

# Ordovician ostracods from east central Iran

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Ordovician ostracods are described for the first time from Iran, enhancing the record of this group from the Lower Palaeozoic of the Middle East. The ostracods occur in the Shirgesht Formation, in the east central part of the country, and comprise *Ogmoopsis achaemenid* sp. nov., *Cerninella aryana* sp. nov., *Ordovizona amyitisa* sp. nov., cf. *Aechmina? ventadorni*, *Vogdesella* sp., and podocope taxa tentatively identified as species of *Longiscula*, *Pullvillites*, and *Rectella*. These taxa were hitherto unknown from this region. The ostracod-bearing interval is associated with trilobites (*Nesouretinus*) and brachiopods (*Nicolella*) that suggest a late Middle Ordovician age. Although the ostracod fauna is small, it demonstrates biogeographical links at genus-level, and possibly at species-level, with the fauna of the late Middle Ordovician Travesout Formation of western France, which also lay in a peri-Gondwanan palaeogeographical setting. It also suggests the potential use of some ostracods as stratigraphical tools for correlating Ordovician rock successions between Europe and the Middle East.

Key words: Ostracoda, Palaeocopa, Podocopa, biogeography, Ordovician, Shirgesht Formation, Iran.

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## Introduction

Ostracods have been documented from Ordovician rock-sequences worldwide, with the richest faunas known from Northern Europe and North America (for some reviews and overviews see Schallreuter and Siveter 1985; Jones 1986, 1987; Vannier 1986a, b; Vannier et al. 1989; Olempska 1994; Meidla 1996; Williams et al. 2003; Siveter in press; and references therein). They have proven ability for biogeographical analysis (e.g., Vannier et al. 1989) and for inter-regional correlation of Ordovician rock successions (e.g., Williams et al. 2000). Nevertheless, Ordovician ostracods are sparsely documented from the Middle East, probably because they have been largely overlooked in rock successions there. However, Vannier and Vaslet (1987) have reported a few species from the Middle Ordovician of Saudi Arabia, and Sayar and Schallreuter (1989) have recorded three species from the Ordovician of the Asiatic part of Turkey. Here we report the first Ordovician ostracod fauna from Iran, sourced from the Shirgesht Formation in the Derenj Mountains in the east central part of the country (Fig. 1).

The ostracod fauna that we have recovered comes from the upper part of the Shirgesht Formation and comprises some eight species, including new species of *Ogmoopsis*, *Cerninella*, and *Ordovizona* that are given formal taxonomic description. These ostracods provide new evidence about the distribution of Ordovician faunas in peri-Gondwanan loci, and also suggest the utility of some ostracods for inter-regional correlation of Ordovician rock successions between Europe and the Middle East.

## Geographical and geological setting

The sequence of rocks in the Derenj Mountains of east central Iran preserves Cambrian, Ordovician, Silurian, and Devonian strata, the best sections being located to the east and west of Dahaneh Kolut, about 65 km north of Tabas (Fig. 1). Ostracods are sourced from the upper part of the Shirgesht Formation in the Derenj Mountains to the west side of

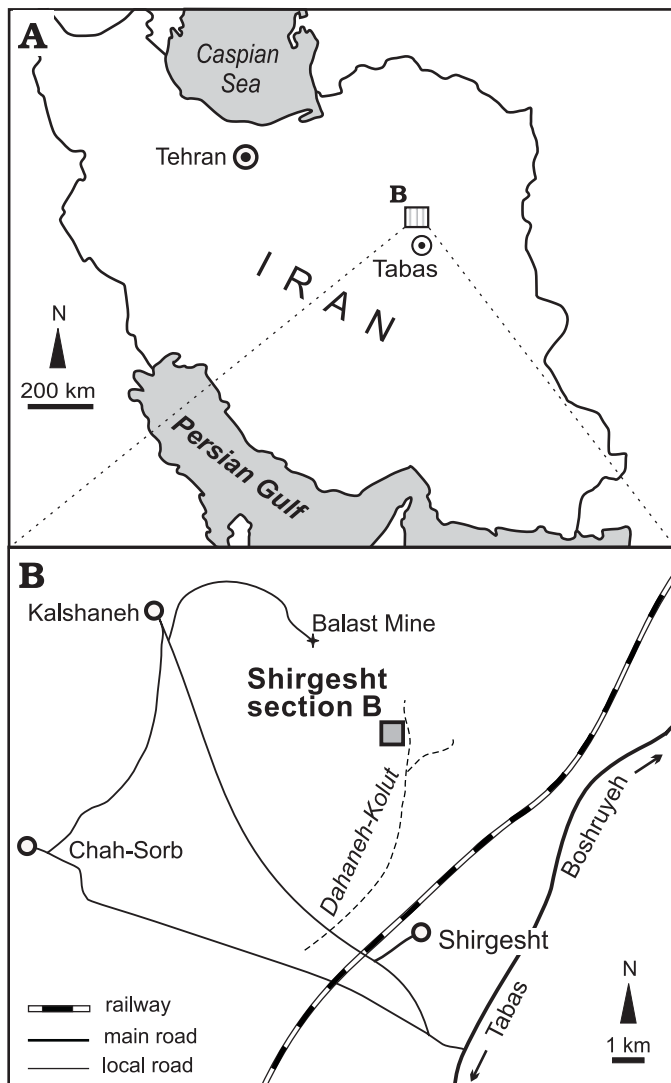


Fig. 1. Geographical map of Iran (A) showing the position of the Shirgesht Formation in Section B, Derenjal Mountains (B), north of Tabas, east central Iran.

