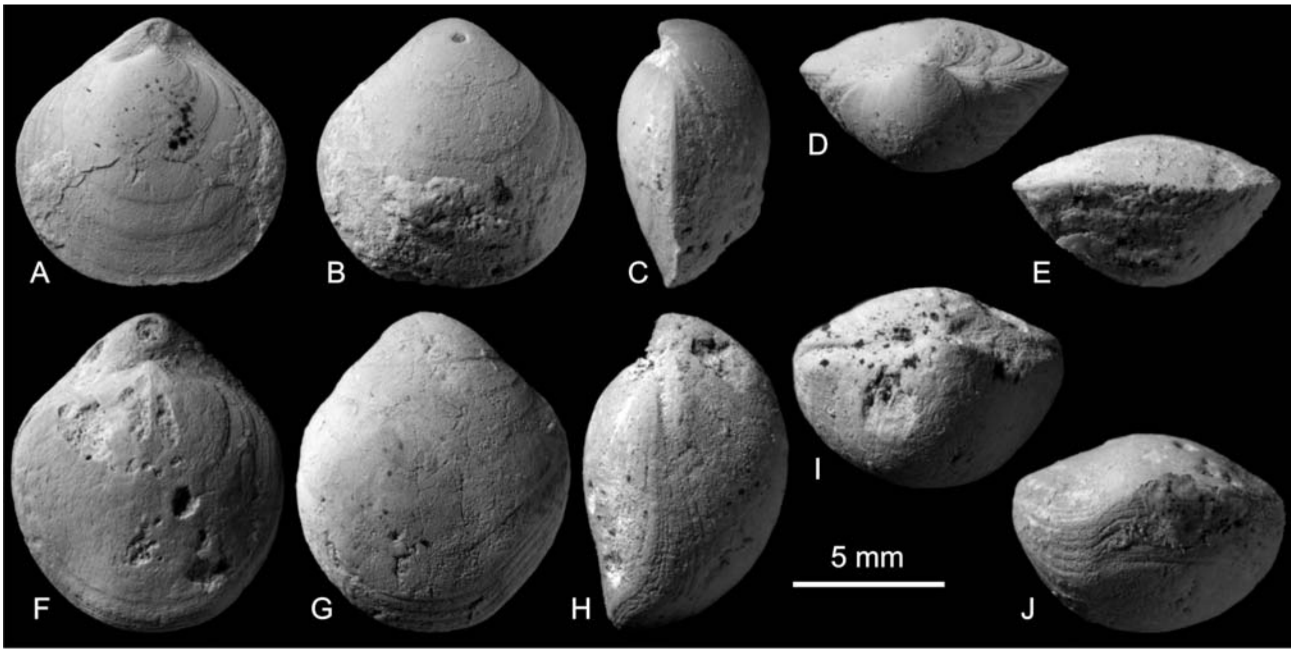

Fig. 9. *Zittelina* sp. Articulated shells UKM-LGS Bp 1/15, 16 from outcrop B (middle Oxfordian) in dorsal (**A, F**), ventral (**B**, **G**), lateral (**C**, **H**), posterior (**D**, **I**), and anterior (**E, J**) views.

Zittelina sp.
Figs 9–11

Material: Six specimens from outcrop B, one serially sectioned; collection numbers UKM-LGS Bp 1/15–20.

Description: Shell up to 10 mm long, pentagonal in outline, about as wide as long to weakly elongate (length-to-width ratio 1.0–1.1), markedly to strongly ventribiconvex. Beak suberect, foramen permesothyrid. Anterior commissure straight (Fig. 9E) to broadly and shallowly plicate (Fig. 9J).

