Chitinozoan biostratigraphy and palaeogeography of lower Silurian strata (Sarchahan Formation) in the Zagros Basin of southern Iran

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Palynological investigations were undertaken on sixty samples from the Sarchahan Formation. All samples contain abundant, well-preserved chitinozoans. A total of 9 genera and 28 species were recognized in this study, with eight described as new; viz. *Ancyrochitina faraghanensis, Ancyrochitina florentini, Ancyrochitina iranensis, Ancyrochitina zagrosiensis, Ancyrochitina zakeenensis, Plectochitina kazhdumiensis* and *Hyalochitina sarchahanensis*. Based on these chitinozoan data, the Sarchahan Formation ranges from the earliest Rhuddanian (*fragilis* global biozone) to late Telychian (*longicollis* global biozone). Thus, there is a hiatus between the this unit and the overlying Upper Devonian Zakeen Formation which encompasses most of the middle and late Silurian. Several chitinozoan species from the Sarchahan Formation are common in contemporaneous chitinozoan assemblages from Saudi Arabia, Algeria and Libya, with some also occurring in northwestern Spain, Estonia, Florida and Paraguay. These include: *Pterochitina deichai, Conochitina alagarda, Spinachitina fragilis, Angochitina macclurei, Ancyrochitina udayanensis, Plectochitina paraguayensis, Plectochitina pseudoagglutinans, Plectochitina saharica, Plectochitina nodifera, Plectochitina ralphi, Clathrochitina* aff. *clathrata, Ancyrochitina convexa,* and *Ancyrochitina vikiensis*. Most of the chitinozoan taxa from the Sarchahan Formation have previously been recorded from the Qusaiba and Sharawra members of Qalibah Formation in Saudi Arabia, and there is a great deal of similarity in much of the lithological and palaeontological data. This similarity suggests that the same environmental conditions prevailed in northern and southern Persian Gulf throughout the early Silurian.

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CHITINOZOA from Palaeozoic strata in the Zagros basin of southern Iran have received minimal attention. The only previous paper on chitinozoans is a preliminary survey of the Seyahou (Upper Ordovician) and Sarchahan (Lower Silurian) formations in southern Iran (Ghavidel-syooki, 2000). The current investigation is based on more extensive sampling and intensive SEM examination of the fauna. Moreover, recent studies of graptolites from the Sarchahan Formation by Rickards *et al.* (2000) provide reliable age control for this formation.

Lithological and palaeontological descriptions of the Qalibah Formation in Saudi Arabia are similar to those of the Sarchahan Formation in Iran. Chitinozoan and graptolite biozonations have been established in the Qalibah Formation (Paris *et al.*, 1995), providing a base for correlation of the Sarchahan Formation and Qalibah Formation on the northern and southern shores of Persian Gulf respectively. Herein, we describe chitinozoan taxa from the Sarchahan Formation, distinguish local biozones and determine their utility for regional and cross-continental correlations.

STRATIGRAPHY

The area under study is located in Tang Zakeen of Kuh Faraghan (Tang = gorge; Kuh = mountain), approximately 100 km north of Bandar Abbas city (Fig. 1). The road from Bandar Abbas city to Seyahou town is the principle link to the study area. A thick Palaeozoic sequence is well

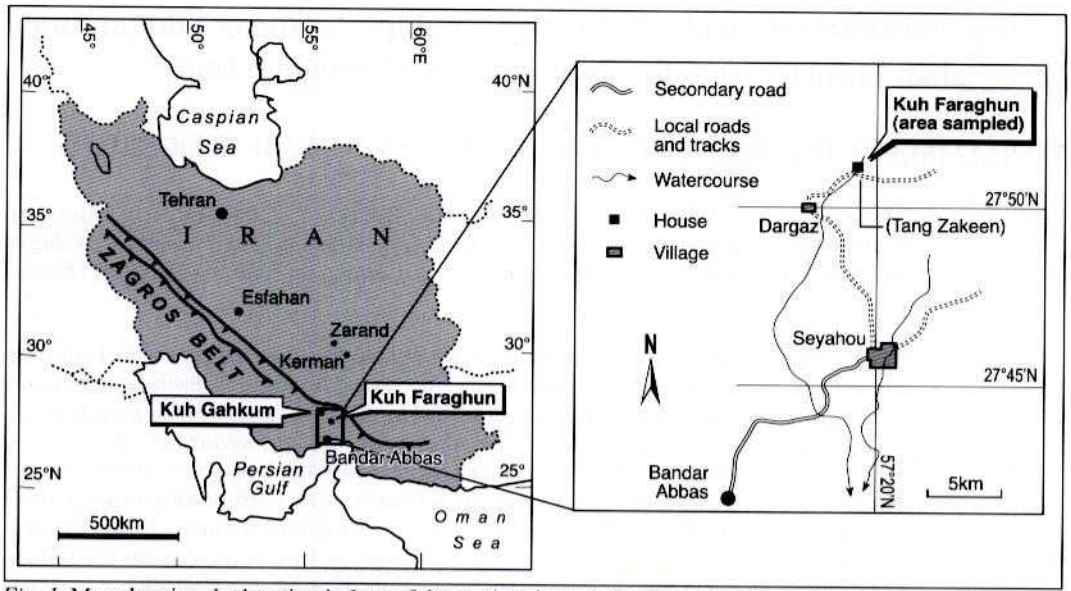

Fig. 1. Map showing the location in Iran of the section through the Sarchahan Formation.

developed in Tang Zakeen and comprises, in ascending stratigraphic order, the Seyahou, Sarchahan, Zakeen, Faraghan and Dalan formations (Fig. 2). The Upper Ordovician Seyahou Formation is the lowest Palaeozoic unit in Tang Zakeen of Kuh Faraghan and consists of alternating shale, siltstone and sandstone. It contains well preserved graptolites, brachiopods, acritarchs and chitinozoans (Ghavidel-syooki, 1997, 2000; Ghavidel-syooki & Khosravi, 1995; Rickards *et al.*, 2000).

The Sarchahan Formation is disconformably overlain by the Zakeen Formation, and varies in thickness from 66 to 86 m thick in Kuh Faraghan to 102 m in Kuh Gahkum. In Kuh Faraghan, it comprises mainly black shales with abundant graptolites, but at the base of the formation, which outcrops in Kuh Gahkum, there are 40 metres of conglomerate; the remainder is an alternation of black shale, siltstone and sandstone. This unit is of Early Silurian age, based on data from graptolites, acritarchs and chitinozoans (Ghavidel-syooki, 1997, 2000; Ghavidel-syooki & Khosravi, 1995; Rickards *et al.*, 2000).

The Zakeen Formation has a thickness of 285 m in Tang Zakeen of Kuh Faraghan as well as in Kuh Gahkum and comprises mainly white sandstone with intercalated shale. Most of this unit is barren, but the shale horizons contain abundant miospores and acritarchs. Based on palaeontological data, the Zakeen Formation is Frasnian (Ghavidel-syooki, 1998).

The Faraghan Formation has a thickness of 58 m in Tang Zakeen of Kuh Faraghan and mainly consists of alternating shale, sandstone and subordinate limestone. There are abundant miospores and a few foraminiferal species, which indicate an Early Permian age for the unit (Ghavidel-syooki, 1997, 1998).

The uppermost Palaeozoic unit of Kuh Faraghan is the Dalan Formation which is a gas reservoir in the Zagros Basin. It comprises mainly limestone and dolomite with abundant corals, brachiopods and fusulinids, and is Middle to Late Permian in age (Kalantari, 1994; Szabo & Kharadpir, 1978).

MATERIALS AND METHODS

A total of 60 surface samples over 86 m of the Sarchahan Formation were examined for chitinozoan taxa (sample numbers MG-8024 to MG-8079). These samples were collected at regular 1.5 m intervals, except for the last interval MG-8079, where 5 further samples (i.e. MG-8079A – MG8079E) were taken to more precisely date the boundary between Sarchahan and Zakeen formations. The chitinozoans were extracted from black, silty shales using standard palynological procedures, including treatment of the residues of each sample with 30 ml of saturated zinc bromide in order to separate the light organic residue from the heavy inorganic minerals, and screening of organic residues through 20 micron nylon mesh sieves. Extensive scanning electron and transmitted light microscopic examination were carried out on selected specimens.

