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Latest Ordovician–early Silurian chitinozoans from the eastern Alborz Mountain Range, Kopet–Dagh region, northeastern Iran: biostratigraphy and palaeobiogeography

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Received 24 March 2006; received in revised form 14 September 2006; accepted 24 October 2006

Abstract

Chitinozoans were extracted from latest Ordovician to early Silurian strata in the Alborz Mountain Range, northeastern Iran; 24 species were identified and six local biozones established. Five new chitinozoan species are described: *Ancyrochitina bojnourdensis*, *Ancyrochitina fatemae*, *Ancyrochitina longifilosa*, *Angochitina iranica*, and *Angochitina multipodspina*. Correlation with existing formal biozonations suggests that the uppermost part of the Ghelli Formation is of mid-Ashgill age and that Member I of the Niur Formation ranges from early Rhuddanian to late Telychian. The recovered chitinozoan fauna is dominated by species which are endemic to the study area. A significant proportion of taxa is shared with typical Baltican assemblages, suggesting palaeobiogeographical affinities between Iran and the Baltica palaeocontinent. Taxa shared with typical North Gondwanan assemblages are only a minor component of the Iranian chitinozoan fauna. The present results confirm previous observations that current appreciation of chitinozoan provincialism may be affected by sample-and (palaeo)geographic coverage biases, particularly for the Silurian. Similarly, the application of existing biostratigraphic schemes for the dating of the Iranian Silurian sediments proved problematical, confirming the need of incorporating more data from little known areas (such as Iran) in global databases.

Keywords: Chitinozoans; early Silurian; Alborz Mountain Range; Iran; biostratigraphy; palaeobiogeography

1. Introduction

Chitinozoans (Miller, 1996) are increasingly used as valuable tools not only for biostratigraphic dating at regional scale, but also for global chronostratigraphic correlation, especially in Ordovician and Silurian times (Verniers et al., 1995; Vandenbroucke et al., 2003; Paris et al., 2004; Vandenbroucke, 2004). Recent research (Verniers et al., 1995; Paris et al., 2004) has shown that geographic coverage of documentation of Ordovician and Silurian chitinozoan faunas is strongly biased, the majority of published papers concerning the Baltic regions, the North African craton, and North America. This has negative implications for the establishment of reliable and stable chitinozoan-based chronostratigraphic correlation charts, as well as for the understanding of the patterns of palaeobiogeographical distribution of chitinozoan faunas. Compared to other regions

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Keywords: Chitinozoans; early Silurian; Alborz Mountain Range; Iran; biostratigraphy; palaeobiogeography

1. Introduction

Chitinozoans (Miller, 1996) are increasingly used as valuable tools not only for biostratigraphic dating at regional scale, but also for global chronostratigraphic correlation, especially in Ordovician and Silurian times (Verniers et al., 1995; Vandenbroucke et al., 2003; Paris et al., 2004; Vandenbroucke, 2004). Recent research (Verniers et al., 1995; Paris et al., 2004) has shown that geographic coverage of documentation of Ordovician and Silurian chitinozoan faunas is strongly biased, the majority of published papers concerning the Baltic regions, the North African craton, and North America. This has negative implications for the establishment of reliable and stable chitinozoan-based chronostratigraphic correlation charts, as well as for the understanding of the patterns of palaeobiogeographical distribution of chitinozoan faunas. Compared to other regions

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belonging to the Gondwana palaeocontinent (e.g., North Africa, the Arab Peninsula, central and southern Europe, South America), Iranian chitinozoans are poorly known. Previous studies of chitinozoan faunas in Iran are restricted to the Late Ordovician Seyahou Formation in the south (Ghavidel-syooki, 2000a) and the coeval Ghelli Formation in the northeastern part of the country (Ghavidel-syooki and Winchester-Seeto, 2002). Published reports of early Silurian chitinozoans from the Iranian Platform are limited to the Sarchahan Formation in southern Iran (Ghavidel-syooki, 2000a,b; Ghavidel-syooki and Winchester-Seeto, 2004). Relevant to the present investigation is also the recent work from Saudi Arabia by Al-Hajri (1995), Paris et al. (2000) which may provide a basis for comparison and regional correlation.

We report here a rich and diverse chitinozoan association from the upper part of the Ghelli Formation and from the Niur Formation in the eastern Alborz Mountain Range of northeastern Iran. The objectives of this paper are: 1) the taxonomical description of the chitinozoan assemblages; 2) to determine if and to what extent existing Ordovician–Silurian biozones can be applied to the study area; 3) to evaluate the palaeobiogeographical affinities of the latest Ordovician–Silurian chitinozoan assemblages of northeastern Iran.

2. Geological setting, stratigraphy, and palaeogeography

The study area is located in the eastern flank of Kuh-e-Saluk, approximately 35 km south-east of Bojnourd city (Fig. 1). A thick Lower Palaeozoic sequence is well-developed at Pelmis–Gorge (between the cities of Bojnourd and Esfarayien) and comprises, in ascending stratigraphical order, the Lalun, Mila, Lashkarak, Ghelli, and Niur Formations. The red sandstone unit of the Early Cambrian Lalun Formation is conformably overlain by the Mila Formation. The latter is an essentially calcareous unit, yielding rare trilobites and brachiopods. Based on its stratigraphical position (Afshar-harb, 1979) and palynological content (Ghavidel-syooki, 2000a,b, 2001), the Mila Fm has been assigned to the Middle and Late Cambrian. The Lashkarak Fm is 250-m thick and consists mainly of olive-grey shales with interbedded thin, brecciated limestone layers. Based on acritarch assemblage zones, the Lashkarak Fm has been assigned to the Early Ordovician (Ghavidel-syooki, 2000a,b, 2001). The succeeding Ghelli Fm has a thickness of *ca*. 1000 m and is characterized by dark to olive-grey shales associated with subordinate siltstone and fine-grained sandstone beds. Acritarchs (Ghavidel-syooki, 2000a,b, 2001) and chitinozoans (Ghavidel-syooki and Winchester-Seeto, 2002) indicate a Middle–Late Ordovician for this unit. The Niur Formation is the youngest Early Palaeozoic rock unit in the study area. Its Silurian age was first proved by Afshar-harb (1979), who subdivided the Niur Fm into a lower and an upper member, based on lithological grounds. The lower part (Member I) of the Niur Fm is 500-m thick and consists of dark to olive-grey shales interbedded with sparse fossiliferous limestone beds. In certain horizons, this member contains corals (e.g. *Crystiphyllum siluriense*, *Halysites catenularis*, *Halysites labyrinthicus*), whereas abundant and well preserved palynomorphs have been recorded throughout its entire thickness. More recent palaeontological investigations indicate that Member I of the Niur Fm is of early Silurian age (Ghavidel-syooki, 2000a,b, 2001).

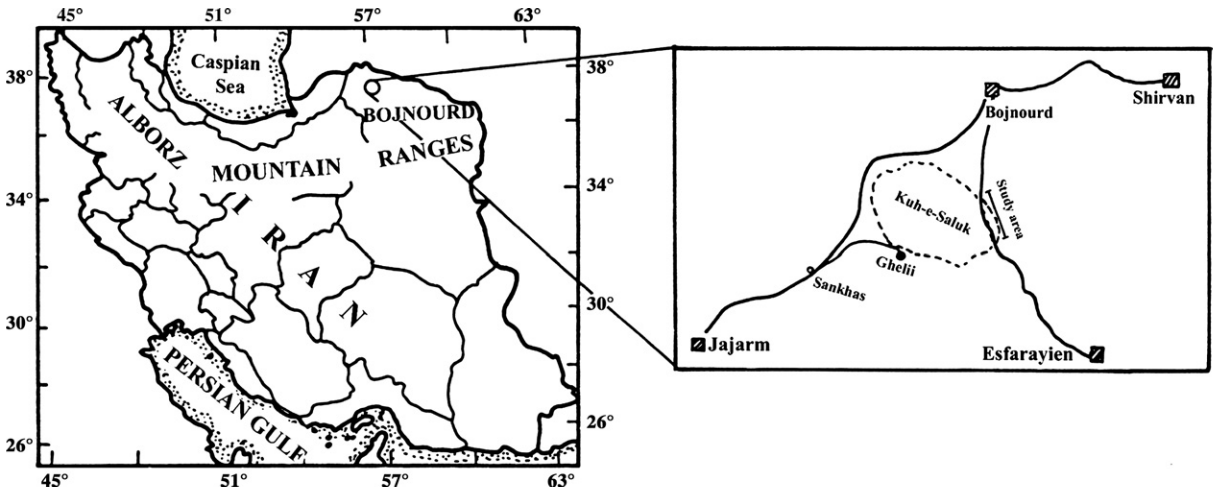

Fig. 1. Geographic setting and location of study section.

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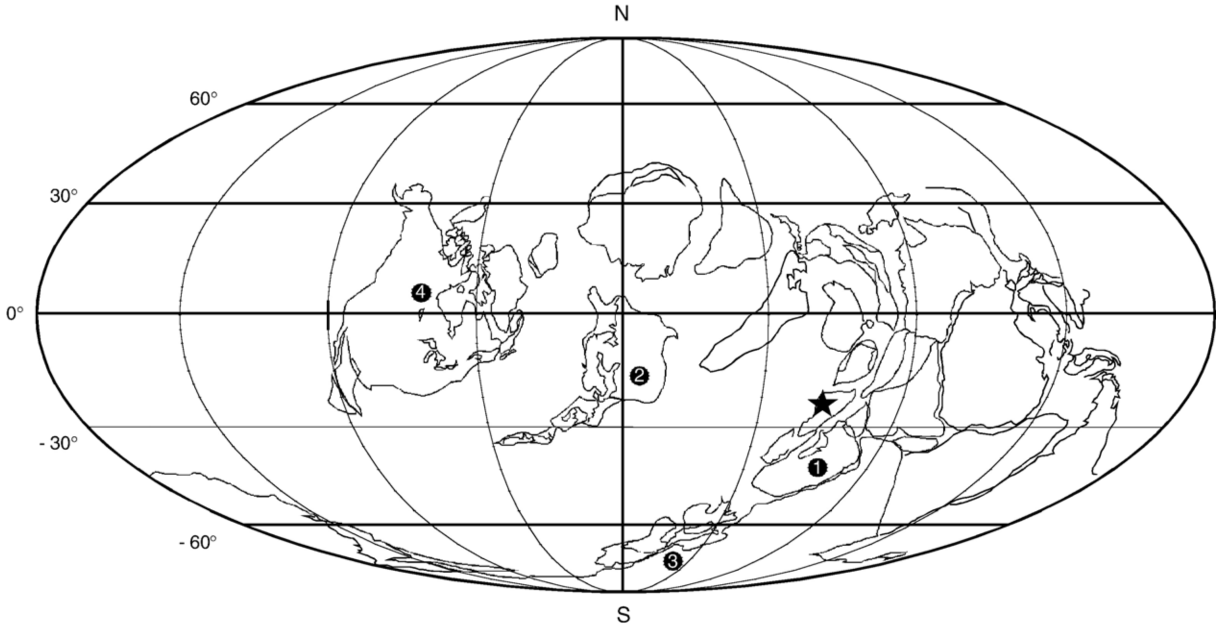

Fig. 2. Early Silurian palaeogeographic map with location of study area (star) and other localities discussed in the text. 1, Arabia; 2, Baltica; 3, North Gondwana; 4, Laurentia. Map from Scotese and McKerrow (1990).