Ventral interior: dental plates strong, but rather short, weakly divergent; lateral cavities either distinct or obliterated by callus; teeth stout (Fig. 12E). Dorsal interior: hinge platform convex, posteriorly supported by the median septum (Fig. 12G); a very short ventral enlargement of the septum (Fig. 12F) situated dorsally with respect to the hinge platform; lateral cavities on both sides of the septum rather small. Inner socket ridges stout. Laterovertical connecting bands massive; lateral connecting bands thin posteriorly (Fig. 12B), becoming thicker anteriorly (Fig. 12A), long. Transverse band narrow posteriorly (Fig. 12D). Crural bases rather thick, ventrally convergent (Fig. 10, section at 2.7 mm). Descending branches concave both when connecting to the septum (Fig. 12B) and more anteriorly. Ascending branch anteriorly high (occupying about half of the shell thickness in the section at 4.2 mm), ventrally divergent. Anterior end of the loop flanged with long spines, the latter first appearing as thickenings of the ascending lamella (Fig. 11, section at 5.1 mm), continuing anteriorly as separated projections (Fig. 11, section at 5.5 mm). In the sectioned specimen ca. 10 mm long the connection between the median septum and the loop begins at 3.1 mm and is lost at 3.6 mm from the umbo, the anterior end of the lamella of the loop is at ca. 5.4 mm from the umbo (thus about 0.57 of the shell length) and the spines can be traced up to 5.9 mm from the umbo.

Remarks: The material studied includes markedly ventribiconvex individuals with a straight anterior commissure (Fig. 9A–E) and strongly ventribiconvex individuals with a plicate anterior commissure (Fig. 9F–J). These are interpreted as juveniles and adults of a single species, even if they correspond to morphotypes described as separate taxa.

PALAEOECOLOGY

The two assemblages studied (outcrop A with 2 species represented by 5 specimens; outcrop B with 3 species, 15 specimens) are similar in general character, insofar as they altogether lack costate rhynchonellides and larger terebratulides (over 25 mm in length) are very sparse (a single specimen of Loboithyridoidea? gen. et sp. indet.). This is in sharp contrast to both Oxfordian brachiopod assemblages, reported by Tchoumatchenco (1994). The assemblage from the Tellian Domain is a monospecific accumulation of *Lacunosella selliformis* (a costate rhynchonellide) and that from the Tiaret Mountains in the Tlemcenian Domain is composed mostly of costate rhynchonellides (*Somalirhynchia*, *Septaliphoria*) and large terebratulides (*Moeschia*, *Sellithyris*), although some elements of the latter are comparable to the fauna studied herein (*Trigonellina* and *Terebratulina*, small or middle-sized terebratulides).

The bulk of the two assemblages studied herein is thus made up of small brachiopods (not exceeding 25 mm in length). The slight difference between the two is that *Dictyothyris kurri*, the most common species in assemblage A, has a moderately fine ornamentation, whereas brachiopods from assemblage B are either smooth (*Zittelina*, Terebratulida 2) or very finely ornamented (*Monticlarella*). In view of the small number of specimens at hand, this difference is disregarded.

Small, smooth or finely ornamented shells are common in low-energy environments (Fürsich and Hurst, 1974; Vörös, 2005 and references therein). The assemblage with *Dictyothyris*, *Monticlarella*, and *Zittelina* studied herein is quite similar to the *Dictyothyris-Monticlarella* association, described from the Upper Jurassic of the External Pre-Betic Zone by Reolid (2005) and related to spongiolithic lithofacies. Similarly, *Monticlarella striplicata*, *Zittelina billoden-*