All microscopic slides and stubs from this study are housed in the palaeontological collections of the Exploration Directorate of the National Iranian Oil Company under sample

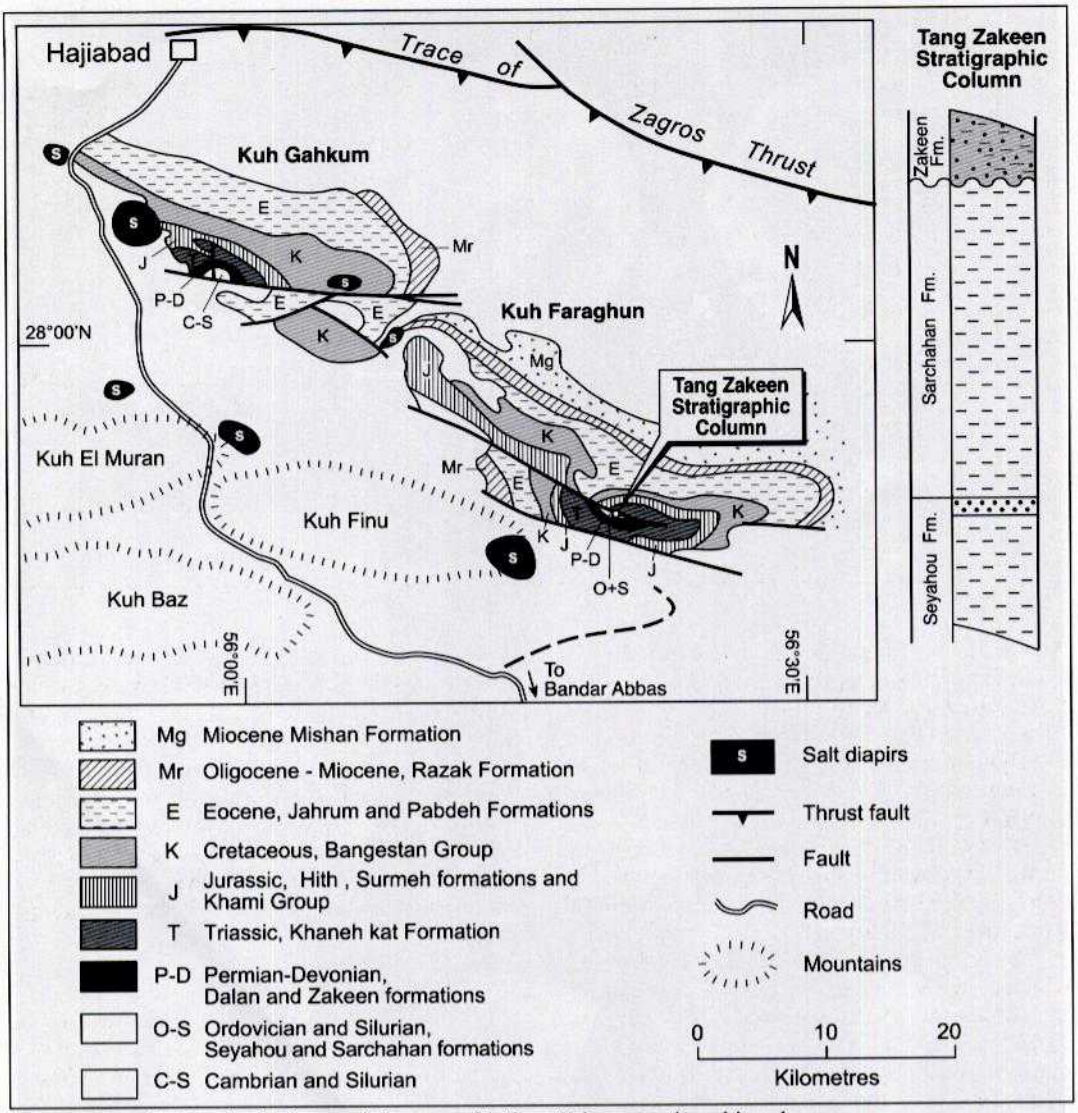

Fig. 2. Generalised geological map of the area, with Tang Zakeen stratigraphic column.

numbers MG-8024 to MG-8079, individual specimens are listed with their sample number (e.g. MG8024-A).

All samples contain well preserved palynomorphs including acritarchs, cryptospores, and chitinozoans as well as scolecodonts and graptolites. Geochemical analysis indicates that the Sarchahan Formation is a source rock for hydrocarbons reservoired in the Zakeen (Devonian), Faraghan (Lower Permian) and Dalan (Middle-Upper Permian) formations of the Zagros Basin.

SYSTEMATIC PALAEONTOLOGY

The classification system proposed by Paris *et al.* (1999) for chitinozoan genera is used in the following descriptions. Where species have been well described previously, only relevant remarks are made herein, but new species have been fully described. All measurements are given in microns.

The following symbols have been adopted for the systematic description and biometric values: L = total length of vesicle, 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 diameter of vesicle, and L/Ln = total length of vesicle / length of neck. A correction factor of 0.7 has been used on all individuals where the diameter has been distorted by complete flattening; this follows in part, the precedent set by Jaglin (1986).

Fig. 3. A, *Calpichitina acollaris* Eisenack, MG8073-A (scale bar =10μm). B, *Pterochitina deichai* Taugourdeau, MG8042-A (scale bar =20μm). C, *Cingulochitina* sp., MG8072-A (scale bar =20μm). D, *Conochitina alargada* Cramer, MG8051-A (scale bar = 30μm). E, F, *Spinachitina fragilis* Nestor, MG8026-A (scale bar for E =20μm, scale bar for F =10μm). G, I, *Angochitina macclurei* Paris & Al-Hajri, G, MG8071-A (scale bar =20μm), I, MG8071-B, (scale bar=20μm). H, *Ancyrochitina convexa* Nestor, MG8051-B (scale bar =10μm).

Order OPERCULATIFERA Eisenack, 1972
Family DESMOCHITINIDAE (Eisenack, 1931) emend. Paris, 1981
Subfamily DESMOCHITININAE Paris, 1981

Calpichitina Wilson & Hedlund, 1964

Type species. Calpichitina scabiosa Wilson & Hedlund, 1964

Calpichitina acollaris Eisenack, 1959 (Fig. 3A)

1959 *Desmochitina acollare* n. sp.; Eisenack, p. 16-17, pl. 3, fig. 14
1968 *Desmochitina acollaris*; Eisenack, p. 182
1974 *Desmochitina acollaris*; Laufeld, p. 75-77, figs 38A-D
1994 *Calpichitina acollaris*; Nestor, p. 12-13, Pl. 24, figs 1-2
1995 *Calpichitina acollare*; Verniers *et al.*, fig. 6d

Material. 325 specimens from samples MG8053 (48m above the base of section) to MG8079c (89.6m above the base of section) inclusive.

Remarks. This species is common in the upper part of Sarchahan Formation. It is similar to that recorded from the Wenlock in Gotland (Laufeld, 1974) and Estonia (Nestor,1994). Eisenack (1964) reported *C. acollaris* from the late Llandovery Visby Beds, but this was not confirmed by Laufeld (1974). Verniers *et al.* (1995) record *C. acollaris* from the Wenlock (*margaritana to pachycephala* global chitinozoan biozones)

Subfamily PTEROCHITININAE Paris, 1981

Pterochitina Eisenack, 1955

Type species. Bion perivelatum Eisenack, 1937

Pterochitina deichai Taugourdeau, 1963 (Fig. 3B)

1963 *Pterochitina deichaii* n. sp.; Taugourdeau
1985 *Pterochitina deichaii*; Hill *et al.*, pl. 13, fig. 5, pl. 14, fig. 6, 10
?1991 *Pterochitina* sp.; Wood & Miller, p. 190, pl. 4, figs 1-3
1995 *Pterochitina deichaii*; Paris *et al.*, pl. 1, fig. 5
2001 *Pterochitina deichaii*; Grahn & Gutiérrez, fig. 9G

Material. 103 specimens from samples MG8030 (9.6 m above the base of section) to MG8079c (89.6 m above the base of section).