The upper part (Member II) of the same unit has a thickness of 250 m and mainly consists of white sandstones, red-purple shales with interbedded olive-bluish shale layers in its middle part. Sedimentary structures such as cross-bedding, graded bedding, asymmetrical ripple marks and mud-cracks are abundant in this member, which yielded only some cryptospores from specific horizons, but no other palynomorphs or macrofossils. Based on the cryptospore content, the age of Member II of the Niur Fm has been determined as middle Silurian (Wenlock; Ghavidel-syooki, 2000a,b, 2001). The upper contact of this unit is disconformable with the Padeha Formation of Late Devonian age.

Palaeogeographically, northeastern Iran belonged to eastern peri-Gondwana, thus located at intermediate latitudes (ca. 45°) in the southern hemisphere (Fig. 2); it is considered by some authors as belonging to a larger separate terrane (Cimmeria: Scotese and McKerrow, 1990) but it could as well have formed part of core Gondwana during Ordovician and Silurian times (Cocks and Torsvik, 2004).

3. Materials and methods

Ninety-two surface samples from the upper part of the Ghelli Formation (samples MG-2865, MG-2870, and MG-2875) and from the Niur Formation (89 samples: from MG-7682 to MG-7771, see Fig. 3 for sampling levels) were treated and investigated for chitinozoans. The palynomorphs were extracted from a 20-gram sediment sample (whose lithology varied among shale, siltstone and fine-grained sandstone) using standard palynological procedures. This included treatment of the palynological residues with saturated zinc bromide for density separation of the organic matter, and screening through 20-μm nylon mesh sieve. The scanning electron and transmitted light microscopic slides studied here are permanently housed at the Palaeontological Collections of the Exploration Directorate of the National Iranian Oil Company. In general, the chitinozoans are abundant and well-preserved in the uppermost Ghelli Fm and in Member I of the Niur Fm, and are often accompanied by other palynomorphs (acritarchs, rare trilete spores and scolecodonts). The thermal maturity is medium to low, but many specimens show some degree of flattening, due to their preservation in shales and siltstones. Member II of the Niur Fm did not yield chitinozoans, but contained cryptospores and rare acritarchs. Chitinozoan diversity is relatively low in the lower part of the section (5 to 9 species per sample), and increase regularly to a maximum values towards the top of Member I of the Niur Fm (15 species in sample MG-7758).

4. Systematic palaeontology

For taxonomic descriptions, the classification system of Paris et al. (1999) is used. Following conventional practices, full taxonomic treatment is restricted to the

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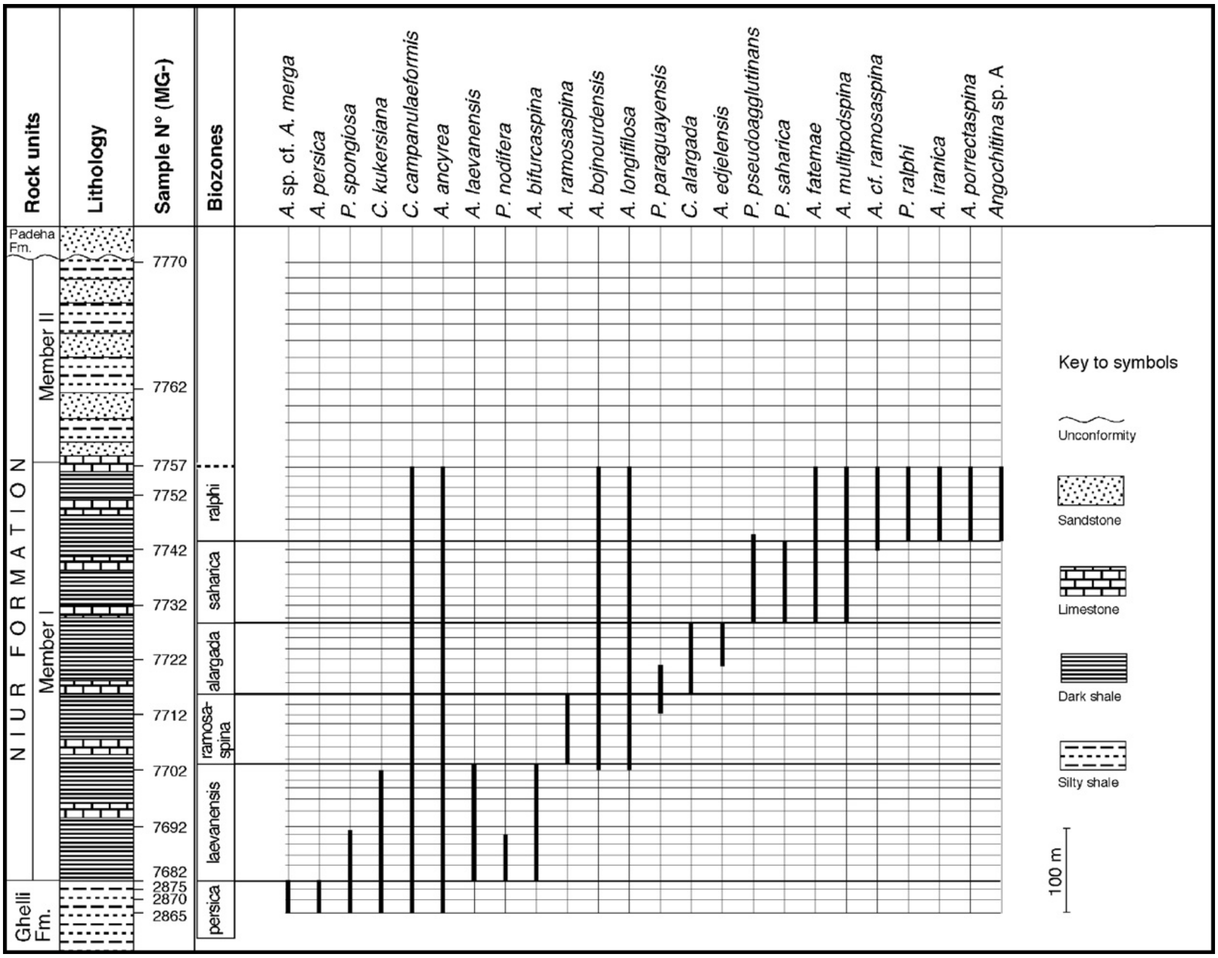

Fig. 3. Lithological log of study section, ranges of described species, and biozonation.

newly proposed species. The following symbols are adopted for the systematic and biometric descriptions: *L*, total length of vesicle; *l*, length of chamber; ln, length of neck with collarette; *D*, maximum diameter of vesicle; dcoll, diameter of collarette; ls, length of spines; *L*/*D*, total length of vesicle/maximum vesicle diameter; and *L*/ln, total vesicle length/length of neck.

When the chamber is less flattened than the neck, the chamber/neck diameter is restored according to the method proposed by Paris (1981) using a coefficient of 0.7 and 0.8, respectively.

Abundance values are expressed semi-quantitatively, as follows: rare = 2–3 identified specimens; uncommon = 4–8 identified specimens; common = 9–20 identified specimens; abundant = >20 identified specimens.

Order Prosomatifera Eisenack, 1972
Family Conochitinidae Eisenack, 1931
Subfamily: Conochitininae Paris, 1981
Genus: *Conochitina* Eisenack, 1931
Type species: *Conochitina claviformis* Eisenack, 1931

Conochitina alargada Cramer, 1967
Plate IV, fig. 3

Dimensions (based on 169 specimens): *L*, 271 (278) 285 μm; ln, 190 (192) 194 μm; *D*, 61 (65) 69 μm; dcoll, 53 (55) 57 μm; *L*/*D*, 4; *L*/ln, 1.5.

Previous records: Lower Silurian: Sarchahan Formation, southern Iran (Ghavidel-syooki and Winchester-Seeto, 2004). Middle Llandovery: Qalibah Formation, Saudi Arabia (Paris et al., 1995); Solvik Formation (*pro parte*) and Rytteraker (*p.p.*) Formation, Norway (Nestor, 1999). Llandovery: Saarde and Rumba Formation, lower Adavere regional Stage, Estonia and northern Latvia (Nestor and Nestor, 2002). Formigo Formation, northern Spain (Cramer, 1967); Sweden (Grahn, 1998).

Occurrence and abundance: Member I of Niur Formation, samples MG-7714 to MG-7721: common; samples MG-7722 to MG-7729: uncommon.

Conochitina edjelensis Taugourdeau, 1963

Plate I, figs. 6, 8

Dimensions (based on 87 specimens): *L*, 200 (210) 220 μm; ln, 97 (104) 107 μm; *D*, 91 (93) 95 μm; dcoll, 65 (67) 69 μm; *L*/*D*, 2.3; *L*/ln, 2.

Previous records: This species has been previously recorded from lower Silurian strata in Saudi Arabia (Paris et al., 1995), Libya (Hill et al., 1985; Paris, 1988), Spain (Cramer, 1967) and Estonia (Nestor, 1994). The global stratigraphic distribution of *C. edjelensis* has been reviewed in detail by Verniers et al. (1995); according to these authors the species' stratigraphic range is restricted to the middle Llandovery.

Occurrence and abundance: Member I of Niur Formation, samples MG-7721 to MG-7725: common; samples MG-7726 to MG-7729: uncommon.

Family Lagenochitinidae Eisenack, 1931

Subfamily Angochitininae Paris, 1981

Genus *Angochitina* Eisenack, 1931

Type species: *Angochitina echinata* Eisenack, 1931

Angochitina iranica n. sp.

Plate IV, fig. 5; Plate V, fig. 1

Derivation of name: With reference to Iran, the country in which the species was first discovered.

Type locality: Kuh-e-Saluk, 35 km southeast of Bojnourd city, eastern Caspian Sea, Iran.