Dahaneh Kolut (Figs. 1, 2). Section B of Figs. 1 and 2 is one of four sections used to reconstruct the composite Lower Palaeozoic sequence of this area. A full outline of the sequence will be published elsewhere. Geographical coordinates for the base and top of Section B are  $34^{\circ}05'32''$  N and  $56^{\circ}47'7.3''$  E, and  $34^{\circ}05'21.7''$  N and  $56^{\circ}47'06.7''$  E respectively. The Shirgesht Formation (Fig. 2) represents the Ordovician part of the succession in the Derenjal Mountains, though its lowermost interval, as traditionally defined, is of Cambrian age (Ruttner et al. 1968; but see Bruton et al. 2004). Due to complicated tectonics, the sequence of rocks referred to the Shirgesht Formation is composite and correlation between individual sections is controversial. Contact with units underlying and succeeding the formation are both faulted (Fig. 2) and though its thickness has been estimated at 1236 m (Ruttner et al. 1968), new observations on the composite sequence suggest that it is hardly more than 800 m. The upper boundary of the Shirgesht Formation, with the Silurian Niur Formation, was considered to be

transitional (Ruttner et al. 1968), but studies by Hamedei (Bruton et al. 2004: 118) have shown that this contact represents a major disconformity and is also faulted.

## Material and methods

The ostracod material comes from four sample points within a sequence of limestone mudstone interbeds within lithological units B5 and B6 (Fig. 2) of the Shirgesht Formation. These samples were initially collected in an attempt to recover conodonts from the rock residues. The ostracods, which number several hundred valves, have been studied using scanning electron microscopy at Cardiff.

Many Ordovician ostracod assemblages sourced from limestone-mudstone sequences are silicified (e.g., Jones 1986, 1987; Williams et al. 2001), and this is the case with the fauna from Iran. In the Shirgesht Formation the silicification ranges from finely crystalline (e.g., Fig. 3A–I, P, Q) to more coarsely crystalline (e.g., Fig. 3J–O, R, S). In the former case, some of the shell features appear to have been obscured during the process of replacement of the original calcite. Where the silicification process has produced a very coarsely crystalline texture, much of the original ornament of the shell is obliterated.

*Institutional abbreviation.*—NMW, National Museum of Wales, Cardiff, United Kingdom.

## Systematic palaeontology

(by M. Williams, J. Vannier, and T. Meidla)

Class Ostracoda Latreille, 1802

Order Beyrichiocolpa Pokorný, 1954

Suborder Palaeocolpa Henningsmoen, 1953a

Family Ctenonotellidae Schmidt, 1941

Genus *Cerninella* Přibyl, 1966

*Type species:* *Beyrichia bohémica* Barrande, 1872; Caradocian (Upper Ordovician), Bohemia, Czech Republic.

*Species included:* In addition to the type species (for which see Schallreuter and Krůta 2001: 87) and *Cerninella aryana* sp. nov., *Ogmoopsis? arcadelti* Vannier, 1986b is also included in *Cerninella*.

*Discussion.*—Jones (1986: 29) considered *Cerninella* to be a monotypic subgenus of *Piretopsopsis* Henningsmoen, 1953b. Only one incomplete right valve of the type species of *Piretopsopsis* (*P. donsi*) was described by Henningsmoen (1953b: pl. 2: 7, 8). The lobal morphology of this specimen resembles *Protallinnella* Jaanusson, 1957 and *Cerninella* Přibyl, 1966, but there are insufficient morphological data to determine its precise systematic position. For this reason we regard *Cerninella* to be of generic rank and leave its relationship to *Piretopsopsis* open, subject to additional material being recovered. *Tallinnella? bloubetinensis* Jaanusson, 1957 was referred to *Cerninella* by Vannier (1986b) but was assigned to *Brepho-*