Remarks. This species is common in the Sarchahan Formation of Kuh Faraghan and Kuh Gahkum and in the G-3 well in the Persian Gulf. It has been recorded from the lower Silurian Qalibah Formation in Saudi Arabia (Paris *et al.*, 1995) and from Libya (Hill *et al.*, 1985), Europe (Verniers *et al.*, 1995) and the Tarija Basin of Argentina (Grahn & Gutiérrez, 2001). *Pterochitina* sp. was recorded from the lower Silurian Vargas Peña Shale of the Chaco Basin in Paraguay (Wood & Miller,1991). As the Paraguayan specimens are very similar to those from Iran, *Pterochitina* sp. may belong to *P. deichai.* Verniers *et al.* (1995) show *P. deichai* ranging through most of the Llandovery.

Cingulochitina Paris, 1981

Type species. Desmochitina cingulata Eisenack, 1937

Cingulochitina sp. (Fig. 3C)

Material. 426 specimens from samples MG8071 (73.6 m above the base of section) to MG8079c (89.6 m above the base of section).

Description. Cingulochitina sp. has a small conical vesicle. The flanks and base are convex. The shoulder is absent and neck widens slightly towards aperture. The basal margin bears a short, narrow edge and has a short copula. The fine rugose ornamentation is distributed over the whole vesicle.

Order PROSOMATIFERA Eisenack, 1972
Family CONOCHITINIDAE Eisenack, 1931
Subfamily CONOCHITININAE Paris, 1981

Conochitina Eisenack, 1931

Type species. Conochitina claviformis Eisenack, 1931

Conochitina alargada Cramer, 1967 (Fig. 3D)

1967 *Conochitina edjelensis alargada* n. var.; Cramer p. 88, Pl. III, fig. 55
1989 *Conochitina edjelensis alargada*; Asselin, Achab & Bourque, pl. 4, figs 15-16
1995 *Conochitina alargada*; Paris *et al.* pl. 1, fig. 10
1995 *Conochitina alargada*; Verniers *et al.*, fig. 5g
1998 *Conochitina alargada*; Grahn, Fig. 16G
1999 *Conochitina alargada*; Nestor, Pl. 1, fig. 6
2002 *Conochitina alargada*; Nestor & Nestor, Pl. 1, fig. 1

Material. 390 specimens from samples MG8045 (33.6 m above the base of section) to MG8059 (56 m above the base of section).

Remarks. This species is abundant in the Sarchahan Formation and has been recorded from middle Llandovery (Aeronian – basal Telychian) beds of the Qalibah Formation in Saudi Arabia (Paris *et al.*,1995), Llandovery beds of the Formigoso Formation in northern Spain (Cramer, 1967), Telychian of Chaleurs Bay Québec (Asselin *et al.*, 1989), the middle and upper Llandovery in Sweden (Grahn, 1998), Solvik and Rytteråker formations from the middle Llandovery of Norway (Nestor, 1999) and the middle and uppermost upper Llandovery Saarde and Rumba formations of Estonia and Latvia (Nestor & Nestor, 2002).

Subfamily TANUCHITININAE, Paris 1981

Hyalochitina Paris, Grahn, Nestor & Lakova 1999

Type species. Cyathochitina hyalophrys Eisenack, 1959

Hyalochitina sarchahanensis n. sp. (Fig. 8H)

Derivation of name. Named for the Sarchahan Formation, the type formation for this species

Type locality. Kuh Faraghan, approximately 103 km north of Bandar Abbas city, Iran.

Type stratum. From the Sarchahan Formation of Kuh Faraghan, Zagros Mountains, Iran, sample number, MG8071, 75.2 m above the base of section.

Holotype. Fig. 8H, MG8071-B

Material. 443 specimens from samples MG8071 (75.2 m above the base of section) to MG8079c (89.6 m above the base of section).

Diagnosis. This is a subcylindrical species of *Hyalochitina* with a narrow carina and a wide, flared collarette.

Description. This species has a subcylindrical vesicle without surface ornamentation. The flexure and shoulder are inconspicuous. The neck widens towards the aperture and forms a distinct collar. The basal margin has a narrow carina. The vesicle has a flat or convex base with basal scar.

Remarks. This species differs from species of *Cyathochitina* in having a straight subcylindrical vesicle, a narrow carina, a flat to slightly convex base and a basal scar. There are some similarities to *Cyathochitina elenitae* Cramer (1964), but *H. sarchahanensis* has straight flanks in contrast to the more distinct flexure of *C. elenitae.*

Dimensions. Taken from 29 specimens: L=144-179; Ln=62-69; D=63-95; dcoll=60-67; L/D=1.5-2.8; L/Ln=1.8-2.9

Subfamily SPINACHITININAE Paris, 1981

Spinachitina Schalleuter, 1963

Type species. Conochitina cervicornis Eisenack, 1931

Spinachitina fragilis Nestor, 1980 (Fig. 3E-F)

1980a *Coronochitina fragilis* n. sp.; Nestor, p. 104, pl. 5, fig. 1
1994 *Spinachitina fragilis*; Nestor, p. 47, pl. 22, figs 1-2
1995 *Spinachitina fragilis*; Paris *et al.*, pl. 1, fig. 1

Material. 152 specimens from samples MG8024 (0 m above the base of section) to MG8030 (9.6 m above the base of section).

Description. The vesicle has a cylindrical or subcylindrical shape with flat to slightly concave base. The basal edge is bluntly rounded with a crown of more than twenty simple or branching spines. The spines are short, fragile and numerous. The neck progrades into chamber and flexure is usually inconspicuous. The vesicle surface is smooth.

Remarks. This species is common in the basal Sarchahan Formation, and has been recorded from the lower Llandovery (Rhuddanian) in Saudi Arabia (Paris *et al.*, 1995), southern Iran (Ghavidel-syooki, 2000) and Estonia (Nestor, 1980a, 1994). Verniers *et al.* (1995) designated the *S. fragilis* Zone as the lowermost global Silurian chitinozoan biozone.

Family LAGENOCHITINIDAE Eisenack, 1931
Subfamily ANGOCHITININAE Paris, 1981

Angochitina Eisenack, 1931

Type species. Angochitina echinata Eisenack, 1931

Angochitina macclurei Paris & Al-Hajri, 1995 (Fig. 3G-I)

1995 *Angochitina macclurei* n. sp.; Paris & Al-Hajri, p. 321, pl. 1, figs 1, 2a-b, 3

1995 *Angochitina macclurei*; Paris *et al.*, pl. 1, figs 7, 13
2000 *Angochitina macclurei*; Ghavidel-syooki, pl. 2, figs D-E

Material. 419 specimens from samples MG8054 (48 m above the base of section) to MG8079c (89.6 m above the base of section).

Remarks. Although shorter than the specimens from Saudi Arabia (Paris & Al-Hajri, 1995), the material from the Zagros Basin falls within the range of variation of total length vs. length of neck (Ln/L= 0.73-0.77 for Zagros Basin; Ln/L=0.65-0.73 for specimens from Saudi Arabia) and shows a slightly lower proportion of total length vs. maximum diameter (L/D=2.7-3.3 for Zagros Basin; L/D=3.3-4.6 for specimens from Saudi Arabia).

The species is common in the uppermost part of the Sarchahan Formation, and has been recorded from upper Llandovery (Telychian) beds of the Qalibah Formation in Saudi Arabia (Paris *et al.*, 1995; Paris & Al-Hajri, 1995), and from the Alborz Range (Ghavidel-syooki, 2000).

Dimensions. Taken from 60 specimens: L=206-209; Ln=139-152; D=62-79; dcoll=42-48; L/D=2.7–3.3; L/Ln=1.3-1.5.

