Earth and Environmental Science Transactions of the Royal Society of Edinburgh, **105**, 159–187, 2015 (for 2014)

Late Ordovician and early Silurian brachiopods from the Zagros Ranges, Iran

Mohammad Ghavidel-Syooki[1,*], Leonid E. Popov[2,*], Mansoureh Ghobadi Pour[3], J. Javier Álvaro[4] and Mohammad H. Ehsani[1]

[1]Institute of Petroleum Engineering, Technical Faculty of Tehran University, P.O. Box 11365-4563, Tehran, Iran
Email: m_ghavidelsyooki@yahoo.com; mh_ehsani@hotmail.com
[2]Department of Geology, National Museum Cardiff, Cathays Park, Cardiff CF10 3NP, Wales, UK
Email: Leonid.Popov@museumwales.ac.uk; lepbarry@yahoo.co.uk
[3]Department of Geology, Faculty of Sciences, Golestan University, Gorgan 49138-15739, Iran
Email: mghobadipour@yahoo.co.uk
[4]Centre of Astrobiology (CSIC/INTA), Ctra. de Torrejón a Ajalvir km 4, 28850 Torrejón de Ardoz, Spain
Email: alvarobjj@cab.inta-csic.es
*Corresponding authors

ABSTRACT: Brachiopods are among the most common components of the Late Ordovician benthic faunal assemblages recorded in the Faraghan Mountains, Zagros Ranges, Iran. A total of 19 species referable to 16 genera are identified, including seven new species; namely *Drabovia elegans*, *Hibernodonta bonehensis*, *Hedstroemina zakeenensis*, *Jezercia faraghani*, *Protomendacella multicostata*, *Tafilaltia dargazensis* and *Tafilaltia seyahouensis*. Reported brachiopod assemblages are oligotaxic (2–3 species per assemblage) to monotaxic. The only exception is the medium diversity *Aegiromena-Hedstroemina* Association, with up to ten species, which occurs at the lower part of the *A. nigerica* Zone. Low diversity patterns were probably controlled by the palaeogeographical position of the region in high southern latitudes throughout the Ordovician. *Paterula* sp. and *Iranospirifer* sp. are the only brachiopods documented from the Silurian (Llandovery) Sarchahan Formation. This paper gives the first detailed report of shelly fossils from the Llandovery 'hot shale' of the Arabian margin of Gondwana. Most of the Katian genera, and many of their species, are shared with neighbouring high- to mid-latitude peri-Gondwanan margins, including Morocco, Spain, France, Sardinia and Bohemia.

KEY WORDS: biofacies, biogeography, Faraghan Mountains, Gondwana, Katian, Llandovery

Most of the existing records of Late Ordovician (Katian) rhynchonelliform brachiopod faunas of temperate to high latitude Gondwana are from the western Mediterranean region (Spain, France, Sardinia, the Carnic Alps and Bohemia), which fringed Gondwana throughout the Ordovician (Torsvik & Cocks 2011). The only continuous record of Late Ordovician brachiopod faunas is preserved in the Anti-Atlas, Morocco (Havlíček 1971), which contrasts with the absence of Late Ordovician rhynchonelliform brachiopods in the rest of North Africa and the neighbouring Arabian Peninsula. Thus, the recent discovery of a rich Late Ordovician (Katian) brachiopod fauna in the Faraghan Mountains of the Zagros Ranges, southeast Iran, is important. The Zagros Ranges, which are located along the northeastern margin of the Arabian plate, were the integral part of the core Gondwana Craton for most of the Phanerozoic (Torsvik & Cocks 2011). Remarkably, newly-discovered Iranian brachiopod assemblages (Table 1) show distinct a similarity to contemporaneous brachiopod faunas of Morocco, Spain, France, Sardinia and the Carnic Alps. The age of the Iranian brachiopod fauna is well constrained by chitinozoan biostratigraphy, and ranges from the *Acanthochitina barbata* to the *Armoricochitina nigerica* zones.

Brachiopod occurrences in the black shales of the Silurian Sarchahan Formation are very rare. In the Faraghan Mountains, the lingulide *Paterula* sp. occurs occasionally in the Rhuddanian part of the Sarchahan Formation, whilst *Iranospirifer* sp. was recovered from the upper part of the Silurian (Aeronian) in the *Demirastrites triangulatus* Zone.

1. Geological and geographical settings

The Faraghan Mountains are situated about 100 km north of Bandar-Abbas. The sampled Ordovician section is exposed at the southern foothills of Bone Mountain, between the Tang-e Pashagh and Tang-e Zakeen valleys, north of Dargaz village (Fig. 1). Geographical coordinates of the base of the studied section are 27°51′46″N, 56°19′33″E.

The most recent outline of the Ordovician–Silurian geology and revised stratigraphy of the area can be found in Ghavidel-Syooki *et al.* (2011). The lowermost Palaeozoic lithostratigraphical unit recognised in the area is the Zard–Kuh Formation (Lower Ordovician, Tremadocian to Floian). Its lower contact is faulted, and it is conformably overlain by the Seyahou Formation (Lower to Upper Ordovician), ca. 870 m thick, which is subdivided into three members. The lower and middle heterolithic members, up to 460 m thick, are black and green shales and sandstones, with thin interbeds of bioclastic carbonate siltstone. The Lower to Middle Ordovician part of the succession is extremely condensed at the top of a paraconformable phosphoarenite bed, which marks the contact of both members. The entire Dapingian and the lower part of

 doi:10.1017/S1755691015000079

Table 1 Distribution of the studied brachiopod species in the Seyahou Formation of the Faraghan Section. Symbols: ● = dominant species (>50 %); ○ = common species (50–10 %); + = rare species (<10 %, or less than five specimens).

	Fossil localities																
List of brachiopod species	MG KF-3b	MG KF-6a	MG10027	MG10031	MG10033	MG10037	MG10064	MG10066	MG10068	MG10074	MG10077	MG10078-1.5 m	MG10078	MG10078+10.5 m	MG Sy/4	MG Sy/5	MG Sy/6
1. *Paracraniops* sp.													+				+
2. *Iberomena sardoa*												+	+	+			+
3. *Hedstroemina zakeenensis*												○	○	+			+
4. *Hibernodonta bonehensis*							+	○		○							
5. *Eostropheodonta*? sp.			○														
6. *Aegiromena descendens*								○				○	○	○	+		○
7. Aegiromeninae gen. et sp. indet.																	
8. *Kozlowskites* cf. *ichnusae*											+		+				
9. *Triplesia cymbula*													+				+
10. *Jezercia faraghani*													+			+	+
11. *Dalmanella* sp.								+					○			+	○
12. *Onnizetina* aff. *carinata*													+				+
13. *Protomendacella multicostata*			+					○					+		+	+	+
14. *Heterorthina* sp.			○														
15. *Svobodaina havliceki*							●	○	●	●							
16. *Tafilaltia dargasensis*	●																
17. *Tafilaltia seyahouensis*			○	●	●	●											
18. *Drabovia* cf. *tenuiseptata*		●															
19. *Drabovia elegans*			○		○												

the Darriwilian Stage below the *Siphonochitina formosa* Zone are missing at this paraconformity (Ghavidel-Syooki *et al.* 2014). The first Katian chitinozoans characteristic of the *Acanthochitina barbata* Zone, including the index species, are documented from sample MG10011, at 33 m above the base of the Middle Ordovician, which is marked by the reported paraconformity, and above a barren interval of ca. 18 m (Fig. 2). The first occurrence of *Armoricochitina nigerica* (Bouché, 1965) is from sample MG10075, ca. 252 m above the base of the Middle Ordovician (Fig. 2).

The upper member of the Seyahou Formation, ca. 390 m thick, consists of thin-bedded, rhythmic claystone/sandstone couplets, extremely rich in ichnofossils, and contains chitinozoans of the *Armoricochitina nigerica* and *Ancyrochitina merga* zones. Recently, Ghavidel-Syooki *et al.* (2011) have documented the presence of Hirnantian glaciogenic strata assigned to the Dargaz Formation, which is separated by an erosive unconformity from the underlying Seyahou Formation.

The uppermost Ordovician (Hirnantian) and Silurian (Llandovery to Wenlock) strata are represented in the area by the

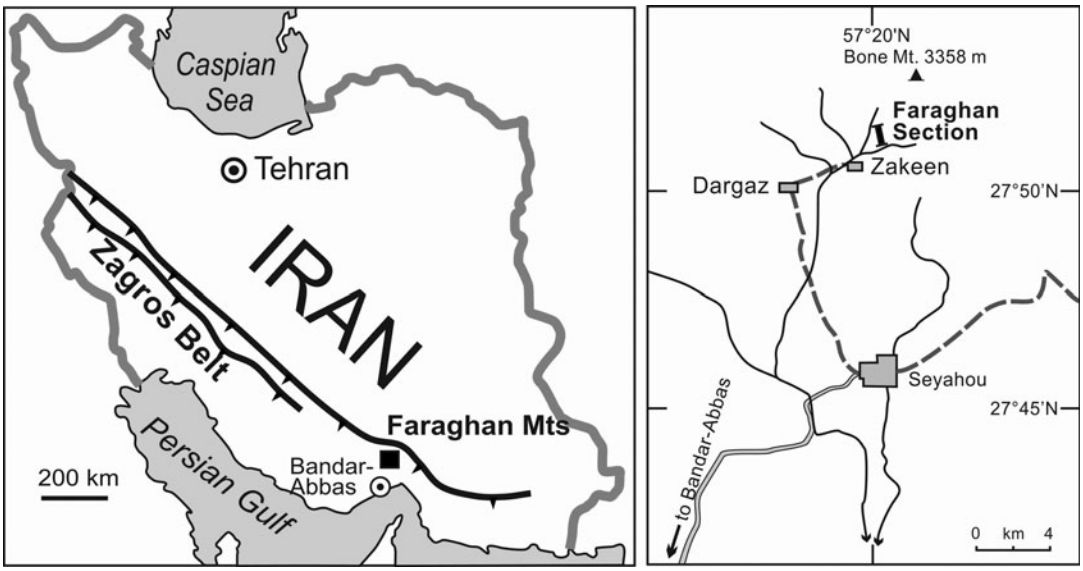

Figure 1 Geographical map of the Seyahou district in southeastern Iran, showing location of the Faraghan section.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

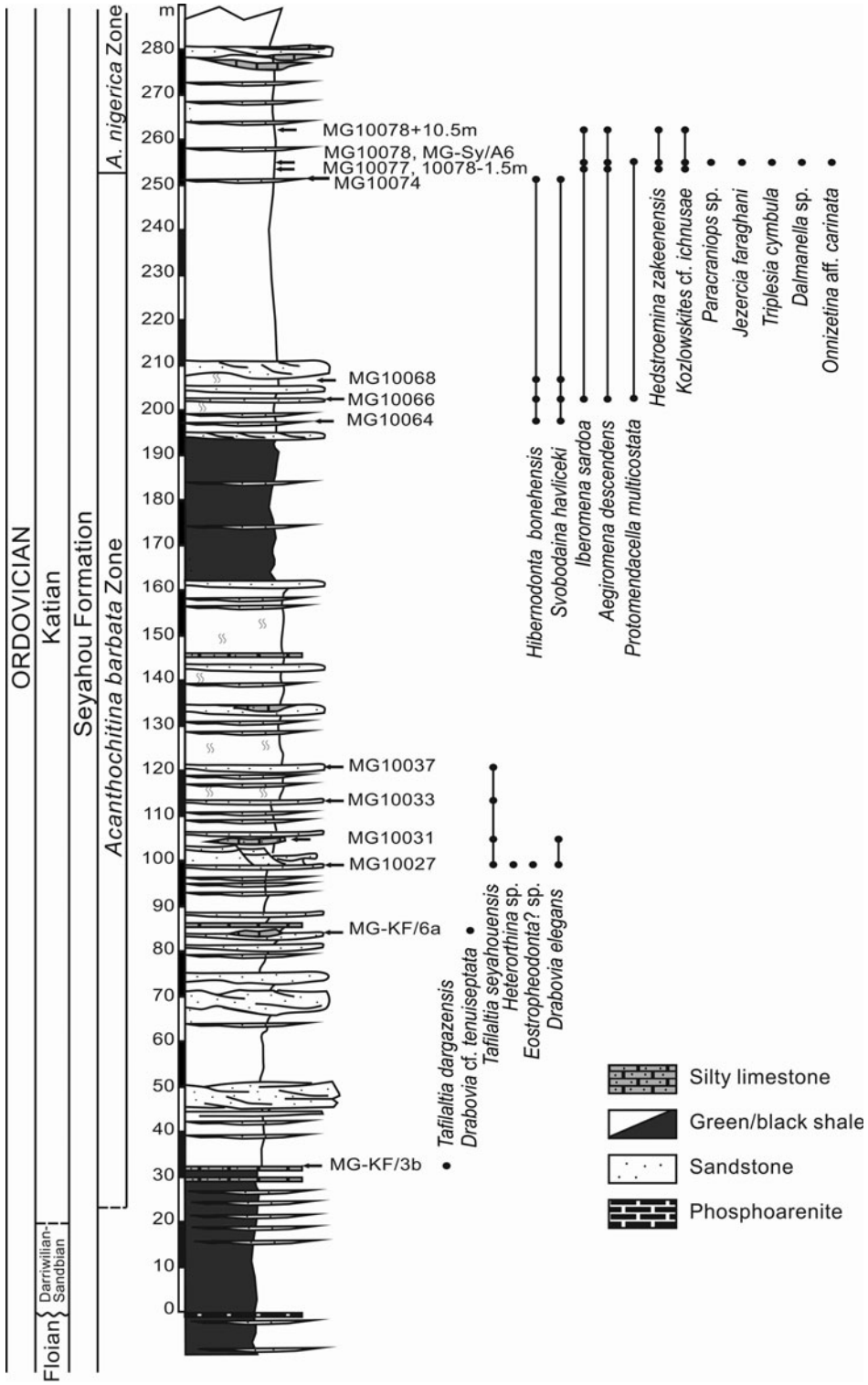

Figure 2 Middle–Upper Katian stratigraphical log from the eastern side of the Tange–Pashag Gorge, showing stratigraphical position of fossil samples and distribution of brachiopods.

black to greyish shale succession, widely known as 'hot shale' and up to 90 m thick, of the Sarchahan Formation. The Silurian hedeinopsid brachiopod *Iranospirifer* sp. was found on the western side of Tang-e Pashag (sample MG20010; 27°51′ 5.18″N, 56°19′5″E), where it occurs in association with graptolites of the Aeronian *Demirastrites triangulatus* Zone. Another Silurian brachiopod locality (MG10173, 27°51′48″N; 56°19′19″E), also on the western side of the Pashag valley, has yielded few specimens of the lingulide *Paterula* sp. from a loose sample below the base of the *Demirastrites triangulatus* Zone. The exposed interval is dated by graptolites as lower Rhuddanian (A. Suyarkova, pers. comm. 2012).

2. Faunal assemblages and biostratigraphical signature

The lowermost silty shell bed of the Faraghan section, bearing Late Ordovician rhynchonelliform brachiopods, is ca. 30 m above the phosphoarenite bed (Fig. 2, sample MG-KF/3b). It

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

contains a low diversity brachiopod association dominated by *Tafilaltia dargazensis* sp. nov. Another taxon is represented by a single dorsal valve of Hesperonomiidae, which is not assignable to any genus. An earliest Katian age of this endemic brachiopod fauna is attested by the occurrence of chitinozoans characteristic of the *Acanthochitina barbata* Zone, which has the first documented occurrence in sample MG10011, including the index-species (Ghavidel-Syooki *et al*. 2014). The *Acanthochitina barbata* Zone is the fourth chitinozoan biozone recognised from the base of the Katian Stage in the Mediterranean Sector of Gondwana.

The next fossiliferous unit is separated from the shell bed by a barren interval of about 58 m thick and comprises intercalating fine grained sandstones, siltstones and dark claystones, up to 14 m thick, with seven shell beds, about 0.25–0.50 m thick, rich in coquina accumulations of large bivalve shells and, secondarily, of disarticulated brachiopod valves, gastropod and cephalopod shells, bryozoans, trilobites and echinoderms (mainly crinoid and cystoid plates). The brachiopod fauna in all studied samples is of low diversity and usually dominated by a single orthide species (Table 1). All samples contain the graptolite *Orthograptus amplexicaulis abbreviatus* Elles & Wood, 1907, which has a wide stratigraphic range within the Katian Stage.

The lowermost shell bed in this unit (Fig. 2, sample MG-KF/6a) contains a single brachiopod species, identified as *Drabovia* cf. *tenuiseptata* Havlíček, 1971. These shells show a close similarity to *D. tenuiseptata* from the Lower Ktaoua Formation of the Anti-Atlas, Morocco (Havlíček 1971); however, identification of the Iranian shells at the species level is provisional because of the general description and poor illustrations provided in the original publication.The second shell bed in this unit (Fig. 2, Table 1, sample MG10027) contains an oligotaxic association, including *Eostropheodonta*? sp., *Heterorthina* sp. *Protomendacella multicostata* sp. nov. and *Tafilaltia seyahouensis* sp. nov. This new taxon may be potentially useful for regional biostratigraphy, as it occurs in abundance in overlying shell beds. *Heterorthina* sp. shows some similarity to *Heterorthina morgatensis* Mélou, 1975, which was previously documented from the Sandbian Alpatir Member of the Castillejo Formation in Central Spain and from the Postolonnec Shale Formation of the Armorican Massif in France (Mélou 1975). In Zagros, *Heterorthina* sp. occurs in rocks of mid Katian age, as it occurs well above the base of the *Acanthochitina barbata* Zone.

Three upper shell beds in this unit (Fig. 2 & Table 1, samples MG10031, MG10033, MG10037) contain a common monotaxic brachiopod association dominated by *Tafilaltia seyahouensis* sp. nov. Specimens identified as *Drabovia elegans* sp. nov. occur with *T. seyahouensis* in samples MG10027, MG10033 and MG2/2008. The two uppermost shell beds contain echinoderm ossicles and bivalve shells, but they lack identifiable brachiopods and trilobites.

The next fossiliferous unit consists of up to 6 m of rippled and cross-bedded sandstones overlain by shales, with a few sandstone interbeds. Brachiopods occur in lens-like coquina accumulations (Fig. 2 & Table 1, sample MG10064) in the upper 2 m of the overlying sandstone bed, which is about 6 m thick. *Svobodaina havliceki* Villas, 1985 is the main component of the coquinas. *Hibernodonta bonehensis* sp. nov. rarely occurs, and there are numerous tentaculite shells and echinoderm ossicles. Above them are shales with a few fossiliferous beds of impure limestonetocalcareous sandstone, about 0.1–0.3 m thick.

Sample MG10066 (Fig. 2 & Table 1) contains *Hibernodonta bonehensis* sp. nov., with *Aegiromena descendens* (Havlíček, 1952), *Iberomena sardoa* (Vinassa, 1927), *Protomendacella multicostata* sp. nov. and *Svobodaina havliceki* as minor components of the association, but in sample MG10068, *Svobodaina havliceki* forms a monotaxic association. This fossiliferous level is capped by a sandstone lens of about 14 m thick, with several shell accumulations (Fig. 2 & Table 1, sample MG10074) similar to those reported from sample MG10064. *Svobodaina havliceki* is a dominant taxon in the shell beds, although *Hibernodonta bonehensis* and tentaculitides also occur in abundance. Overlying claystones (Fig. 2 & Table 1, samples MG10077, MG10078-1.5 m, MG10078, MG10078 + 10.5 m, MG Sy/A4-Sy/A6) contain a medium diversity brachiopod association dominated by *Aegiromena descendens* (Havlíček, 1952) and *Hedstroemina zakeenensis* sp. nov. Other components of the assemblage include *Paracraniops* sp., *Iberomena sardoa* (Vinassa, 1927), *Kozlowskites* cf. *ichnusae* (Vinassa, 1927), *Triplesia cymbula* Havlíček, 1981, *Jezercia faraghani* sp. nov., *Dalmanella* sp., *Onnizetina* aff. *carinata* Havlíček & Kříž *in* Havlíček *et al*., 1987 and *Protomendacella multicostata* sp. nov.

The brachiopods from samples MG10064 to MG10078+10.5 m represent three recurrent faunal associations: (1) the oligotaxic *Svobodaina havliceki* Association, with *Hibernodonta bonehensis* as a minor component, probably characteristic of sandy shoal complex systems (samples MG10064, MG10068); (2) the *Hibernodonta bonehensis* Association, characteristic of an offshore substrate neighbouring shoal systems rich in cystoid–crinoid meadows (MG10066); and (3) the *Aegiromena-Hedstroemina* Association (samples MG10077, MG10078-1.5 m, MG10078, MG10078 + 10.5 m, MG Sy/A4-Sy/A6) representing distal offshore substrates. In sample MG10074, the *Svobodaina havliceki* and *Hibernodonta bonehensis* associations were probably mixed. The recurrent pattern of faunal replacement within this interval coincided with three regressive episodes, marked by the progradation of shoal complexes followed by progressive deepening as a result of transgressive intervals. A sea-level peak was synchronous with immigration of the *Aegiromena-Hedstroemina* Association at the base of the *Armorochitina nigerica* Zone.

Aegiromena descendens was previously described from the Bohdalec Formation (middle Katian) of Bohemia and the Upper Tiouririne Formation of the Anti-Atlas, Morocco (Havlíček 1971) (Fig. 2). It is closely related to *Aegiromena aquila* (Barrande, 1848) from the upper Sandbian of Bohemia, but differs in the absence of dorsal geniculation and subrectangular cardinal extremities (Havlíček 1967). *Aegiromena descendens* is also known from Central Spain, where it occurs in the middle part of the 'Bancos Mixtos' (Villas 1995), which is correlated with the Bohdalec Formation of Bohemia (Fig. 2).

Svobodaina havliceki was originally described from the uppermost part of the Fombuena Formation in the Iberian Chains (Villas 1985) and is also in the uppermost 'Bancos Mixtos' of the Central Iberian Zone (Villas 1995), Spain and in the Lower Bedian Shale Formation of the Turkish Taurides (Villas *et al*. 1995), the lowermost part of the Portixeddu Formation of Sardinia, the Porto de Santa Ana Formation of Portugal (Leone *et al.* 1991) and the upper part of the Glauzy Formation of the Montagne Noire in southern France (Colmenar *et al.* 2013, 2014). In Spain, *Svobodaina havliceki* is regarded by Villas (1995) as the index species of a regional brachiopod zone.