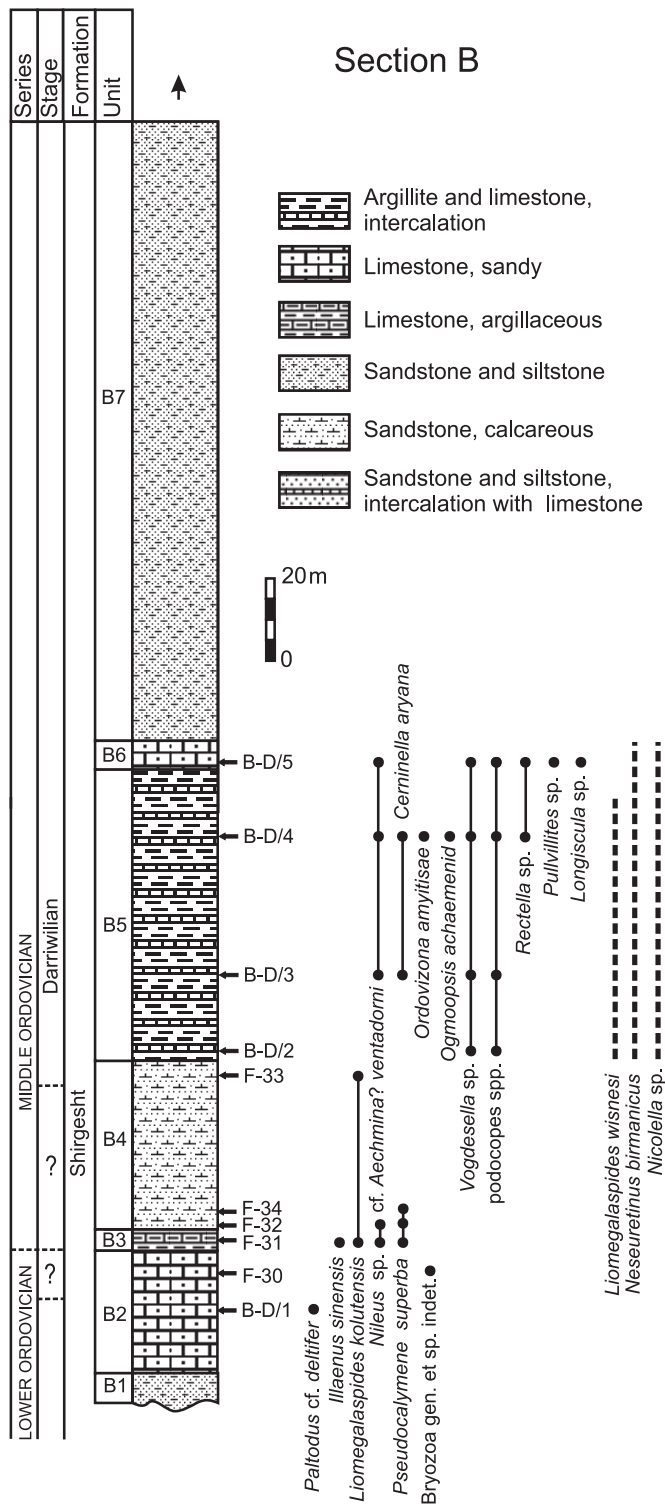


Fig. 2. Lithological details for Section B of the Shirgesht Formation in the Derenj Mountains on the west side of the Dahaneh Kolut valley. The position of fossil sample points, and the stratigraphical distribution of ostracods and selected trilobites, brachiopods and conodonts are also shown. Within lithological Unit B5, ostracod sample B-D/2 was taken from the base of the unit, sample B-D/3 at 18.85 m and sample B-D/4 at 46.7 m above the base of the unit. Ostracod sample B-D/5 was taken at the base of lithological Unit B6. The dashed lines for *Liomegalaspides winsnesi*, *Neseuretinus birmanicus*, and *Nicolella* sp. indicate that this fossil material was collected from loose blocks directly adjacent to the upper part of lithological Unit B5 in the field.

*charieis* by Schallreuter and Krůta (1994). *Ogmoopsis* (*Quadrigitalis*) *siveteri* Jones, 1986 is also reminiscent of *Cerninella*, but was assigned to *Brephocharieis* by Schallreuter and Krůta (1988). Material of *Cerninella complicata* (Salter, 1848 in Phillips and Salter 1848 *sensu* Přibyl 1966) was included in the new species *Brephocharieis? citrada* by Schallreuter and Krůta (1988).

One of the species assigned here to *Cerninella* (*C. arcadelti*) has previously been referred to *Ogmoopsis* Hessland, 1949, but its similarity to *Cerninella* was pointed out by Vannier (1986b). *Cerninella* differs most clearly from *Ogmoopsis* by having very narrow lobes (sometimes referred to as cristae), which often protrude over the dorsal margin. *Cerninella arcadelti* was assigned to *Ogmoopsis* because Sarv (1959) assigned his new species *Ogmoopsis ramosa* to this genus. Of the three specimens of *Og. ramosa* figured by Sarv (1959: pl. 17: 13–15), one is a damaged *Ogmoopsis bocki* (Öpik, 1935), in which the anterior lobe (L1) is broken and appears in its upper part like a double crista (Sarv 1959: pl. 17: 15). Whilst the two other specimens (the holotype included) possess very narrow lobes of uniform width, three of which overreach the dorsal margin, and they may be assignable to another genus.

#### *Cerninella aryana* sp. nov. Williams, Vannier, and Meidla

Fig. 3A, B, D–F.

*Derivation of the name:* After the name “Iran”, which in its oldest form means the “land of the Aryans”.

*Holotype:* NMW2004.22.G.300, a complete heteromorphic left valve.

*Type locality:* Dahaneh Kolut, east central Iran.

*Type horizon:* Shirgesht Formation, Section B, lithological Unit B5, sample B-D/3, probably late Middle Ordovician.

*Material.*—Over one hundred specimens in the NMW collection (NMW.2004.22.G.300, NMW.2004.22.G.329–332, NMW.2004.22.G.380, and many others) from samples B-D/3 and B-D/4. Specimens we have examined range from 0.8 to 1.8 mm in length, probably representing several instars.

*Diagnosis.*—*Cerninella* species in which the dorsal termination of the anterior lobe (L1) forms a posterior directed hook shape as it overreaches the dorsum. *C. aryana* is similar to *C. arcadelti* Vannier, 1986b, with which it shares narrow lobes, weakly sinusoidal posterior lobes (L3, L4) that overreach the dorsal margin, a short and straight preadductorial lobe (L2), and a similar length to height ratio (1.4 to 1.8), but it differs in the unique morphology of its anterior lobe. *C. aryana* is much smaller than the type species, *C. bohémica*, which is over 3 mm in length.

*Description.*—Weakly preplete, quadrilobate valves. Length to height ratio ranges from 1.4 to 1.8 in the specimens we have measured. Dimorphism is subtle, but heteromorphs appear to have valves that are much higher relative to their length (see Fig. 3F). Lobes are very narrow and are typically of even width throughout, and are separated by broad, well-developed sulci. All lobes are already well developed in

small juveniles less than 1 mm in length. Anterior lobe (L1) and third and fourth lobes from anterior (L3, L4), overreach the dorsal margin in adults. Dorsal termination of L1 forms a posterior directed “hook shape” which overreaches the dorsal margin. L3 and posterior-most lobe (L4) weakly sinusoidal. Second lobe from anterior (L2) short, about 3/4 the length of the other lobes. Lobes join ventrally to form a connecting ridge. L4 sometimes divides into two sub-lobes as it approaches the dorsal margin. In adults the velum is well developed, flange like and entire between cardinal corners.

*Discussion.*—This is the most common palaeocope ostracod in the material we have examined from the Shirgesht Formation. Subtle variation in the length to height ratio of heteromorphs and tecnomorphs of *Cerninella* was also noted by Vannier (1986b: pl. 8: 3, 4)

### Family Tetradellidae Swartz, 1936

#### Genus *Ogmoopsis* Hessland, 1949

*Type species:* *Ogmoopsis nodulifera* Hessland, 1949; Kunda (Middle Ordovician), Siljan District, Sweden.