Subfamily ANCYROCHITININAE Paris, 1981

Ancyrochitina Eisenack, 1955

Type species. Conochitina ancyrea Eisenack, 1931

Ancyrochitina aff. ancyrea (Eisenack, 1931) (Fig. 4A-D)

Material. 742 specimens from samples MG8024 (at base of section) to MG8079c (89.6 m above the base of section).

Description. Ancyrochitina aff. *ancyrea* (Eisenack, 1931) from the Sarchahan Formation has a cylindro-conical to cylindro-ovoid vesicle which is flat to slightly concave at the base. At the chamber edge there are 4-8 long processes of variable thickness, which branch once or twice at the distal end. Individuals of this species in the Sarchahan Formation display short, fine, simple and bifurcate spines on the upper part of chamber and neck. Some of these spines have broad, lambda-shaped bases.

Remarks. These individuals from the Zagros Basin may belong to the very large, long-ranging complex of *Ancyrochitina ancyrea*, but have been kept in open nomenclature due to the presence of the fine spines on the neck and upper chamber.

Dimensions. Taken from 32 specimens: L=122-171; Ln=66-85; D=76-84; dcoll=36-45; ls=16-20; L/D=1.6-2; L/Ln=1.5-2.

Ancyrochitina convexa Nestor, 1980a (Fig. 3H)

1994 *Ancyrochitina convexa*; Nestor, p. 62-63, pl. 2, figs 3-5 (cum. syn.)

Material. 533 specimens from samples MG8045 (33.6 m above the base of section) to MG8055 (48 m above the base of section).

Remarks. Individuals of this species from the Zagros Basin are very similar to those described and depicted by Nestor (1994) except that there is no evidence of strongly curved, fine spines on the neck. The neck is also slightly shorter than those from Estonia.

This species has been recorded from Ikla and Kolka members of Raikkula stage in Estonia (Nestor, 1994) and northern Latvia (middle Llandovery).

Dimensions. Taken from 41 specimens: L=135-144; Ln=81-85; D=80-85; dcoll=40-45; ls=16; L/D=1.7; L/Ln=1.6-1.8.

Ancyrochitina faraghanensis n. sp. (Fig. 4E)

Derivation of name. The name makes reference to Kuh Faraghan in which the lower Silurian is well exposed.

Type locality. Kuh Faraghan, approximately 103 km north of Bandar Abbas city, Iran

Type stratum. From the Sarchahan Formation of Kuh Faraghan, Zagros Mountains, sample number MG8074, 80m above the base of the section.

Holotype. Fig. 4E, MG8074-A

Material. 320 specimens from samples MG8071 (73.6 m above the base of section) to MG8079c (89.6 m above the base of section).

Diagnosis. This is a relatively small species of *Ancyrochitina*, which is densely covered with spines. The spines range from simple to bifurcate and lambda-shaped, and are quite large in size at the base of the chamber. The spines decrease in length and width on the upper chamber and lower neck, and are reduced to minute tubercles on the upper neck.

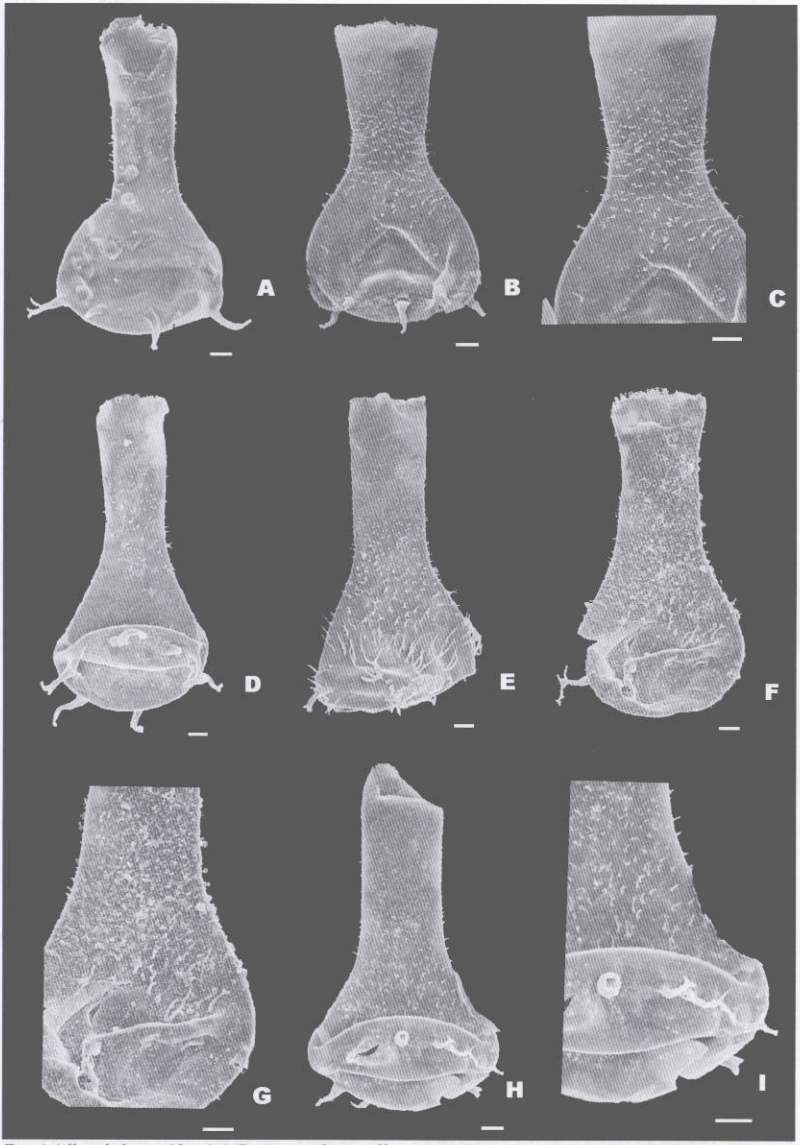

Fig. 4. (all scale bars =10μm) A-D, *Ancyrochitina* aff. *ancyrea* Eisenack. A, MG8027-A. B, C, MG8027-B, D, MG8027-C. E, *Ancyrochitina faraghenensis* n. sp., MG8074-A, holotype. F, G, *Ancyrochitina florentini* n. sp., MG8076-A, holotype. H, I, *Ancyrochitina zagrosiensis* n. sp., MG8075-A, holotype.

Description. Ancyrochitina faraghanensis has a cylindro-conical vesicle, with a conspicuous flexure and shoulder. The flexure is broadly rounded and the neck widens slightly towards aperture. The basal margin is bluntly rounded and carries numerous simple or bifurcate processes. Two processes are thick and bifurcate, the rest are simple or lambda-shaped. The whole vesicle is covered by small spines which are lambda-shaped and many are bifurcate or multifurcate at the distal end. The size of the spines decrease towards the aperture.

Remarks. Ancyrochitina faraghenensis differs from *A.* aff *ancyrea* in having spines dominantly on the lower part of the chamber, in contrast the spines on *A.* aff *ancyrea* occur mainly on the upper chamber and neck.

Dimensions. Taken from the holotype: L=166; Ln=96; D=84; dcoll=40; ls=12; L/D=2; L/Ln=1.6 Taken from 25 specimens : L=160-166; Ln=92-96; D=83-86; dcoll=38-40; ls=10-12; L/D=1.9-2; L/Ln= 1.6-1.7

Ancyrochitina florentini n. sp. (Fig. 4F-G)

Derivation name. Named for Dr Florentin Paris in honour of his work in chitinozoan biostratigraphy.

Type locality. Kuh Faraghan, approximately 103 km north of Bandar Abbas city, Iran.

Type stratum. From Sarchahan Formation of Kuh Faraghan, Zagros Mountains, sample number MG8076, 83.3m above the base of section.

Holotype. Fig 4F-G, MG8076-A

Material. 331 specimens from samples MG8071 (75.2 m above the base of section) to MG8079c (89.6 m above the base of section).

Diagnosis. This species is characterised by the cylindro-sphaerical vesicle, with a convex base and 4-6 complex branching processes. Relatively long, bifurcating spines occur near the base of the chamber; fine, short, simple spines occur on the upper part of the chamber and on the neck.