Type stratum: Niur Formation at Pelmis–Gorge, sampling level MG-7752.

Holotype: Plate V, fig. 1.

Material: 100 specimens.

Dimensions (based on 25 specimens): *L*, 120 (122) 124 μm; ln, 54 (56) 58 μm; *D*, 61 (64) 67 μm; dcoll, 38 (40) 42 μm; ls, 17–19 μm; *L*/*D*, 1.8; *L*/ln, 2.

Diagnosis: This species has a subcylindro-sphaerical vesicle with distinct flexure and poorly developed shoulder. The vesicle surface is covered by filose spines which are perpendicularly arranged to the vesicle's longitudinal axis. The filose spines are lambda-shaped, simple distally and coalescent at their bases. The spinose ornamentation is denser on the chamber than towards aperture. The neck widens towards aperture and forms a fringed collarette.

Dimensions of holotype: *L*, 121 μm; ln, 57 μm; *D*, 65 μm; dcoll, 41 μm; ls, 19 μm; *L*/*D*, 1.8; *L*/ln, 2.

Remarks and comparison: This species differs from all other species of *Angochitina* by its filose-spinose ornamentation, consisting of lambda-shaped, flexible spines.

Occurrence and abundance: Member I of Niur Formation, samples MG-7743 to MG-7753: common; samples MG-7754 to MG-7757: uncommon.

Angochitina sp. *A*.

Plate IV, figs. 1, 6

Dimensions (based on 20 specimens): *L*, 125 (127) 129 μm; ln, 55 (57) 59 μm; *D*, 65 (67) 69 μm; dcoll, 36–38 μm; ls, 4–6 μm; *L*/*D*, 1.9; *L*/ln, 2.2.

Description: Cylindro-sphaerical vesicle, with conspicuous flexure and indistinct shoulder. The neck widens towards the aperture with a distinct collarette. The basal margin is rounded, and the base is slightly convex. The spinose ornamentation is regular and distributed on the whole vesicle surface. Spines mostly simple, rarely bifurcate; very rarely 2 spines merging in their proximal part, to form a single, simple spine (lambda-shaped spines).

Remarks: The present species is characterized by its slightly convex base (which may result from preservation effects), and its rather small dimensions. It might represent a new species but the open nomenclature is preferred here because of the relative scarcity and unfavourable preservation of the recovered specimens.

Occurrence and abundance: Member I of Niur Formation, samples MG-7743 to MG-7746: uncommon; samples MG-7747 to MG-7757: common.

Angochitina multipodspina n. sp.

Plate IV, fig. 4

Derivation of name: With reference to its characteristic spinose ornamentation (multirooted).

Type locality: Kuh-e-Saluk, 35 km southeast of Bojnourd city, eastern Caspian Sea.

Type stratum: Niur Formation at Pelmis–Gorge, sampling level MG-7752.

Holotype: Plate IV, fig. 4.

Material: 265 specimens.

Dimensions (based on 20 specimens): *L*, 110 (115) 120 μm; ln, 56 (58) 60 μm; *D*, 58 (60) 62 μm; dcoll, 27–29 μm; ls, 5–7 μm; *L*/*D*, 2; *L*/ln, 2.

Diagnosis: The vesicle is cylindro-sphaerical in shape, with a slightly concave antiapertural pole. The length of neck is 1/2 vesicle length. The flexure is broadly rounded, shoulder indistinct. The basal margin is rounded and provided with short, simple spines. The neck widens slightly towards aperture. The whole vesicle surface is covered by spinose ornamentation, becoming gradually denser towards antiapertural pole. The spines are lambda-shaped to multirooted, distally simple; they are evenly distributed on the vesicle surface.

Dimensions of holotype: *L*, 120 μm; ln, 60 μm; *D*, 62 μm; dcoll, 29 μm; ls, 7 μm; *L*/*D*, 2; *L*/ln, 2.

Remarks and comparison: This species differs from all other species of *Angochitina* in its characteristic spinose ornamentation consisting of bi- to multi-rooted, distally simple spines, unevenly disposed on the vesicle surface (denser towards antiapertural pole). *Angochitina iranica* n. sp. has significantly longer spines which are much more densely distributed on the vesicle surface.

Occurrence and abundance: Member I of Niur Formation, samples MG-7729 to MG-7753: common to abundant; samples MG-7754 to MG-7756: uncommon; sample MG-7757: rare.

Subfamily Ancyrochitininae Paris, 1981

Genus *Ancyrochitina* Eisenack, 1955

Type species *Conochitina ancyrea* Eisenack, 1931

Ancyrochitina ancyrea (Eisenack, 1931)

Plate II, fig. 5

Dimensions (based on ca. 400 specimens): *L*, 95 (100) 105 μm; ln, 45 (47) 49 μm; *D*, 78 (82) 86 μm; dcoll, 31 (35) 39 μm; ls, 46 (49) 52 μm; *L*/*D*, 1.2; *L*/ln, 2.1.

Remarks: The present specimens show a finely spinose ornamentation on the upper part of the chamber and on the neck. Processes are often broken distally, but, when intact, they possess all characteristics of *A. ancyrea*.

Previous records: common in Upper Ordovician to upper Silurian strata worldwide.

Occurrence and abundance: Ghelli Formation, samples MG-2865 to MG-2875: abundant. Member I of Niur Formation, samples MG-7682 to MG-7710: abundant; samples MG-7711 to MG-7742: common; samples MG-7743 to MG-7757: uncommon.

Ancyrochitina bifurcaspina Nestor, 1994

Plate VI, fig. 4

Dimensions (based on 237 specimens): *L*, 117 (120) 123 μm; ln, 61 (60) 62 μm; *D*, 57 (58) 60 μm; dcoll, 27 (32) 35 μm; ls, 26 (30) 35 μm; *L*/*D*, 2; *L*/ln, 1.7 (1.9) 2.

Remarks: The vesicle is cylindro-conical with conspicuous flexure and lack of shoulder. The basal margin is rounded and bears short appendices which are coalescent in the proximal part and bifurcate distally. The neck widens towards aperture and carries short indented spines. The vesicle surface is smooth to finely granulate.

Previous records: Upper Ordovician: uppermost part of the Ohne Formation, Juuru Stage, and Slitere Member of the Raikktila Stage, Estonia (Nestor, 1994).

Occurrence and abundance: Ghelli Formation, sample MG-2875: common. Member I of Niur Formation, samples MG-7682 to MG-7692: common; samples MG-7693 to MG-7702: uncommon.

Ancyrochitina bojnourdensis n. sp.

Plate VI, figs. 6, 7

Derivation of name: With reference to Bojnourd city, eastern Caspian Sea, northern Iran.

Type locality: Kuh-e-Saluk, 35 km southeast of Bojnourd city, eastern Caspian Sea, northern Iran.

Type stratum: Niur Formation at Pelmis–Gorge, sampling level MG-7752.

Holotype: Plate VI, fig. 7.

Material: 270 specimens.

Dimensions: *L*, 108 (110) 112 μm; ln, 42 (45) 48 μm; *D*, 64 (67) 70 μm; ls, 14 (16) 18 μm; dcoll, 24 (26) 38 μm; ls, 14–16 μm; *L*/*D*, 1.6; *L*/ln, 2.8.

Diagnosis: Cylindro-conical vesicle with flat or concave base, with conspicuous flexure and undeveloped shoulder; maximum vesicle diameter is equivalent to the total vesicle length. The vesicle surface is densely covered by grana and short (largely less than 10 μm on average), filiform spines. The neck widens towards aperture, and is approximately as long as the chamber. The basal margin is bluntly rounded and carries numerous appendices at basal edge. The appendices are lambda-shaped and distally branched up to third order, rarely to fourth order. Dimensions of holotype: *L*, 110 μm; ln, 41 μm; *D*, 66 μm; dcoll, 30 μm; ls, 16 μm; *L*/*D*, 1.6; *L*/ln, 2.8.

Remarks: This species is somewhat similar to *Ancyrochitina fatemae* n. sp., but we retain it as a separate species because of consistently, not range-overlapping, smaller dimensions and because of difference in ornamentation (shorter and less robust spines, higher-order branching of basal processes).

Occurrence and abundance: Member I of Niur Formation, sample MG-7703 to MG-7735: common; sample MG-7736 to MG-7757: uncommon.

Ancyrochitina fatemae n. sp.

Plate III, figs. 3, 4; Plate V, figs. 2, 3

Derivation of name: Refers to the name of the first author's wife who encouraged him on research works.

Type locality: Kuh-e-Saluk, 35 km southeast of Bojnourd city, eastern Caspian Sea, northern Iran.

Type stratum: Niur Formation at Pelmis–Gorge, sampling level MG-7742.

Holotype: Plate III, figs. 3, 4.
Dimensions: *L*, 111 (128) 147 μm; ln, 52 (63) 81 μm; *D*, 59 (66) 75 μm; ls, 17 (22) 28 μm; dcoll, 28 (32) 36 μm; *L*/*D*, 1.8 (2.1) 2.3; *L*/ln, 1.6–1.8.
Material: 110 specimens.
Diagnosis: Cylindro-conical vesicle with flat or convex base; flexure broadly rounded, shoulder inconspicuous. Chamber gradually merging to neck, measuring 1/2 of total vesicle length. Neck widening towards aperture and provided with a distinct collarette carrying fringed or indented simple spines. Basal margin bluntly rounded and carrying 4–8 appendices at basal edge. Basal appendices branching up to fourth order at distal end and coalescing at their bases. Entire vesicle surface covered by homomorphic, small spines, often broken off.
Dimensions of holotype: *L*, 145 μm; ln, 80 μm; *D*, 72 μm; ls, 28 μm; dcoll, 35 μm; *L*/*D*, 2.2; *L*/ln, 1.8.
Remarks and comparison: This species differs from other species of previously described *Ancyrochitina* species in the nature of its spinose ornamentation covering entire vesicle surface.
Occurrence and abundance: Member I of Niur Formation, samples MG-7739 to MG-7742 and MG-7754 to MG-7757: uncommon; samples MG-7743 to MG-7753: common.

Ancyrochitina laevanensis Nestor, 1980
Plate VI, fig. 5
Dimensions (based on ca. 200 specimens): *L*, 110 (120) 130 μm; ln, 56 (58) 60 μm; *D*, 60 (64) 68 μm; dcoll, 20 (22) 24 μm; ls, 18 (21) 24 μm; *L*/*D*, 1,9; *L*/ln, 2.2.
Previous records: Early Llanvirnian: Estonia (Juuru Regional stage; Nestor, 1980, 1994); southern Iran (Ghavidel-syooki, 2000a,b); Libya (Hill et al., 1985; Molyneux and Paris, 1985; Paris, 1988).
Occurrence and abundance: Ghelli Formation: sample MG-2875: common. Member I of Niur Formation: sample MG-7682 to MG-7693: abundant; sample MG-7694 to MG-7703: common.