Onnizetina aff. *carinata* and *Kozlowskites* cf. *ichnusae* are similar to the species previously reported from the middle Katian of Sardinia (Havlíček *et al*. 1987). The latter species is also documented from the upper part of the 'Bancos Mixtos' in Spain (Villas 1985).

Iberomena sardoa and *Triplesia cymbula* are widespread in France (Armorican Massif), Sardinia and Spain, where they co-occur in the lower part of the *Iberomena sardoa* Zone (Villas 1985), which succeeds the *Svobodaina havliceki* Zone.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

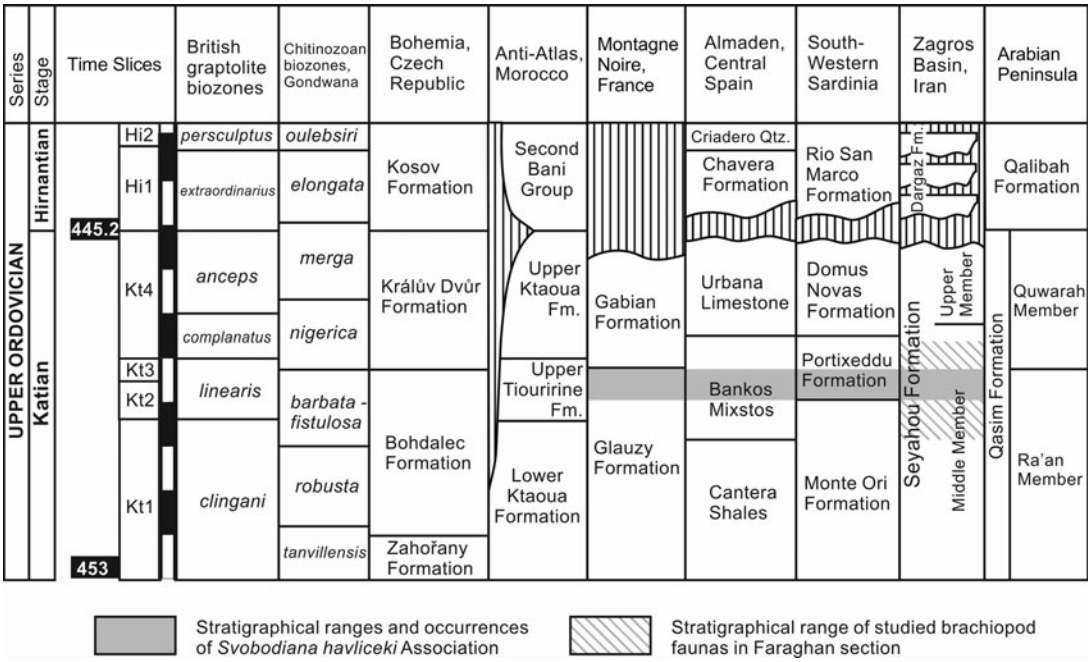

Figure 3 Summarised Ordovician chrono- and lithostratigraphical chart of the Arabian and Mediterranean segments of Gondwana, based on Leone *et al*. (1991), Loi *et al*. (2010), Villas *et al*. (2006), Ghavidel-Syooki *et al*. (2011), Colmenar *et al*. (2013) and this work.

The range of *Svobodaina havliceki* (from sample MG10064 to MG10074) suggests a good correlation with the 'Bancos Mixtos' in Spain and with the lower part of the Bohdalec Formation of Bohemia. The *Aegiromena-Hedstroemina* Association can be correlated with the upper part of the Bohdalec Formation in Bohemia and the uppermost part of the 'Bancos Mixtos' in Spain (Fig. 3). In Zagros, it appeared in the lowermost part of the *Armorochitina nigerica* Zone.

Protomendacella was previously unknown outside Morocco and France, where it occurs in the uppermost Upper Ktaoua Formation in the Anti-Atlas, Morocco (Havlíček 1971) and the Gabian Formation in the Montagne Noire, France (Havlíček 1981).

The brachiopod faunas recovered from the Upper Ordovician interval of the Seyahou Formation share affinities with high to temperate latitude faunas that characterise the western Mediterranean region of Gondwana. In particular, the Late Ordovician (Katian) genera *Jezercia*, *Iberomena*, *Onnizetina*, *Protomendacella*, *Svobodaina* and *Tafilaltia* are diagnostic of high- and temperate-latitude settings of Gondwana (Armorican Massif, Spain, Sardinia, North Africa, Turkish Taurides). Although *Drabovia* and *Hedstroemina* also occur in Baltica and Avalonia, both genera are most characteristic of the western Mediterranean region of Gondwana. *Hibernodonta* has a restricted geographical distribution and it tends to form low-diversity (oligotaxic), abundant brachiopod associations. Proliferation of this genus, which is otherwise known only from the Katian of Ireland (Harper *et al.* 1985), occured synchronously with the proliferation of *Svobodaina*. It is likely that *Hibernodonta bonehensis* and *Svobodaina havliceki* were cold-water taxa and their abundance may point to intervals of cooler climate.

The *Svobodaina havliceki* Association proliferated in Zagros at the time of sea-level lowstand corresponding to the uppermost *Acanthochitina barbata* Zone, which was probably synchronous with the regressive phase of Sequence 3 of the Upper Ordovician succession in the Anti-Atlas, Morocco (Loi *et al.* 2010), as recorded in the Upper Tiouririne Formation (Fig. 3). Development of the *Aegiromena-Hedstroemina* Association occurred at the transgressive event that marks the base of the *Armorochitina nigerica* Zone and it was probably also synchronous with the proliferation of the *Nicolella* Community in the Mediterranean region of Gondwana during the late Katian (Colmenar *et al*. 2013, 2014). Indeed, there are common species, such as *Iberomena sardoa*, *Kozlowskites* cf. *ichnusae* and *Triplesia cymbula*, and their generic composition is also closely similar, but *Nicolella* is virtually absent from the Katian brachiopod fauna of Zagros.

Brachiopod occurrences in the Silurian Sarchahan Formation are very rare. In the Faraghan Mountains, the lingulid *Paterula* sp. occasionally occurs in the Rhuddanian part of the Sarchahan Formation. A single spiriferide, *Iranospirifer* sp., has been recovered from the upper part of the Silurian (Aeronian) *Demirastrites triangulatus* Zone in the Faraghan Mountains. It is probably conspecific with shells from the Aeronian Qarabil Limestone of the Iranian Kopet-Dagh, which were described and illustrated by Popov & Cocks (2013) as *Iranospirifer qarabilensis*.

A brief note in Loydell *et al*. (2013), reporting the presence of small strophomenides and so called 'orbiculoid linguloids' up to 3 mm in diameter (possibly *Paterula*) in the Rhuddanian graptolitic shales of Jordan, is the only existing account of the occurrence of brachiopods in the Silurian 'hot' shales. Suggestions for their epiplanktonic habit seem unfounded. Strophomenides lack pedicle attachment and were liberosessile, and thus could not be attached to floating objects; whereas *Paterula* was in symbiotic relationships with hexactinellide sponges, which is confirmed by life associations described by Lenz (1993) from Silurian black shales in Cornwallis Island, Arctic Canada (for further discussion see Holmer *et al*. 2005). Therefore, it is unlikely that the basin was permanently anoxic near the sediment-water interface during deposition of the 'hot shale', but there were repetitive episodes of reduced oxygen conditions, which made it possible for brachiopods to colonise the sea floor.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

3. Systematic palaeontology (by L. E. Popov and M. Ghobadi Pour)

Abbreviations for parameters measured on specimens are: BBl = brachiophore length; BBw = distance between outer margins of brachiophores; Iw = maximum width of interarea; L = maximum length of shell; Ld = maximum length of dorsal valve; Lv = maximum length of ventral valve; max = maximum observed size; min = minimum observed size; Ml = length of muscle field; Mw = width of muscle field; n = number of specimens; s = standard deviation from the mean; Sl = distance from the umbo to anterior termination of median ridge; T = maximum thickness of the shell; W = maximum width of shell; x = mean. All measurements are in millimetres.

The illustrated and described material is housed in the National Museum of Wales (NMW) under accession number NMW 2011.10G.

3.1. Ordovician brachiopods

Order Craniopsida Goryansky & Popov, 1985
Superfamily Craniopsoidea Williams, 1963
Family Craniopsidae Williams, 1963

Genus *Paracraniops* Williams, 1963

Type species. By original designation; *Craniops*? *pararia* Williams, 1962 from the Kiln Mudstones (Upper Ordovician, Sandbian) of Girvan, Scotland.

Paracraniops sp.
(Fig. 4g–i, k–l)

Material. From sample MG10078: NMW 2011.10G.300, ventral internal mould; NMW 2011.10G.303, ventral external mould; NMW 2011.10G.304, ventral valve; NMW 2011.10G.301, 302, dorsal internal moulds. From sample MG Sy-A/6: NMW 2011.10G.305, ventral valve; NMW 2011.10G.554, dorsal valve. A total of four ventral valves and three dorsal valves.

Remarks. Specimens from the Seyahou Formation exhibit holoperipheral growth of both valves, ornament of regular, fine concentric lamellae, low ventral muscle platforms, but the lack of a cicatrix attachment scar and dorsal muscle platforms characteristic of *Paracraniops*, and the small number of specimens and their poor preservation prevent identification at specific level. There was no previous record of the occurrence of *Paracraniops* and other craniopsides in the Katian sediments of mainland; apart from Wolfart (1970), who recorded an occurrence of *Paracraniops*? in the Upper Ordovician of eastern Afghanistan. During the Katian Epoch, *Paracraniops* was widespread in subequatorial latitudes, including Laurentia (Cooper 1956; Williams 1962), Siberia (Nikiforova 1982) and Kazakhstan terranes (Gorjansky 1972). It is also relatively common in Baltica (Popov & Pushkin 1986) and Avalonia (Williams 1963; Hurst 1979; Lockley & Williams 1981), which occupied subtropical positions during the mid Katian.

Order Strophomenida Öpik, 1934
Superfamily Strophomenoidea King, 1846
Family Strophomenidae King, 1846
Subfamily Furcitellinae Williams, 1965

Genus *Iberomena* Villas, 1985

Type species. By original designation; *Strophomena sardoa* Vinassa, 1927 from the Upper Ordovician, Katian of Sardinia.

Iberomena sardoa (Vinassa, 1927)
(Fig. 4a–f)

1927 *Strophomena sardoa* Vinassa; p. 481, pl. 4, figs 7–9.
1995 *Iberomena sardoa* (Vinassa); Villas, p. 79, pl. 12, figs 5–6 (full synonymy).

Lectotype. Selected by Havlíček (1981), Museum of Geology, University of Pavia no. P2 CA 011, ventral external mould, Upper Ordovician, Katian, Portixeddu Formation, Caput Acquas, Sardinia.

Material. From sample MG10066: NMW 2011.10G.578, dorsal valve. From sample MG10078-1.5 m: NMW 2011.10G.151 (Lv = 12.4, W = 17.8, Ml = 4.6, Mw = 5.6), ventral valve; NMW 2011.10G.153, ventral valve; NMW 2011.10G.150, dorsal valve. From sample MG10078 + 10.5 m: NMW 2011.10G.152, dorsal valve; NMW 2011.10G.154 (Ld = 9.7, W = 12.6), dorsal valve. From sample MG10078: NMW 2011.10G.240, 241, ventral valves; NMW 2011.10G.239, ventral internal mould; NMW 2011.10G.155, dorsal valve. From sample MG Sy-A/6: NMW 2011.10G.238, ventral internal mould. A total of six ventral and five dorsal valves.

Description. Shell weakly resupinate, transverse, semioval in outline, about two-thirds as long as wide, with maximum width at the hinge line. Cardinal extremities slightly acute to almost right angled. Anterior commissure rectimarginate. Lateral profile of the ventral valve with a raised umbonal region, becoming weakly concave anteriorly. Ventral interarea planar, apsacline with a delthyrium covered apically by the minute pseudodeltidium. Lateral profile of the dorsal valve weakly resupinate, with maximum height anterior to mid-length. Dorsal interarea low, planar, apsacline, lacking chilidium. Radial ornament unequally parvicostellate with six accentuated ribs per 3 mm and 1–4 parvicostellae in interspaces between them, along the anterior margin of mature specimens. Concentric ornament of regular, fine closely spaced fila.

Ventral interior, with teeth supported by divergent dental plates. Muscle field subcircular, extending anteriorly for slightly more than one-third of sagittal shell length and flanked laterally by fine muscle-bounding ridges. Dorsal interior with a bifid cardinal process merged with straight but widely divergent socket plates, a very short median ridge and three pairs of closely-spaced transmuscle septa, with a longer, slightly divergent to almost parallel inner pair extending slightly beyond mid-length.

Remarks. The Iranian specimens are closely similar to the types of *Iberomena sardoa* as revised by Havlíček (1981). Minor differences include weaker ventral muscle bounding ridges and slightly divergent to almost parallel inner side septa.

Family Rafinesquinidae Schuchert, 1893
Subfamily Rafinesquininae Schuchert, 1893

Genus *Hedstroemina* Bancroft, 1929

Type species. By original designation; *Hedstroemina fragilis* Bancroft, 1929 from the Longville Flags (Upper Ordovician, Katian) of Shropshire, England.

Hedstroemina zakeenensis sp. nov.
(Figs 5a–i, k, l, n–p; 10n)

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

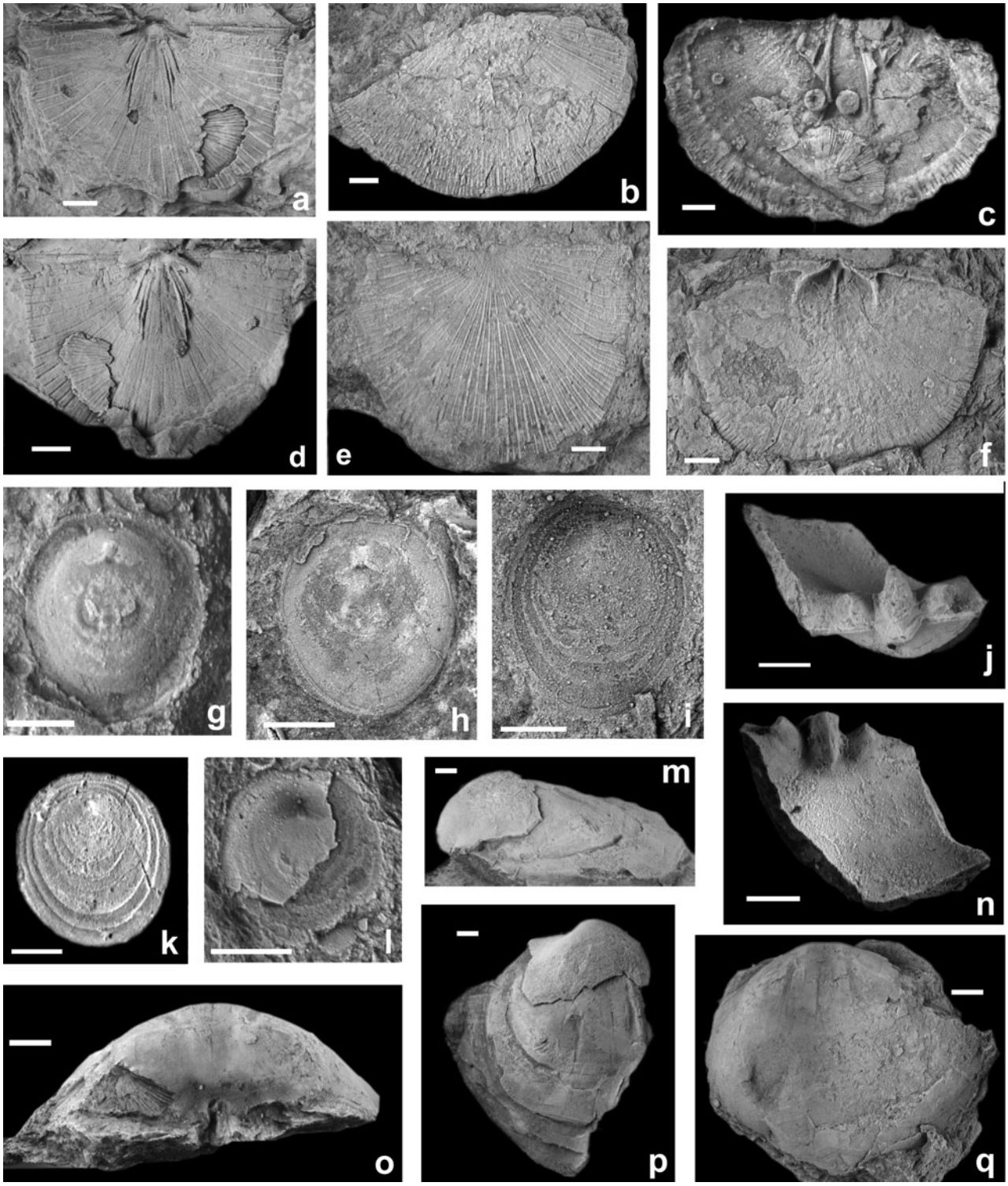

Figure 4 (a–f) *Iberomena sardoa* (Vinassa, 1927): (a, d) NMW 2011.10G.153, dorsal internal mould and latex cast, sample MG10078-1.5 m; (b, c) NMW 2011.10G.152, dorsal valve exterior and latex cast of interior, sample MG10078 + 10.5 m; (e) NMW 2011.10G.150, dorsal valve exterior, sample MG10078 + 10.5 m; (f) NMW 2011.10G.154, ventral valve interior, sample MG10078 + 10.5 m. (g–i, k, l) *Paracraniops* sp.: (g) NMW 2011.10G.300, ventral internal mould; (h) NMW 2011.10G.301, dorsal internal mould; (i) NMW 2011.10G.302, dorsal internal mould; (k) NMW 2011.10G.303, dorsal external mould; (l) 2011.10G.304, incomplete ventral valve interior; all from sample MG10078. (j, m–q) *Triplesia cymbula* Havlíček, 1981: (j, n) NMW 2011.10G.293, oblique posterior and oblique interior view of dorsal cardinalia; (m, p) NMW 2011.10G.294, dorsal valve, lateral and dorsal views; (o, q) NMW 2011.10G.295, dorsal valve, posterior and dorsal views; all from sample MG10078. Scale bars = 2 mm (a–f, j, m–q); 1 mm (g–i, k, l).

Derivation of name. After the village of Zakeen, close to the type locality.

Holotype. NMW 2011.10G.196 (Ld = 16.3, W = 17.8, Sl = 4.6, BBw = 4.0), dorsal internal mould, Upper Ordovician, Katian, Seyahou Formation, sample MG10078, Faraghan Mountains, Zagros Range, Iran.

Paratypes. From loose sample: NMW 2011.10G.159 (Lv = 22.5, Ld = 22.2, W = 30.2), a pair of conjoined valves. From sample MG-Sy/A6: NMW 2011.10G.173–188, 194, 195, 241–249, ventral valves; NMW 2011.10G.157.1 (Lv = 24.0, W = 30.8, Mw = 11.3), 157.2, ventral internal moulds; NMW 2011.10G.156, dorsal valve; NMW 2011.10G.243, 266, dorsal

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

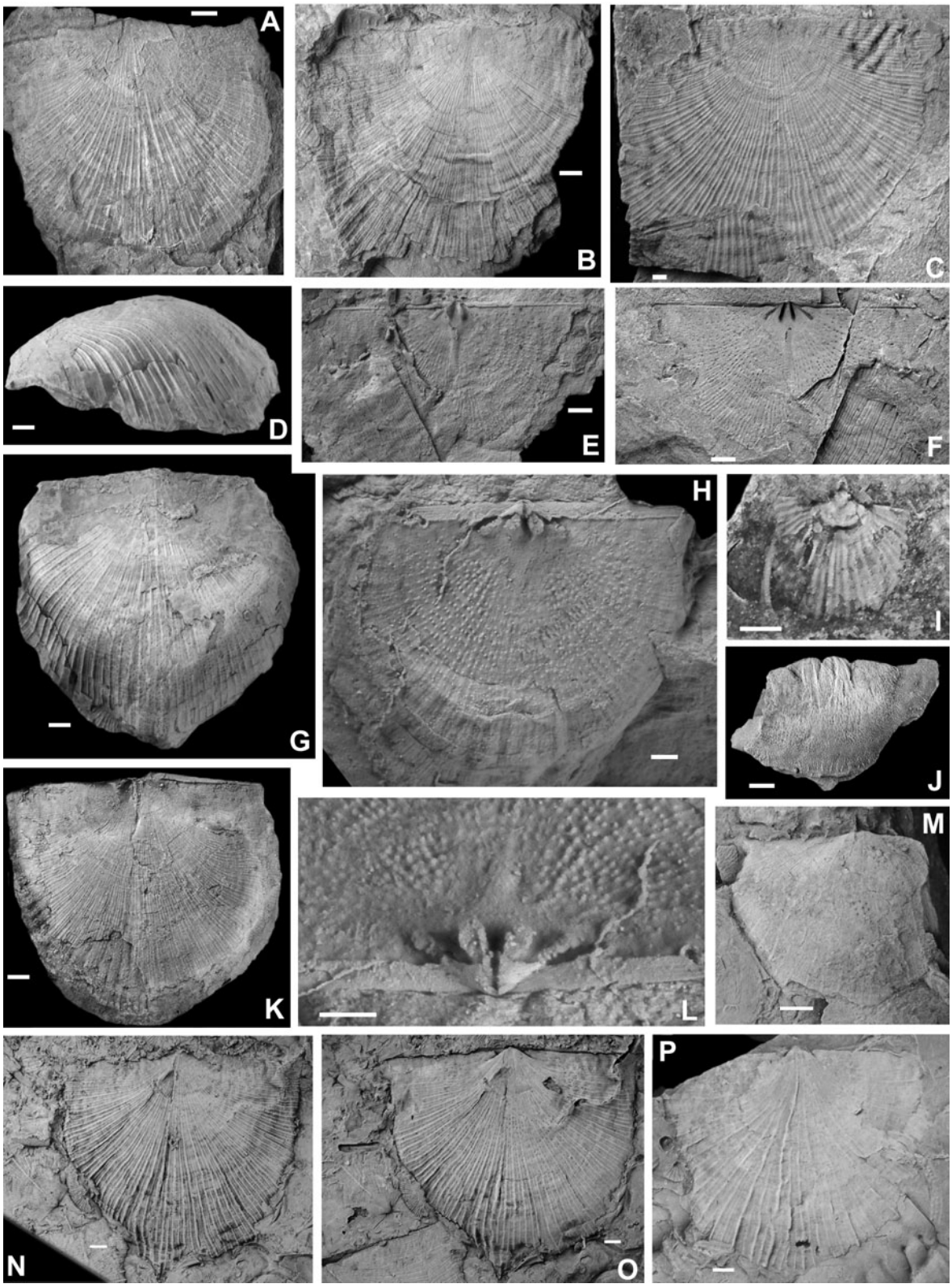

Figure 5 (a–i, k, l, n–p) *Hedstroemina zakeenensis* sp. nov.: (a) NMW 2011.10G.189, ventral valve exterior, sample MG10078; (b) NMW 2011.10G.155, dorsal valve exterior, sample MG Sy-A/6; (c) 2011.10G.192, dorsal valve exterior, sample MG10078; (d, g) NMW 2011.10G.159, conjoined valves, lateral and dorsal views, loose sample; (e, f) NMW 2011.10G.158, latex cast of dorsal valve interior and dorsal internal mould, sample MG10078; (h, l) NMW 2011.10G.196, holotype, latex cast of dorsal valve interior and oblique posterior view of cardinalia, sample MG10078; (i) NMW 2011.10G.194, juvenile ventral valve exterior showing pedicle sheath, sample MG Sy-A/6; (k) NMW 2011.10G.193, latex cast of dorsal valve exterior, sample MG10078 + 10.5 m; (n, o) NMW 2011.10G.156 and 157, latex casts of two ventral valve exteriors, internal moulds, sample MG-Sy/A6; (p) NMW 2011.10G.168, ventral valve internal mould, sample MG10078. (j, m) *Kozlowskites* cf. *ichnusae* (Vinassa, 1927), sample MG10078: (j) NMW 2011.10G.289, ventral internal mould; (m) NMW 2011.10G.288, incomplete ventral valve exterior. Scale bars = 2 mm (a–h, j–p); 0.5 mm (i).