Description. This species has a cylindro-sphaerical vesicle with inconspicuous flexure and shoulder. The vesicle is covered with spines, which are long on the lower part of the chamber and shorter on the upper part of the chamber and on the neck. The neck, which occupies more than half the vesicle length (Ln/L = 0.58-0.6), widens towards the aperture, and the collarette bears short spines. The basal margin is rounded and carries 4-6 processes which branch three times.

Remarks. Ancryochitina florentini differs from *A. zakeenensis* n. sp. in having branching processes, from *A.* aff. *ancyrea* in the having no shoulders and a less definite flexure, and from *A. zagrosiensis* n. sp. in the shape of the chamber.

Dimensions. Taken from the holotype: L=157; Ln=88; D=77; dcoll=46; ls=12. Taken from 25 specimens: L=145-160; Ln=69-93; D=70-79; dcoll=40-45; ls=18-21.

Ancyrochitina iranensis n. sp. (Fig. 5G-H)

?1995 *Ancryochitina* cf. *tomentosa*; Taugourdeau & Jekhowsky; Paris, pl. 14, fig. 4

Derivation of name. This makes reference to Iran, where this species was described formally for the first time.

Type locality. Kuh Faraghan, approximately 103 km north of Bandar Abbas city, Iran.

Type stratum. From the Sarchahan Formation of Kuh Faraghan, Zagros Mountains, Iran, sample number MG8075, 81.6 m above the base of section

Holotype. Fig 5G-H, MG8075-C

Material. 319 specimens from samples MG8071 (75.2 m above the base of section) to MG8079c (89.6 m above the base of section).

Diagnosis. This is a species of *Ancyrochitina* characterised by a cylindo-conical vesicle, with 7-9 groups of 2-3 short, simple or branched processes on the basal margin. The upper part of chamber and the whole neck is covered by densely simple spinose ornamentation.

Description. The vesicle of this species has a conspicuous flexure and a well defined shoulder. The flexure is broadly rounded and the short neck (Ln/L= 0.55-0.56) widens towards the aperture with minute spines on the collarette. The basal margin is bluntly rounded and has numerous groups of processes, which coalesce at the proximal end.

Remarks. The grouping of the processes differentiates this species from others of the genus.

Dimensions. Taken from the holotype: L=131; Ln=73; D=86; dcoll=35; ls=11. Taken from 45 specimens: L=125-140; Ln=70-77; D=80-87;

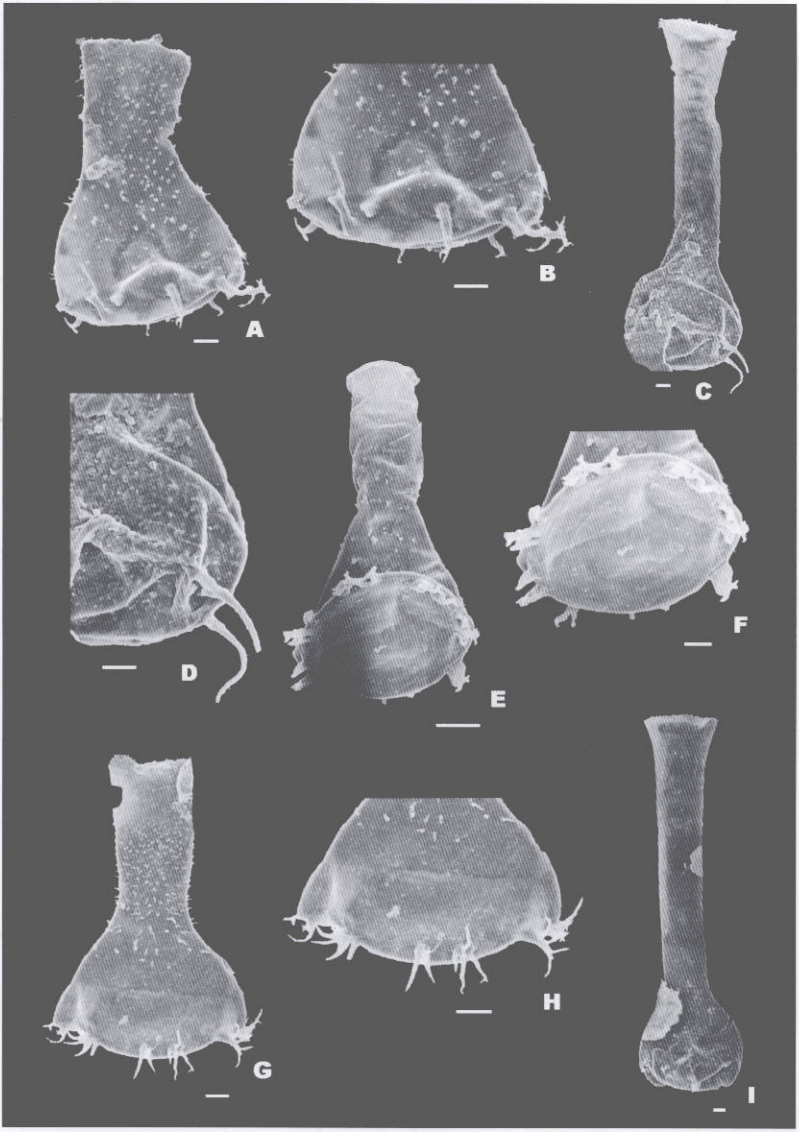

Fig. 5. A, B, *Ancyrochitina udayanensis* Paris & Al-Hajri, MG8034-A (scale bar =10μm). C, D, I, *Ancyrochitina* cf. *parafragilis* Al-Hajri & Paris, C, D, MG8075-B, I, MG8075-C (scale bar =10μm). E, F, *Ancyrochitina vikiensis* Nestor, MG8074-B (scale bar for E =20μm, scale bar for F =10μm). G, H, *Ancyrochitina iranensis* n. sp., MG8075-C, holotype (scale bar for G =10μm, scale bar for H =10μm).

dcoll=35-42; ls=20-30.

Ancyrochitina cf. parafragilis Al-Hajri & Paris, 1998 (Fig. 5C-D, I)

Material. 309 specimens from samples MG8071 (75.2 m above the base of section) to MG8079c (89.6 m above the base of section).

Description. This species has a cylindro-ovoid vesicle, with a relatively long neck (Ln/L = 0.68-0.77), which widens towards the aperture. The collar is smooth with a denticulate aperture and short spines. The flexure and shoulder are conspicuous. The basal edge is broadly to bluntly rounded. The processes are simple and split in the proximal part. Tubercules are distributed over the whole vesicle, but are denser on the chamber than on the neck. The are 4-10 processes of variable length (3-21 microns) and width.

Remarks. Ancyrochitina cf. *parafragilis* is abundant in the middle and upper Sarchahan Formation and is very similar to *A. parafragilis* in size, shape and general proportions, but has thinner and shorter processes. However, it may be just a regional variant of the same species.

Dimensions. Taken from 40 specimens: L=250-327; Ln=171-240; D=70-92; dcoll=52-67; ls=3-21.

Ancyrochitina udayanensis Paris & Al-Hajri, 1995 (Fig. 5A-B)

Material. 1360 specimens from samples MG8030 (9.6 m above the base of section) to MG8046 (35.2 m above the base of section).

Remarks. Ancyrochitina udayanensis has previously been recorded from the Qalibah Formation of Saudi Arabia (Paris and Al-Hajri,1995). The specimens from Iran differ slightly from those in Saudi Arabia, in being slightly wider and in having fine, branched spines on the neck.

Dimensions. Taken from 50 specimens: L=115-119; Ln=53-54; D=70-77; dcoll=43-45; L/D=1.5-1.7; L/Ln=2-2.2.

Ancyrochitina vikiensis Nestor, 1994 (Fig. 5E-F)

1994 *Ancyrochitina vikiensis* n. sp.; Nestor, p. 70, pl. 1, fig. 8

Material. 316 specimens from samples MG8071 (75.2 m above the base of section) to MG8078 (86.4 m above the base of section).