Ancyrochitina longifilosa n. sp.
Plate IV, figs. 2, 7
Derivation of name: Refers to the characteristic ornamentation of the vesicle surface.
Type locality: Kuh-e-Saluk, 35 km southeast of Bojnourd city, eastern Caspian Sea, northern Iran.
Type stratum: Niur Formation at Pelmis–Gorge, sampling level MG-7752.
Holotype: Plate IV, figs. 2, 7.
Material: 60 specimens.
Dimensions (based on 60 specimens): *L*, 89 (91) 93 μm; ln, 38 (40) 42 μm; *D*, 53 (55) 57 μm; dcoll, 28–30 μm; ls, 15–17 μm; *L*/*D*, 1.6; *L*/ln, 2.2.
Diagnosis: Vesicle cylindro-sphaerical with flat or concave base; the chamber gradually changes into the neck so that flexure and shoulder are absent. The neck and chamber are equal in length. Basal margin bluntly rounded, carrying 4 to 8 thick, nodular appendices. Vesicle surface granulate, covered by bi-rooted, long, flexible and distally simple spines. Dimensions of holotype: *L*, 91 μm; ln, 40 μm; *D*, 56 μm; dcoll, 30 μm; ls, 16 μm; *L*/*D*, 1.6; *L*/ln, 2.2.
Remarks and comparison: The presence of 4–8 thick, nodular appendices on basal edge justifies the generic assignment to *Ancyrochitina*. This new species differs from all previously described *Ancyrochitina* species by having bi-rooted, long, flexible spines on vesicle surface.
Occurrence and abundance: Member I of Niur Formation, samples MG-7703 to MG-7724: uncommon; samples MG-7725 to MG-7757: common.

Ancyrochitina sp. cf. *A. merga* Jenkins, 1970
Plate I, figs. 4, 5
Dimensions (based on 30 specimens): *L*, 101 (103) 105 μm; ln, 39 (41) 43 μm; *D*, 67 (69) 71 μm; dcoll, 40 (41) 43 μm; ls, 19–21 μm; *L*/*D*, 1.5, *L*/ln, 2.4.
Remarks: The observed specimens possess all the morphological characteristics of *A. merga*, but their basal processes appear to be arranged along two to three parallel rows, an untypical feature for *A. merga*.
Occurrence and abundance: Ghelli Formation, sample MG-2865: common; samples MG-2870 and MG-2875: uncommon. Member I of Niur Formation, sample MG-7682: rare.

Ancyrochitina persica Ghavidel-syooki and Winchester-Seeto, 2002
Plate I, figs. 2, 3, 7
Dimensions (based on 20 specimens): *L*, 104 (110) 114 μm; ln, 57 (71) 82 μm; *D*, 70 (76) 79 μm; dcoll, 32 (41) 50 μm; ls, 24 (26) 30 μm; *L*/*D*, 1.4; *L*/ln, 1.4 (1.6) 1.8.
Remarks: This is the second record of *A. persica* in northeastern Iran; the present well-preserved specimens are illustrated to supplement the previous description of the species (Ghavidel-syooki and Winchester-Seeto, 2002). In the Iranian assemblages, *A. persica* characteristically occurs in association with *A.* cf. *merga*.
Previous records: Upper Ordovician: Ghelli Formation, Alborz Range, Iran (Ghavidel-syooki and Winchester-Seeto, 2002).

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Occurrence and abundance: Ghelli Formation, samples MG-2865 and MG-2870: uncommon; sample MG-2875: rare.

Ancyrochitina porrectaspina Nestor, 1994

Plate V, fig. 4

Dimensions (based on 167 specimens): *L*, 79 (81) 83 μm; ln, 39 (40.5) 42 μm; *D*, 49 (51) 53 μm; dcoll, 22 (23.5) 25 μm; ls, 18 (20) 22 μm; *L*/*D*, 1,6; *L*/ln, 2.

Remarks: Although somewhat smaller, the present specimens show all morphological characteristics of *A. porrectaspina*.

Previous records: Adavere to lower Jaani Estonian regional stages (upper Llandovery; Nestor, 1994)

Occurrence and abundance: Member I of Niur Formation, samples MG-7744 to MG-7748: uncommon; samples MG-7749 to MG-7750: abundant; samples MG-7751 to MG-7755: common; samples MG-7756 and MG-7757: rare.

Ancyrochitina ramosaspina Nestor, 1994

Plate VI, figs. 2, 3

Dimensions (based on 167 specimens): *L*, 130 (132) 135 μm; ln, 50 (58) 67 μm; *D*, 67 (64) 70 μm; dcoll, 27 (33) 39 μm; ls, 22 (29) 35 μm; *L*/*D* 1.3 (1.9) 2.6; *L*/ln, 1.7 (1.9) 2.2.

Remarks: The observed specimens show a cylindro-conical vesicle with convex base bearing 4–8 appendices which are branched 3–4 times. Flexure is broadly rounded and the shoulder is absent. The neck widens towards aperture which is provided with fringed or short indented spines. The flexure carries short triangular spines.

Previous records: Middle Llandovery (Raikküla Stage) of Estonia (Nestor, 1994).

Occurrence and abundance: Member I of Niur Formation, samples MG-7702 to MG-7710: abundant; samples MG-7711 to MG-7713: uncommon.

Ancyrochitina sp. cf. *A. ramosaspina* Nestor, 1994

Plate VI, fig. 1

Dimensions (based on 45 specimens): *L*, 61 (72) 83 μm; ln, 30 (36) 42 μm; *D*, 40 (45) 50 μm; dcoll, 25 (26.5) 28 μm; ls, 29 (31) 33 μm; *L*/*D*, 1.7; *L*/ln, 2.

Remarks: The present specimens show all morphological characteristics of *A. ramosaspina* Nestor, 1994, but are consistently and significantly smaller, with clearly non-overlapping dimensional ranges. Accordingly, the specimens are retained in open nomenclature.

Occurrence and abundance: Member I of Niur Formation, samples MG-7742 to MG-7756: uncommon; sample MG-7757: rare.

Genus: *Plectochitina* Cramer, 1964

Type species: *Plectochitina carminae* Cramer, 1964

Plectochitina nodifera Nestor, 1994

Plate II, fig. 6

Dimensions (based on 25 specimens): *L*, 95 (102) 105 μm; ln, 41 (45) 49 μm; *D*, 68–70 μm; dcoll, 25 (27) 29 μm; ls, 16–18 μm; *L*/*D*, 1.6; *L*/m, 2.3.

Remarks: The observed specimens possess all morphological characteristics of *Plectochitina nodifera* Nestor, 1994, although their dimensional ranges are slightly smaller than those of the topotype material from Estonia (Nestor, 1994).

Previous records: *Plectochitina nodifera* has been previously recorded in the lowermost part of the Juum Stage, mostly in the lowermost beds of the Ohne and Staciunia formations and the lower half of the Ruja and Sturi members in Estonia (Nestor, 1994), the early Silurian Qalibah Formation in Saudi Arabia (Paris et al., 1995) and the lower Silurian Sarchahan Formation of Iran (Ghavidel-syooki, 2000a; Ghavidel-syooki and Winchester-Seeto, 2004).

Occurrence and abundance: Ghelli Formation, sample MG-2875: common. Member I of Niur Formation, samples MG-7682 and MG-7683: common; samples MG-7684 to MG-7690: uncommon.

Plectochitina paraguayensis Wood and Miller, 1991

Plate II, fig. 3; Plate III, fig. 1

Dimensions (based on 30 specimens): *L*, 90 (94.5) 99 μm; ln, 53 (55.5) 58 μm; *D*, 60 (62) 64 μm; dcoll, 35–37 μm; ls 129 (132) 135 μm; *L*/*D*, 1.5; *L*/ln, 1.7.

Remarks: The vesicle is cylindro-conical. The surface of vesicle is smooth, but often deformed by internally grown pyrite crystals. The flexure is well-developed, but the shoulder and flank are unconspicuous. The basal margin is rounded and provided with 2–4 long, spongy appendices. The neck widens towards the aperture. The collarette is distinct and provided with small simple spines. The basal part of vesicle is convex, or concave in this species.

Previous records: This species has been previously recorded from lower Silurian strata in the Qalibah Formation of Saudi Arabia (Paris et al., 1995), the Vargas Pena Shale of Paraguay (type locality: Aeronian–Telychian boundary beds, Wood and Miller, 1991) and the Sarchahan Formation of Iran (Ghavidel-syooki, 2000a; Ghavidel-syooki and Winchester-Seeto, 2004) .Verniers et al. (1995) considered this species to be characteristic of the lower and middle Llandovery.

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Occurrence and abundance: Member I of Niur Formation, samples MG-7712 to MG-7717: abundant; samples MG-7718 to MG-7722: common.

Plectochitina pseudoagglutinans (Taugourdeau, 1963)

Plate II, figs. 1, 2, 4

Dimensions (based on 25 specimens): *L*, 108 (120) 145 μm; ln, 43 (50) 86 μm; *D*, 35 (53) 77 μm; ls, 30 (40) 52 μm; *L*/*D*, 1.9–2.5; *L*/ln, 1.4–1.7.

Previous records: *Plectochitina pseudoagglutinans* has been previously recorded from lower Silurian strata in North Africa (Taugourdeau et al., 1967; Paris, 1988), Spain (Cramer, 1967; Priewalder, 1997), Saudi Arabia (Paris et al., 1995), southern Iran (Ghavidel-syooki, 2000a,b; Ghavidel-syooki and Winchester-Seeto, 2004). Palaeogeographically, this species is restricted to the northern Gondwana domain.

Occurrence and abundance: Member I of Niur Formation, samples MG-7721 to MG-7724: uncommon; samples MG-7725 to MG-7738: common; samples MG-7739 to MG-7745: uncommon.

Plectochitina ralphi Nestor, 1994

Plate III, fig. 7

Dimensions (based on 30 specimens): *L*, 98 (103) 108 μm; ln, 47 (48.5) 50 μm; *D*, 53 (56) 59 μm; dcoll, 29 (31.5) 34 μm; ls, 16 (20) 24 μm; *L*/*D*, 1.8; *L*/ln, 2.2.

Remarks: The observed specimens are somewhat smaller than the topotype Estonian material of *Plectochitina ralphi* Nestor, 1994.