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

external moulds; NMW 2011.10G.244, 250, dorsal internal moulds. From sample MG-Sy/A6: NMW 2011.10G.265, dorsal external mould. From sample MG 10078: NMW 2011.10G.160 (Lv = 21.1, W = 23.4), 162, 164, 171, ventral valves; NMW 2011.10G.158, 172, 189, 192, 251, 252, dorsal valves. From sample MG10078 + 10.5 m: NMW 2011.10G.193, dorsal external mould. From sample MG-Sy/A4: NMW 2011.10G.191, a pair of conjoined valves; NMW 2011.10G.192, ventral valve. From loose sample: NMW 2011.10G.159 (Lv = 23.3, T = 8.3), a pair of conjoined valves; NMW 2011.10G.160, 161, ventral valves. A total of three articulated shells, 36 ventral valves and 14 dorsal valves.

Diagnosis. Shell concavoconvex, geniculated dorsally at 18–20 mm from the umbo, about four-fifths as long as wide. Radial ornament unequally parvicostellate with 8–12 ribs per 3 mm. Concentric ornament of weak, impersistent rugellae covering the disc. Dorsal interior with short straight socket ridges bearing 5–6 crenulations on the outer side; cardinal process with plate-like lobes and a weakly defined median ridge. No transmuscle ridges.

Description. Shell concavoconvex, weakly geniculated dorsally at 18–20 mm from the umbo, slightly transverse, semioval, about four-fifths as long as wide, with maximum width at the hinge line or slightly anterior to the hinge line. Cardinal extremities from obtuse to almost right-angled. Anterior commissure rectimarginate. Ventral valve with lateral profile gently and evenly convex posterior to geniculation, then strongly curved towards the anterior margin. Ventral interarea low, planar, apsacline, with a small, apical pseudodeltidium. Dorsal valve almost flat posterior to the geniculation. Interarea low, anacline with a large, convex chilidium bisected by a deep furrow. Radial ornament parvicostellate with 8–12 parvicostellae per 3 mm. Accentuated ribs stronger in the ventral valve at and anterior to the geniculation, with 2–3 parvicostellae in interspaces. Ribs finer and more even near the hinge line. Weak, impersistent concentric wrinkles crossing all the shell surface posterior to geniculation and more prominent close to the hinge line.

Ventral interior with small teeth, supported by thin, divergent dental plates. Outer surface of teeth bearing 5–6 crenulations. Ventral muscle field large, weakly defined laterally and open anteriorly. Dorsal interior with short straight, divergent socket ridges, bearing 5–6 crenulations on the outer side facing the sockets (Fig. 5f). Cardinal process of 'Type B' (*sensu* Rong & Cocks 1994) with plate-like lobes slightly divergent anteriorly. Dorsal median ridge weakly defined. Inner surface of both valves finely tuberculate.

Remarks. *Hedstroemina zakeenensis* sp. nov. resembles the type species *Hedstroemina fragilis* revised by Hurst (1979), but differs in having coarser (8–12 parvicostellae per 3 mm as compared to 15 in *H. fragilis*) and more strongly differentiated radial ornament, and a crenulated outer side of socket ridges, which was not reported before in the descriptions of other known species of *Hedstroemina*; although fine crenulations on the socket ridges can be seen on the dorsal valve of *Hedstroemina inaequiclina* (Alikhova, 1951), shown by Cocks & Rong (2000, fig. 148.2e). This taxon was designated as the type species of the *Rakverina* by Rõõmusoks (1993) and subsequently synonymised by Cocks & Rong (2000) with *Hedstroemina*. Rong & Cocks (1994, pp 687–88) reported on the presence of crenulations on the socket ridges posterior surface in *Hedstroemina*, but did not give ilustrations or reference to the species.

Unlike *Hedstroemina ungula* Spjeldnaes, 1957 from the lower Katian Norderhov Formation of the Oslo Region, Norway, *Hedstroemina zakeenensis* has a less transverse shell with coarser radial ornament, a significantly larger disc, with the position of geniculation at 18–20 mm from the umbo (instead of <15 mm in *H. ungula*), and weakly developed concentric rugellae.

The Iranian species can be easily distinguished from *Hedstroemina almadenensis* Villas, 1995, from the Upper Ordovician (Katian) 'Bancos Mixtos' of Central Spain by its parvicostellate (not multicostellate) ornament, less prominent rugellae along the hinge line, thin, blade-like cardinal process lobes, a weakly defined dorsal median ridge and a complete absence of transmuscle ridges.

Genus *Hibernodonta* Harper & Mitchel *in* Harper *et al.*, 1985

Type species. By original designation; *Hibernodonta praeco* Harper & Mitchel *in* Harper *et al.*, 1985 from the Clashford House Formation (Upper Ordovician, Katian) of Ireland.

Remarks. Originally, *Hibernodonta* was considered by Harper *et al.* (1985) as the early representative of the Family Strophreodontidae Caster, 1939. Rong & Cocks (1994) restudied the types of *Hibernodonta praeco*. They did not confirm the presence of the denticulate hinge line, as reported in the original description of the species by Harper *et al.* (1985), which indicated a presence of crenulations on the teeth fassets and corresponding crenulations on the posterior faces of the socket ridges in the dorsal valve; but did come to the conclusion that *Hibernodonta* can be considered within the generic concept of *Eostropheodonta* (Rong & Cocks 1994, p. 687). Subsequently, *Hibernodonta* was questionably reassigned by the same authors (Cocks & Rong 2000) to the Family Rafinesquinidae; whilst the intermediate position of the genus between rafinesquinids, and leptostrophiids was pointed out in the generic diagnosis. Indeed, the cardinalia with promiment lobes, observed in the species of *Hibernodonta*, has a closer similarity to the cardinalia of some rafinesquenids (e.g. *Hedstroemina*; Fig. 5h, l), whereas crenulations on teeth and sockets also occur in some rafinesquenid genera (Rong & Cocks 1994).

Hibernodonta bonehensis sp. nov.
(Fig. 6a–k, n)

Derivation of name. After the Boneh Mountain, located about 2.5 km north of the type locality.

Holotype. NMW 2011.10G.208, ventral internal mould, Upper Ordovician, Katian, Seyahou Formation, sample MG10074 of Faraghan Mountains, Zagros Range, Iran.

Paratypes. From sample MG10064: NMW 2011.10G.257, 523, ventral valves. From sample MG 10066: NMW 2011.10G.207 (L = 21.0, W = 23.2), ventral external mould; NMW 2011.10G.212 (L = 23.0, W = 29.3), 214.1–3, 225–229, ventral valves; NMW 2011.10G.206, 213, 215.4, 230, dorsal valves. From sample MG10074: NMW 2011.10G.197–200 (Lv = 19.4, W = 22.7, T = 2.7), 204 (Lv = 29.7, W = 37.3, T = 3.1), 205 (Lv = 28.4, W = 36.5), 209, 210, 211.1–4, 215.1–3, 218–221, 235, 236.1–2, ventral valves; NMW 2011.10G.193, 201, 202, 211.5, 215.4, 223, 224, 231–234, 236.3–4, dorsal valves. A total of 35 ventral valves and 17 dorsal valves.

Diagnosis. Shell planar, weakly concavoconvex to almost planoconvex. Radial ornament unequally and finely parvicostellate, with up to 20 ribs per 3 mm along the anterior margin, but finer and more even at the posterolateral corners of the shell. Concentric rugellae absent. Ventral interior with widely divergent dental plates. No ridge between blade-like, slightly divergent cardinal process lobes.

Description. Shell planar, weakly concavoconvex to almost planoconvex, about four-fifths as long as wide, with maximum width at the hinge line or slightly anterior to the hinge

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

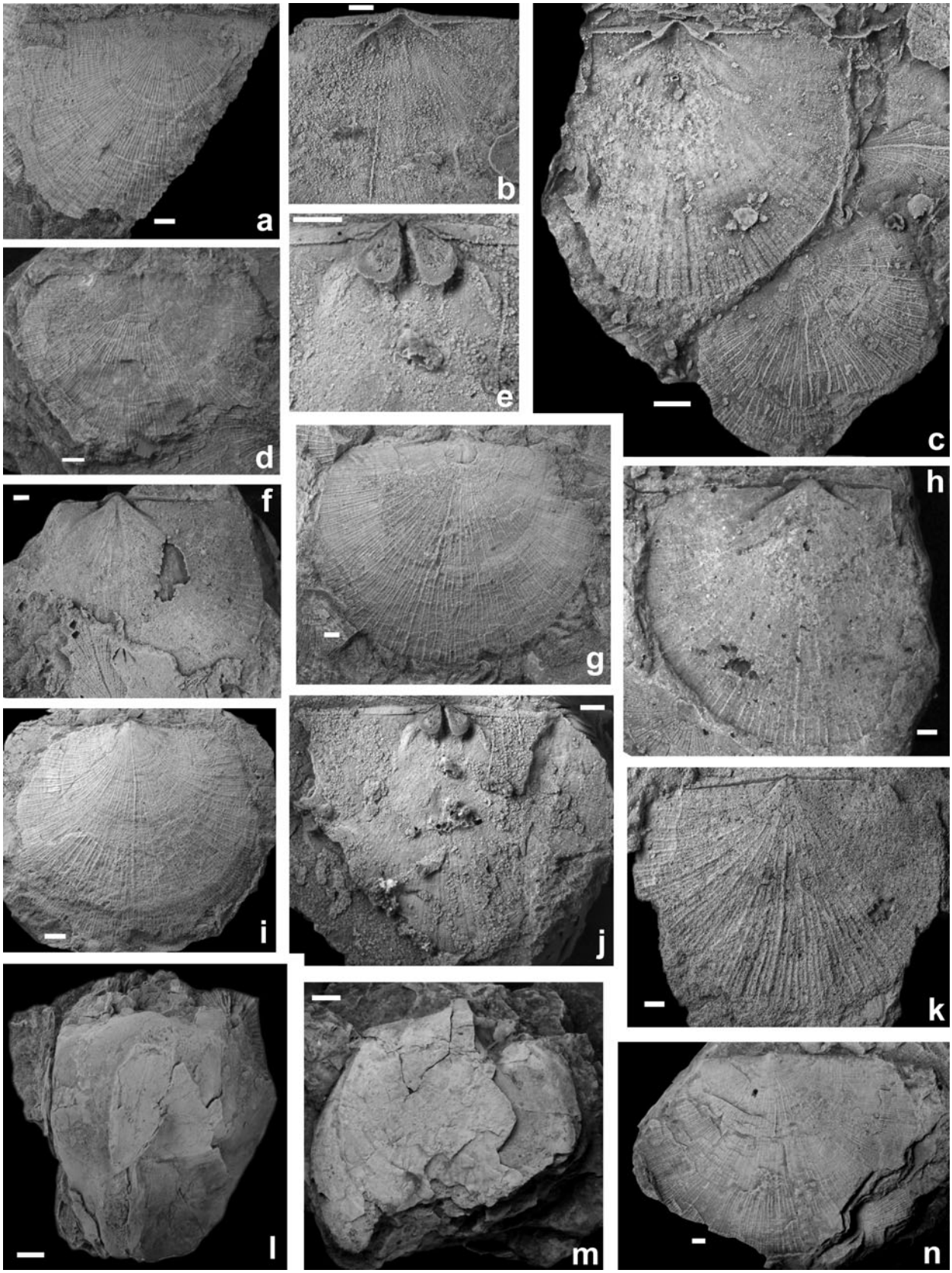

Figure 6 (a–k, n) *Hibernodonta bonehensis* sp. nov.: (a) NMW 2011.10G.201, dorsal valve exterior, sample MG10074; (b) NMW 2011.10G.214.1, latex cast of ventral interior showing muscle field and dental plates, sample MG10074; (c, h) NMW 2011.10G.208, holotype, latex cast of ventral interior plus NMW 2011.10G.209, latex cast of ventral exterior, ventral internal mould of holotype, sample MG10074; (d) NMW 2011.10G.210, dorsal valve exterior, sample MG10074; (e, j) NMW 2011.10G.201, dorsal valve, enlarged view of cardinalia and latex cast of interior, sample MG10066; (f) NMW 2011.10G.210.2, ventral internal mould, sample MG10074; (g) NMW 2011.10G.200, ventral valve exterior, sample MG10074; (i) NMW 2011.10G.207 ventral valve exterior, sample MG10074; (k) NMW 2011.10G212, ventral internal mould, sample MG10066; (n) NMW 2011.10G.204, ventral valve exterior, sample MG10074. (l, m) *Triplesia cymbula* Havlíček, 1981: (l) NMW 2011.10G.296, dorsal valve exterior, sample MG10078; (m) NMW 2011.10G.299, incomplete ventral valve exterior, sample MG Sy-A/6. Scale bars = 2 mm.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

line. Cardinal extremities slightly obtuse to right-angled. Anterior commissure rectimarginate. Ventral valve with lateral profile very gently convex, and maximum height between one-third and a quarter of sagittal valve length from the umbo. Ventral interarea low, planar, anacline, with a minute pseudodeltidium. Dorsal valve almost flat, with a low, planar anacline interarea. Chilidium large, bisected medially by a groove. Radial ornament unequally and finely parvicostellate, with up to 15 ribs per 3 mm along the anterior margin and up to 20 ribs per 3 mm at the posterolateral end of the shell; 2–5 parvicostellae in interspaces between the accentuated ribs. Radial ornament finer and more even towards posterolateral corners of the shell.

Ventral interior with denticulate teeth and low, thin, widely divergent anteriorly dental plates. Ventral muscle field large, subpentagonal, open anteriorly, occupying about two-fifths of sagittal valve length. Ventral muscle scars weakly impressed, with a narrow triangular adductor scar slightly elevated above the weakly impressed diductor scars. Dorsal interior with cardinal process bilobed with elongate, blade-like, slightly divergent lobes completely separated at their bases. Socket ridges low, straight, widely divergent, with denticulate outer sides.

Remarks. In the morphology of the cardinalia, with prominent lobes, and in the absence of the ridge between cardinal process lobes, a large, open ventral muscle field, thin, widely divergent dental plates and teeth with denticulate posterior surface (Fig. 6e, j), the Iranian shells show a distinct similarity to *Hibernodonta praeco* and they are considered as congeneric. *Hibernodonta bonehensis* can be distinguished from the former species by its significantly larger shell, finely parvicostellate radial ornament, and the absence of concentric rugellae, except 3–4 oblique, discontinuous rugae, which are occasionally present in some individuals (Fig. 6g), but not characteristic of the species. *Hibernodonta bonehensis* has the delthyrium with a minute, apical pseudodeltidium; whereas in *Hibernodonta praecox*, the delthyrium is apparently open, according to the original description.

Family Leptostrophiidae Caster, 1939

Genus *Eostropheodonta* Bancroft, 1949

Type species. By original designation; *Eostropheodonta hirnantensis* M'Coy, 1851 from the Upper Ordovician (Hirnantian) of Britain.

Eostropheodonta? sp.
(Fig. 7a–d)

Material. NMW 2011.10G.255 (L = 10.0, W < 11.8), 256 (L = 16.4, W = 21.8), ventral valves; NMW 2011.10G.257, 258, ventral internal moulds; NMW 2011.10G.259, dorsal internal mould; all from sample MG10027. A total of four ventral valves and one dorsal valve.

Remarks. A few specimens recovered from sample MG10027 have a planar, slightly concavoconvex shell with parvicostellate radial ornament, widely divergent dental plates, an open ventral muscle field, a double cardinal process, small lobes not separated by a ridge and low, straight divergent socket plates. These shells are provisionally assigned to *Eostropheodonta*. Unlike *Hibernodonta bonehensis*, they are considerably smaller and have an accentuated ventral median ridge, which is only occasionally present in *Eostropheodonta bonehensis*. Denticulation on the teeth and socket ridges was not observed, probably because of insufficient preservation of the internal moulds; therefore, generic affiliation of the specimens is tentative.

Superfamily Plectambonitoidea Jones, 1928
Family Xenambonitidae Cooper, 1956
Subfamily Aegiromeninae Havlíček, 1961

Genus *Aegiromena* Havlíček, 1961

Type species. By original designation; *Leptaena aquila* Barrande, 1848 from the Záhořany Formation (Upper Ordovician, Katian), Bohemia.

Aegiromena descendens (Havlíček, 1952)
(Figs 7e–q, 8c)

1952 *Aegiria descendens* Havlíček, p. 402; pl. 2, figs 1–9.
1967 *Aegiromena descendens* (Havlíček); Havlíček, p. 43; pl. 4, figs 7–16; text-figs 14–15.
1971 *Aegiromena descendens* (Havlíček); Havlíček, p. 68, pl. 20, figs 1–3.
1995 *Aegiromena descendens* (Havlíček); Villas, p. 76; pl. 11, figs 10–22.

Holotype. NM 1702/63, ventral valve, Upper Ordovician, Katian, Bohdalec Formation of Velká Chuchle, Bohemia.

Material. From sample MG10066: NMW 2011.10G.563.1–5, ventral valves; NMW 2011.10G.563.6, dorsal valve. From sample MG Sy-A/7: NMW 2011.10G269.1–3, ventral valves; NMW 2011.10G269.4–6, dorsal valves. From sample MG Sy-A/6: NMW 2011.10G.265, 282.1–4, articulated shells; NMW 2011.10G.268, 269.1–8, 270.1–7, 271, 272.1, 282.5–17, 284, 286.1–5, 287, 311.1–8, ventral valves; NMW 2011.10G.553, ventral external mould; NMW 2011.10G.253.1–4, 260, 261, 265, 272.12–13, 282.18–25, 286.6–8, dorsal valves. From sample MG Sy-A/4: NMW 2011.10G.277-280, ventral valves; NMW 2011.10G.281, dorsal valve. From sample MG10078: NMW 2011.10G.283.1–5, articulated shells; NMW 2011.10G.264, 273, 275–277, 283.25–53, 579, ventral valves; NMW 2011.10G.285, 381, 552.4–5, ventral internal moulds; NMW 2011.10G.283.6–24, 308–310, dorsal valves; 2011.10G.552.3, dorsal external mould; NMW 2011.10G.552.1–2, dorsal internal moulds. From sample MG-10078+10.5 m: NMW 2011.10G.263, a pair of conjoined valves; NMW 2011.10G.262, ventral valve. A total of 11 articulated shells, 100 ventral valves and 50 dorsal valves.

Remarks. Iranian specimens are referred to *Aegiromena descendens* because they have slightly acute, rather than alate, cardinal extremities, a weakly impressed ventral muscle field and *vascula media*. Well-preserved specimens also exhibit four clusters of strong papillae on both sides of the *vascula media* in front of the ventral muscle field. All these features are considered diagnostic for *Aegiromena descendens*. Detailed characteristics of this species were given by Havlíček (1967) and Villas (1992, 1995).

Aegiromeninae gen. et sp. indet.
Fig. 12j–k

Material. NMW 2011.10G.115, dorsal internal and external mould from sample MG-KF/3b.