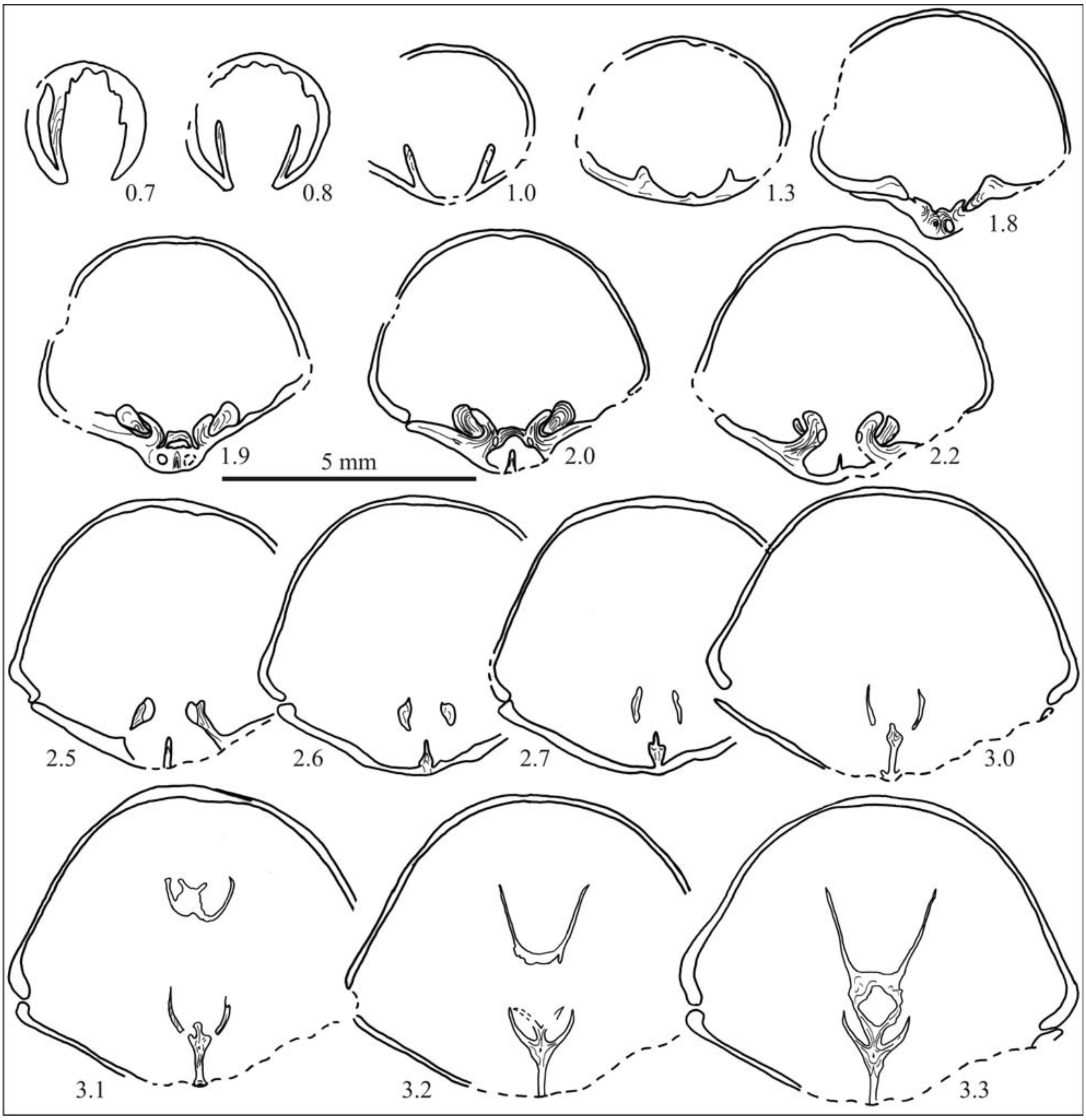

Fig. 10. Transverse serial sections of *Zittelina* sp. (camera lucida drawings) through the shell UKM-LGS Bp 1/20 from outcrop B (middle Oxfordian). Distances measured in millimetres from the tip of the ventral umbo.

sis, and *Dictyothyris kurri* co-occur in the middle Oxfordian Birmensdorf beds in the Jura Mountains (clayey limestones and marls with sponge bioherms; Boullier, 1981, p. 26). *Zittelina billodensis* and *Monticlarella striocincta* co-occurring in the middle Oxfordian *theoi* marls at Pamproux (Deux-Sèvres, France) are interpreted as having dwelt on soft muds (Quereilhac and Guinot, 2011). The ecological characters of the brachiopods studied are in contrast to a relatively high-energy environment revealed by sedimentological analysis (wave and tidal activity, see above), the fauna appears thus as allochthonous. Brachiopods related to high-energy environments are mostly large and often strongly ornamented (see e.g., Heliasz and Racki, 1980 and references therein) and, as noted, they are altogether absent from the material studied. Landward transport of deeper-water brachiopods by storms was observed in the Lower Devonian Bukowa Góra section (Holy Cross Mountains, Poland; Szulczewski and Porębski, 2008) and perhaps may serve as an analogue to the situation studied herein.