#### *Ogmoopsis achaemenid* sp. nov. Williams, Vannier, and Meidla

Fig. 3C.

*Derivation of the name:* After the Achaemenid dynasty of ancient Persia, which ruled in the first millennium B.C.

*Holotype:* NMW2004.22G.301, a complete tecnomorphic right valve.

*Type locality:* Dahaneh Kolut, east central Iran.

*Type horizon:* Shirgesht Formation, Section B, lithological Unit B5, sample B-D/4, probably late Middle Ordovician.

*Material.*—More than 20 specimens, NMW2004.22G.301, NMW2004.22G.333–353, from sample B-D/4. Specimens are 1.1 to 1.8 mm long, representing instars and adults.

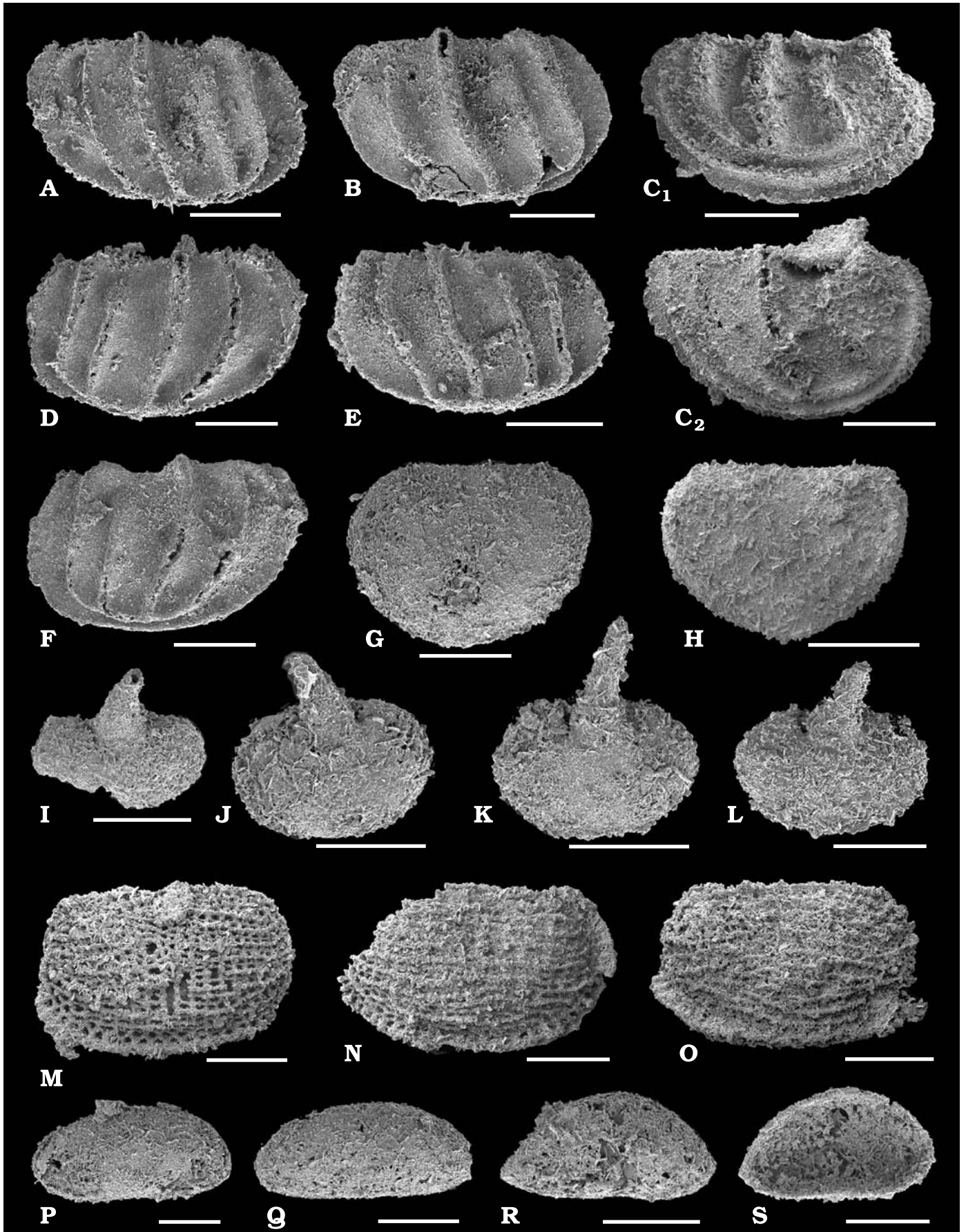
*Diagnosis.*—*Ogmoopsis* species with narrow lobes (about 200 µm wide for specimens over 1 mm length), all of which are of similar width including the posterior lobe (L4). Anterior lobe (L1) inflated dorsally and overreaches the dorsal margin. L3 and L4 may also overreach the dorsal margin, but are not inflated dorsally. *Ogmoopsis achaemenid* is similar to *Ogmoopsis bocki* (Öpik, 1935), in having dimorphic juveniles with the velar ridge much broader in the heteromorph. Both *Og. bocki* and *Og. achaemenid* possess a dorsally inflated anterior lobe that overreaches the dorsal margin, but