Previous records: This species has been previously recorded from the Rumba Formation of Adavere Stage in Estonia (Nestor, 1994) and the lower Silurian Sarchahan Formation of Iran (Ghavidel-syooki, 2000a; Ghavidel-syooki and Winchester-Seeto, 2004).

Occurrence and abundance: Member I of Niur Formation, samples MG-7743 to MG-7753: common; samples MG-7754 to MG-7757: uncommon.

Plectochitina saharica (Taugourdeau, 1962)

Plate III, fig. 5

Dimensions (based on 20 specimens): *L*, 131 (134) 137 μm; ln, 58 (59) 60 μm; *D*, 70 (73) 76 μm; dcoll, 40 (42) 44 μm; ls, 56 (58) 60 μm; *L*/*D*, 1.8; *L*/ln, 2.3.

Remarks: This species is characterized by a cylindro-conical vesicle and spongy processes on the basal margin. The appendices are short, flexible and their tips are interconnected by a rim. The flexure and shoulder are conspicuous and the neck widens towards the collar. The vesicle surface is smooth. The basal part of this species ranges from convex, or flat to concave.

Previous records: This species has been recorded from lower Silurian strata of Algerian Sahara (Taugourdeau, 1962; Taugourdeau et al., 1967), middle-upper Silurian subsurface material from Florida (Cramer, 1973) and the lower Silurian Sarchahan Formation of southern Iran (Ghavidel-syooki, 2000a; Ghavidel-syooki and Winchester-Seeto, 2004). Verniers et al. (1995) considered the species as having a stratigraphic range restricted to the middle and upper Llandovery.

Occurrence and abundance: Member I of Niur Formation, samples MG-7728 to MG-7743: uncommon; samples MG-7744 and MG-7745: rare.

Plectochitina spongiosa Achab, 1977

Plate I, fig. 1

Dimensions (based on 30 specimens): *L*, 130 (132) 134 μm; *D*, 95 (97) 99 μm; dcoll, 48 (49.5) 51 μm; ln, 51 (54) 57 μm; ls, 12 (13.5) 15 μm, *L*/*D*, 1.4, *L*/ln, 2.3.

Remarks: This species is characteristically abundant in the upper part of the Ghelli Formation where it occurs in association with *Ancyrochitina* cf. *merga* and *A. persica*.

Previous records: Ashgill through Llandovery strata of northern Gondwana (Paris, 1988, 1990), Laurentia (Achab, 1977; Paris, 1996), and Baltica (Estonia: Nestor, 1994).

Occurrence and abundance: Ghelli Formation, samples MG-2865 to MG-2875: abundant. Member I of Niur Formation, samples MG-7682 to MG-7691: common.

Subfamily: Cyathochitininae Paris, 1981

Genus: *Cyathochitina* Eisenack, 1955

Type species: *Conochitina campanulaeformis* Eisenack, 1931

Cyathochitina campanulaeformis (Eisenack, 1931)

Plate III, fig. 2

Dimensions (based on 35 specimens): *L*, 179 (182.5) 186 μm; ln, 70 (73.5) 76 μm; *D*, 120 (122.5) 125 μm; dcoll, 49 (51) 53 μm; *L*/*D*, 1.2; *L*/ln, 2.5.

Remarks: This species has a cylindro-conical vesicle. The vesicle surface is smooth or granulate. The flanks are convex and sometimes straight.

Previous records: This species has a broad palaeobiogeographical diffusion, with a long stratigraphic range comprised between the Middle Ordovician and the early Silurian (Nestor, 1994; Paris, 1996)

Occurrence and abundance: Ghelli Formation, samples MG-2865 to MG-2875: abundant. Member

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I of Niur Formation, samples MG-7682 to MG-7757: common to abundant.

Cyathochitina kuckersiana (Eisenack, 1934)

Plate III, fig. 6

Dimensions (based on 25 specimens): *L*, 200 (205) 210 μm; ln, 72 (74) 76 μm; *D*, 190 (193) 196 μm; dcoll, 45 (48) 51 μm; *L*/*D*, 1; *L*/ln, 2.7.

Remarks: This species has a cylindro-conical vesicle with a transparent carina on the basal edge. The base is flat and carries a weak concentric sculpture with a scar in the centre. The flanks are concave to almost straight.

Previous records: This species ranges from Middle Ordovician to the early Silurian. It constitutes a typical component of early Silurian chitinozoan assemblages from Estonia, occurring commonly in the lowermost beds of Juuru Stage and lowermost part of the Kolka Member of the Raikküla Stage (Nestor, 1994).

Occurrence and abundance: Member I of Niur Formation, samples MG-7682 to MG-7688: common; samples MG-7689 to MG-7699: uncommon; MG-7700 to MG-7702: rare. Ghelli Formation, samples MG-2865 to MG-2875: abundant.

Plate I. Scale bars equal to 10 μm. (see on page 3)

1. *Plectochitina spongiosa* Achab, 1977; sample MG-2865.
2, 3. *Ancyrochitina persica* Ghavidel-syooki and Winchester-Seeto, 2002; sample MG-2875.
4. *Ancyrochitina* sp. cf. *A. merga* Jenkins, 1970; sample MG-7682.
5. Enlargement of Fig. 4.
6. *Conochitina edjelensis* Taugourdeau, 1963; sample MG-7614.
7. Enlargement of Fig. 2.
8. Enlargement of Fig. 6.

Plate II. Scale bars equal to 10 μm. (see on page 4)

1, 2, 4. *Plectochitina pseudoagglutinans* (Taugourdeau, 1963); all specimens from sample MG-7734.
3. *Plectochitina paraguayensis* Wood and Miller, 1991 (specimen with broken appendages); sample MG-7722.
5. *Ancyrochitina ancyrea* (Eisenack, 1931); sample MG-7755.
6. *Plectochitina nodifera* Nestor, 1994; sample MG-2875.

Plate III. Scale bars equal to 10 μm. (see on page 5)

1. *Plectochitina paraguayensis* Wood and Miller, 1991; sample MG-7722.
2. *Cyatochitina campanulaeformis* (Eisenack, 1931); sample MG-7720.
3. *Ancyrochitina fatemae* n. sp., holotype; sample MG-7742.
4. Enlargement of Fig. 3 showing detail of process structure.
5. *Plectochitina saharica* (Taugourdeau, 1962); sample MG-7738.
6. *Cyatochitina kuckersiana* (Eisenack, 1934); sample 7703.
7. *Plectochitina ralphi* Nestor, 1994; sample MG-7750.

Plate IV. Scale bars equal to 10 μm. (see on page 6)

1. *Angochitina* sp. *A.*; sample MG-7752.
2. *Ancyrochitina longifilosa* n. sp., holotype; sample MG-7752.
3. *Conochitina alargada* Cramer, 1967; sample MG-7735.
4. *Angochitina multipodspina* n. sp., holotype; sample MG-7752.
5. *Angochitina iranica* n. sp., paratype; sample MG-7752.
6. Enlargement of Fig. 1
7. Enlargement of Fig. 2.

Plate V. Scale bars equal to 10 μm. (see on page 7)

1. *Angochitina iranica* n. sp., holotype; sample MG-7752.
2. *Ancyrochitina fatemae* n. sp., paratype; sample MG-7752.
3. *Ancyrochitina fatemae* n. sp., paratype, sample MG-7752.
4. *Ancyrochitina porrectaspina* Nestor, 1994; sample MG-7752.

Plate VI. Scale bars equal to 10 μm. (see on page 8)

1. *Ancyrochitina* sp. cf. *A. ramosaspina* Nestor, 1994; sample MG-7752.
2. *Ancyrochitina ramosaspina* Nestor, 1994; sample MG-7710.
3. Enlargement of Fig. 2.
4. *Ancyrochitina bifurcaspina* Nestor, 1994; sample MG-7692.
5. *Ancyrochitina laevanensis* Nestor, 1980; sample MG-7695.
6, 7. *Ancyrochitina bojnourdensis* n. sp. Holotype: Fig. 7; sample MG-7752.

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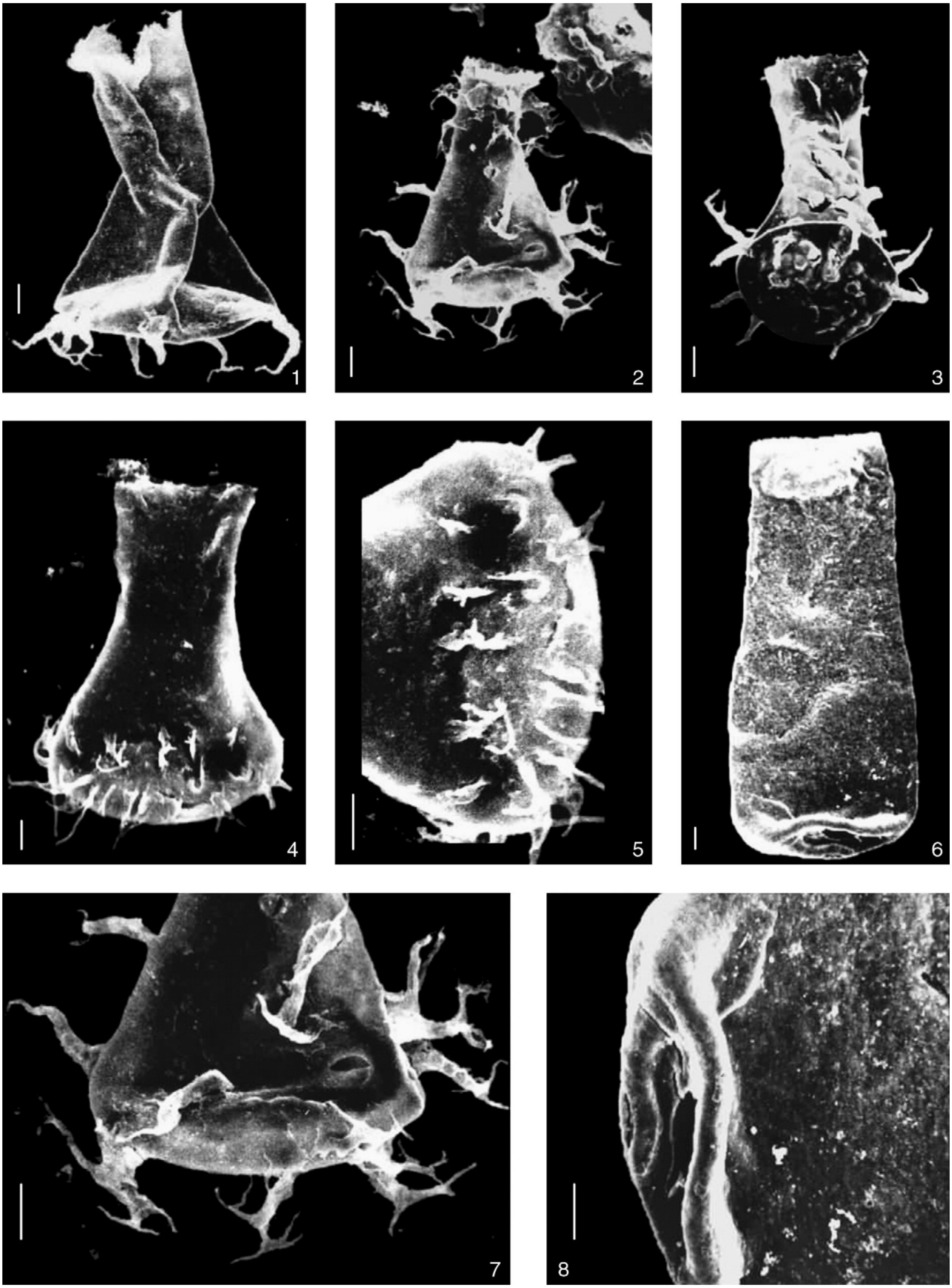

Plate I (*caption on page 10*).