Remarks. Ancyrochitina vikiensis occurs in the upper part of the Sarchahan Formation. This species has previously been recorded from the boundary beds of the Adavere and Jaani stages, or uppermost beds of the Early Silurian of Estonia. (Nestor, 1994).

Dimensions. Taken from 35 specimen: L=123-125; Ln=72-73; D=79-80; dcoll=32-33; ls=8-10; L/D=1.5-1.6; L/Ln=1.6-1.7.

Ancyrochitina zagrosiensis n. sp. (Fig. 4H-I)

Derivation of name. This makes reference to the Zagros Mountain Ranges which extend from northwest to southeast Iran.

Type locality. Kuh Faraghan, approximately 103 km north of Bandar Abbas city, Iran.

Type stratum. From the Sarchahan Formation of Kuh Faraghan, in the Zagros Mountain Ranges of Iran, sample number MG8075, 81.6m above the base of section.

Holotype. Fig. 4H-I, MG8075-A

Material. 398 specimens from samples MG8071 (75.2 m above the base of section) to MG8079c (89.6 m above the base of section).

Diagnosis. A species of *Ancyrochitina* with a cylindro-conical vesicle, and characterised by short, bifurcating processes and fine, short spines covering the chamber, decreasing in size and density on the neck.

Description. This species has a cylindro-conical vesicle with a flat to slightly concave base. The flexure is broadly rounded, leading to a relatively long, cylindrical neck that widens slightly towards the aperture. The bifurcate processes are relatively short, and are 8-10 in number. Simple spines are densely distributed over the chamber, decreasing to minute tubercles on the neck.

Remarks. Ancyrochitina zagrosiensis is similar to *A. udayanensis* Paris & Al-Hajri (1995) but is much larger. *Ancyrochitina udayanensis* also has more complex branching processes.

Dimensions. Taken from holotype: L=150; Ln=85; D=80; Dn=30; ls=30. Taken from 21 specimens: L=140-157; Ln=81-93; D=75-86; dcoll=; ls=20-30.

Ancyrochitina zakeenensis n. sp. (Fig. 6D-G)

Derivation of name. This refers to the Zakeen

Fig. 6. (all scale bars =10μm) A, *Clathrochitina* aff. *clathrata* Eisenack, MG8075-D. B, C, *Plectochitina khosravii* Ghavidel-syooki, with broken appendices, MG8067-A. D-G, *Ancyrochitina zakeenensis* n. sp., D, MG8074-C; E, F, MG8074-D, holotype; G, MG8074-E. H, I, *Plectochitina kazhdumiensis* n. sp., MG8075-E, holotype.

Valley which cuts the Kuh Faraghan.

Type locality. Kuh Faraghan, approximately 103 km north of Bandar Abbas city, Iran.

Type stratum. From the Sarchahan Formation of Kuh Faraghan, Zagros Mountains, Iran, sample number MG8074, 80 m above the base of section.

Holotype. Fig 6D, MG8074-C

Material. 345 specimens from samples MG8071 (75.2 m above the base of section) to MG8079c (89.6 m above the base of section).

Diagnosis. This is a species of *Ancyrochitina* with a cylindro-sphaerical vesicle and simple processes on the rounded basal margin. The vesicle surface is relatively densely covered with fine, short spines that range from simple to lambda-shaped, many with bent tips.

Description. *Ancyrochitina zakeenensis* has a cylindro-sphaerical vesicle with conspicuous shoulder and a broadly rounded flexure. The neck widens towards the aperture, and the collar has short, fine spines. The rounded basal margin has numerous simple processes of variable length and width. The basal part of vesicle is strongly convex. Small simple, bifurcate or lambda-shaped spines densely cover the vesicle.

Remarks. *Ancryochitina zakeenensis* is similar to *A. qusaibaensis* Paris & Al-Hajri in shape, but is much smaller and can be readily differentiated by the ornamentation.

Dimensions. Taken from Holotype: L=163; Ln=97; D=82; Dn=44; ls=15; Taken from 35 specimens: L=124-159; Ln=45-82; D=63-75; Dn=29-44; ls=3-17

Clathrochitina Eisenack, 1959

Type species. *Clathrochitina clathrata* Eisenack, 1959

Clathrochitina aff. clathrata Eisenack, 1959 (Fig. 6A)

?1994 *Clathrochitina* aff. *clathrata*; Nestor, 1994, p. 72, Pl. 9, figs 4-5

Material. 350 specimens from samples MG8071 (75.2 m above the base of section) to MG8079c (89.6 m above the base of section).

Description. This species has a cylindro-conical vesicle with conspicuous flexure but without shoulder. The basal part of vesicle is flat to slightly convex to concave. The basal margin is rounded and has processes which form a circular net around the base. The processes are partly, or completely covered by a transparent membrane. The neck widens towards aperture and has sparse, short, simple spines. The chamber is smooth.

Remarks. *Clathrochitina* aff. *clathrata* differs from *C. clathrata* in having fewer spines on the neck. Similar specimens have been recorded from the uppermost Velise Formation and Irlava beds (Adavere stage; upper Llandovery) in Estonia by Nestor (1994).

Dimensions. Taken from 56 specimens: L=147-150; Ln=87-89; D=92-93; dcoll=42-44; L/D=1.5-1.7; L/Ln = 1.5-1.7.

Plectochitina Cramer, 1964

Type species. *Plectochitina carminae* Cramer, 1964

Plectochitina cf. carminae (Fig. 7A-D)

Material. 384 specimens from samples MG8071 (75.2 m above the base of section) to MG8079c (89.6 m above the base of section).

Description. This species has a cylindro-conical vesicle with a concave base. The flexure and shoulder are conspicuous. The basal margin is rounded with spongy anastomosing processes at the edge. The neck slightly widens towards aperture, and occupies approximately half the length of the vesicle (Ln/L = 0.55-0.61). The chamber is smooth, but the neck is covered by simple spinose ornamentation. The spongy anastomosing processes have a network pattern which varies from specimen to specimen.

Remarks. The anastomosing processes and vesicle are similar to *P. carminae* Cramer (1964), but *P.* cf. *carminae* differs in having a shorter neck than that reported by Priewalder (1997), with spinose ornamentation. Priewalder (1997) reviewed the range of *P. carminae* and concluded that it is restricted to the upper Ludlow-middle Pridoli. Herein, *P.* cf. *carminae* has been kept in open nomenclature because it occurs with species known from the Llandovery, such as *P. saharica, P. pseudoagglutinans* and *P. paraguayensis*.

Dimensions. Taken from 25 specimens: L=106-138; Ln=65-77; D70-83; Dn=35-39

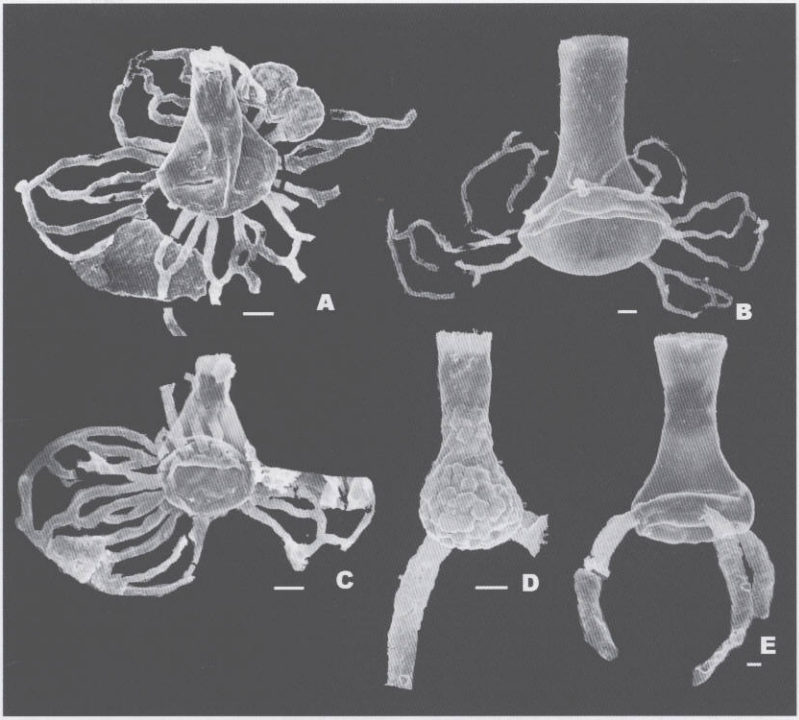

Fig. 7. A-C, *Plectochitina* cf. *carminae* Cramer, A, MG8075-F; B, MG8075-G; C, MG8075-H (scale bar for A and C =20μm, scale bar for B =10μm). E-F, *Plectochitina paraguayensis* Wood & Miller; E, MG8075-I (scale bar for E =20μm); F, MG8075-J (scale bar for F = 10μm).