*Og. achaemenid* differs from *Og. bocki* by having all of its lobes of even width and by being longer (up to 1.8 mm long, compared to ca. 1.1 mm in *Og. bocki*). In the type species *Og. nodulifera*, the lobes are long and relatively narrow, and the anterior lobe (L1) is weakly bulbous, and may overreach the dorsal margin (see Tinn and Meidla 2003: fig. 7.18). Lobe L2 and occasionally also L1 are narrow, but L3 and L4 are wider and flattened compared to the lobes of *Og. achaemenid*. *Og. vesperi* Sarv, 1959 differs from *Og. achaemenid* by having both L1 and often L3 inflated dorsally, overreaching the dorsal margin (see Sarv 1959: pl. 18: 12, 13). Relative to *Og. achaemenid*, *Og. variabilis* Sarv, 1959, has stout lobes and the posterior lobe, in particular, is flattened (see Sarv 1959: pl. 19: 1, 5, 6). *Og. estonica* Sarv, 1959 has lobes of even width (Sarv 1959: pl. 18: 14–21), but none of these overreach the dorsal margin and they are broader, relative to the size of the valve, than for *Og. achaemenid*. In *Og. terpylae* Sarv, 1959, L2 is isolated from the connecting ridge, giving this species a distinctive morphology by which it can be differentiated from *Og. achaemenid* and other *Ogmoopsis* (Sarv 1959: pl. 19: 7, 10, 11). *Og. alata* Sarv, 1959 has a strongly inflated L3 in its ventral portion, a feature which is particularly obvious from a dorsal view (see Sarv 1959: pl. 19: 13; see also Schallreuter 1985: pl. 4: 1, 2), and which is absent from *Og. achaemenid*.

*Description.*—Valves weakly preplete and quadrilobate: all lobes narrow, including the posterior-most lobe (L4), and separated by well-developed sulci (S1–S3). S1 is narrow, S2 and S3 are broad. All lobes connected ventrally by a connecting ridge. L1 inflated and markedly overreaching the dorsal margin; L2 sigmoidal, not overreaching the dorsal margin; L3 curved (crescent-shaped), overreaches the dorsal margin; L4 curved, its outline following that of the posterior lateral outline, sometimes weakly overreaching the dorsal margin. In both dimorphs the velar ridge extends from the mid-posterior to the anterocardinal corner, but is much broader in heteromorphs. In ventral view the velar ridge overreaches the concave ventral surface. There are no other ventral ridges in either dimorph. Velar dimorphism is also manifested in pre-adult specimens.

*Discussion.*—Schallreuter (1993: 80–83) provides more modern description of several *Ogmoopsis* species based on material from erratic boulders (Geschieben in German), but ques-

Fig. 3. Middle Ordovician ostracods from the Shirgesht Formation in the Derenjal Mountains, Iran. **A, B, D–F.** *Cerninella aryana* sp. nov. →  
**A.** NMW2004.22.G.329, sample B-D/3, right valve in lateral view. **B.** NMW2004.22.G.330, sample B-D/4, right valve in lateral view.  
**D.** NMW2004.22.G.331, sample B-D/3, left valve in lateral view. **E.** NMW2004.22.G.332, sample B-D/3, tecnomorph right valve in lateral view.  
**F.** NMW2004.22.G.300, sample B-D/3, holotype heteromorph left valve in lateral view. **C.** *Ogmoopsis achaemenid* sp. nov. NMW2004.22.G.301, sample B-D/4, holotype heteromorph right valve in oblique lateral (C<sub>1</sub>) and lateral (C<sub>2</sub>) views. **G.** *Vogdesella* sp. NMW2004.22.G.358, sample B-D/3, right valve in lateral view. **H.** Ostracod sp. NMW2004.22.G.379, sample B-D/4, left valve? in lateral view. **I–L.** cf. *Aechmina? ventadorni* Vannier 1986a.  
**I.** NMW2004.22.G.311, sample B-D/5, incomplete left valve in lateral view. **J.** NMW2004.22.G.312, sample B-D/4, right valve in lateral view.  
**K.** NMW2004.22.G.313, sample B-D/4, left valve in lateral view. **L.** NMW2004.22.G.314, sample B-D/4, left valve in lateral view. **M–O.** *Ordovizona amyitisa* sp. nov. **M.** NMW2004.22.G.302, sample B-D/4, holotype left valve in lateral view. **N.** NMW2004.22.G.303, sample B-D/4, incomplete valve in lateral view. **O.** NMW2004.22.G.304, sample B-D/4, left valve in lateral view. **P.** *Rectella* sp. NMW2004.22.G.354, sample B-D/4, right valve in lateral view.  
**Q.** *Longiscula* sp. NMW2004.22.G.355, sample B-D/5, right valve in lateral view. **R, S.** *Pullvillites* sp. **R.** NMW2004.22.G.356, sample B-D/5, right valve in lateral view. **S.** NMW2004.22.G.357, sample B-D/5, left valve in internal view. Scale bars 500 µm.



tions the affinity of *Og. variabilis* and *Og. vesperi* to *Ogmoopsis*. He also refers *Og. estonica* to his new genus *Ahla* Schallreuter, 1993, in which he also includes *Og. terpylae*, though somewhat tentatively, and *Ceratopsis bocki* Öpik, 1935. As Tinn and Meidla (2003: 70) have shown, *Ahla* is a synonym of *Ogmoopsis*, and *Og. bocki* is very similar to the type species *Og. nodulifera*.

#### Family Ordovizonidae Becker, 1997

##### Genus *Ordovizona* Schallreuter, 1969

*Type species: Ordovizona sulcata* Schallreuter, 1969; Harju (Upper Ordovician), erratic boulder (Geschiebe of Gotlandian type), North Germany.

##### *Ordovizona amyitisae* sp. nov. Williams, Vannier, and Meidla

Fig. 3M–O.

*Derivation of the name:* Amyitis, granddaughter of the king of Media and wife of Nebuchadnezzar the great king of Babylonia. Later legend credited Nebuchadnezzar with building the Hanging Gardens of Babylon, for his wife Amyitis.

*Holotype:* NMW2004.22G.302, a complete left valve.

*Type locality:* Dahaneh Kolut, east central Iran.

*Type horizon:* Shirgesht Formation, Section B, lithological Unit B5, sample B-D/4, probably late Middle Ordovician.

*Material.*—Nine specimens (NMW2004.22G.302–310) from sample B-D/4. The largest specimen in our collection is 1.7 mm long.