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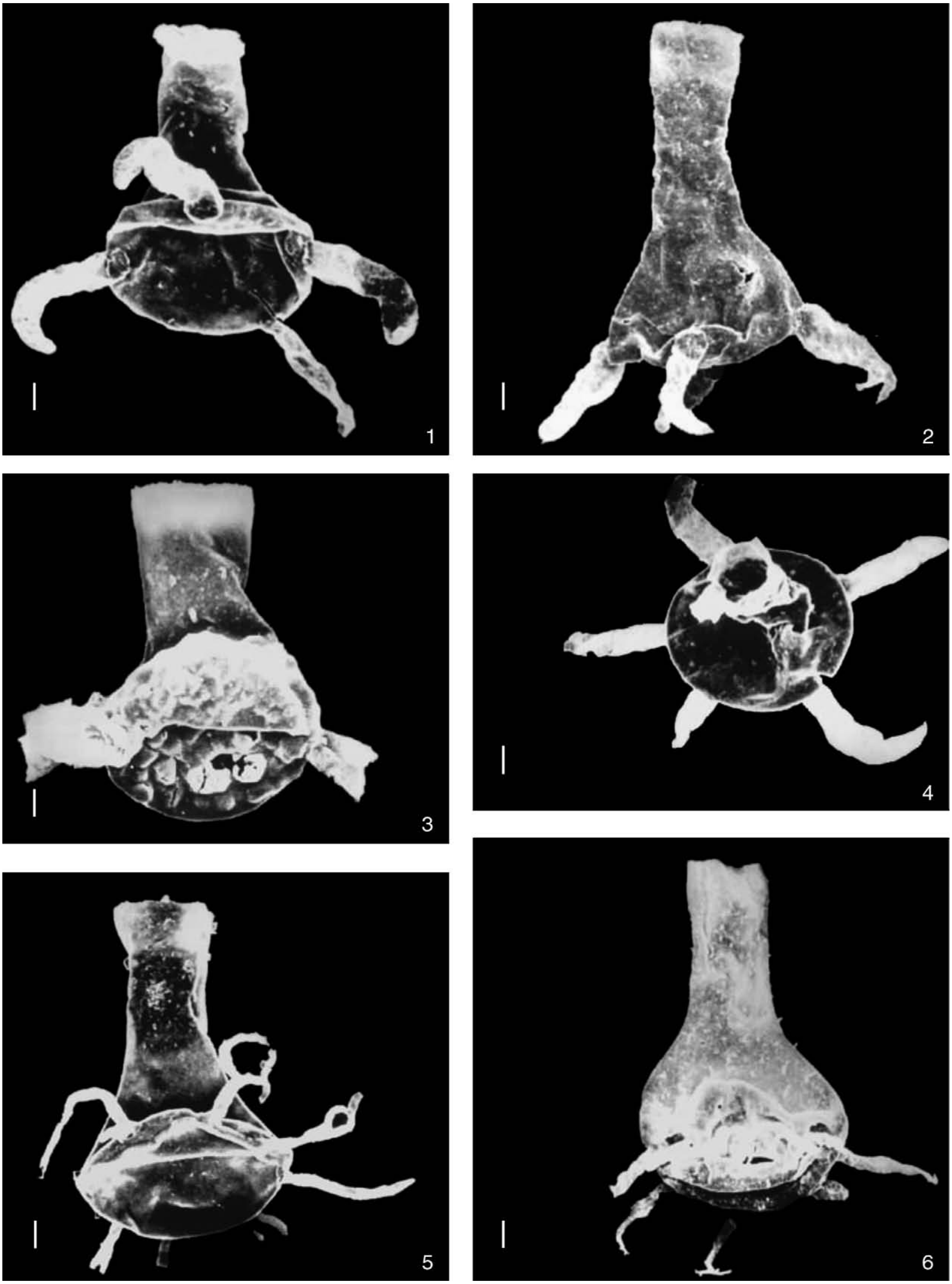

Plate II (*caption on page 10*).

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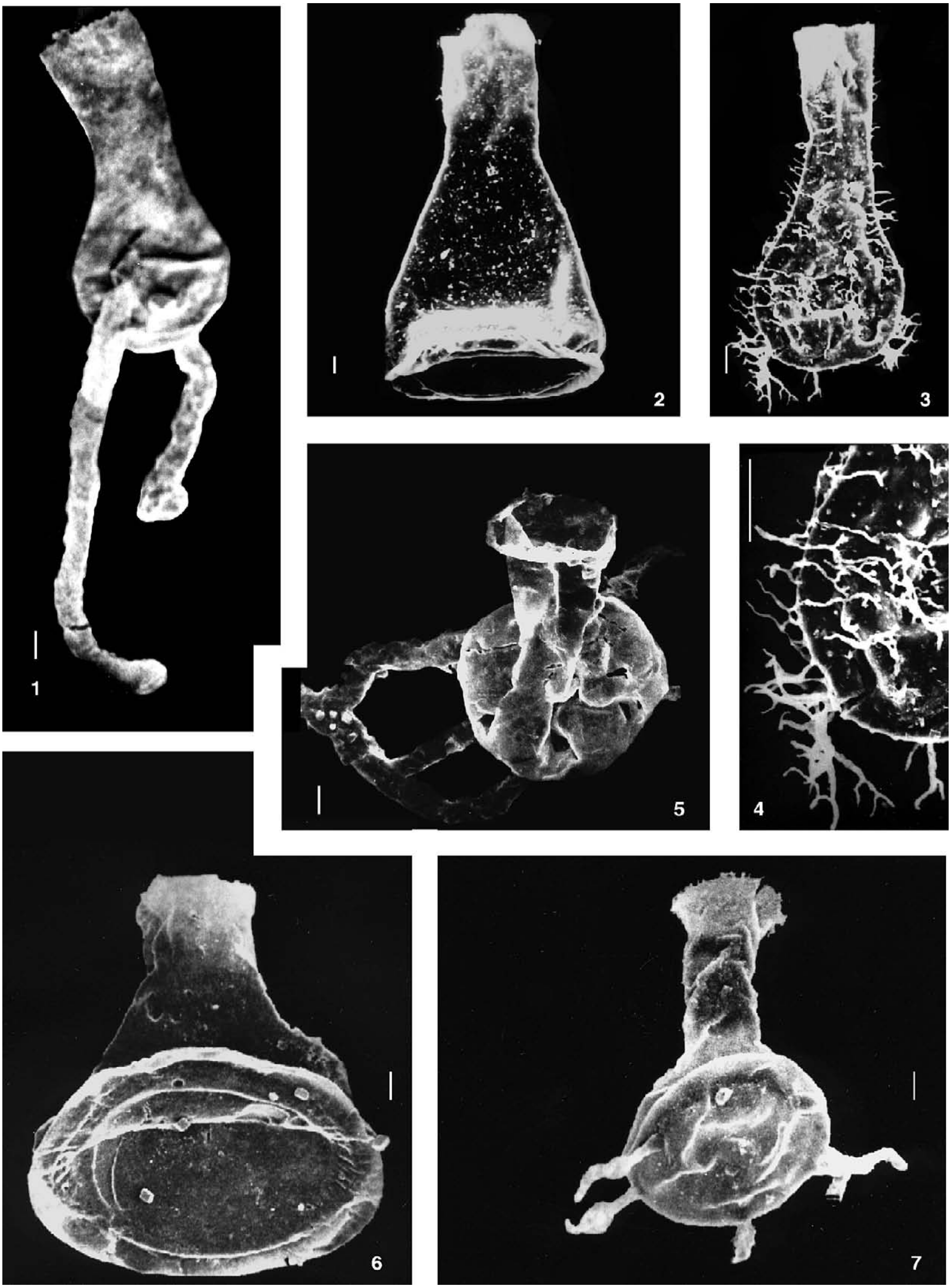

Plate III (*caption on page 10*).