Remarks. This unnamed taxon is represented by a single gently concave dorsal valve, characterised by fine, parvicostellate radial ornament, an undercut cardinal process, a pair of fine side septa originating at some distance from the umbo, and a number of poorly preserved septules. It can be assigned to the Aegiromeninae because it lacks a dorsal platform, but double dorsal septa are unknown in genera presently assigned to this subfamily. Poor preservation and absence of data in the ventral valve prevent a formal identification.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

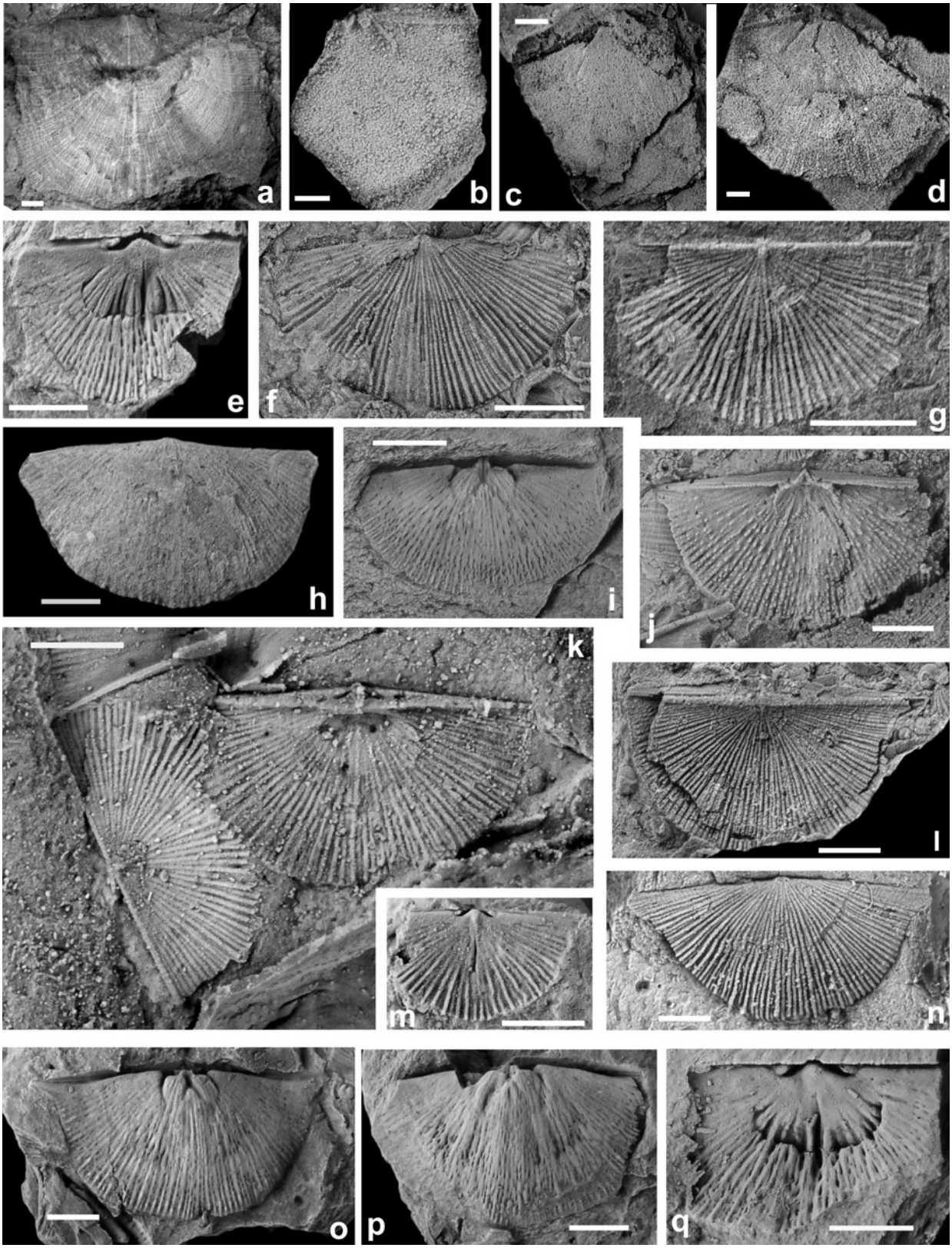

Figure 7 (a–d) *Eostropheodonta*? sp.: (a) NMW 2011.10G.256, ventral valve exterior; (b) NMW 2011.10G.259, latex cast of incomplete dorsal valve interior; (c) NMW 2011.10G.257, incomplete ventral internal mould; (d) NMW 2011.10G.258, incomplete ventral internal mould; all from sample MG10027. (e–q) *Aegiromena descendens* (Havlíček, 1952): (e) NMW 2011.10G.260, dorsal internal mould, sample MG Sy-A/6; (f) NMW 2011.10G.262, ventral valve exterior, sample MG-10078 + 10.5 m; (g) NMW 2011.10G.306, dorsal valve exterior, sample MG Sy-A/6; (h) NMW 2011.10G.286, ventral view of conjoined valves, sample MG10078; (i) NMW 2011.10G.285, ventral internal mould, sample MG Sy-A/6; (j) NMW 2011.10G.284, latex cast of ventral interior, sample MG-10078 + 10.5 m; (k) NMW 2011.10G.308, 309, latex casts of dorsal valve exterior and dorsal view of conjoined valves, sample MG10078; (l) NMW 2011.10G.263, latex cast of dorsal exterior, sample MG Sy-A/6; (m) NMW 2011.10G.287, dorsal internal mould, sample MG Sy-A/6; (n) NMW 2011.10G.264, latex cast of ventral exterior, sample MG10078; (o) NMW 2011.10G.287, ventral internal mould, sample MG10078; (p) NMW 2011.10G.291, ventral internal mould, sample MG10078; (q) NMW 2011.10G.307, dorsal internal mould, sample MG10078. Scale bars = 2 mm.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

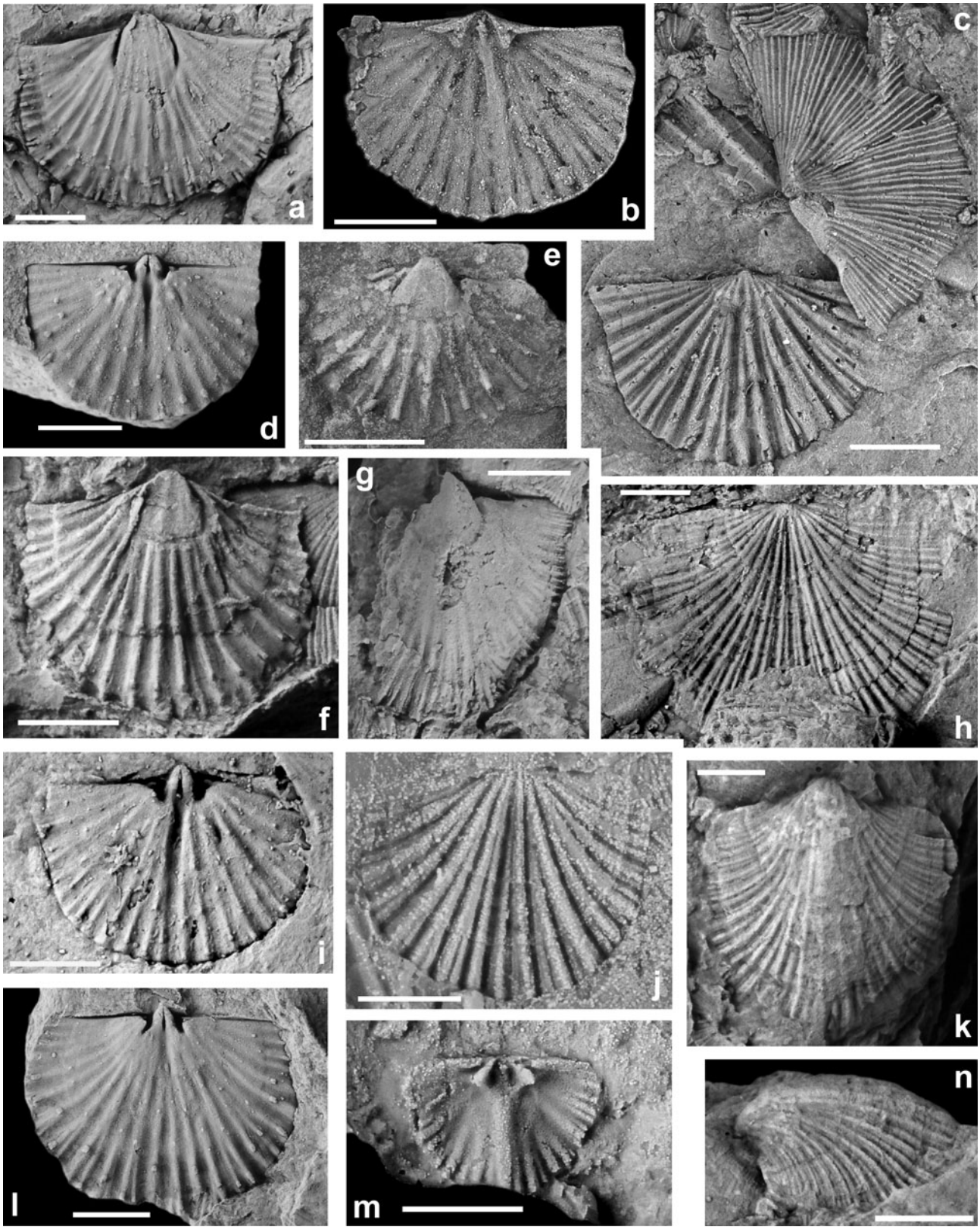

Figure 8 (a, b, d–f, i, l) *Jezercia faraghani* sp. nov.: (a) NMW 2011.10G.314, ventral internal mould, sample MG10078; (b, d) NMW 2011.10G.317, latex cast and dorsal internal mould, sample MG Sy-A/6; (e) NMW 2011.10G.316, ventral internal mould, sample MG Sy-A/5; (f) NMW 2011.10G.315, ventral internal mould, sample MG10078; (i) NMW 2011.10G.313, holotype, dorsal internal mould, sample MG10078; (l) NMW 2011.10G.318, dorsal internal mould, sample MG10078. (c) NMW 2011.10G.313, holotype, latex cast of dorsal valve exterior of *Jezercia faraghani* sp. nov., and NMW 2011.10G.311, latex cast of ventral valve exterior of *Aegiromena descendens* (Havlíček); sample MG10078. (g, h, j, k, m, n) *Onnizetina* aff. *carinata* Havlíček & Kříž *in* Havlíček *et al.*, 1987: (g) NMW 2011.10G.325, ventral internal mould, sample MG10078; (h) NMW 2011.10G.328, latex cast of dorsal valve exterior, sample MG Sy-A/6; (j) NMW 2011.10G.327, latex cast of dorsal exterior, sample MG Sy-A/6; (k, n) NMW 2011.10G.324, ventral valve, exterior and side view, sample MG10078; (m) NMW 2011.10G.326, latex cast of dorsal valve interior, sample MG Sy-A/6. Scale bars = 2 mm.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

Family Sowerbyellidae Öpik, 1930
Subfamily Sowerbyellidae Öpik, 1930

Genus *Kozlowskites* Havlíček, 1952

Kozlowskites cf. *ichnusae* (Vinassa, 1927)
(Figs 5j, m, 11n–o)

Type species. By original designation; *Strophomena nuntia* Barrande, 1879 from the Králův Dvůr Formation (Upper Ordovician, Katian) of Bohemia.

Material. NMW 2011.10G.292, ventral valve from sample MG10077. NMW 2011.10G.288-291, ventral valves and internal moulds from sample MG10078. A total of five ventral valves.

Remarks. In spite of the absence of any dorsal valve, the Iranian shells are tentatively assigned to *Kozlowskites* cf. *ichnusae*, because of their characteristic transverse shell about half as long as wide, sigmoid ventral *vascula media* and narrow, tear-shaped ventral diductor muscle scars with subparallel inner margins.

Order Orthotetida Waagen, 1884
Suborder Triplesiidina Moore, 1952
Superfamily Triplesioidea Schuchert, 1913
Family Triplesiidae Schuchert, 1913

Genus *Triplesia* Hall, 1859

Type species. By subsequent designation by Hall & Clarke, 1892; *Atrypa extans* Emmons, 1842 from the Upper Ordovician (lower Katian) of Trenton, New York, USA.

Triplesia cymbula Havlíček, 1981
(Figs 4j, m–q, 6l–m)

1981 *Triplesia cymbula* Havlíček; p. 19, pl. 9, figs 5–13.
1985 *Triplesia* cf. *cymbula* Havlíček; Villas, p. 80, pl. 15, figs 18–19; pl. 16, figs 1, 2, 4–5.

Holotype. USTL HAV-89 (housed in the University of Montpellier), conjoined valves, Upper Ordovician (Katian) Gabian Formation, La Grange-du-Pin, southern Montagne Noire, France.

Material. From sample MG10078: NMW 2011.10G.293–297, dorsal valves. From sample MG Sy-A/6: NMW 2011.10G.298, dorsal valve; NMW 2011.10G.299, ventral valve. A total of one ventral valve and six dorsal valves.

Remarks. The specimens from the Seyahou Formation have a strongly dorsibiconvex, almost globose, shell, with an inflated dorsal umbonal area and a very short ventral interarea, characteristic of the *Triplesia cymbula* topotype specimens. No pseudodeltidium is preserved in the single known ventral valve, while the dorsal interior exhibits the cardinal process with a keeled shaft and a cowl, characteristic of *Triplesia*.

Order Orthida Schuchert & Cooper, 1932
Suborder Orthidina Schuchert & Cooper, 1932
Superfamily Orthoidea Woodward, 1852
Family Chrustenoporidae Havlíček & Mergl, 1982

Remarks. Villas *et al*. (2002) gave a comprehensive discussion of the affinities of the Chrustenoporidae and thus this family is considered here within the impunctate orthides.

Genus *Jezercia* Havlíček & Mergl, 1982

Type species. By original designation; *Jezercia ostiarea* Havlíček & Mergl, 1982 from the Králův Dvůr Formation (Upper Ordovician, Katian) of Bohemia.

Jezercia faraghani sp. nov.
(Fig. 8a, b, d–f, i, l)

Derivation of name. After the type locality at Faraghan Mountains.

Holotype. NMW 2011.10G.313 (L = 4.3, W = 6.4), dorsal internal and external mould, Upper Ordovician, Katian, Seyahou Formation, sample MG10078, Faraghan Mountains, Zagros Range, Iran.

Paratypes. From sample MG 10078: NMW 2011.10G.314 (L = 6.1, W = 7.9, Ml = 2.1, Mw = 1.9), 315 (L = 4.7, W = 5.8), ventral internal moulds; NMW 2011.10G.318, 320, 321, dorsal internal moulds. From sample MG Sy-A/6: NMW 2011.10G.317, 319, dorsal internal moulds; NMW 2011.10G.322, 323, dorsal external moulds. From sample MG Sy-A/5: NMW 2011.10G.316, ventral internal mould. From sample MG Sy-A/4: NMW 2011.10G.268, ventral internal mould. A total of four ventral valves and eight dorsal valves.

Diagnosis. Transverse, semioval, ventribiconvex shell, with maximum width at hinge line and slightly acute to almost right-angled cardinal extremities. Shallow dorsal sulcus posterior to mid-length. Radial ornament of 13 primary ribs and up to 32 ribs in total, with five ribs per 2 mm along the anterior margin of mature specimens.

Description. Shell ventribiconvex, transverse, semi-oval in outline, about four-fifths as long as wide, with maximum width at the hinge line. Cardinal extremities slightly acute to almost right-angled, anterior commissure weakly unisulcate to rectimarginate. Ventral valve moderately and evenly convex. Ventral interarea gently curved, low, apsacline, with an open, triangular delthyrium. Dorsal valve weakly convex, with maximum depth in the umbonal area. Dorsal interarea low, anacline, with an open chilidium. Shallow dorsal sulcus originating at the umbonal area, fading anterior to mid-length. Radial ornament unequally ramicostellate, with 13 primary ribs at the dorsal valve, with a median rib occupying the sulcus; total of 28–32 ribs; up to five ribs per 2 mm along the anterior margin of mature specimens. Rib crests perforated by oblique fenestrae.

Ventral interior with small teeth, supported by long, thin, divergent dental plates extending anteriorly as low muscle bounding ridges. Muscle field subtriangular, mainly occupying a delthyrial cavity floor, about one-third as long as valve. Adductor scar gently impressed, subtriangular, as long as wide; diductor scars gently impressed. Dorsal interior with ridge-like cardinal process crenulated posteriorly and shaft merged with weakly-defined median ridge. Brachiophores short, slightly convergent towards the valve floor. Dental sockets small, subtriangular.

Remarks. *Jezercia faraghani* differs from the type species *Jezercia ostiarea*, *Jezercia chrustenicensis* (Havlíček, 1951) and *Jezercia wrighti* (Havlíček, 1977) in having a ventribiconvex shell with maximum width at the hinge line and uneven ramicostellate radial ornament. This is unlike the Iranian species *Jezercia wrighti* and *Jezercia chrustenicensis*, which are characterised by multicostellate radial ornament with a number of ribs exceeding 50 in the adult individuals of both species.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

Suborder Dalmanellidina Moore, 1952
Superfamily Dalmanelloidea Schuchert, 1913
Family Dalmanellidae Schuchert, 1913

Genus *Dalmanella* Hall & Clarke, 1892

Type species. By original designation; *Orthis testudinaria* Dalman, 1828 from the Loka Formation (Upper Ordovician, Hirnantian), Borenshult, Östergötland, southern Sweden.

Dalmanella sp.
(Figs 9r–t, v–x, 10l–n)

Material. From sample MG10066: NMW 2011.10G.565.1, ventral external mould; NMW 2011.10G.562, ventral internal mould; NMW 2011.10G.577.1–3, dorsal valves; NMW 2011.10G.565.3, dorsal external mould. From sample MG10078: NMW 2011.10G.566, a pair of conjoined valves; NMW 2011.10G.368 (L = 9.5, W = 12.0), 369, 381 (L = 7.6, W = 9.1, Iw = 7.1), ventral valves; NMW 2011.10G.367 (L = 12.5, W = 15,9, Iw = 13.2, Ml = 4.6, Mw = 4.4), 376, ventral internal moulds; NMW 2011.10G.372 (L = 9.7, W = 12.8, Iw = 9.9), dorsal valve; NMW 2011.10G.380 (L = 10.5, W = 13.6, Iw = 10.6, Sl = 5.0), dorsal internal mould. From sample MG10078-1.5 m: NMW 2011.10G.374, ventral valve. From sample MG Sy-A/6: NMW 2011.10G.371, 377, ventral valves; NMW 2011.10G.372 (L = 7.8, W = 11.7, Iw = 9.6; ribbing pattern: I, Iā, II, IIā, III, IIIā, IIIā1, IIIb̄, IIIå), 378, 545, dorsal valves; NMW 2011.10G.254, dorsal internal mould. A total of one pair of conjoined valves, ten ventral valves and ten dorsal valves.

Remarks. The specimens from samples MG10078, MG10078–1.5 m and MG Sy-A/6 are characterised by a finely punctate, dorsibiconvex shell with a cordate, weakly impressed ventral muscle field, a faint, bilobed cardinal process with a short, linear shaft and a broad, short dorsal median ridge. Radial ornament is weakly fascicostellate, with about seven ribs per 3 mm along the anterior margin of the mature specimens, with internally bifurcating ribs within sectors I to III, and a median interspace between ribs in the dorsal valve. These shells can be assigned to *Dalmanella* as revised by Jin & Bergström (2010), but identification at the species level remains uncertain because of the small number of specimens available for study and the poor preservation of the ventral valves.

Genus *Onnizetina* Havlíček, 1974

Type species. By original designation; *Onnizetina mellita* Havlíček, 1974 (=*Orthis tribunensis* Barrande, 1879), from the Vinice Formation (Upper Ordovician) of Bohemia.

Onnizetina cf. *carinata* Havlíček & Kříž *in* Havlíček *et al*., 1987
(Figs 8g, h, j, k, m, n; 9a)

Material. From sample MG10078: NMW 2011.10G.324 (L = 6.7, W = 7.7, Iw = 5.5, T = 1.9), ventral valve; NMW 2011.10G.325 (L = 6.0), ventral internal mould. From sample MG Sy-A/6: NMW 2011.10G.326 (L = 2.2, W = 3.1), 393 (L = 5.2, W = 7.3, Iw = 6.2), dorsal internal moulds; NMW 2011.10G.327 (L = 4.5, W = 5.6), 328 (W = 9.4, Iw = 7.6), dorsal external moulds. A total of two ventral valves and four dorsal valves.

Description. Shell strongly ventribiconvex, slightly transverse, subcircular, with a hinge line about 71–84 % as wide as maximum valve width, which is located between the posterior margin and mid-length. Cardinal extremities rounded; anterior commissure weakly unisulcate. Ventral valve with lateral profile moderately convex, with maximum height at about quarter of sagittal valve length from the umbo; transverse profile carinate, accentuated by a median rib, with almost straight lateral slopes. Ventral interarea low, curved, strongly apsacline, with a narrow, open, triangular delthyrium. Dorsal valve gently convex, with low, anacline interarea and open notothyrium. Dorsal sulcus sharp, but shallow, originated at the umbo and considerably widening towards the anterior margin of mature specimens. Radial ornament fascicostellate, with 14 primary costae at the dorsal umbo and three generations of costellae, numbering about 7–10 per 2 mm at the anterior margin of mature specimens.

Ventral interior with small teeth, supported by thin, divergent dental plates. Ventral muscle field small, almost confined to the delthyrial cavity, defined anteriorly by fine muscle bounding ridge. Dorsal interior with a bilobed cardinal process; short shaft occupying most of a narrow triangular notothyrial platform. Brachiophores high, divergent, triangular, blade-like, with the maximum height anteriorly. Dorsal median ridge, broad, bisecting a small subcircular adductor muscle field delineated by fine muscle bounding ridges.

Remarks. The shells from the Seyahou Formation show a distinct similarity to the specimens of *Onnizetina carinata* Havlíček & Kříž *in* Havlíček *et al*., 1987 from the Upper Ordovician (Katian) of Sardinia, in having a carinate ventral valve with almost flat lateral flanks, a small, weakly differentiated ventral muscle field and cardinalia morphology; but they are about twice as large as the Sardinian shells and have a more distinctly fascicostellate radial ornament.

Family Heterorthidae Schuchert & Cooper, 1931

Genus *Heterorthina* Bancroft, 1928

Type species. By original designation; *Heterorthina praeculta* Bancroft, 1928 from the Cheney Longville Formation (Upper Ordovician, Katian) of Shropshire, England.

Heterorthina sp.
(Fig. 10b, c, e–k)

Material. NMW 2011.10G.384, 385, 394, ventral internal moulds; NMW 2011.10G.382, 383, 390, 391, 395, dorsal external moulds; NMW 2011.10G.386–389, 392, 393, dorsal internal moulds; all from sample MG10027. A total of three ventral valves and 11 dorsal valves.

Description. Shell ventribiconvex, slightly transverse, suboval in outline. Hinge line shorter than maximum shell width, located slightly posterior to mid-length. Cardinal extremities broadly rounded; anterior commissure rectimarginate. Ventral valve moderately convex, with an apsacline interarea and an open, triangular delthyrium. Dorsal valve very gently convex, with a shallow umbonal sulcus fading almost completely anterior to mid-valve. Dorsal interarea low, planar, anacline. Radial ornament multicostellate with four ribs per mm at 5 mm anterior to the dorsal umbo, and with up to eight ribs per 3 mm along the anterior margin of mature specimens. Costellae in posterior region evenly curved backwards to intersect hinge line.