*Diagnosis.*—Species of *Ordovizona*, adults typically greater than 1.5 mm long, with a broad velar ridge (200 µm wide), which is of even width except where it narrows at the cardinal corners. *Or. amyitisae* differs from the type species *Or. sulcata* and from *Or. longa* Schallreuter, 1983 by its broader velar ridge, and by its larger size (about 1/3<sup>rd</sup> greater in length than the other two species). It differs from *Or. immanis* Becker, 1994 (length up to 0.68 mm) by its larger size, broader velar ridge and lack of the bow shaped dorsal plica that characterizes that species.

*Description.*—Valves amplete to weakly preplete. The length to height ratio of the valves we have measured ranges from 1.4 to 1.6. Well-developed adductor pit, traced to the dorsal margin by a shallow sulcament where it meets the narrow dorsal plica. Adductor pit demarcates broadly convex anterior and posterior lobal surfaces. Lateral surface has strong horizontal striae that are joined vertically by reticulae. Velum entire between the cardinal corners, maximum width ventrally (200 µm), narrowing as it approaches the dorsal margin both anteriorly and posteriorly.

*Discussion.*—We follow Becker (1997, 2002) in considering *Ordovizona* and the Ordovizonidae to be presumed palaeocopes.

The reticulae between the lateral ridges on the surface of *Or. amyitisae* are very coarsely preserved when compared to the well-preserved material of *Ordovizona* described by Schallreuter (1969, 1983).

*Ordovizona* is also known from the Precordillera of Argentina (Maria J. Salas, personal communication 2003). This indicates that the genus had wide dispersal between Baltica, Gondwana, and other palaeocontinental entities by the late Middle Ordovician.

#### Suborder Binodicopa Schallreuter, 1972

##### Family Aechminidae Bouček, 1936

##### Genus *Aechmina* Jones and Holl, 1869

*Type species: Aechmina cuspidata* Jones and Holl, 1869; Wenlock (Silurian), southern Britain.

##### cf. *Aechmina? ventadorni* Vannier, 1986a

Fig. 3I–L.

*Discussion.*—Specimens of cf. *Aechmina? ventadorni* from the Shirgesht Formation are typically 0.5–0.9 mm long (more than 27 specimens, including NMW2004.22G.311–328, from samples B-D/3, B-D/4, and B-D/5), and have a length to height ratio ranging from 1.35 to 1.5. Whilst these lie in the size range of specimens from western France, they are generally smaller than the largest French specimens, which are over 1 mm long (Vannier 1986a: 118). Characteristically though, the Iranian specimens possess a pronounced sulcus anterior of the dorsal spine, a feature which is typical of *A.? ventadorni*, and which clearly distinguishes this taxon from the North American and British Ordovician species of *Aechmina* (see Williams et al. 2001).

#### Family Circulinidae Neckaja, 1966

##### Genus *Vogdesella* Baker, 1924

*Type species: Jonesella obscura* Ulrich, 1894; Trenton (Upper Ordovician), Minnesota, USA.

##### *Vogdesella* sp.

Fig. 3G.

*Discussion.*—*Vogdesella* sp. possesses simple carapace morphology with a postplete outline, a valve that is of uniform convexity without distinct lobes and sulci, and with well-marked cardinal angles. It is up to 1.48 mm long and, in the material that we have examined, has a length to height ratio of 1.3 to 1.4 (25 specimens measured, NMW2004.22G.358–378, and additional specimens in the NMW collection, samples B-D/2, B-D/3, B-D/4, and B-D/5?). The species from the Shirgesht Formation is similar to *V. subovata* (Thorslund, 1948) (see Meidla 1996: pl. 16: 9), but it is shorter, more distinctly postplete, and its anterior end is narrowly rounded near the dorsal margin. Species of *Vogdesella* and *Pariconchoprimitia* Schallreuter, 1980 appear to represent end members of a range of morphological variation from flat to nodose forms (see also Jones 1986: 92; Meidla 1996: 86).

## Podcope ostracods

There are a number of podcope species in the Shirgesht Formation, representing a numerically important compo-

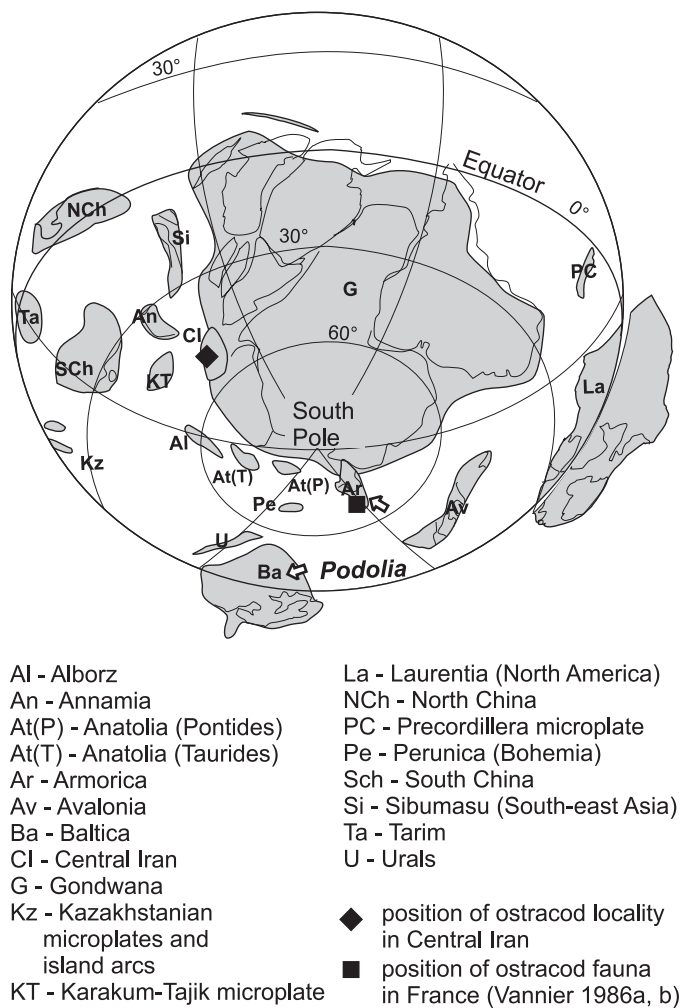


Fig. 4. Palaeogeographical position of Iran during the late Middle Ordovician. The ostracod fauna of the Shirgesht Formation (species of *Cerninella* and *Aechmina*?) appears to show affinity with that of the late Middle Ordovician of Spain and western France (Ibero-Armorica), the position of which is arrowed in the figure, and which also lay in a peri-Gondwanan setting. A second arrow points to the palaeogeographical position of Podolia.