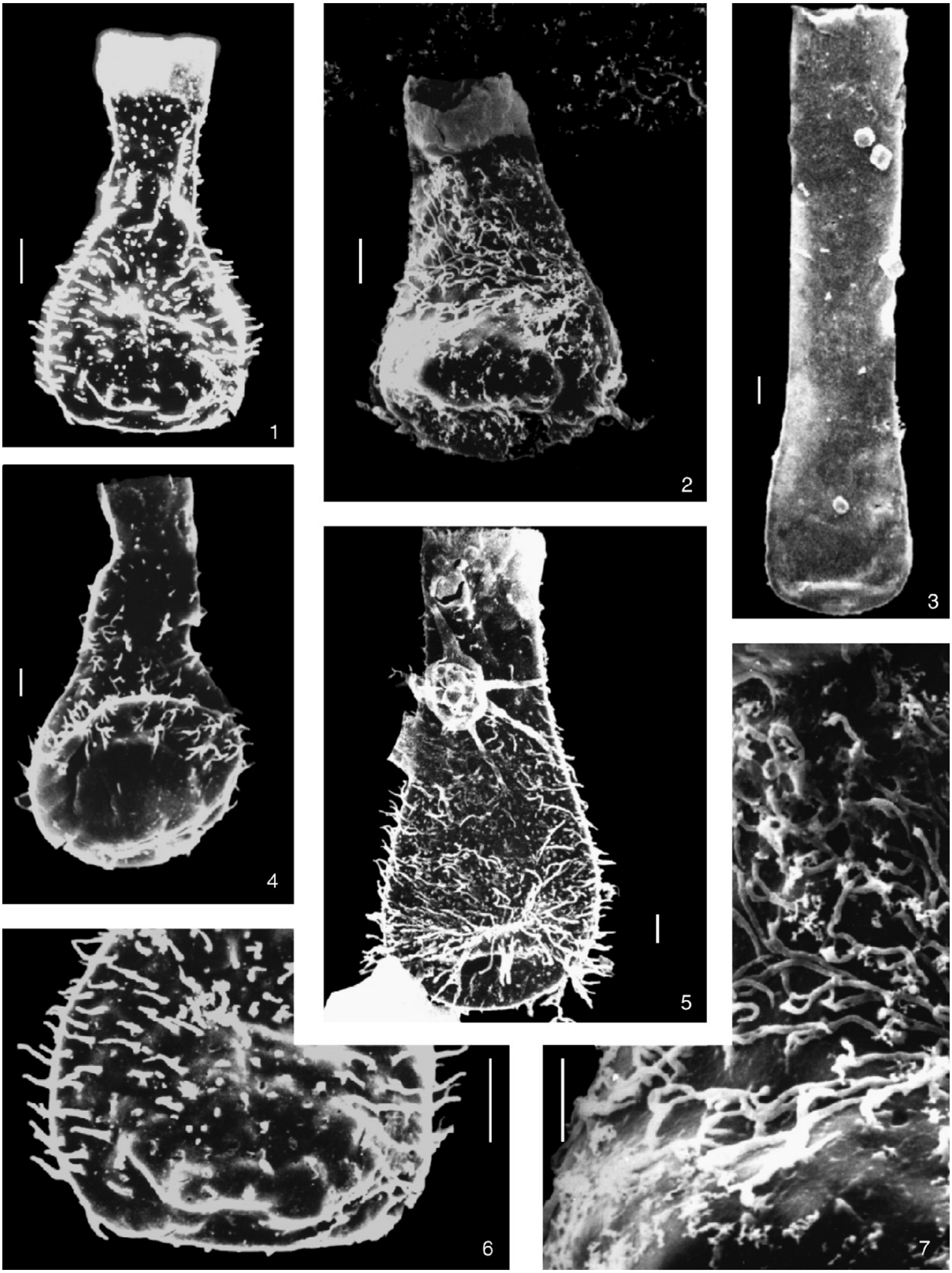

Plate IV (*caption on page 10*).

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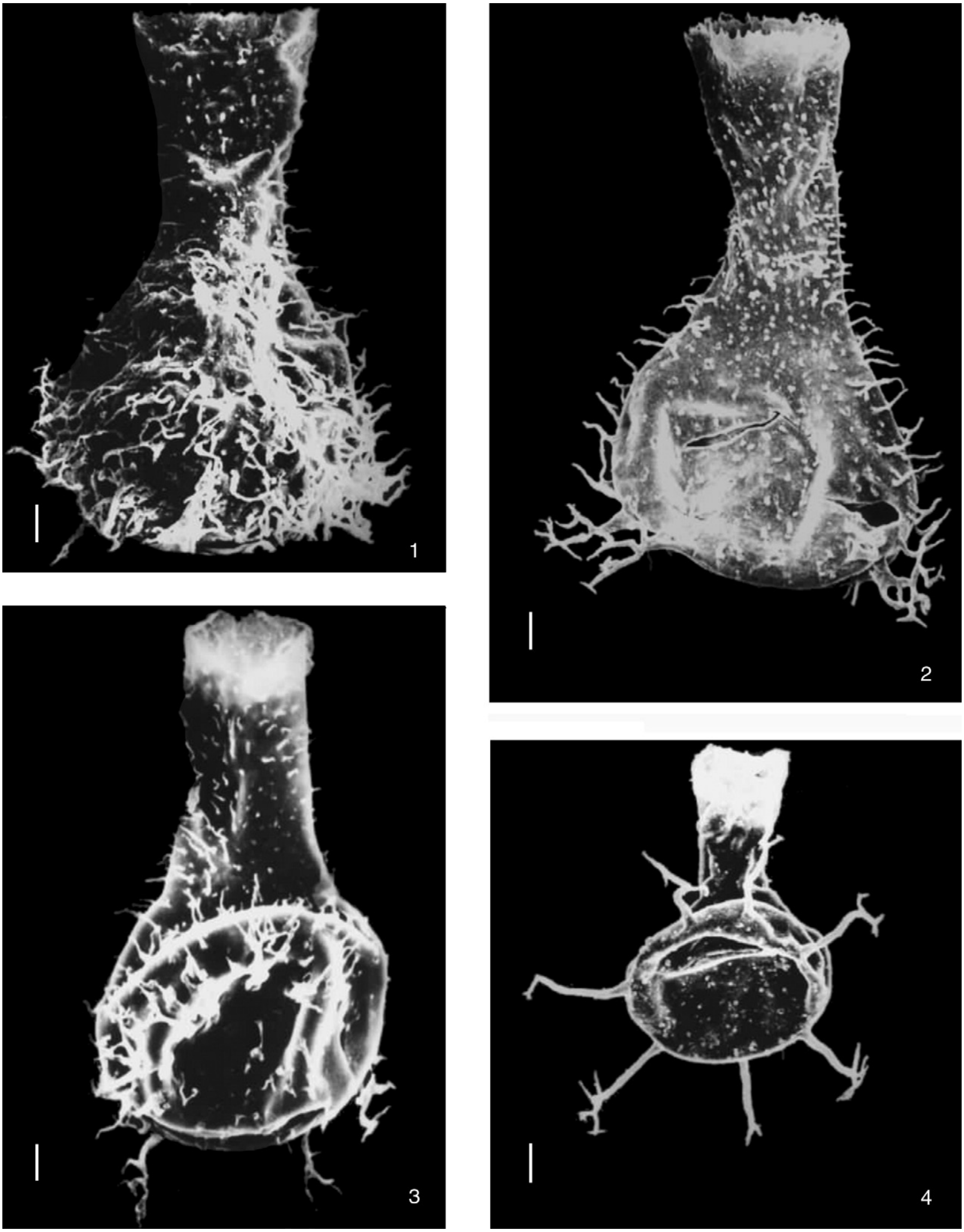

Plate V (*caption on page 10*).

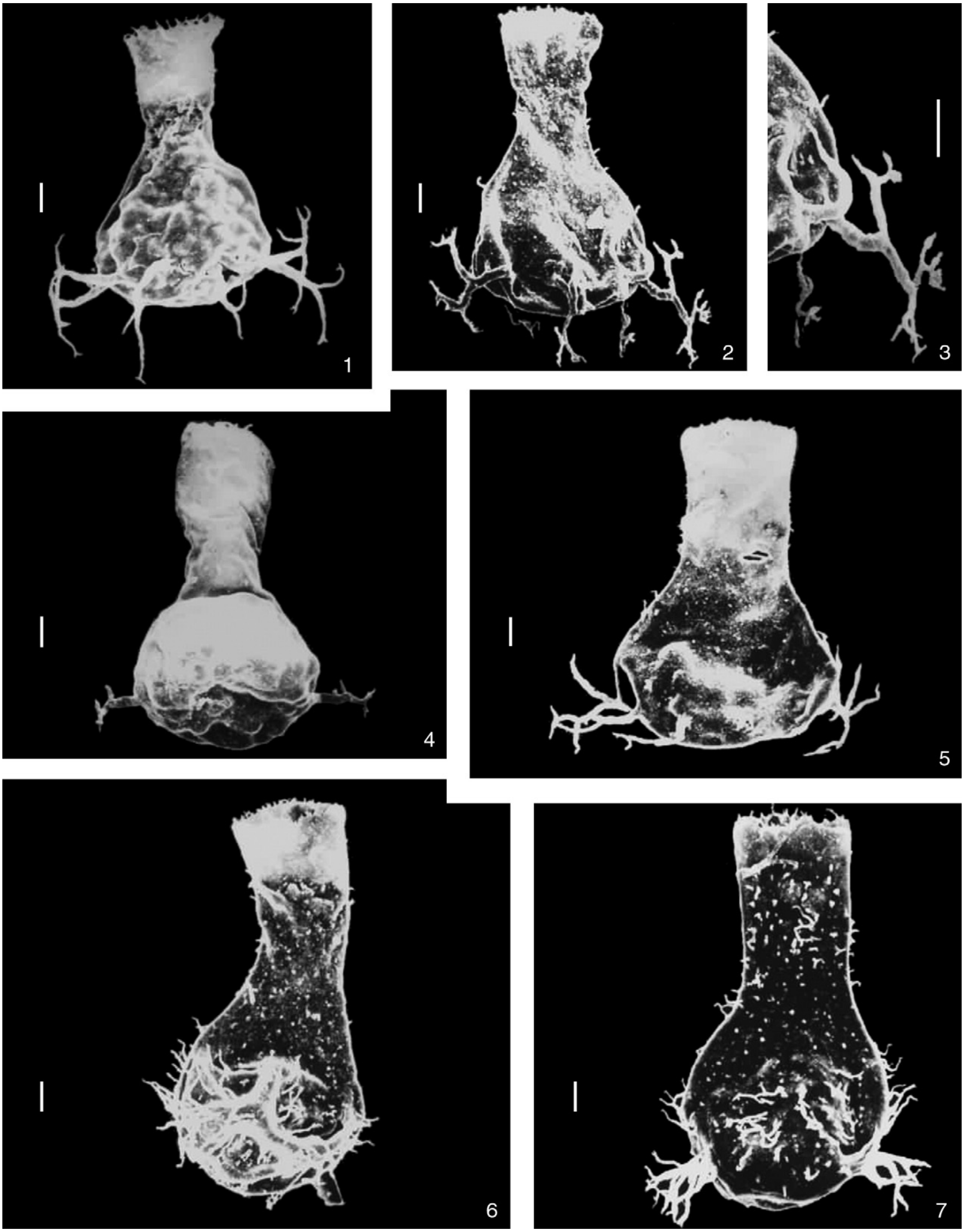

Plate VI (*caption on page 10*).

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5. Biostratigraphy

Based on the vertical distribution of the 24 chitinozoan species identified in this study (Fig. 3), six biozones can be defined, covering the uppermost part of the Ghelli Formation (one biozone) and Member I of the Niur Formation (five biozones). The present biozonation is informally introduced here and has a local application only; nonetheless, the relationships and possible chronostratigraphic equivalence with existing chitinozoan biozones are discussed.