Ventral interior with strong, stout teeth, supported by short, widely divergent dental plates continuing as faint muscle bounding ridges. Ventral muscle field flabellate, extending anteriorly well beyond mid-length. Adductor scars short and narrow, but not enclosed by strongly impressed diductor scars. Dorsal interior with low, narrow notothyrial platform merged

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

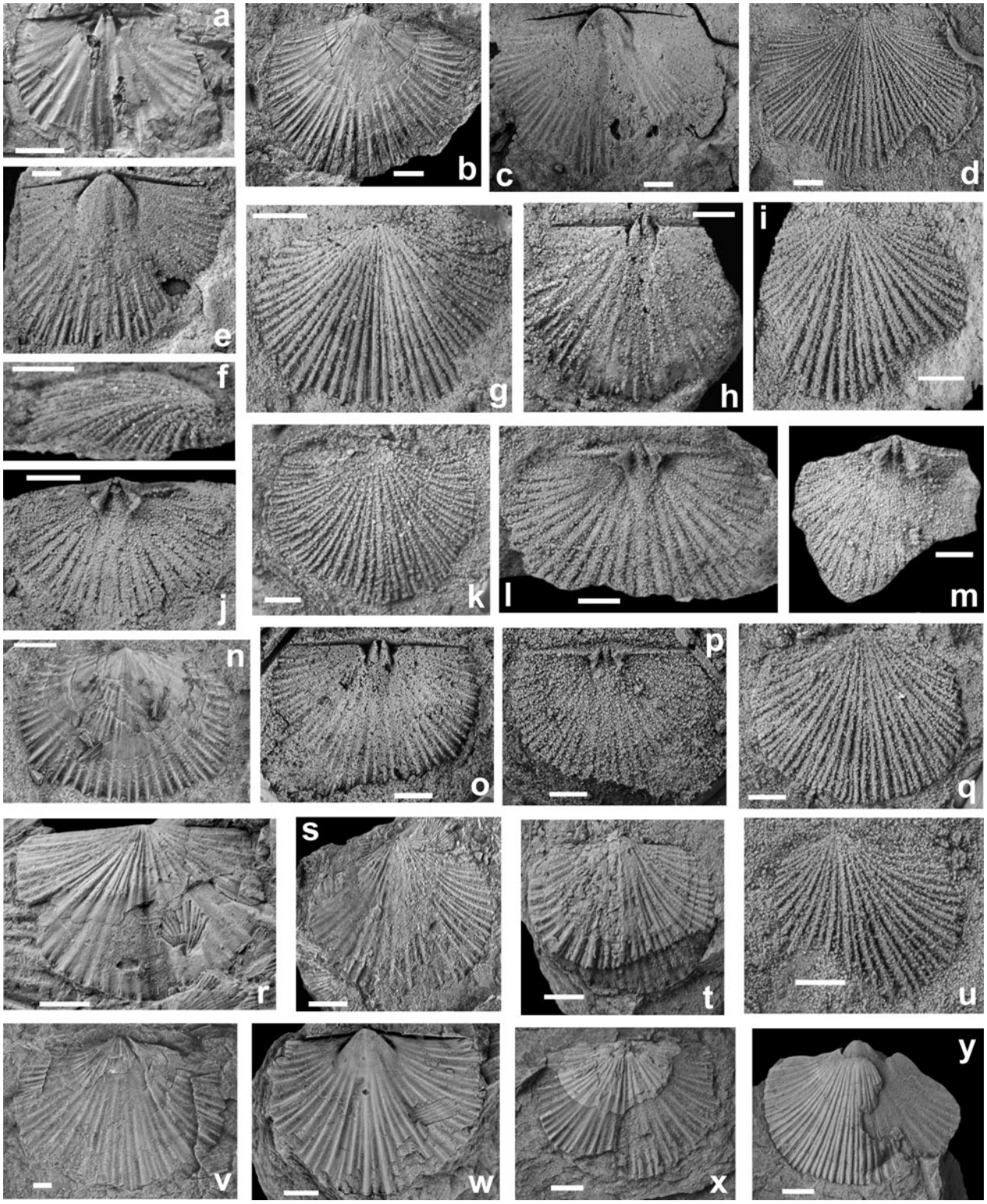

Figure 9 (a) *Onnizetina* aff. *carinata* Havlíček & Kříž *in* Havlíček *et al*., 1987, NMW 2011.10G.329, dorsal internal mould, sample MG Sy-A/6. (b–q, u) *Drabovia* cf. *tenuiseptata* Havlíček, 1971: (b) NMW 2011.10G.330, exfoliated ventral valve exterior; (c, d) NMW 2011.10G.335, ventral internal mould and latex cast of exterior; (e) NMW 2011.10G.333, ventral internal mould; (f, g) NMW 2011.10G.337, latex cast of dorsal exterior, side and dorsal views; (h) NMW 2011.10G.332, dorsal internal mould; (i) NMW 2011.10G.338, latex cast of dorsal exterior; (j) NMW 2011.10G.340, latex cast of dorsal intereior; (k) NMW 2011.10G.344, latex cast of ventral exterior; (l) NMW 2011.10G.334, latex cast of dorsal valve interior; (m) NMW 2011.10G.341, latex cast of dorsal interior; (n) NMW 2011.10G.331, exfoliated dorsal exterior; (o–p) NMW 2011.10G.336, dorsal internal mould and latex cast of dorsal interior; (q) NMW 2011.10G.339, latex cast of dorsal exterior; (u) NMW 2011.10G.357, latex cast of ventral exterior; all from sample MG KF6a. (r–t, v–x) *Dalmanella* sp.; (r) NMW 2011.10G.372, exfoliated dorsal valve exterior, sample MG10078; (s) NMW 2011.10G.369, ventral valve exterior, sample MG10078; (t) NMW 2011.10G.381, ventral valve exterior, sample MG10078; (v) NMW 2011.10G.370, exfoliated ventral valve exterior, sample MG Sy-A/6; (w) NMW 2011.10G.379, ventral internal mould, sample MG Sy-A/4; (x) NMW 2011.10G.545, exfoliated dorsal valve exterior, sample MG Sy-A/6. (y) *Protomendacella multicostata* sp. nov., NMW 2011.10G.368, exfoliated ventral valve exterior, sample MG10078. Scale bars = 2 mm.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

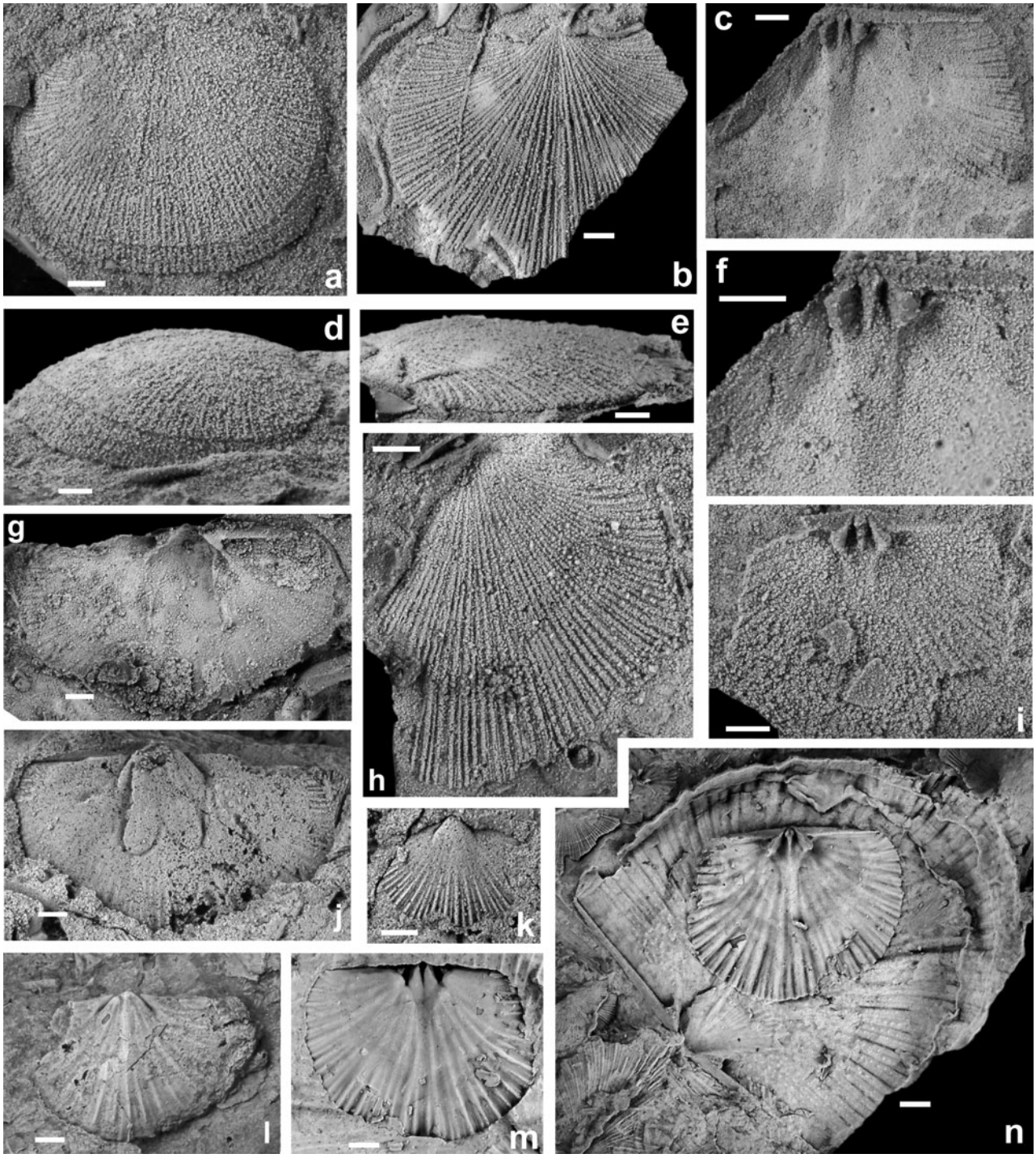

Figure 10 (a, d) *Svobodaina havliceki* Villas, 1985, NMW 2011.10G.396, latex cast of dorsal exterior, dorsal and lateral views, sample MG10071. (b, c, e–k) *Heterorthina* sp.: (b, e) NMW 2011.10G.382, latex cast of incomplete dorsal valve, exterior and side views; (c, f) NMW 2011.10G.389, latex cast of incomplete dorsal valve interior, enlarged view of cardinalia; (g, j) NMW 2011.10G.392, latex cast of incomplete ventral valve interior and internal mould; (h) NMW 2011.10G.383, latex cast of incomplete dorsal valve exterior; (i) NMW 2011.10G.386, latex cast of incomplete dorsal valve interior; (k) NMW 2011.10G.385, ventral internal mould of juvenile specimen; all from sample MG10027. (l–n) *Dalmanella* sp.: (l) NMW 2011.10G.385, ventral internal mould; (m) NMW 2011.10G.380, dorsal internal mould; (n) NMW 2011.10G.380, latex cast of dorsal interior of *Dalmanella* sp. and NMW 2011.10G.162, latex cast of ventral interior of *Hedstroemina zakeenensis* sp. nov.; all from sample MG10078. Scale bars = 2 mm.

anteriorly to low, broad median ridge. Cardinal process with moderately thick, ridge-like shaft and bilobed myophore. Brachiophores short, blade-like, divergent anteriorly. Dental sockets narrow, lacking fulcral plates. Dorsal adductor scars weakly impressed.

Remarks. The specimens from the Seyahou Formation show some similarities to *Heterorthina morgatensis*, described by Mélou (1975) from the Postolonnec Shale Formation of Finistère, France, in having a large, flabellate ventral muscle field and in characteristics of the cardinalia and radial ornament, but differ in having a more delicate cardinal process with less developed lobes. Because of these differences, and due to the poor preservation of the material available, the Iranian shells are left in open nomenclature.

Genus *Svobodaina* Havlíček, 1950

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

Type species. By original designation; *Orthis ellipsoides* Barrande, 1848 from the Záhořani Formation (Upper Ordovician, Katian) of Bohemia.

Svobodaina havliceki Villas, 1985
(Figs 10a, d; 11a–m)

1985 *Svobodaina havliceki* Villas; p. 55, pl. 10, figs 1–10, pl. 11, figs 1–10.
2013 *Svobodaina havliceki* Villas; Colmenar *et al.*, p. 151, fig. 5A–E.
2014 *Svobodaina havliceki* Villas; Colmenar *et al.*, p. 212, fig. 11A–K (full synonymy).

Holotype. DPZ 514, dorsal valve; Upper Ordovician, Katian, Fombuena Formation, Huerva Member, Huerva river, Herrera de los Navarros, Zaragoza, Spain.

Material. From sample MG10064: NMW 2011.10G.438.1–9, 524.1–3, 525.1–6, 526.1–5, 543.1–5, 544.1–4, 563.1–3, ventral valves; NMW 2011.10G.438.3, 439.10, 560, ventral external moulds; NMW 2011.10G.438.4–9, 439.11, 524.4–6, 525.7–15, 526.6–9, 543.5–9, 544.5–7, 363.4–5, dorsal valves; NMW 2011.10G.438.10–13, 439.12, 524.5, dorsal external moulds; NMW 2011.10G.524.6, 544.8, 561, dorsal internal moulds. From sample MG10066: NMW 2011.10G.437.1–2, ventral valves; NMW 2011.10G.437.3, ventral external mould; NMW 2011.10G.437.4–6, dorsal valves; NMW 2011.10G.437.7, dorsal internal mould. From sample MG10068: NMW 2011.10G.352, 519, 520, ventral internal moulds; NMW 2011.10G.351, 521, dorsal internal moulds. From sample MG10071: NMW 2011.10G.433.1–3, 434.1-13, 435,1–4, ventral valves; NMW 2011.10G.403 (Lv = 20.7, W = 21.2, Iw = 13.6), 404, 429, 434.14, 435.5, ventral external moulds; NMW 2011.10G.398 (Lv = 17.8, W = 23.2, Iw = 14.0, Ml = 10.7, Mw = 8.7), 401, 402 (Lv = 18.9, W = 19.4, Ml = 9.5, Mw = 8.2), 405, 406, 419–421 (Lv = 14.0, W = 18.4, Iw = 14.6, Ml = 8.2, Mw = 7.7), 422, (Lv = 18.0, Ml = 9.9, Mw = 8.0), 430, 431, ventral internal moulds; NMW 2011.10G.407–410, 433.4–6, 434.15–27, 435.6, dorsal valves; NMW 2011.10G.396 (Ld = 16.8, W = 19.8; T = 3.3), 407–410, 423–428, 435.7, dorsal external moulds; NMW 2011.10G.397 (Ld = 17.7, W = 18.3; Iw = 13.0, T = 4.2, BBw = 4.3, Sl = 7.2), 399, 400, 411–414, 415 (Ld = 17.7, W = 18.5, Iw = 12.6, BBw = 4.6, Sl = 7.1), 416–418, 432, dorsal internal moulds. From sample MG10074: NMW 2011.10G.436, dorsal valve. A total of 80 ventral valves and 95 dorsal valves.

Description. Shell strongly dorsibiconvex, subcircular to slightly transverse, suboval, about 76–98 % as long as wide. Hinge line relatively narrow, about two-thirds of maximum shell width at mid-length. Cardinal extremities broadly rounded; anterior commissure weakly uniplicate. Ventral valve flattened anteriorly and lateral profile gently convex, with maximum height at the umbonal area. Ventral interarea slightly curved at the umbonal region, high, subtriangular, with a broad, open delthyrium. Ventral sulcus very weakly defined, originating anterior to mid-length. Dorsal valve lateral profile strongly and evenly convex, with a low, almost orthocline, interarea. Shallow sulcus in umbonal area, but fading completely at mid-valve. Radial ornament finely and equally multicostellate, with 9–10 ribs per 3 mm along the anterior margin of adult shells. Concentric ornament of a few fine growth lamellae.

Ventral interior with a large pedicle callist and strong stout teeth, supported by low divergent dental plates extending anteriorly as strong muscle bounding ridges. Ventral muscle field large, flabellate, 105–123 % as long as wide and and almost half as long as valve. Adductor scars narrow, subtriangular, significantly shorter than strongly impressed diductor scars. Dorsal interior with a strong ovoid cardinal process on a high, ridge-like shaft, occupying most of the notothyrial cavity. Posterior face of the cardinal process bilobed and finely crenulated. Brachiophores simple, blade-like, divergent, supported by a moderately high, triangular notothyrial platform. Median ridge short, merged with the notothyrial platform posteriorly, narrowing anteriorly and terminated at the anterior margin of the dorsal adductor muscle field at about two-fifths of sagittal valve length from the beak. Dorsal adductor muscle scars small, weakly impressed with slightly larger anterior pair.

Remarks. Shells from the Seyahou Formation are closely similar to the types of *Svobodaina havliceki* described and illustrated by Villas (1985) and considered here as conspecific. Their only slight difference is a shorter ventral muscle field, which does not extend significantly beyond mid-valve. Detailed discussion of the affinities of *Svobodaina havliceki* was given by Villas (1985) and Colmenar *et al.* (2013, 2014).

Genus *Tafilaltia* Havlíček, 1970

Type species. By original designation; *Tafilaltia occidentalis* Havlíček, 1970 from the Lower Ktaoua Formation (Upper Ordovician, Katian) of the Anti-Atlas, Morocco.

Tafilaltia dargazensis sp. nov.
(Figs 12a–i, 15p–r; Tables 2, 3)

Derivation of name. After Dargaz village near the type locality.

Holotype. NMW 2011.10G.90, ventral internal and external mould; Upper Ordovician, lower Katian, Seyahou Formation, sample MG KF3b, Faraghan Mountains, Zagros Ranges, Iran.

Paratypes. NMW 2011.10G.1–3, 9–11, 14, 15 (Lv = 7.3, W = 8.6, Iw = 7.6, T = 2.4), 17 (Lv = 7.7, W = 9.0, Iw = 7.5, T = 1.7), 20, 26, 45, 49, 99, ventral external moulds; NMW 2011.10G.22–25, 27 (Lv = 6.8, W = 9.2, Iw = 7.0, T = 1.4, Ml = 4.4, Mw = 3.3), 28, 30–33, 36–40, 44, 46, 47, 53, ventral internal moulds; NMW 2011.10G.51, 56, 58, 60, 64, 65, 68, 69, 71–74, 76–79, 81, 82, 84, 88–90 (Lv = 7.4, W = 9.1, Iw = 8.0, T = 2.0, Ml = 4.4, Mw = 3.8), 91, 93, 99, 101, 104, 108–110 (L = 4.6, W = 5.1, Iw = 5.0, T = 1.2, Ml = 2.3, Mw = 2.0), 112, 113, ventral internal and external moulds; NMW 2011.10G.57, 59, 61–63, 67, 68, 75, 80, 83, 85, 86, 92, 94, 100, 102 (Ld = 6.0, W = 7.4, Iw = 6.1, Ml = 3.6, Mw = 0.6, BBw = 2.5), 103, 105, 107, 111 (Ld = 6.0, W = 7.4, Ml = 3.2, Mw = 2.2, BB2 = 2.2), 114, dorsal external and internal moulds; NMW 2011.10G.8, 5, 18, 42, 48, 50, 52, 54, 70, 95, 97, 98, dorsal external moulds; NMW 2011.10G.4–7, 12, 13, 19, 21, 29, 34, 35, 41, 43, 55, 96, dorsal internal moulds; locality and age as for the holotype. A total of 66 ventral and 48 dorsal internal and external moulds.

Diagnosis. Shell planoconvex, transverse, suboval, about four-fifths as long as wide, with a hinge line about four-fifths as wide as the shell. Ventral valve subcarinate posteriorly, dorsal valve with a shallow sulcus, fading gradually anterior to mid-length. Ventral interior with a slightly elongate, bilobate muscle field, open anteriorly and extending well beyond mid-length; dorsal adductor muscle field strongly elongate, with deeply impressed adductor scars.

Description. Shell planoconvex, transverse, suboval, on average about 77 % as long as wide, with maximum width slightly posterior to mid-length. Hinge line straight, about

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

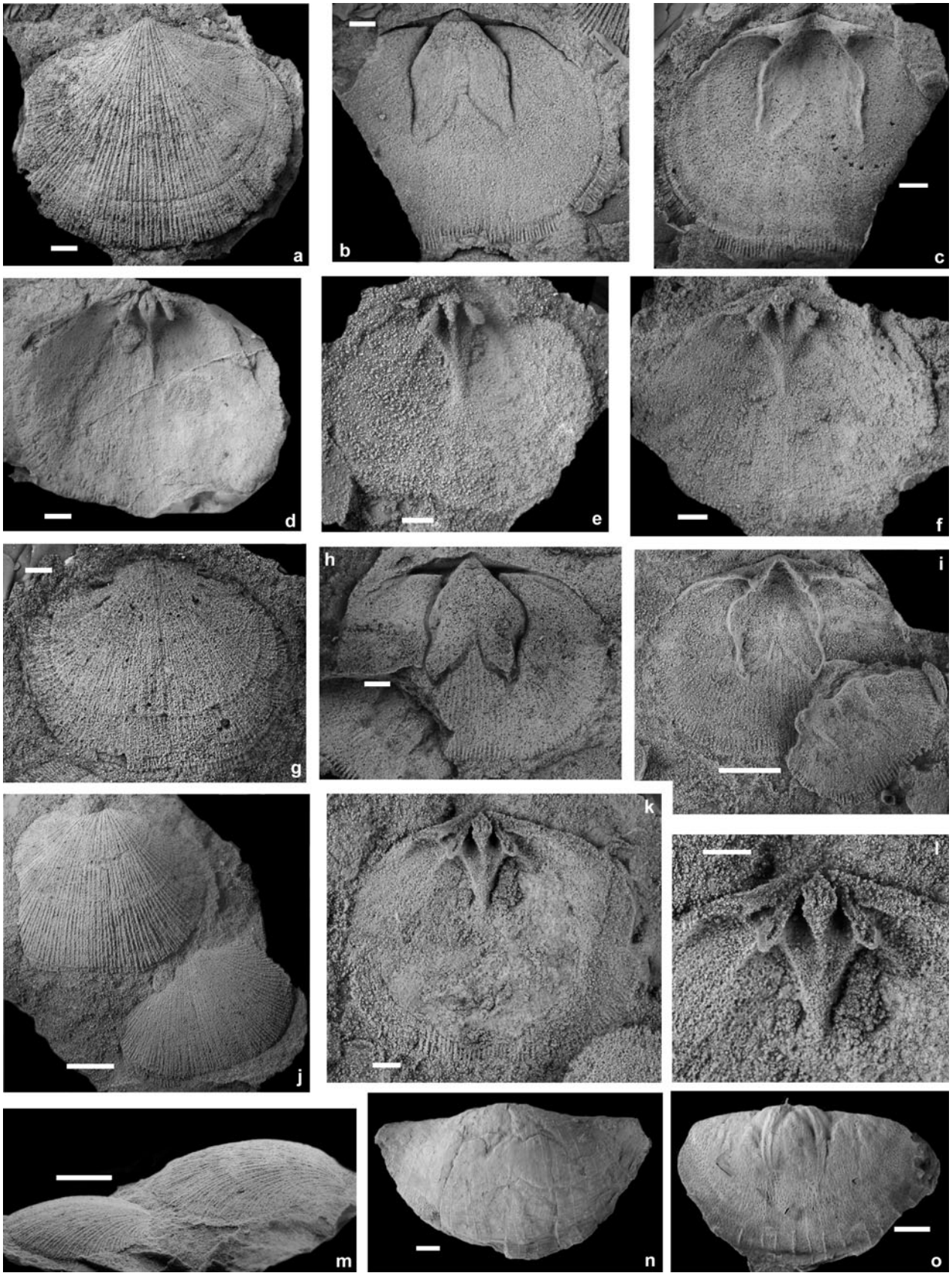

Figure 11 (a–m) *Svobodaina havliceki* Villas, 1985: (a) NMW 2011.10G.403, latex cast of ventral exterior, sample MG10071; (b, c) NMW 2011.10G.422, ventral internal mould and latex cast of ventral interior, sample MG10071; (d) NMW 2011.10G351, latex cast of dorsal interior, sample MG10068; (e) NMW 2011.10G.416, latex cast of dorsal interior, sample MG10071; (f) NMW 2011.10G.415, latex cast of dorsal interior, sample MG10071; (g) NMW 2011.10G.425, latex cast of dorsal exterior, sample MG10071; (h, i) NMW 2011.10G.398, ventral internal mould and latex cast, sample MG10071; (j, m) NMW 2011.10G.423, 424, latex casts of dorsal exterior, dorsal and side views, sample MG10071; (k, l) NMW 2011.10G.397, latex cast of dorsal interior and enlarged view of cardinalia, sample MG10071. (n, o) *Kozlowskites* cf. *ichnusae* (Vinassa, 1927); (n) NMW 2011.10G.292, ventral valve exterior, sample MG100077; (o) NMW 2011.10G.290, ventral internal mould, sample MG10078. Scale bars = 2 mm (a–h, k, l, n, o); 5mm (i, j, m).