ment of the fauna, particularly from sample B-D/5. This material is generally poorly preserved, and the presence of a sulcament on the internal surface of the valves or the presence of stop ridges cannot be determined, possibly because of the coarse silicification of specimens. Also, valve overlap is difficult to determine, as the valves of carapaces are typically disarticulated. For these reasons, the identification of the material is somewhat tentative, and we do not present a formal description of the podocope taxa. Nevertheless, the fauna appears to include species of the genera *Longiscula* Neckaja, 1958, *Pullvillites* Öpik, 1937, and *Rectella* Neckaja, 1952.

*Longiscula* sp. (Fig. 3Q) is recognised by its elongate valve shape with an irregularly arched dorsal margin and a nearly straight ventral margin with minor concavity antero-ventrally. It possesses a valve with uniform convexity without lobes and sulci. The material from the Shirgesht Forma-

tion is similar to the coeval *Longiscula parrectis* Neckaja, 1958 from the Baltic region (see Meidla 1993: fig. 1.9–15), differing by possessing a more widely rounded posterior end to the right valve.

The genus *Pullvillites* differs from the closely related *Longiscula* in its relatively higher valve shape. The material of *Pullvillites* from the Shirgesht Formation (Fig. 3R, possibly also the specimen of Fig. 3S) possesses a relatively high, elongate-triangular right valve, with irregularly arched dorsal and distinctly concave ventral margins, and distinctly angular anterior and posterior ends. The material is similar to *Pullvillites laevis* Abushik and Sarv, 1983 (pl. 9: 1–8), but is more elongate. From coeval *Pullvillites sinclivula* Neckaja, 1958 the Iranian material differs in having more angular anterior and posterior ends and in its distinctly concave ventral margin.

Material referred to *Rectella* sp. (Fig. 3P) is characterised by roughly parallel ventral and dorsal margins, the dorsal one being broadly arched and the ventral one distinctly concave. Characteristically for *Rectella*, the ends of the valves are broadly rounded and higher than in *Longiscula*, and the valves lack a sulcament. According to the original description (Neckaja 1952: 228) the carapace of *Rectella* is inequivalved. In particular the antero- and posteroventral areas of the right valve may often bear different structures (spines, inflations etc.), which serve as outer stop-ridges (Meidla 1996: 143). The simple right valve structure of the Iranian material resembles *Rectella romboformis* Neckaja, 1966 from the Upper Ordovician of Baltica, but is relatively shorter and has a shallower ventral concavity.

## Stratigraphy and biogeography of the ostracod fauna

**Stratigraphy.**—Detailed biostratigraphical study of the Shirgesht Formation in Section B on the west side of Dahaneh-Kolut, which corresponds to units 22 to 35 of Ruttner et al. (1968), indicates several succeeding faunal assemblages ranging from the Late Tremadocian *Paltodus deltifer* conodont biozone to the late Middle Ordovician or higher (Fig. 2). Conodonts from limestone within lithological Unit B2 (sample B-D/1) include rare *Paltodus* cf. *deltifer* (Fig. 2), whilst the uppermost part of this unit contains numerous brachiopods and a few bryozoan colonies suggesting an Early Arenigian age (L.E. Popov, unpublished data). Most of the trilobites described by Pillet (1973) were probably derived from a single fossiliferous interval that is about five metres thick (lithological Unit B3), and contains *Illaeus sinensis* Yabe in Yabe and Hayasaka, 1920 (= *Illaeus hinomotoensis* Kobayashi, 1934 after Bruton et al. 2004), *Nileus* sp. nov. (= *Nileus* cf. *exarmatus* Tjernvik, 1956 after Bruton et al. 2004), *Pseudocalymene superba* Pillet, 1973, and *Liomegalaspides* (= *Megalaspides* after Bruton et al. 2004) *kolutensis* (Pillet, 1973). The age of this assemblage must be younger than the *Paltodus*

*deltifer* conodont biozone and not older than the Arenigian, because the uppermost part of lithological Unit B2 contains the trilobites *Illiaenus sinensis* and *Liomegalaspides* that suggest correlation to the Dawan Formation of South China (Arenigian to Early Darriwilian).

The trilobites *Liomegalaspides* (= *Megalaspides*) *winsnesi* (Bruton in Bruton et al. 2004) and *Neseuretinus birmanicus* (Reed, 1906) (= *Neseuretus gavidelii* Bruton in Bruton et al. 2004) occur in the uppermost part of the fossiliferous interval (Fig. 2) together with *Ovalocephalus* sp. and the brachiopod *Nicolella* sp. Occurrence of *Neseuretinus* and *Nicolella* suggests the Late Darriwilian or a younger age for this faunal assemblage (Hamman and Leone 1997; Fortey and Cocks 2003). Ostracods from this interval (lithological units B5 and B6) are represented by *Cerninella aryana*, *Ogmoopsis achaemenid*, *Ordovizona amyitissae*, *Vogdesella* sp., cf. *Aechmina? ventadorni* Vannier 1986a and species of *Longiscula*, *Pullvillites*, and *Rectella*.