BIOSTRATIGRAPHY

The brachiopods studied allow the fauna-bearing beds to be dated with confidence as middle to late Oxfordian. *Dictyothyris kurri* is the only brachiopod in the assemblages studied with a sufficiently precisely defined stratigraphic range (see details under that species). On the contrary, rep-

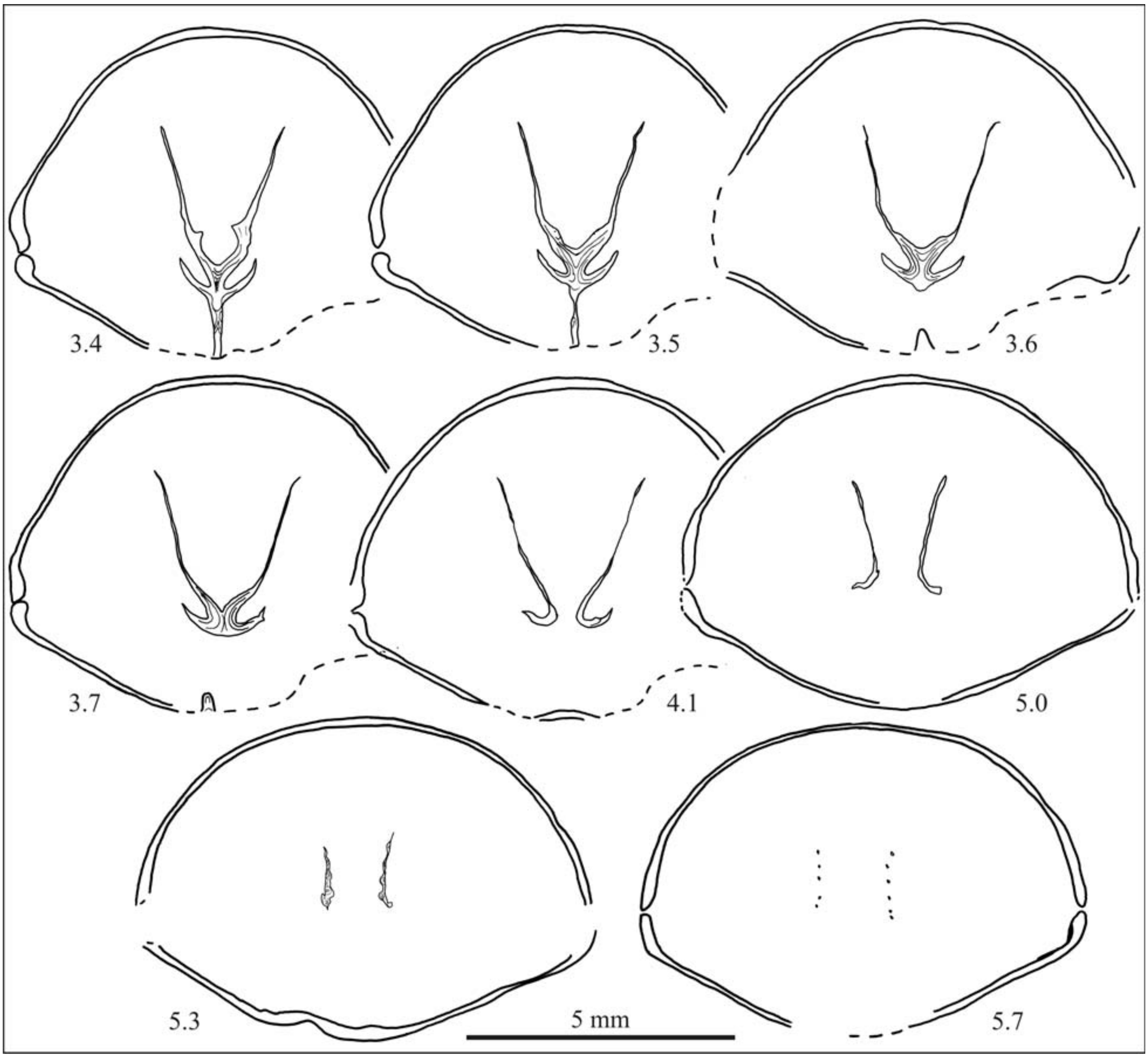

Fig. 11. Transverse serial sections of *Zittelina* sp. (camera lucida drawings) through the shell UKM-LGS Bp 1/20 from outcrop B (middle Oxfordian), continued. Distances measured in millimetres from the tip of the ventral umbo.

resentatives of *Monticlarella* and *Zittelina*, potentially useful, are lacking modern revisions (*Zittelina* as pointed out by Courville and Boullier, 2014; *Monticlarella rollieri* not covered by Childs, 1969, see also remarks under that species) and thus are of limited value as index fossils. Brachiopod-based stratigraphic schemes have often allowed a better time resolution (see references in the introduction), unobtainable in the present case, owing to uncertain taxonomy. In some cases (such as *Monticlarella striocincta*, see above) interregional diachronism cannot be excluded either.