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

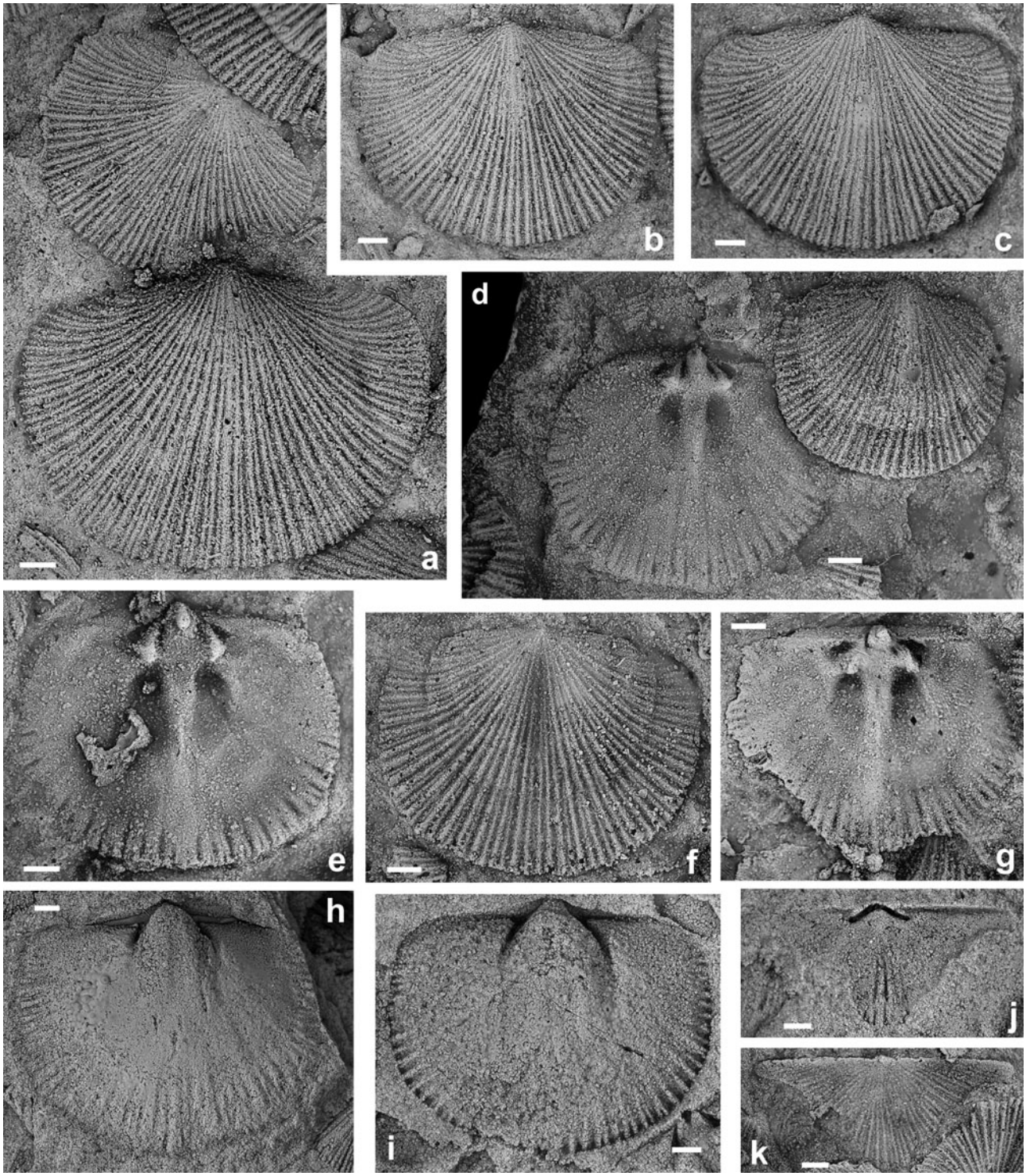

Figure 12 (a–i) *Tafilaltia dargazensis* sp. nov.: (a) NMW 2011.10G.17, latex cast of ventral exterior and NMW 2011.10G.18, latex cast of dorsal exterior; (b) NMW 2011.10G.15, latex cast of ventral exterior; (c, i) NMW 2011.10G.90, latex cast of ventral exterior and ventral internal mould; (d) NMW 2011.10G.110, latex cast of ventral exterior and NMW 2011.10G.111, latex cast of dorsal internal mould; (e) NMW 2011.10G.102, latex cast of dorsal interior; (f) NMW 2011.10G.116, latex cast of dorsal exterior; (g) NMW 2011.10G.13, latex cast of dorsal interior; (h) NMW 2011.10G.99, ventral internal mould; all from sample MG KF3b. (j, k) Aegiromeninae gen. et sp. indet., NMW 2011.10G.115, dorsal internal mould and latex cast of exterior, sample MG KF3b. Scale bars = 1 mm.

four-fifths of maximum shell width, cardinal extremities broadly rounded; anterior commissure weakly unisulcate. Ventral valve lateral profile moderately convex, with maximum height at about one-fourth of sagittal valve length from the umbo. Ventral valve transverse profile subcarinate posterior to mid-length, on average 24 % as deep as long. Ventral interarea slightly curved, low, subtriangular, apsacline, with a narrow, open delthyrium. Dorsal valve flat, with a shallow sulcus originating at umbo and fading gradually from mid-valve to the anterior margin. Dorsal interarea low, planar, anacline, with an open notothyrium. Radial ornament multicostellate, becoming weakly fascicostellate anterior to mid-valve in mature specimens, numbering 11–15 ribs per 3 mm along the anterior margin of mature specimens in 2, 4, 5, 6, 3 ventral valves.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

Table 2 Basic statistics for 32 ventral valves of *Tafilaltia dargazensis* sp. nov., sample MG KF3b.

	Lv	Iw	W	T	Sw	St	Lv/W	Iw/W	T/Lv	Ml/Lv	Ml/Mw
n	32	31	32	27	21	22	32	31	26	20	20
x	5.6	6.0	7.3	1.8	3.2	2.6	77.3 %	82.7 %	26.4 %	55.6 %	116.9 %
s	1.36	1.42	1.63	1.51	1.10	0.74	5.9	5.5	5.7	8.9	13.6
min	3.0	3.6	4.1	0.6	1.2	1.4	63.4 %	70.6 %	17.6 %	35.7 %	80.0 %
max	8.0	9.1	10.7	9	4.9	3.8	86.1 %	91.5 %	40.9 %	69.5 %	140.0 %

Table 3 Basic statistics for 22 dorsal valves of *Tafilaltia dargazensis* sp. nov., sample MG KF3b.

	Ld	Iw	W	BBw	Ml	Mw	Lv/W	Iw/W	Ml/Ld	Ml/Mw
n	22	19	22	19	16	15	22	19	16	15
x	5.6	5.8	7.1	2.1	3.1	2.2	79.6 %	82.5 %	53.2 %	141 %
s	0.79	0.91	0.97	0.35	0.51	0.43	6.6	5.9	5.8	20
min	3.9	4.3	5.2	1.6	2.3	1.6	69.3 %	64.9 %	45.1 %	109.5 %
max	7	7.3	8.7	2.7	4.2	3	98.4 %	90.4 %	66.7 %	180 %

Ribs along the posterior margin incurved posterolaterally and intersecting the hinge line.

Ventral valve interior with small pedicle callist and teeth supported by thin, divergent dental plates. Ventral muscle field large, bilobate, open anteriorly, bounded laterally by weak muscle bounding ridges, on average 56 % as long as valve. Adductor scar slightly raised anteriorly, narrow subtriangular, shorter than the large, weakly impressed diductor scars. Dorsal interior with trifid cardinal process, completely filling the narrow notothyrial cavity. Brachiophores short, slightly divergent, strongly thickened at the base. Notothyrial platform high, merged anteriorly with a broad median ridge bisecting the adductor muscle field. Adductor muscle scars strongly impressed with larger anterior pair; anterior border extends anteriorly on average for 53 % of sagittal length.

Remarks. *Tafilaltia dargazensis* sp. nov. differs from *Tafilaltia brevimusculosa* Villas, 1995, from the Upper Ordovician (Katian) 'Bancos Mixtos' of Central Spain in having a more transverse shell with a wide ventral muscle field extending anterior to mid-valve. The Iranian species can easily be distinguished from other species assigned to the genus (e.g., *Tafilaltia occidentalis* Havlíček, 1970 and *Tafilaltia destombesi* Havlíček, 1970, from the Upper Ordovician (Katian) of the Anti-Atlas, and *Tafilaltia dalmanelloides* Havlíček, 1970, from the Upper Ordovician (Katian) Dobrotivá Formation of Bohemia), by its bilobed (not flabellate) and weakly impressed ventral muscle field, open anteriorly.

Tafilaltia seyahouensis sp. nov.
(Fig. 13; Tables 4, 5)

Derivation of name. After the Seyahou Formation, which yields the type horizon for the taxon.

Holotype. NMW 2011.10G.453 (L = 7.4, W = 12.0, Iw = 7.9, Ml = 5.2, Mw = 4.2, BBw = 2.8), dorsal internal and external mould; Upper Ordovician, Katian, Seyahou Formation, sample MG10033, Faraghan Mountains, Zagros Range, Iran.

Paratypes. From sample MG10027: NMW 2011.10G.502, ventral external mould; NMW 2011.10G.497, 501, ventral internal moulds; NMW 2011.10G.498, dorsal internal mould. From sample MG10031: NMW 2011.10G.494.4–5, 495, ventral internal moulds; NMW 2011.10G.494.6–7, 559, dorsal external moulds; NMW 2011.10G.440, 491.1–2, 492, 493, 494.1–3, 496, dorsal internal moulds. From sample MG10033: NMW 2011.10G.473.2, 575.1, ventral valves; NMW 2011.10G.440–447, 478.1, ventral external and internal moulds; NMW 2011.10G.468, 471.5–6, 473.1, 477.1, 478.3, 479.3–4, 483.2–8, 484.1–2, 510.1, 511.1, ventral external moulds; NMW 2011.10G.471.1–4, 478.4, 479,1–2, 480.1–2, 482.1, 483.1, 484.3–5, 510.2, 518, ventral internal moulds; NMW 2011.10G.473.3–5, 575.2–3, dorsal valves; NMW 2011.10G.448–452, 454–456, 463–465, 478.2, 480.3, dorsal internal and external moulds; NMW 2011.10G.466, 469, 473.7–8, 474–476, 477.2, 479.4–8, 482.2, 483.9, 487, 488.4–5, 489.3–4, 510.3–4, 555.1–3, dorsal external moulds; NMW 2011.10G.467, 471.7–8, 477.3, 483.10–17, 484.6–7, 485, 486, 488.1–3, 489.1–2, 510.5–6, 511.2–4, 555.4–6, dorsal internal moulds. From sample MG10037: NMW 2011.10G.502.1–6, 515, ventral valves, NMW 2011.10G.470, 491.3–4, ventral external moulds; NMW 2011.10G.462, ventral internal mould; NMW 2011.10G.502.7–10, dorsal valves, NMW 2011.10G.499, 500.1–2, dorsal external moulds; NMW 2011.10G.500.3, dorsal internal mould. From sample MG2/2008: NMW 2011.10G.557.1–3, ventral valves, NMW 2011.10G.505.1, 527.4, 530.1, 535.1, ventral external moulds; NMW 2011.10G.495, 505.2–3, 527.1–2, 528, 531.5–8, 532.1–3, ventral internal moulds; NMW 2011.10G.505.4, 530.2, 532.4–5, 534.1–2, dorsal external moulds; NMW 2011.10G.496, 527.3, 530.3, 531.1–4, 535.2–3, 556, dorsal internal moulds; NMW 2011.10G.557.1, dorsal valve. A total of 83 ventral valves and 111 dorsal valves.

Diagnosis. Shell planoconvex, suboval in outline, about four-fifths as long as wide, with a hinge line about four-fifths as wide as the shell. Ventral valve subcarinate; dorsal valve with shallow sulcus shallowing and widening towards the anterior margin. Radial ornament multicostellate. Ventral interior characterised by slightly elongate, flabellate muscle field about 55 % as long as valve, with poorly defined anterior border; dorsal adductor muscle field strongly elongate, suboval, with deeply impressed adductor scars.

Description. Shell planoconvex, suboval, on average 78 % as long as wide, with maximum width at about mid-length. Hinge line straight, about four-fifths of maximum shell width, cardinal extremities broadly rounded; anterior commissure weakly unisulcate. Lateral profile of ventral valve moderately convex, with maximum height at about one-fourth to one-third of sagittal length from the umbo; transverse profile subcarinate; interarea slightly curved, low, subtriangular, apsacline, with a narrow open delthyrium. Dorsal valve almost flat, with a shallow sulcus originating at the umbo, widening

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

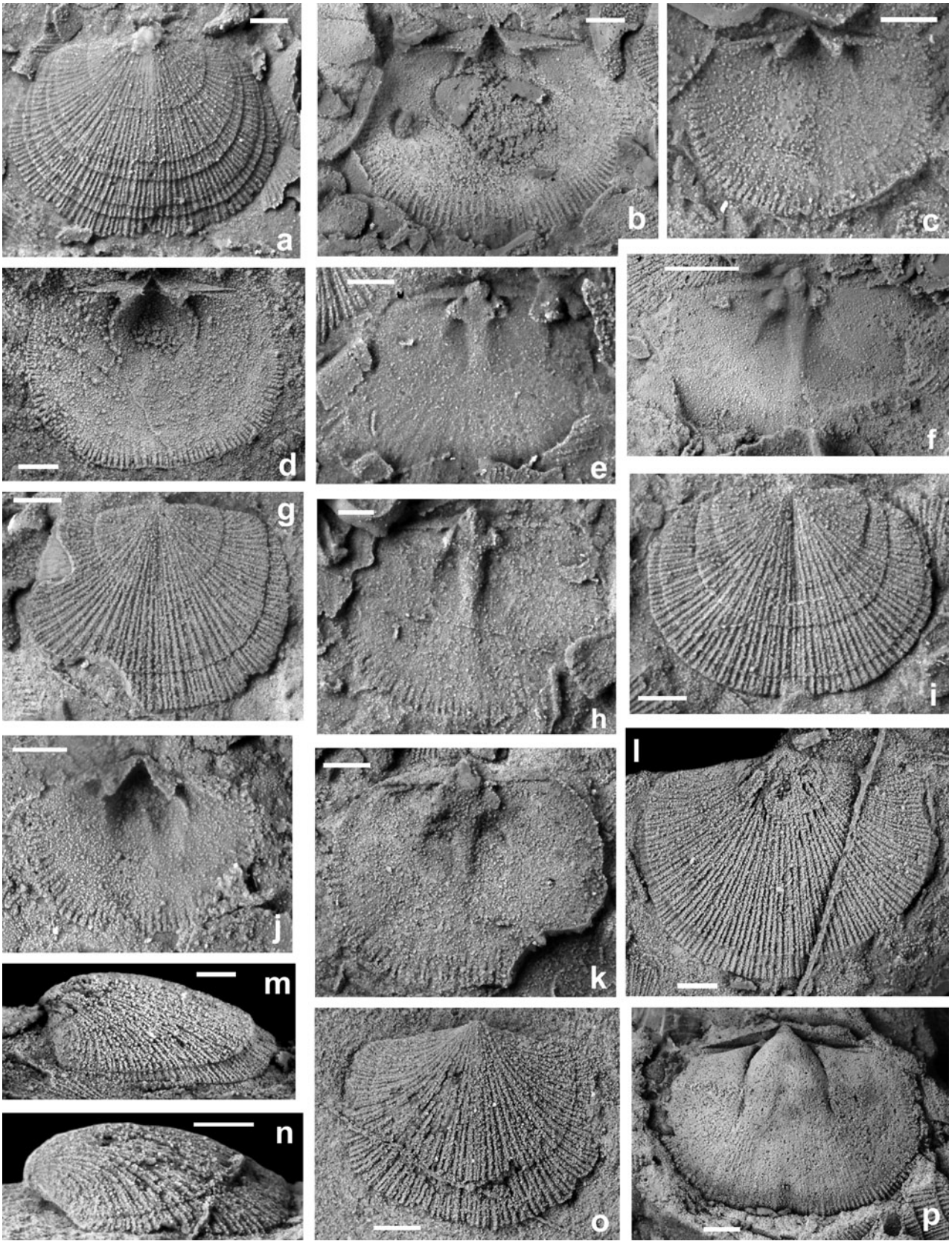

Figure 13 (a–o) *Tafilaltia seyahouensis* sp. nov.: (a, b) NMW 2011.10G.442, latex cast of ventral valve exterior and interior, sample MG10033; (c) NMW 2011.10G.440, latex cast of ventral valve interior, sample MG10033; (d) NMW 2011.10G.462, latex cast of ventral valve interior, sample MG10037; (e, g) NMW 2011.10G.448, latex cast of dorsal valve interior and exterior, sample MG10033; (f) NMW 2011.10G.461, latex cast of dorsal valve interior, sample MG10031; (h, i) NMW 2011.10G.453, holotype, latex cast of dorsal valve interior and exterior, sample MG10033; (j) NMW 2011.10G.497, latex cast of ventral interior, sample MG10027; (k) NMW 2011.10G.454, latex cast of dorsal valve interior, sample MG10033; (l, m) NMW 2011.10G.511.1, latex cast of ventral valve exterior, ventral and side views, sample MG10037; (n, o) NMW 2011.10G.468, latex cast of ventral valve exterior, side and ventral views, sample MG10033; (p) NMW 2011.10G.518, ventral internal mould, sample MG10037. Scale bars = 2 mm.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

Table 4 Basic statistics for 16 ventral valves of *Tafilaltia seyahouensis* sp. nov., sample MG 10033.

	Lv	Iw	W	Ml	Mw	Lv/W	Iw/W	Ml/Lv	Ml/Mw
n	16	10	13	10	10	13	10	10	9
x	9.1	8.9	11.4	4.5	4.0	78.3 %	80.7 %	55.8 %	113.8 %
s	1.91	1.68	2.45	1.06	0.69	6.8	10.3	6.1 %	12.7 %
min	5.2	5.6	6.4	2.8	2.6	65.4 %	64.6 %	43.7 %	97.2 %
max	12.3	11	14.4	6.4	4.8	87.3 %	95.5 %	62.9 %	133.3 %

Table 5 Basic statistics for 23 ventral valves of *Tafilaltia seyahouensis* sp. nov., sample MG 10033.

	Ld	Iv	W	BBw	Mw	Mt	Lv/W	Iw/W	Ml/Ld	Ml/Mw
n	23	21	23	7	12	11	22	19	12	11
x	8.6	8.7	11.2	2.6	4.9	3.8	77.0 %	79.2 %	54.4 %	131.6 %
s	1.51	1.48	1.81	0.15	0.53	0.60	6.7	25.6	5.8	14.6
min	4.6	4.4	5.8	2.4	3.9	2.8	61.7 %	39.3 %	47.4 %	107.1 %
max	10.5	10.8	14.5	2.8	5.8	4.9	86.2 %	175.9 %	70.3 %	157.6 %

and shallowing towards the anterior margin. Dorsal interarea low, planar, anacline, with open notothyrium. Radial ornament multicostellate, numbering 9-15 ribs per 3 mm along the anterior margin of mature specimens in 2, 8, 10, 10, 13, 3 and 1 specimens. Ribs along the posterior margin incurved posterolaterally, intersecting hinge line. Concentric ornament with up to five fine growth lamellae, more developed anterior to mid-length in mature specimens.

Ventral valve interior with a small pedical callist and teeth supported by thin, divergent dental plates. Ventral muscle field large, flabellate, on average 54 % as long as valve, bounded by weak muscle bounding ridges gradually fading anteriorly; adductor scar weakly defined, narrow, subtriangular, about three-fifths as short, as large, gently impressed diductor scars. Dorsal interior with trifid cardinal process completely filling the narrow notothyrial cavity. Brachiophores short, slightly divergent, strongly thickened at the base. Notothyrial platform high, merged anteriorly with a broad median ridge bisecting the adductor muscle field. Adductor muscle scars strongly impressed, with a larger anterior pair, extending anteriorly for 54 % of sagittal valve length from the umbo.