*Aechmina? ventadorni* occurs in the late Middle Ordovician (Llandeilian) of western France (Vannier 1986a) at levels equivalent to the *Hustedograptus teretiusculus* graptolite biozone (Vannier 1986a; Vannier et al. 1989). The age of French material of *A.? ventadorni* is consistent with trilobite and brachiopod age evidence for the late Middle Ordovician occurrence of cf. *Aechmina? ventadorni* in the Shirgesht Formation, suggesting that this species might, with further evaluation, prove useful for inter-regional correlation. The other ostracods of the Shirgesht Formation do not have direct stratigraphical value at present, but the overall assemblage is consistent with a latest Middle Ordovician age. For example, *Cerninella aryana* is most similar to *C. arcadelti* from the late Middle Ordovician of France and Spain (Vannier 1986b: 176). *Ogmoopsis* is typical for Arenigian age strata of the Baltic region (Sarv 1959; Tinn and Meidla 2003). Younger material referred to *Ogmoopsis* from Britain and France (e.g., Jones 1986; Vannier 1986b) appears to be referable to *Brephocharieis* and *Cerninella* (see discussion above), so that the Iranian occurrence of *Ogmoopsis* may be towards the top of the stratigraphical range of the genus. *Ordovizona* is known from erratic boulders in Northern Europe dated as Late Ordovician (Schallreuter 1969, 1983, 1993), from material dredged from the surface of Orphan Knoll in the Labrador Sea that might be of Middle or Late Ordovician age (Becker 1994), and is also known from the earliest Caradocian of Argentina (Maria J. Salas, personal communication 2003). The record of *Ordovizona* from Iran is the oldest so far. Of the podocope ostracods in the Shirgesht Formation, the long-ranging (Ordovician–Early Silurian) *Longiscula* is geographically widespread (North America, Europe, China, central Asia, see Meidla 1996: 116), whilst *Rectella* and *Pullvillites* are essentially Baltic and Podolian during the Ordovician (Meidla 1996), the tentative records from Iran perhaps extending their geographical occurrence.

**Biogeography.**—The Shirgesht Formation yields ostracods with wide biogeographical dispersal during the Ordovician.

*Aechmina* is one of the most widely dispersed of Ordovician ostracod genera (Williams et al. 2001), though the material from the Shirgesht Formation is more closely allied with those of palaeogeographical Armorica (France), which lay on the margins of the Gondwana palaeocontinent (Fig. 4). These *Aechmina* possess a well-developed sulcus anterior of the dorsal spine. They may have had a different phylogenetic origin to those Late Ordovician forms of Laurentia, Avalonia and the Argentine Precordillera (Williams et al. 2001, 2003; Salas 2002), which lack this well-developed sulcus. *Vogdesella* is known from the Klabava Formation (Arenigian) of Bohemia (Schallreuter and Krüta 1988, material referred to *Pariconchoprimita*), Llanvirnian of Saudi Arabia (Vannier and Vaslet 1987), and variously from the Middle and Upper Ordovician of southern Britain (Jones 1987), Sweden (Schallreuter 1980), Poland (Olempska 1994), North America and elsewhere (see Vannier et al. 1989; Williams et al. 2003). *Cerninella* was well established in mid to high-latitudes (Perunica and Armorica) by the late Middle Ordovician and early Late Ordovician (Schallreuter and Krüta 2001; Vannier 1986b: 177, material referred to *Ogmoopsis*). The Iranian material is morphologically most similar to that from the late Middle Ordovician of France and Spain (Vannier 1986b, *C. arcadelti*).

*Ogmoopsis* is common in the Baltic region during the Early and early Middle Ordovician (Sarv 1959; Tinn and Meidla 2003). As the French and British records of *Ogmoopsis* appear to be referable to *Cerninella* and *Brephocharieis* (see also Schallreuter and Krüta 1988), the occurrence of *Ogmoopsis achaemenid* in a peri-Gondwanan setting during the late Middle Ordovician is one of several biogeographical links at the generic level, between Baltica and Gondwana. These also include *Ordovizona*, which appears to have been capable of wide dispersal, occurring in the Late Ordovician of the Argentine Precordillera (Maria J. Salas, personal communication 2003) and Baltica, in the late Middle Ordovician of Gondwana (Iran), and possibly in the Middle or Late Ordovician of Laurentia, dependent on the record from Orphan Knoll in the Labrador Sea (Becker 1994). The podocopes *Longiscula*, *Rectella*, and *Pullvillites*, tentatively recorded in the Shirgesht Formation, are also common in Baltic and Podolian Ordovician rock sequences (palaeogeographical Baltica), *Longiscula* being a very widely dispersed Ordovician genus found also in North America, central Asia, China and possibly Bohemia (Meidla 1993: 290; Meidla 1996: 116). If this distribution is confirmed, *Longiscula* was virtually cosmopolitan in the Ordovician, from mid latitude Gondwana to low latitude Laurentia (Fig. 4).

## Conclusions

Ordovician ostracods are described for the first time from Iran. The small fauna, sourced from four samples in the Shirgesht Formation of the Dahaneh Kolut region in the east central part



of the country, includes species of *Cerninella*, *Ogmoopsis*, *Ordovizona*, *Aechmina?*, *Vogdesella*, *Longiscula*, *Pullvillites*, and *Rectella*. These occur at levels associated with the trilobite *Neseuretinus* and the brachiopod *Nicolella* that suggest a late Middle Ordovician age. The species of *Aechmina?* and *Cerninella* in the Shirgesht Formation bear close similarity to those from the late Middle Ordovician of France and Spain, which, like Iran, also lay in a peri-Gondwanan setting during the Ordovician. This suggests that some ostracod species, particularly *Aechmina? ventadorni*, might be useful for inter-regional correlation of Gondwanan Ordovician sequences.

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