5.1. Ancyrochitina persica local biozone

This biozone is defined by the total range of *Ancyrochitina persica* and *Ancyrochitina* cf. *merga*; it is recognized through a 37-m thick interval of silty shales in the uppermost part of the Ghelli Formation (Ghavidel-syooki, 2000a,b; Ghavidel-syooki and Winchester-Seeto, 2002; Fig. 3). The species *Plectochitina spongiosa*, *Cyathochitina kuckersiana*, *C. campanulaeformis*, and *Ancyrochitina ancyrea* also occur in, although they are not confined to, this biozone. This biozone may be equivalent to the *Ancyrochitina merga* Biozone, of mid-Ashgill age, defined in the North Gondwana Domain (Paris, 1990; Paris et al., 2000). The latter has been previously recognized also in the Late Ordovician of Seyahou Formation of southern Iran (Ghavidel-syooki, 2000b). If these biozones are found to be equivalent, there is good potential for accurate chronostratigraphic correlation between the eastern Alborz Mountain Range and the Zagros Mountain Range in northern and southern Iran, respectively, and between these areas and other regions of North Gondwana.

5.2. Ancyrochitina laevaensis Biozone of Nestor (1994)

This biozone occurs in the basal part of the Niur Formation; it comprises a thickness of 141 m in the Pelmis Gorge section, mainly composed of black-olive and grey shales (Fig. 3), and corresponds to the total range of *Ancyrochitina laevaensis* Nestor, 1980. The early Llandovery *A. laevanensis* Biozone has been defined in Estonia and northern Latvia by Nestor (1994), and appears to be applicable in the present study area. Other chitinozoan species occurring exclusively in this biozone are *Ancyrochitina bifurcaspina* and *Plectochitina nodifera*; these two species characteristically occur in early Llandovery strata of Baltica and northern Gondwana (Nestor, 1980, 1994; Verniers et al., 1995). The following species are also characteristic component of the present biozone, although they range upwards in the section: *Ancyrochitina ancyrea*, *Plectochitina spongiosa*, *Cyathochitina kuckersiana*, and *Cyathochitina campanulaeformis*.

5.3. Ancyrochitina ramosaspina local biozone

This chitinozoan biozone corresponds to total range of the eponymous species and extends through a thickness of 81 m (Fig. 3) within Member I of the Niur Formation, consisting of black shales with subordinate interbedded fossiliferous limestone layers. It is characterized by a remarkably high diversity of the chitinozoan assemblage. Accompanying species include *Ancyrochitina bojnourdensis* n. sp, *A. longifilosa* n. sp., and *Plectochitina paraguayensis*.

Ancyrochitina ramosaspina has been previously recorded from Slitere, Kolka and Ilka members of the Saarde Formation, which ranges from upper Juuru Stage to the Raikküla Stage in Estonia (Nestor, 1994). *Plectochitina paraguayensis* appears in the upper part of this biozone and ranges upwards into the succeeding zone; it has been previously recorded from lower Silurian strata including the Qalibah Formation of Saudi Arabia (Paris et al., 1995), the Vargas Pena Shale of Paraguay (Wood and Miller, 1991), and the Sarchahan Formation of Iran (Ghavidel-syooki, 2000a; Ghavidel-syooki and Winchester-Seeto, 2004). Verniers et al. (1995) have shown this species to be a characteristic and palaeogeographically widespread component of early and middle Llandovery chitinozoan assemblages.

5.4. Conochitina alargada local Biozone

This biozone is defined in the study section, by the total range of *C. alargada*; it occurs through 87 m of strata consisting of black-olive grey shales and subordinate fossiliferous limestone in Member I of the Niur Formation (Fig. 3).

Typical accompanying species is *Conochitina edjelensis*. *Conochitina alargada* has been previously recorded from middle Llandovery beds of the Qalibah Formation in Saudi Arabia (Paris et al., 1995); Llandovery beds of the Formigo Formation in northern Spain (Cramer, 1967); in the early Silurian Sarchahan Formation of southern Iran (Ghavidel-syooki and Winchester-Seeto, 2004), in middle to late Llandovery sediments of Sweden (Grahn, 1998), Norway (Nestor, 1999) and Estonia and Latvia (Nestor and Nestor, 2002). *Conochitina edjelensis* has been recorded in lower Silurian strata in Saudi Arabia (Paris et al., 1995), Libya (Molyneux and Paris, 1985), Spain (Cramer, 1967), and Estonia (Nestor, 1994).

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Based on the occurrence of diagnostic chitinozoan species, this biozone probably corresponds at least in part to the *Conochitina alargada* Biozone of Verniers et al. (1995) and possibly to the *Belonechitina postrobusta–Conochitina electa* biozones of Nestor (1994) defined for the Baltic area.

5.5. *Plectochitina saharica* local biozone

This biozone extends through a thickness of 105 m in the upper part of Member I of the Niur Fm; its base is defined by the appearance of *Plectochitina saharica*, *P. pseudoagglutinans*, *Ancyrochitina fatemae* n.sp., and *Angochitina multipodspina* n. sp., and its top coincides with the base of the succeeding biozone.

Plectochitina saharica and *P. pseudoagglutinans* have been previously recorded from middle Llandovery strata in the Algerian Sahara (Taugourdeau and de Jekhowsky, 1960), Libya (Hill et al., 1985; Paris, 1988), Saudi Arabia (Paris et al., 1995), southern Iran (Ghavidel-syooki, 2000a,b), northwestern Spain (Cramer, 1967), Florida (Cramer, 1973) and Estonia (Nestor, 1980, 1994). This biozone is possibly correlative to the early-late Llandovery *Eisenackitina dolioliformis* Biozone of the global chitinozoan biozonation scheme of Verniers et al. (1995).

5.6. *Plectochitina ralphi* local biozone

This biozone embraces the uppermost 86 m of Member I of the Niur Formation (Fig. 3); its base is defined by the first occurrence of *Plectochitina ralphi*. The top of the biozone cannot be defined due to the non-productive samples in the member II of the Niur Formation (Fig. 3). Other species characteristic for this biozone are *Angochitina iranica*, and *Ancyrochitina porrectaspina*.

Plectochitina ralphi has been previously recorded from the Rumba Formation of the Adavere Stage in Estonia (Nestor, 1994) and lower Silurian of Sarchahan Formation of Iran (Ghavidel-syooki, 2000a,b; Ghavidel-syooki and Winchester-Seeto, 2004). Likewise, *Ancyrochitina porrectaspina* has been recorded in Estonia from the Velise Formation and the Irlava Beds of the Jurmala Formation (Adavere Stage, late Llandovery; Nestor, 1994).

The age of this local biozone is probably late Llandovery, but no more precise correlation with existing biozonations is possible.

6. Palaeobiogeography

Comparison of the present chitinozoan fauna with coeval assemblages previously described from other areas (Figs. 2 and 4) shows an important degree of endemism for the Iranian latest Ordovician and early Silurian chitinozoans (33.3% of endemic species, including the newly described taxa). Cosmopolitan species (20.8% of total assemblage) and species previously known to occur in the Baltica palaeocontinent (also 20.8%) constitute the second more important contribution to the study assemblage. Taxa with a definite North Gondwana palaeobiogeographical affinity make up to 12.5% of the total assemblage, as much as the taxa which are known to occur both in North Gondwana and in Baltica (Fig. 4).

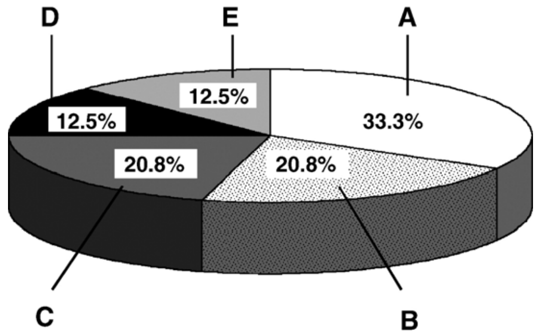

Fig. 4. Synthetic diagram showing the palaeobiogeographic affinity of the described chitinozoan fauna from Iran. A, proportion of endemic species; B, proportion of cosmopolitan species; C, proportion of species previously described from Baltican localities; D, proportion of species with know occurrence in Baltica and North Gondwana; E, proportion of species occurring exclusively in North Gondwana.

Like all planktonic groups, the biogeographical distribution of chitinozoans was in part controlled by temperature, which can be generally associated with palaeolatitude (Verniers et al., 1995). The palaeobiogeographical similarity of the early Silurian Iranian chitinozoans with the Baltica palaeocontinent may thus reflect the similar palaeolatitudinal locations of the two areas (Fig. 2). The present data also confirm previous observations of a low bioprovincialism of Silurian chitinozoan faunas (Miller, 1996), which is also recorded in other microplaktonic groups (i.e., acritarchs; Molyneux et al., 1996). On the other hand, it is necessary to take into consideration the relatively high proportion of endemic taxa, which suggests that the present appreciation of chitinozoan provincialism in Silurian times may be affected by sample- and (palaeo) geographic coverage biases (Paris, 1989; Miller, 1996).

7. Discussion and conclusions

Discounting the five new species, those left in open nomenclature, and the long-ranging species such as *Cyathochitina campanulaeformis*, most of the remaining species are chronostratigraphically significant, and permit the dating of the uppermost part of the Ghelli Formation to the middle Ashgill, and member I of the Niur Formation to the early-late Llandovery (Rhuddanian–Telychian). Accordingly, the latter stratigraphical unit is age-equivalent to the Sarchahan Formation of the Zagros Basin in southern Iran. Moreover, a hiatus is evidenced between the Ghelli and the Niur formations, encompassing the late Ashgill. These age attributions are based on the known ranges of chitinozoan species, but the direct application of the proposed Silurian global chitinozoan zonation (Verniers et al., 1995) is not possible in the study area, due to the absence of many of the index species. We proposed in this paper an informal and preliminary biozonation for the early Silurian of northeastern Iran, and discussed the possible relationships with the global Silurian biozones of Verniers et al. (1995) and other biostratigraphic schemes (e.g., Nestor, 1994). In addition, the taxonomical analysis of the present chitinozoan fauna, numerically dominated by endemic taxa, highlights the need of incorporating more data from little known areas (such as Iran) in global biostratigraphic compendia. From a palaeobiogeographical point of view, a significant proportion of taxa are shared with typical Baltican assemblages, suggesting palaeobiogeographical affinities between Iran and the Baltica palaeocontinent. Taxa shared with typical North Gondwanan assemblages are only a minor component of the Iranian chitinozoan fauna. These results confirm previous observations of a low degree of bioprovincialism of Silurian chitinozoan faunas, but also point to the fact that our current appreciation of chitinozoan provincialism may possibly be affected by sample- and (palaeo)geographic coverage biases, particularly for the Silurian.

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