Remarks. *Tafilaltia seyahouensis* sp. nov. shows similar proportions of the shell, dorsal adductor scars, and morphology of cardinalia to *Tafilaltia dargazensis* sp. nov., but differs in being almost twice as large and in having a flabellate ventral muscle field with a significantly shorter adductor scar, a more prominent carina in the ventral valve and dorsal median sulcus, a more even multicostellate radial ornament and numerous concentric lamellae in the anterior half of the shell.

Tafilaltia dargazensis differs from *Tafilaltia brevilimnulosa* Villas, 1995 from the Upper Ordovician (Katian) 'Bancos Mixtos' of Central Spain in having a smaller, more transverse shell, with a wide ventral muscle field extending well beyond the mid-valve. *Tafilaltia dargazensis* differs from other species assigned to the genus (e.g., *Tafilaltia occidentalis* Havlíček, 1970 and *Tafilaltia destombesi* Havlíček, 1970 from the Upper Ordovician, Katian, of the Anti-Atlas, and *Tafilaltia dalmanelloides* Havlíček, 1970 from the Upper Ordovician, Katian, Dobrotivá Formation of Bohemia) in having a weakly-defined anteriorly ventral muscle field, with a longer ventral adductor scar occupying more than half of the muscle field length, and less prominent muscle bounding ridges surrounding the dorsal adductor muscle field.

Superfamily Enteletoidea Waagen, 1884
Family Draboviidae Havlíček, 1950
Subfamily Draboviinae Havlíček, 1950

Genus *Drabovia* Havlíček, 1950

Type species. By original designation; *Orthis redux* Barrande, 1848 from the Letná Formation (Upper Ordovician, Katian) of Bohemia.

Drabovia cf. *tenuiseptata* Havlíček, 1971
(Fig. 9b–q)

cf. 1971 *Drabovia tenuiseptata* Havlíček; p. 54, pl. 14, figs 7–9.

Material. NMW 2011.10G.330 (LV = 10.5, W = 14.2, Iw = 11.9), 360–362, ventral valves; NMW 2011.10G.335 (LV > 10.9, W = 15.9, Iw = 11.6, Ml = 4.5, Mw = 4.2), ventral internal and external mould; NMW 2011.10G.343, 345, 348, 349, 352, 357, ventral external moulds; NMW 2011.10G.332 (L = 11.2, Ml = 4.2, Mw = 3.8), 335, 342, 346, 353, ventral internal moulds; NMW 2011.10G.331 (L = 7.0, W = 9.9, Iw = 8.0), 363–366, dorsal valves; NMW 2011.10G.337 (L = 6.6, W = 9.2, Iw = 8.4; ribbing pattern: I, Iā, II, IIā, IIb̄, III, IIIā, IIIā1, IIIb̄, IIIå), 338 (L = 8.4; ribbing pattern: I, Iā, II, IIā, III, IIIā, IIIā1, IIIb̄), 339 (L = 9.5, W = 11.2, Iw = 9.1; ribbing pattern: I, Iā, II, IIā, IIb̄, III, IIIā, IIIā1, IIIb̄, IIIå), 344 (ribbing pattern: I, Iā, II, IIā, IIā1, IIb̄, III, IIIā, IIIā1, IIIb̄, IIIå), 355 (I, Iā, II, IIā, III, IIIā, IIIā1, IIIb̄, IIIå), 358 (L = 6.6, W = 8.9; ribbing pattern: I, Iā, II, IIā, III, IIIā, IIIā1, IIIb̄), dorsal external moulds; NMW 2011.10G.333, 336 (L = 8.4, W = 10.3, Iw = 9.2), 340 (L = 6.8, W = 8.3, Iw = 7.8), 341, 347, 350, 351, 354, 356, 359, dorsal internal moulds; all from sample MG KF6a. A total of 16 ventral valves and 21 dorsal valves.

Description. Shell ventribiconvex, transverse, suboval in outline, about three-quarters as long as wide, with maximum width between the hinge line and mid-length. Hinge line about 85 % shell width; cardinal extremities obtusely rounded; anterior commissure unisulcate. Ventral valve subcarinate with flattened flanks and a moderately and evenly convex lateral profile. Ventral interarea apsacline, low, triangular, gently curved with an open, narrow triangular delthyrium. Dorsal valve very gently convex, with a low apsacline interarea. Dorsal

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

sulcus shallow, originating at the umbonal area and weakening anteriorly. Radial ornament ramicostellate to fascicostellate, with 6–9 rounded ribs per 3 mm along the anterior margin of mature specimens in 2, 6, 11, and 1 specimens. External costellae almost absent in sectors I–III, with the exception of occasional presence of IIIå in the dorsal valve of mature specimens.

Ventral interior with small teeth supported by thin, divergent dental plates. Muscle field cordate, slightly longer than wide and about two-fifths as long as valve, flanked laterally by weak muscle bounding ridges fading anteriorly. Ventral muscle scars weakly impressed with adductor scar slightly narrower and shorter than diductor scars. Dorsal valve with a narrow, triangular notothyrial platform. Weakly bilobed cardinal process consisting of a short, linear shaft and a small, rounded myophore. Brachiophores short, triangular blade-like, slightly divergent. Dental sockets small, without fulcral plates. Median ridge low and broad, fading anteriorly.

Discussion. The Iranian shells are probably conspecific to *Drabovia tenuiseptata* Havlíček, 1971 from the Upper Ordovician (Katian) Lower Ktaoua Formation of the Anti-Atlas, Morocco in their small shell size and radial ornament characterised by internal branching in sectors I–III, the morphology of their cardinalia and the absence of fulcral plates; but differ in having an indistinctly bilobed cardinal process, not seen in *D. tenuiseptata*.

Drabovia elegans sp. nov.
(Fig. 14a–f, h–j)

Derivation of name. From Latin *elegans*, meaning 'elegant, fine, handsome'.

Holotype. NMW 2011.10G.506 (Ld = 6.8, W = 7.9, Iw = 5.3, Sl = 4.1), dorsal internal mould; Upper Ordovician, Katian, Seyahou Formation, sample MG10033, Faraghan Mountains, Zagros Range, Iran.

Paratypes. From sample MG10033: NMW2011.10G.501, dorsal external mould; NMW2011.10G.502, dorsal internal mould; NMW 2011.10G.481.1, ventral external mould; NMW 2011.10G.485, 512 (L = 7.2, W = 9.8, Iw = 8.1, Ml = 3.0, Mw = 3.4), ventral internal moulds; NMW 2011.10G.456–460, dorsal internal and external moulds; NMW 2011.10G.472.1, 507 (L = 7.8, W = 9.8, Iw = 8.5, Sl = 4.4; ribbing pattern: I, Iā, II, IIā, IIb̄, III, IIIā, IIIā1, IIIb̄, IIIå), 503, dorsal external moulds, NMW 2011.10G.472.1, 481.2, 508, 509, 513, 514, 516, 517, dorsal internal moulds. From sample MG10027: NMW 2011.10G.503, dorsal external mould; NMW 2011.10G.504, dorsal internal mould. From sample MG2/2008: NMW 2011.10G.558, dorsal valve, NMW 2011.10G.529, 533, 1–2, dorsal internal moulds. A total of three ventral valves and 22 dorsal valves.

Diagnosis. *Drabovia* with a slightly transverse, subequally biconvex shell and a weakly unisulcate anterior commissure. Radial ornament fascicostellate with external costellae almost absent in sectors I–III. Dorsal interior with characteristic anterior extensions of brachiophore bases convergent towards the median ridge and enclosing a rhomboidal area, which divides posteriorly the weakly-impressed dorsal adductor muscle field. Dorsal median ridge faint, extending anterior to mid-length.

Description. Shell subequally biconvex, slightly transverse, suboval in outline, with a hinge line about 83–87 % as wide as maximum shell length at mid-length. Cardinal extremities obtusely rounded; anterior commissure weakly unisulcate. Ventral valve moderately convex, with a low, apsacline ventral interarea and an open delthyrium. Dorsal valve evenly convex, with maximum depth slightly posterior to mid-length. Dorsal interarea low, flat, apsacline, with open notothyrium. Dorsal sulcus shallow, originating at umbo and gradually fading towards the anterior margin. Radial ornament weakly fascicostellate, with 8–10 rounded ribs per 3 mm along the anterior margin of mature specimens. External costellae almost absent in sectors I–III, with the exception of occasional presence of IIIå in mature specimens.

Ventral interior characterised by small pedicle callist and widely divergent dental plates, extending anteriorly as faint muscle bounding ridges enclosing the muscle field. Adductor scar slightly raised, narrow, triangular, shorter than the weakly impressed diductor scars. Dorsal interior with blade-like, slightly divergent brachiophores. Anterior extensions of brachiophore bases convergent towards median ridge. Cardinal process with a short, ridge-like shaft and an ovoid myophore with a crenulated posterior face filling the narrow notothyrial cavity. Median ridge low, inflated posteriorly, becoming thin anterior to the distal ends of brachiophore bases and terminated anterior to mid-valve. Dental sockets small, without distinct fulcral plates.

Remarks. The most distinctive futures of the new species are: (1) the cardinalia with the anterior extensions of the brachiophore bases converging anteriorly and merging with the median ridge, which form a characteristic rhomboidal platform dividing a posterior part of the weakly-impressed dorsal adductor muscle field; and (2) the faint, long dorsal median ridge extending anterior to the mid-length. Both features are relatively rare in the *Drabovia* species. Smilar morphology of the cardinalia and the long dorsal median ridge are also characteristic of *Drabovia pentagonomya* Havlíček, 1971 from the Upper Ordovician (Katian) Lower Ktaoua Formation of the Anti-Atlas, Morocco; but the latter species is almost twice as large as *Drabovia elegans*, it has anterior terminations of the brachiophore bases not merging with the dorsal median ridge and more even radial ornament, unlike the Iranian species.

Another similar species is *Drabovia postrema* Havlíček, 1951 from the Bohdalec Formation (Upper Ordovician, Katian) of the Brague Basin, Bohemia; however, the brachiophore bases in this species only slightly converge anteriorly and it lacks dorsal median ridge.

Drabovia tenuiseptata Havlíček, 1971 from the ower Ktaoua Formation of the Anti-Atlas, Morocco and *Drabovia* cf. *tenuiseptata* Havlíček, 1971 from the Seyahou Formation of Zagros, Iran can be easily distingwished from *Drabovia elegans* in having shorter brachiophore bases not distinctly converging anteriorly and a very short dorsal median ridge.

Genus Protomendacella Havlíček, 1970

Type species. By original designation; *Protomendacella eos* Havlíček, 1970 from the Lower Ktaoua Formation (Upper Ordovician, Katian) of the Anti-Atlas, Morocco.

Remarks. Havlíček (1970, 1981) considered *Protomendacella* within the Rhipidomellidae; however, we follow here Willliams & Harper (2000, p. 831), who suggested its placement within the Draboviidae.

Protomendacella multicostata sp. nov.
(Figs 9y, 14n–o, 15)

Derivation of name. After characteristic multicostate radial ornament.

Holotype. NMW 2011.10G.537 (L = 13.4, W = 16.0, Iw = 13.6, BBw = 3.0), dorsal internal mould; Upper Ordovician, Katian, Seyahou Formation, sample MG10078, Faraghan Mountains, Zagros Range, Iran.

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

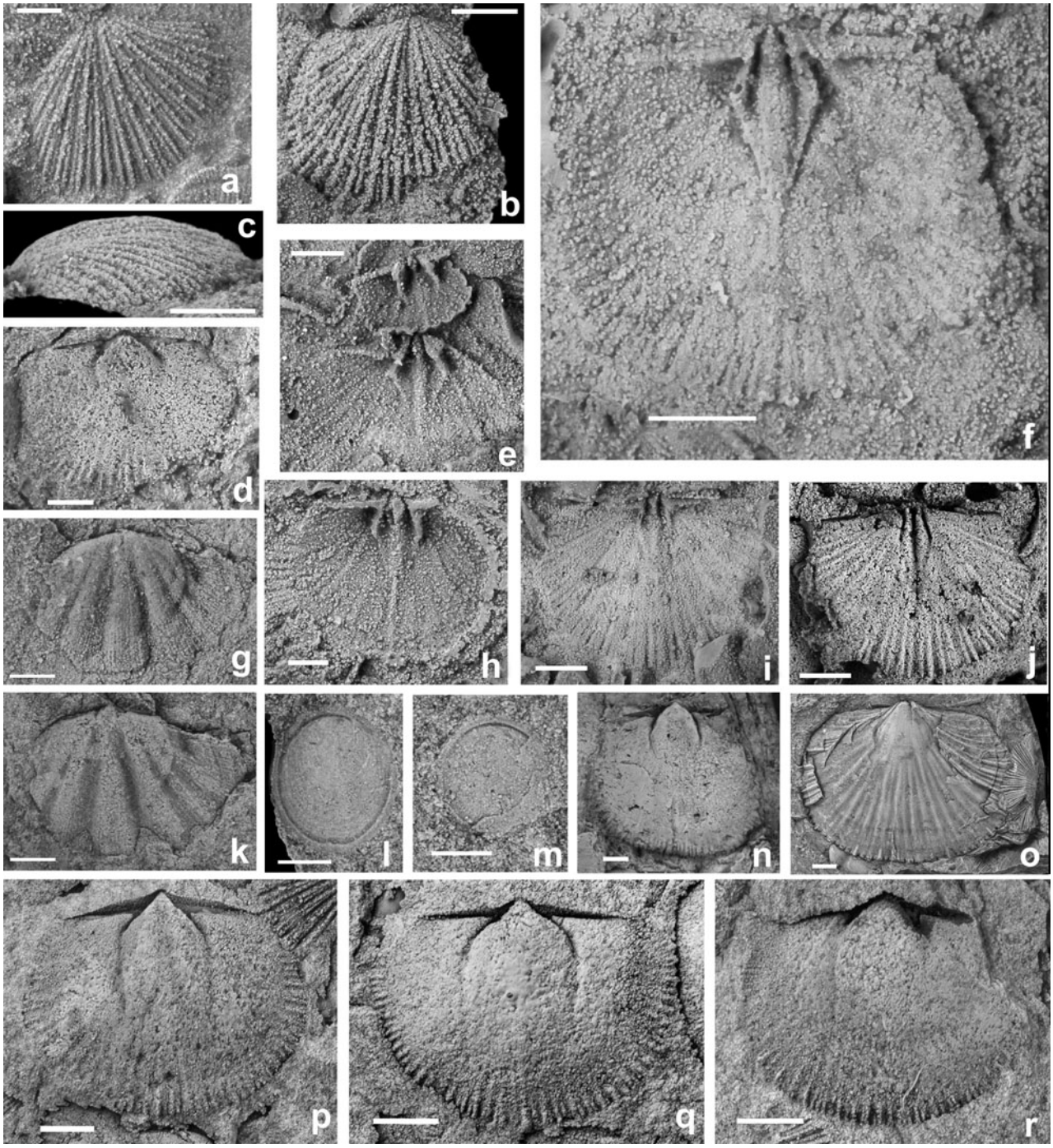

Figure 14 (a–f, h–j) *Drabovia elegans* sp. nov.: (a) NMW 2011.10G.456, latex cast of dorsal valve exterior, sample MG10033; (b, c) NMW 2011.10G.503, latex cast of dorsal valve exterior, dorsal and side views, sample MG10027; (d) NMW 2011.10G.512, ventral internal mould, sample MG10033; (e) NMW 2011.10G.516, 517, latex cast of dorsal valve interior, sample MG10033; (f) NMW 2011.10G.506, holotype, latex cast of dorsal valve interior, sample MG10033; (h) NMW 2011.10G.504, latex cast of dorsal valve interior, sample MG10027; (i, j) NMW 2011.10G.508, latex cast of dorsal valve interior and dorsal internal mould, sample MG10033. (g, k) Hedeinopsidae gen. et sp. indet.: latex cast of dorsal exterior and dorsal internal mould; sample MG20010. (l, m) *Paterula* sp.: (l) NMW 2011.10G.567, dorsal valve exterior; (m) NMW 2011.10G.569, ventral valve exterior; sample MG10173. (n, o) *Protomendacella multicostata* sp. nov.: (n) NMW 2011.10G.538, ventral internal mould, sample MG10066; (o) NMW 2011.10G.375, exfoliated ventral valve, sample MG Sy-A/6. (p–r) *Tafilaltia dargazensis* sp. nov.: (p) NMW 2011.10G.90, holotype, ventral internal mould; (q) NMW 2011.10G.51, ventral internal mould; (r) NMW 2011.10G.78, ventral internal mould; all from sample MG KF3b. Scale bars = 2 mm (a–f, h–j, n–r); 1 mm (g, k, l, m).

Paratypes. From sample MG10027: NMW 2011.10G.536 (Ld = 18.0, W = 22.2, Iw = 19.7, BBw = 3.0), dorsal internal mould. From sample MG10066: NMW 2011.10G.539, ventral external mould; NMW 2011.10G.538, 540, 542.1–2, 549 (Lv10.8, W = 14.5, Ml = 4.7, Mw = 4.0) ventral internal moulds; NMW 2011.10G.541, dorsal valve; NMW 2011.10G.542.1–4, dorsal internal moulds. From sample MG10078: NMW 2011.10G.274, ventral valve; NMW 2011.10G.273, 370, 373, 375 (Lv = 12.2, W = 16.5, Iw = 13.5, Ml = 3.9, Mw = 5.0), ventral internal moulds. From sample MG Sy-A/5: NMW 2011.10G.546 (Ld = 17.8, W = 24.4, Iw = 19.7), dorsal valve. From sample MG Sy-A/6:

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

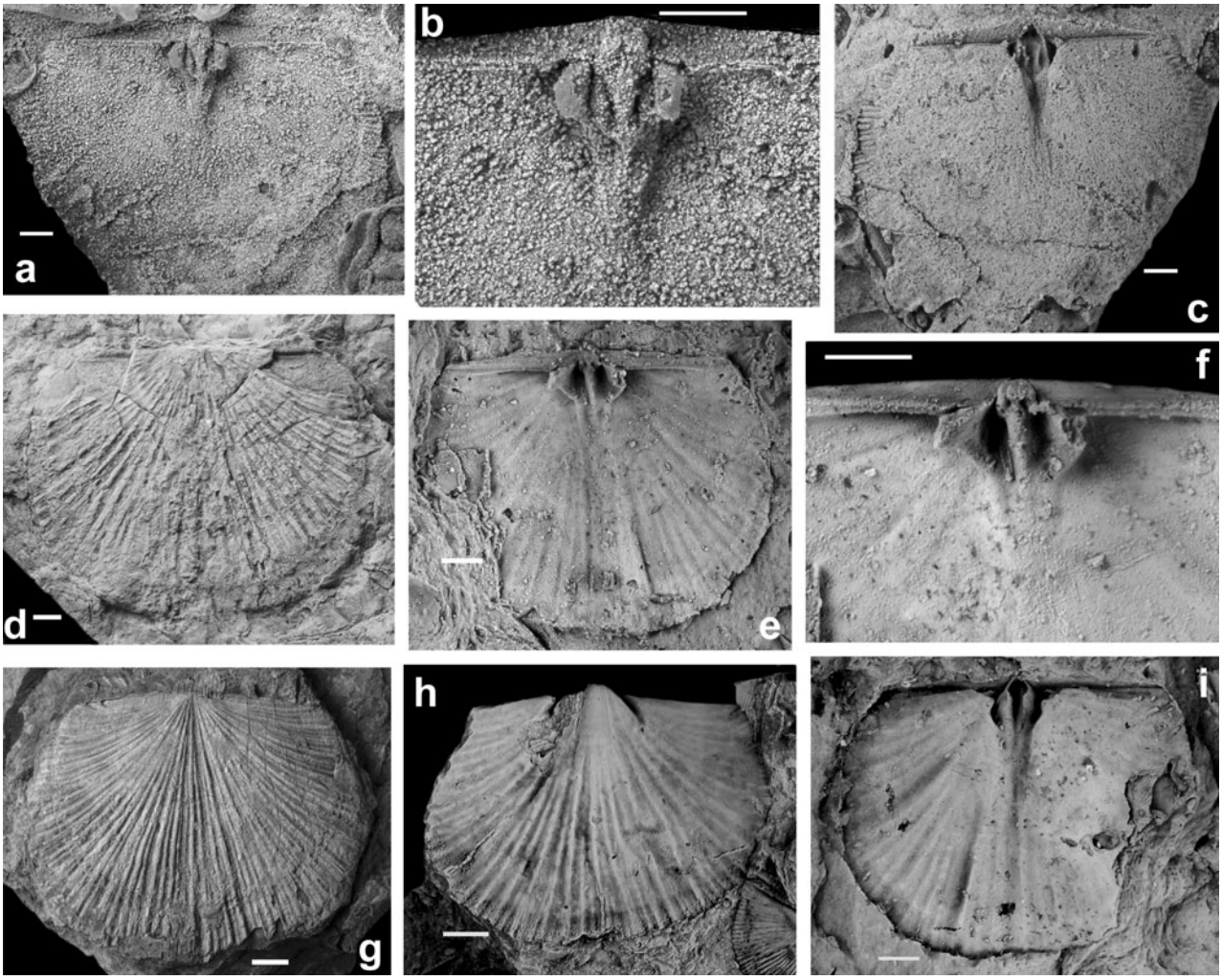

Figure 15 *Protomendacella multicostata* sp. nov.: (a–c) NMW 2011.10G.535, latex cast of dorsal interior, enlarged cardinalia and internal mould, sample MG10027; (d) NMW 2011.10G.547, dorsal valve exterior, sample MG Sy-A/7; (e, f, i) NMW 2011.10G.537, latex cast of dorsal interior, enlarged cardinalia and internal mould, sample MG10078; (g) NMW 2011.10G.546, dorsal valve exterior, sample MG Sy-A/5; (h) NMW 2011.10G.538, ventral internal mould, sample MG10078. Scale bars = 2 mm.

NMW 2011.10G.375, 548, ventral internal moulds. From sample MG Sy-A/7: NMW 2011.10G.547 (Ld = 15.3, W = 19.1, Iw = 14.8), dorsal valve. A total of 13 ventral valves and nine dorsal valves.

Diagnosis. *Protomendacella* with transverse, subrectangular shell about as long as wide; slightly unequally multicostellate radial ornament with 5–7 ribs per 3 mm; weakly impressed, open anteriorly ventral muscle field; and a weak dorsal sulcus in posterior half of the valve.