Plectochitina kazhdumiensis n. sp. (Fig. 6H-I)

Derivation of name. This name refers to scorpions which are abundant in the outcrop area of the Sarchahan Formation.

Type locality. Kuh Faraghan, approximately 103 km north of Bandar Abbas city, Iran.

Type stratum. From the Sarchahan Formation of Kuh Faraghan, Zagros Mountains of Iran, sample number MG8075, 81.6m above the base of section.

Holotype. Fig. 6H-I, MG8075-E

Material. 247 specimens from samples MG8071 (75.2 m above the base of section) to MG8079c (89.6 m above the base of section).

Diagnosis. *Plectochitina kazhdumiensis* is a species of *Plectochitina* with a cylindro-ovoid chamber, with 6-8 long, curved processes with a nodular structure.

Description. This species has cylindro-ovoid vesicle with granulated vesicle surface. The flexure is conspicuous, but the shoulder is absent. The neck widens towards the aperture and basal part of vesicle is convex. The basal margin is rounded, and has 4 curved processes. The processes are long with a nodular structure.

Remarks. This species is similar to *Plectochitina ralphi* Nestor 1994, but has an ovoid chamber, with maximum diameter in the middle of the chamber in contrast to the conical chamber of *P. ralphi*. The neck of *P. ralphi* (L/Ln=2.7) is longer than that of *P. kazhdumiensis* (L/Ln = 1.76 microns, measured from Nestor, 1994, Pl. V, figs 3-6).

Dimensions. Taken from Holotype: L=149; Ln=56; D=80; Dn=47; ls=38. Taken from 26 specimens: L=125-149; Ln=49-56; D=78-80; Dn=40-47; ls=38-55

Plectochitina khosravii Ghavidel-syooki, 2000 (Fig. 6B-C)

2000 *Plectochitina khosravii* n. sp.; Ghavidel-syooki, pl. 2, figs F-G

Material. 348 specimens from samples MG8054 (48 m above the base of section) to MG8075 (81.6 m above the base of section).

Description. This species has a large cylindro-conical vesicle with 2-8 spongy processes and a convex to flat base. The chamber is conical with a granular surface and sparsely distributed, broken spines. The flexure is conspicuous and the shoulder is absent. The neck widens towards the aperture and is covered by simple, bifurcate and lambda-shaped spines.

Remarks. This species is common in the Sarchahan Formation from where it has previously been recorded by Ghavidel-syooki (2000). The length of the holotype of this species is more than 300 microns, slightly longer than the specimens in the present study of the Sarcharhan Formation.

Dimensions. Taken from 36 specimens: L=263-268; Ln=172-178; D=95-99; dcoll=42-44; ls= 23-25; L/D=2.7-2.8; L/Ln=1.5.

Plectochitina nodifera Nestor, 1980b

1980a *Ancyrochitina nodifera* n. sp.; Nestor, p. 100, pl. 2, figs 1-3; pl. 3, fig. 1
1994 *Plectochitina nodifera*; Nestor, p. 73, pl. 4, fig. 4

Material. 327 specimens from samples MG8030 (9.6 m above the base of section) to MG8074 (80.0 m above the base of section).

Remarks. Nestor (1994) reports the species from the lowermost part of the Llandovery of Estonia, while Geng *et al.*, (1997) report a similar range from Yangtze Region of China.

Plectochitina paraguayensis Wood & Miller, 1991 (Fig. 7E-F)

1991 *Plectochitina paraguayensis* n. sp.; Wood & Miller p. 186-188, pl. 1, figs 1-5; pl. 2, figs 1-5
1995 *Plectochitina paraguayensis*; Paris *et al.*, pl. 1, fig. 11
2000 *Plectochitina paraguayensis*; Ghavidel-syooki, pl. 2, figs A-C, H

Material. 1490 specimens from samples MG8045 (33.6 m above the base of section) to MG8079c (89.6 m above the base of section).

Description. The vesicle is cylindro-conical, and the surface is smooth. The flexure is well-developed, but the shoulder is inconspicuous. The basal margin is rounded and has 2-4 long, spongy processes. The neck widens towards aperture. The collarette is distinct, with small simple spines. The basal part of the vesicle ranges from convex to concave.

Remarks. This species has been recorded from lower Silurian strata (Qalibah Formation) of Saudi Arabia (Paris *et al.*, 1995), lower Silurian Vargas Pena Shale of Paraguay (Wood & Miller,1991) and lower Silurian of Sarchahan Formation of Iran (Ghavidel-syooki, 2000). Verniers *et al.* (1995) show *P. paraguayensis* as characteristic of the lower and middle Llandovery. This species is extremely abundant in the Sarchahan Formation

Dimensions. Taken from 32 specimens: L=89-141; Ln=23-82; D=65-80; dcoll=35-47; lappendages =108-220; width of appendages 17-18; L/D=1.4-2; L/Ln=1.7-3.8.

Plectochitina pseudoagglutinans (Taugourdeau, 1963) (Fig. 8A-B)

1963 *Ancyrochitina fragilis pseudoagglutinans* n. subsp.; Taugourdeau, pl. I, figs 5-6
1967 *Plectochitina pseudoagglutinans*; Cramer, p. 125-127, pl. V, figs 145-146
1985 *Plectochitina pseudoagglutinans*; Hill *et al.*, pl. 12, figs 5a-b, pl. 13, fig. 8
2000 *Plectochitina pseudoagglutinans*; Ghavidel-syooki, pl. 1, figs A-B, D-F

Material. 1008 specimens from samples MG8054 (48 m above the base of section) to MG8075 (81.6 m above the base of section).

Description. This species in the Sarchahan Formation has a cylindro-conical vesicle with flat to concave base. There are 5-8 spongy processes on a smooth vesicle. This differs only slightly from Taugourdeau's holotype which has minute nodules and 4-6 processes. The flexure and shoulder are conspicuous.

Remarks. This species has been recorded from lower Silurian strata of Spain (Cramer, 1967), Saudi Arabia (Paris *et al.*, 1995), Libya (Hill *et al.*, 1985),