In the brachiopod-based stratigraphic scheme, proposed by Tchoumatchenco (1984, 1994) for Algeria, the middle and upper Oxfordian of the Tellian Domain belong to the *Lacunosella selliformis* Zone and the upper Oxfordian of the Tlemcenian Domain to the *Septaliphoria arduennensis* Zone (otherwise brachiopods are lacking in the areas discussed). The utility of this zoning is nil for the present study, insofar as it is based mainly on large costate rhynchonellides, which do not occur at all in the sections studied herein.

CONCLUSIONS

A preliminary remark is that the study of the brachiopods described herein was hampered by lack of modern revision of the classical Late Jurassic faunas from Europe. The need for primary research on types and variability of those populations in a stratigraphic context is thus evident.

1. Five middle to late Oxfordian (Late Jurassic) brachiopods are reported from two outcrops, situated in the Tlemcenian Domain (Atlas Mountains, Algeria). Outcrop A (upper Oxfordian) yielded *Dictyothyris kurri* and Loboidothyridoidea? indet., whereas Outcrop B (middle Oxfordian) yielded *Monticlarella rollieri*, *Karadagithyris boullierae* sp. n., and *Zittelina* sp.

2. *Karadagithyris boullierae* sp. n. is assigned to the genus on the basis of the presence of brachidium-supporting structures. It is further characterised by a suberect beak and a plano-uniplicate anterior commissure. The new species is a link between previously known Bajocian to Bathonian