Description. Shell subequally biconvex, transverse, subrectangular, about three-fourths as long as wide, with maximum width at mid-length. Hinge line about 75–90 % as long as wide; anterior commissure rectimarginate. Ventral valve evenly convex, with a gently curved, strongly apsacline interarea. Delthyrium open, narrow and triangular. Dorsal valve with a shallow sulcus fading anterior to mid-length. Dorsal interarea low, flat and anacline. Radial ornament slightly unequally multicostellate, with up to 18 primary ribs and 5–7 ribs per 3 mm along the anterior margin of mature specimens. Concentric ornament of fine, densely spaced fila.

Ventral valve interior with teeth, supported by thin, short and narrowly divergent dental plates. Ventral muscle field slightly elongate, suboval, weakly impressed, open anteriorly and about two-thirds as long as the valve. Adductor scars as long as diductor scars. Dorsal valve interior with a strong cardinal process divided into a broad, ridge-like shaft and bilobate myophore, situated on a narrow notothyrial platform. Brachiophores supported by short, subparallel plates converging towards the notothyrial platform and extending anteriorly as short ridges. Dorsal median ridge broad and short.

Remarks. The Iranian shells differ from the type species *Protomendacella eos*, and from *P. profuga* Havlíček, 1981 from the Gabian Formation (upper Katian), in having a transverse, subrectangular shell, slightly coarser and unequally multicostellate radial ornament, a weak but distinct dorsal sulcus, and a weakly impressed ventral muscle field open anteriorly; however, the presence or absence of the dorsal sulcus cannot be confirmed in *Protomendacella eos*, since all the known dorsal valves are preserved as internal moulds.

3.2. Silurian brachiopods

Order Lingulida Waagen, 1885
Superfamily Linguloidea Menke, 1828
Family Paterulidae Cooper, 1956

Genus *Paterula* Barrande, 1879

Type species. By original designation; *Paterula bohemica* Barrande, 1879 from the Vinice Formation (Upper Ordovician, Sandbian) of Bohemia.

Paterula sp.
(Fig. 15l–m)

https://doi.org/10.1017/S1755691015000079 Published online by Cambridge University Press

Material. NMW 2011.10G.567, 568, dorsal valves; NMW 2011.10G.569, ventral valve; all from sample MG 10173. A total of one ventral valve and two dorsal valves.

Remarks. A few lingulide specimens found in the Rhuddanian part of the the Sarchahan Formation exhibit dorsibiconvex shells with holoperipheral growth and eccentric apex of both valves and a pedicle notch on the ventral valve, which are characteristic of *Paterula*. They may represent a new formerly unknown species, but poor preservation and the paucity of the material collected prevent better identification of the taxon.

Paterula has not been formally described from the Silurian; however, brachiopods found by Lenz (1993) in Silurian black shales of Cornwallis Island, Arctic Canada (Ludlow, *Lobograptus progenitor* Zone) attached around the oscular margin of a sponge belongs, not to *Craniops*, which lacks a pedicle attachment, but to *Paterula*, as noted by Holmer *et al*. (2005).

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Cyrtioidea Frederiks, 1924
Family Hedeinopsidae Gourvennec, 1990

Genus *Iranospirifer* Popov & Cocks, 2013

Type species. By original designation; *Iranospirifer qarabilensis* Popov & Cocks, 2013 from the Qarabil Limestone Formation (Silurian, Aeronian) of Kopet-Dagh, North Khorosan Province, Iran.

Iranospirifer sp.
(Fig. 15g, k)

Material. NMW 2011.10G.570, dorsal external and internal mould from sample MG20010.

Remarks. A single specimen from black shales of the Sarchahan Formation (Aeronian, *D. triangulatus* Zone) was collected as a dorsal external and internal mould. It exhibits a transverse suboval outline and a narrow, evenly curved in cross section dorsal median fold, three broad, rounded plications on flanks and superimposed very fine striae, numbering 12 per mm. The dorsal interior shows minute crura and rudimentary crural plates; ctenophoridium lacking. The specimen is probably conspecific with the shells from the Aeronian Qarabil Limestone of the Iranian Kopet-Dagh, described and illustrated by Popov & Cocks (2013) as *Iranospirifer qarabilensis*. In addition to the delicate cardinalia with rudimentary crural plates, the ventral valves from Kopet-Dagh have a delthyrium, partly covered by a concave apical plate and well-developed, extrasinal dental plates, suggesting their attribution to the family Hedeinopsidae.

4. Acknowledgements

We are grateful to Robin Cocks and Yves Candela for their comprehensive and constructive comments, which were very helpful in improving the manuscript. The research of Dr Mohammad Ghavidel-Syooki has been financed by the Iranian Offshore Oil Company (IOOC). Mansoureh Ghobadi Pour and Leonid Popov acknowledge logistical support from the National Museum of Wales. Fieldwork and research in Iran carried out by Mansoureh Ghobadi Pour was supported by Golestan University. Reza Zare and Yaser Sheikhan are thanked for field assistance.

5. References

Alikhova, T. N. 1951. *Brachiopods of the middle and upper parts of the lower Silurian of the Leningrad region and their stratigraphical significance.* Moscow: Gosgeolizdat. 81 pp, 4 pl.

Bancroft, B. B. 1928. On the notational representation of the rib-system in Orthacea. *Manchester Literary and Philosophical Society, Memoirs and Proceedings* **72**, 53–90.

Bancroft, B. B. 1929. Some new genera and species of Strophomenacea from the Upper Ordovician of Shropshire. *Memoirs and Proceedings of the Manchester Literary and Philosophical Society* **73**, 33–65.

Bancroft, B. B. 1949. *Welsh Valentian brachiopods and the Strophomena antiquata Group of fossil brachiopods.* Mexborough: privately published. 16 pp, 3 pls.

Barrande, J. 1848. Über die Brachiopoden der silurischen Schichten von Böhmen. *Naturwissenschaftliche Abhandlungen* **2**, 155–256.

Barrande, J. 1879. *Système Silurien du Centre de la Bohême, 1ère Partie, Recherches Paléontologiques, vol. 6. Classe des Mollusques: Ordre des Brachiopodes.* Prague and Paris: published by the author.

Bouché, P. M. 1965. Chitinozoaires du Silurien s.1. du Djado (Sahara nigerien). *Révue de Micropaléontologie* **8**, 151–64.

Caster, K. E. 1939. A Devonian fauna from Colombia. *Bulletin of American Paleontology* **24**, 1–218.

Cocks, L. R. M. & Rong Jia-yu. 2000. Order Strophomenida. *In* Kaesler, R. L. (ed.) *Treatise on Invertebrate Paleontology, Vol. H, Brachiopoda 2 (revised)*, 216–348. Boulder, Colorado & Lawrence, Kansas: Geological Society of America & Kansas University Press.

Colmenar, J., Villas, E. & Vizcaïno, D. 2013. Upper Ordovician brachiopods from the Montagne Noire (France): endemic Gondwanan predecessors of Prehirnantian low-latitude immigrants. *Bulletin of Geosciences* **88**, 153–74.

Colmenar, J., Harper, D. A. T. & Villas, E. 2014. Morphofunctional analysis of Svobodaina species (Brachiopoda, Heterorthidae) from southwestern Europe. *Palaeontology* **57**, 193–214.

Cooper, G. A. 1956. Chazyan and related brachiopods. *Smithsonian Miscellaneous Collections* **127**, 1–1245, pls 1–269.

Dalman, J. W. 1828. Uppställning och Beskrifning af de i sverige funne Terebratuliter. *Kungliga Svenska Vetenskapsakademien Handlingar* **3**, 85–155.

Elles, G. L. & Wood, E. M. R. 1907. British graptolites. Part 6. *Monograph of the Palaeontographical Society, London*, 217–72, pls 28–31. (Issue 297, part of Volume 61).

Emmons, E. 1842. *Geology of New York. Part II. Comprising the survey of the second geological district. Natural History of New York*, x + 1–437. Albany, New York: Charles van Benthuysen and Sons.

Frederiks, G. N. 1924. Paleontologitcheskiye etyudy. 2. O verkhnekamenougolnykh spiriferidakh Urala. [Paleontological studies. 2. On Upper Carboniferous spiriferids from the Urals.] *Izvestyia geologicheskogo Komiteta* **38**, 295–324. (Volume 38 (for 1919) was published in 1924).

Ghavidel-Syooki, M., Álvaro, J. J., Popov, L.E., Ghobadi Pour, M., Ehsani, M.H. & Suyarkova, A. 2011. Stratigraphic evidence for the Hirnantian (latest Ordovician) glaciation in the Zagros Mountains, Iran. *Palaeogeography, Palaeoclimatology, Palaeoecology* **307**, 1–16.

Ghavidel-Syooki, M., Popov, L. E., Álvaro, J. J., Ghobadi Pour, M. & Ehsani, M. H. 2014. Dapingian–lower Darriwilian (Ordovician) stratigraphic gap in the Kuh-e Faraghan Mountains, Zagros Ranges, southeastern Iran. *Bulletin of Geosciences* **89**(4), 679–706.

Gorjansky, V. Yu. 1972. Novyie ordovikskiie i silurijskiie bezzamkovyie brakhiopody Kazakhstana. [New Ordovician and Silurian inarticulate brachiopods of the USSR.] *In* Zanina, V. (ed.) *Novyie vidy drevnikh rastenii i bespozvonochnykh SSSR*, 169–73. Moscow: Nauka. [In Russian.]

Gorjansky, V. Yu. & Popov, L. E. 1985. [Morphology, systematic position and the origin of inarticulated brachiopods with carbonate shell.] *Paleontologicheskii Zhurnal* **1985**(3), 3–14. [In Russian.]

Gourvennec, R. 1990. Un genre nouveau de Cyrtiacea (Brachiopoda) du Silurien supérieur d'Espagne. *Geobios* **23**, 141–47.

Hall, J. 1859. Observations on genera of Brachiopoda. *Contributions to the Paleontology of New York, 12th Annual Report*, 8–110. Albany, New York: Charles van Benthuysen and Sons.

Hall, J. & Clarke, J. M. 1892. *An introduction to the study of the genera of Palaeozoic Brachiopoda.* New York State Geological

Survey, Palaeontology of New York, 1–367. Albany, New York: Charles van Benthuysen and Sons.
Harper, D. A. T., Mitchell, W. I., Owen, A. W. & Romano, M. 1985. Upper Ordovician brachiopods and trilobites from the Clashford House Formation, near Herbertstown, Co. Meath, Ireland. *Bulletin of the British Museum (Natural History), Geology* **38**, 287–308.
Havlíček, V. 1950. Ramenonozci Ceského Ordoviku. [The Ordovician Brachiopoda from Bohemia]. *Rozpravy Ústredního ústavu geologického* **13**, 1–72. [In Czech.]
Havlíček, V. 1951. The Ordovician brachiopoda from Bohemia. *Rozpravy Ústředního ústavu geologického* **12**, 1–135.
Havlíček, V. 1952. On the Ordovician representatives of the family Plectambonitidae (Brachiopoda), Sbornik Ústředního ústavu geologického **19**, 397–428.
Havlíček, V. 1961. Plectambonitacea im böhmischen Palaözoikum (Brachiopoda). *Vestník Ústredního ústavu geologického* **36**, 447–51.
Havlíček, V. 1967. Brachiopoda of the suborder Strophomenidina in Czechoslovakia. Rozpravy Ústředního ústavu geologického **33,** 1–235, pls 1–52.
Havlíček, V. 1970. Heterorthidae (Brachiopoda) in the Mediterranean Province. *Sborník Geologickych ved, Paleontologie* **12**, 7–40.
Havlíček, V. 1971. Brachiopodes de l'Ordovicien du Maroc. *Notes et Mémoires du Service Géologique du Maroc* **230**, 1–135.
Havlíček, V. 1974. New genera of Orthidina (Brachiopoda) in the Lower Palaeozoic of Bohemia. *Vestník Ústredního ústavu geologického* **49**, 167–70.
Havlíček, V. 1977. Brachiopods of the Order Orthida in Czechoslovakia. Rozpravy Ústředního ústavu geologického **44**, 1–327.
Havlíček, V. 1981. Upper Ordovician brachiopods from the Montagne Noire. *Palaeontographica (Abt. A)* **176**, 1–34.
Havlíček, V., Kříž, J. & Serpagli, E. 1987. Upper Ordovician brachiopod assemblages of the Carnic Alps, Middle Carinthia and Sardinia. *Bolletino della Societá Paleontologica Italiana* **25**, 277–311.
Havlíček, V. & Mergl, M. 1982. Deep water shelly fauna in the latest Kralodvorian (upper Ordovician, Bohemia). *Vestník Ústredního ústavu geologického*, 57, 37–46.
Holmer, L. E., Popov, L. E., Streng, M. & Miller, J. F. 2005. Lower Ordovician (Tremadocian) lingulate brachiopods from the House and Fillmore formations, Ibex Area, Western Utah, USA. *Journal of Paleontology* **79**, 884–906.
Hurst, J. 1979. The stratigraphy and brachiopods of the upper part of the type Caradoc of south Salop. *Bulletin of the British Museum (Natural History), Geology* **32**, 183–304.
Jin, J. & Bergström, J. 2010 True *Dalmanella* and taxonomic implications for some Late Ordovician dalmanellid brachiopods from North America. *GFF* **132**, 13–24.
Jones, O. T. 1928. *Plectambonites* and some allied genera. *Memoirs of the Geological Survey of Great Britain, Palaeontology* **1,** 367–527.
King, W. 1846. Remarks on certain genera belonging to the class Palliobranchiata. *Annals and Magazine of Natural History, Series 1* **18**, 26–42.
Lenz, A. C. 1993. A Silurian sponge-inarticulate brachiopod life? association. *Journal of Paleontology* **67**, 138–39.
Leone, F., Hammann, W., Serpagli, E. & Villas, E. 1991. Lithostratigraphic units and biostratigraphy of the post-Sardic Ordovician sequence in southwest Sadinia. *Bollettino della Società Paleontologica Italiana* **30**, 201–35.
Lockley, M. G. & Williams, A. 1981. Lower Ordovician Brachiopoda from mid and southwest Wales. *Bulletin of the British Museum (Natural History), Geology* **35**, 1–78.
Loi, A., Ghienne, J. -F., Dabard, M. P., Paris, F., Botquelen, A., Christ, N., Elaouad-Debbaj, Z., Gorini, A., Vidal, M., Videt, B. & Destombes, J. 2010. The Late Ordovician glacio-eustatic record from a high-latitude storm-dominated shelf succession: the Bou Ingarf section (Anti-Atlas, Southern Morocco). *Palaeogeography, Palaeoclimatology, Palaeoecology* **296**, 332–58.
Loydell, D. K., Butcher, A. & Frýda, J. 2013. The middle Rhuddanian (lower Silurian) 'hot' shale of North Africa and Arabia: An atypical hydrocarbon source rock. *Palaeogeography, Palaeoclimatology, Palaeoecology* **386**, 233–56.
M'Coy, F. 1851. On some new Cambro-Silurian fossils. *Annals and Magazine of Natural History (Series 2)* **8**, 387–409.
Mélou, M. 1975. Le genre *Heterorthina* (Brachiopoda, Orthida) dans la formation des Schistes de Postolonnec (Ordovicien), Finistère, France. *Geobios* **8**, 191–208.
Menke, C. T. 1828. *Synopsis methodica Molluscorum generum omnium et specierum earum, quae in Museo Menkeano Adservantur*. Pyrmonti. 91 pp.
Moore, R. C. 1952. Brachiopods. *In* Moore, R. C., Lalicker, C. G. & Fisher, A. G. (eds) *Invertebrate Fossils*, 197–267. New York: McGraw-Hill.
Nikiforova, O. I. 1982. Pervyye nakhodki ordovikskikh bezzamkovykh brakhiopod na Taimyre, [First discovery of the Ordovician inarticulate brachiopods from Taimyr]. *Ezhegodnik Vsesoyuznogo Paleontologicheskogo Obshchestva* **25**, 253–263. [In Russian.]
Öpik, A. A. 1930. Brachiopoda Protremata der estländischen Ordovizischen Kukruse-Stufe. *Acta et Commentationes Universitatis Tartuensis (Dorpatensis)*, *A* **17**, 1–262.
Öpik, A. A. 1934. Über Klitamboniten. *Acta et Commentationes Universitatis Tartuensis (Dorpatensis)*, *A* **26**, 1–239.
Popov, L. E. & Cocks, L. R. M. 2013. The radiation of early Silurian spiriferide brachiopods, with new taxa from the Llandovery of Iran. *Alcheringa* **37**, 558–64.
Popov, L. E. & Pushkin, V. I. 1986. Ordovikskiye brakhiopody yuzhnoi Pribaltiki. [Ordovician brachiopods of the southern East Baltic.]. *In* Garetskii, R. G., Zubovich, S. F. & Pushkin, V. I. (eds) *Novyye i maloizvestnyye vidy iskopayemykh zhivotnykh i rastenii Belorussii*, 11–22. Minsk: Nauka i Tekhnika. [In Russian.]
Rong, J. & Cocks, L. R. M. 1994 True *Strophomena* and a revision of the classification of strophomenind and 'stropheodontid' brachiopods. *Palaeontology* **37**, 651–94.
Rõõmusoks, A. 1993. Four new brachiopod genera of the subfamily Oepikinae (Strophomenacea) from the Ordovician of Estonia. *Eesti Teaduste Akadeemia Toimetised, Geoloogia*, **42**, 48–57.
Schuchert, C. 1893. A classification of the Brachiopoda. *American Geologist* **11**, 141–67.
Schuchert, C. 1913. Class 2. Brachiopoda. *In* von Zittel, K. A. (ed.) *Textbook of Palaeontology, Vol. 1*, 355–420. Second edition. London: MacMillan.
Schuchert, C. & Cooper, G. A. 1931. Synopsis of the brachiopod genera of the suborders Orthoidea and Pentameroidea, with notes on the Telotremata. *American Journal of Science* **22**, 241–51.
Schuchert, C. & Cooper, G. A. 1932. Brachiopod genera of the suborders Orthoidea and Pentameroidea. *Memoirs of the Peabody Museum of Natural History* **4**, 1–270.
Spjeldnaes, N. 1957. The Middle Ordovician of the Oslo Region, Norway, 8. Brachiopods of the suborder Strophomenida. *Norsk Geologisk Tidsskrift* **37**, 1–214.
Torsvik, T. H. & Cocks, L. R. M. 2011. The Palaeozoic palaeogeography of central Gondwana. *In* Van Hinsbergen, D. J. J., Buiter, S. J. H., Torsvik, T. H., Gaina, C. & Webb, S. J. (eds) *The Formation and Evolution of Africa: A Synopsis of 3.8 Ga of Earth History. Geological Society, London, Special Publications* **357**, 137–66. Bath, UK: The Geological Society Publishing House.
Villas, E. 1985. Braquiópodos del Ordovícico Medio y Superior de las Cadenas Ibéricas Orientales. *Memorias del Museo Palaeontológico de la Universidad de Zaragoza* **1**(1–2), 1–22.
Villas, E. 1992. New Caradoc brachiopods from the Iberian Chains (Northeastern Spain) and their stratigraphic significance. *Journal of Paleontology* **66**, 772–793.
Villas, E. 1995. Caradoc through Early Ashgill Brachiopods from the Central-Iberian zone (Central Spain). *Geobios* **28**, 49–84.
Villas, E., Harper, D. A. T., Mélou, M. & Vizcaïno, D. 1995. Stratigraphical significance of the *Svobodaina* species (Brachiopoda, Heterorthidae) range in the Upper Ordovican of South-Western Europe. *In* Cooper, J. D., Droser, M. L. & Finney, S. C. (eds) *Ordovician Odyssey. Short Papers for the Seventh International Symposium on the Ordovician System, Las Vegas 1995*, 97–98. Fullerton, California: SEPM.
Villas, E., Hammann, W. & Harper, D. A. T. 2002. *Foliomena* fauna (Brachiopoda) from the Upper Ordovician of Sardinia. *Palaeontology* **45**, 267–295.
Villas, E., Vizcaïno, D., Álvaro, J. J., Destombes, J. & Vennin, E., 2006. Biostratigraphic control of the latest Ordovician glaciogenic unconformity in Alnif (Eastern Anti-Atlas, Morocco), based on brachiopods. *Geobios* **39**, 727–37.
Vinassa, P. 1927. Fossili ordoviciani sardi. *Memorie Reale Accademia dei Lincei, Rome (series 6a)* **2**(16), 437–96.
Waagen, W. 1883. Salt Range fossils, vol. I, part 4. Productus Limestone fossils, Brachiopoda. *Memoirs of the Geological Survey of India, Palaeontologia Indica (Series 13)* **2**, 391–546.
Waagen, W. 1884. Salt Range Fossils. I. Productus-Limestone Fossils. *Geological Survey of India, Memoirs, Palaeontologia Indica (Series 13)* **4**(3), 547–610.
Waagen, W. 1885. Salt Range fossils, Pt. 4(2), Brachiopoda. *Memoirs, Palaeontologia Indica (Series 13)* **5**, 729–70.

Williams, A. 1962. The Barr and Lower Ardmillan series (Caradoc) of the Girvan District, southwest Ayrshire, with descriptions of the Brachiopoda. *Geological Society, London, Memoir* **3**, 1–267.
Williams, A. 1963. The Caradocian brachiopod fauna of the Bala District, Merionethshire. *Bulletin of the British Museum (Natural History), Geology* **8**, 327–471.
Williams, A. 1965. Strophomenacea. *In* Moore, R. C. (ed.) *Treatise on Invertebrate Paleontology, Part H, Brachiopoda*, 383–403. Lawrence, Kansas: Geological Society of America & University of Kansas Press.
Williams, A. & Harper, D. A. T. 2000. Orthida. *In* Kaesler, R. L. (ed.) *Treatise on Invertebrate Paleontology, Vol. H, Brachiopoda 3 (revised)*, 714–82. Boulder, Colorado & Lawrence, Kansas: Geological Society of America & Kansas University Press.
Wolfart, R. 1970. Fauna, Stratigraphie und Paläogeographie des Ordoviziums in Afghanistan. *Beiheft zum geologischen Jahrbuch* **89**, 1–125.
Woodward, S. P. 1852. *A Manual of the Mollusca; or, a Rudimentary Treatise of Recent and Fossil Shells*, xvi + 1–486 pp. London: John Neale.

MS received 24 February 2014. Accepted for publication 21 July 2014.