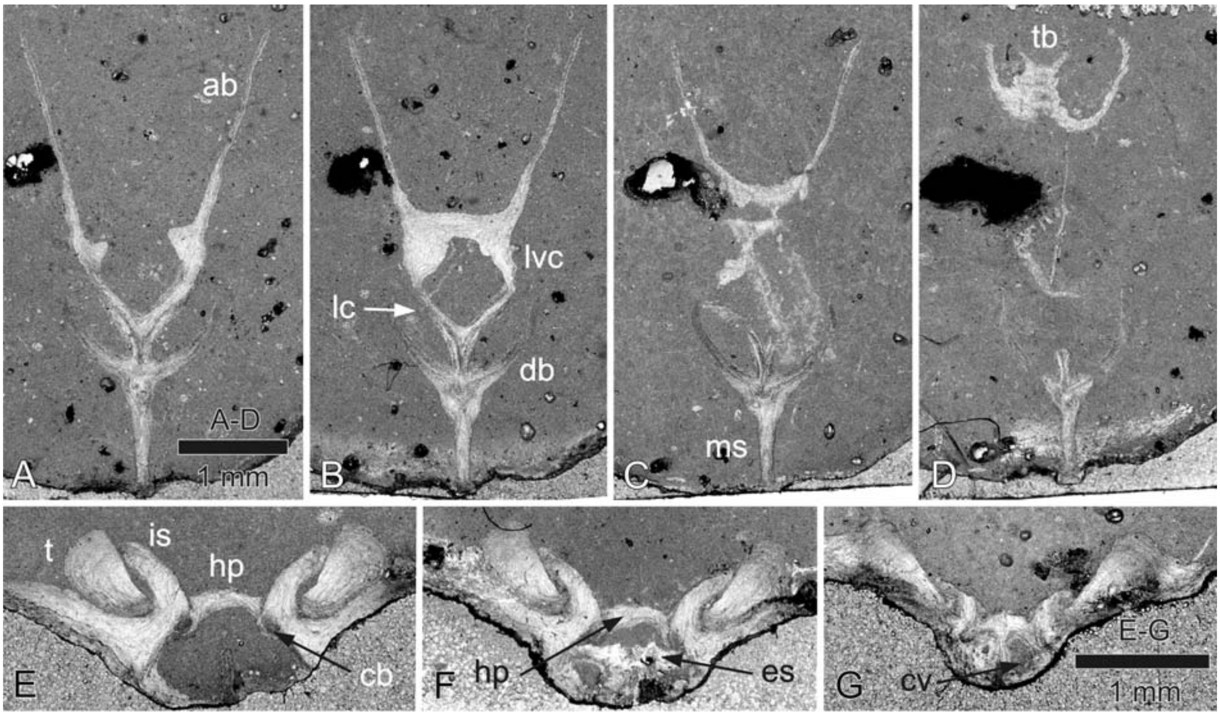

Fig. 12. Selected transverse serial sections of *Zittelina* sp. (photographs of acetate peels) through the shell UKM-LGS Bp 1/20 from outcrop B (middle Oxfordian), showing anatomical features of the dorsal valve and of the teeth. Sections at 1.8 (**G**), 1.9 (**F**), 2.0 (**E**), 3.1 (**D**), 3.2 (**C**), 3.3 (**B**), and 3.4 mm (**A**) from the tip of the ventral umbo. Abbreviations: *ab*, ascending branch of the loop; *cb*, crural base; *cv*, lateral cavities; *db*, descending branch of the loop; *es*, enlargement of the septum; *hp*, hinge platform; *is*, internal socket ridge; *lc*, lateral connecting band; *lvc*, laterovertical connecting band; *ms*, median septum; *t*, tooth; *tb*, transverse band of the loop.

(Callovian?) *Karadagithyris* s.s. and Tithonian to Lower Cretaceous taxa, formerly segregated as *Svaljavithyris*. Following Barczyk (1979) and Cooper (1983), but contrary to Lee *et al.* (2006), *Svaljavithyris* is considered to be a junior subjective synonym of *Karadagithyris*.

3. *Zittelina* sp. (open nomenclature used for lack of revision of European species) is the first report of this genus in Africa. The adult loop is confirmed as bilacunar (kingeniform, as interpreted by Owen, 1970) and not diploform (campagiform, as interpreted by MacKinnon *et al.*, 2006)

4. The bulk of the assemblages comprises small and either smooth or finely ornamented species and must be interpreted as representing a low-energy environment. Given the sedimentology of the brachiopod-bearing strata, the fauna appears to be allochthonous.

5. The brachiopods studied allow dating of the fauna-bearing beds as middle to late Oxfordian, mainly on account of the presence of *Dictyothyris kurri* s.l.; a better time resolution is unobtainable at present for lack of any revision of the genera or species concerned.

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