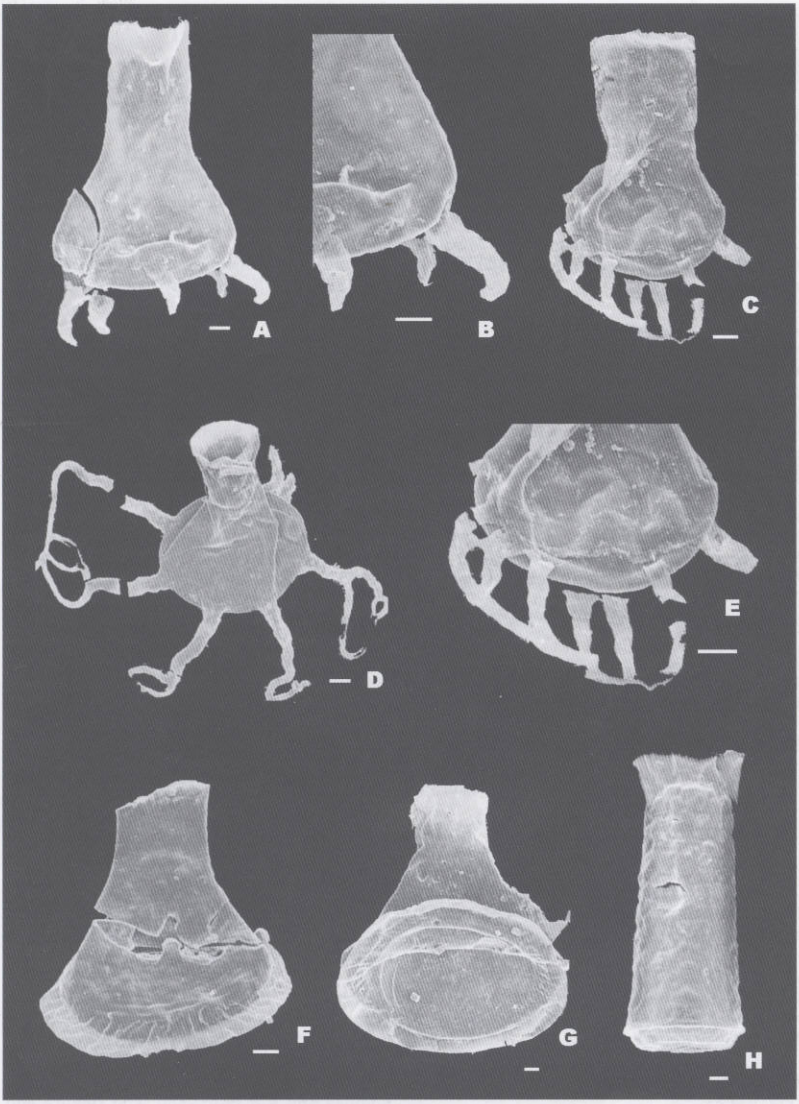

Fig. 8. A-B, *Plectochitina pseudoagglutinans* Taugourdeau, MG8075-K (scale bar =10µm). C-E, *Plectochitina saharica* Taugourdeau, C, E MG8075-L (scale bar =10µm); D, MG8060-A. F-G, *Cyathochitina caputoi* Eisenack, F, MG8053-A (scale bar =20µm); G, MG8053-B (scale bar=10µm). H, *Hyalochitina sarchahanensis* n. sp., MG8071-B, holotype (scale bar =10µm).

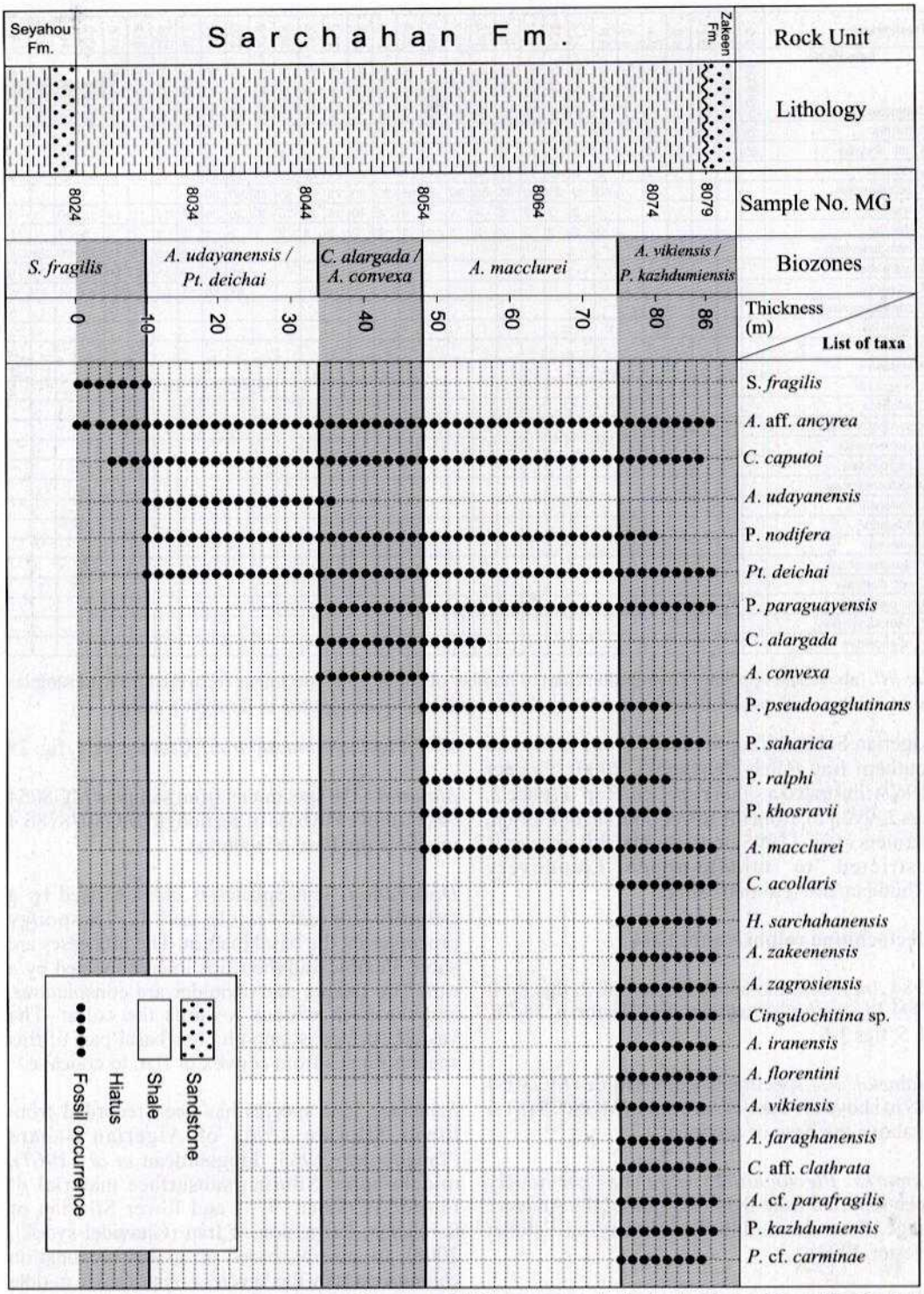

Fig. 9. Range chart showing the stratigraphic range of chitinozoan species in the Sarchahan Formation. Each dot represents the presence of the species in the sample.

Thickness(m)	0.0	1.6	3.2	4.8	6.4	8.0	9.6	11.2	12.8	14.4	16.0	17.6	19.2	20.8	22.4	24.0	25.6	27.2	28.8	30.4	32.0	33.6	35.2	36.8	38.4	40.0	41.6	43.2	44.8	46.4	48.0
Sample No. / Chitinozoans	MG-8024	MG-8025	MG-8026	MG-8027	MG-8028	MG-8029	MG-8030	MG-8031	MG-8032	MG-8033	MG-8034	MG-8035	MG-8036	MG-8037	MG-8038	MG-8039	MG-8040	MG-8041	MG-8042	MG-8043	MG-8044	MG-8045	MG-8046	MG-8047	MG-8048	MG-8049	MG-8050	MG-8051	MG-8052	MG-8053	MG-8054
S. fragilis	25	20	25	30	32	15	5																								
A. aff. ancyrea	85	75	65	50	30	25	12	15	20	10	8	5	7	4	4	5	6	7	12	5	3	2	8	12	10	12	11	15	16	8	17
C. caputoi				2	2	4	5	8	10	11	12	14	15	16	20	25	23	24	28	30	14	18	23	24	40	50	51	60	60	70	70
A. udayanensis							60	70	75	80	85	85	90	95	95	90	80	75	70	75	75	80	80								
P. nodifera							1	2	2	2	3	4	4	4	4	8	10	15	20	20	20	20	25	25	17	13	14	12	10	8	5
P. deichai							2	2	2	2	2	2	1	1	1	3	2	3	4	2	1	2	1	2	1	2	1	3	2	1	2
P. paraguayensis																						9	10	15	15	15	15	20	20	20	25
C. alargada																						20	23	30	35	40	50	55	50	20	15
A. convexa																						45	50	55	60	63	65	70	55	45	25
P. pseudoagglutinans																															5
P. saharica																															2
P. ralphi																															1
P. khosravii																															2
A. macclurei																															2
C. acollaris																															
H. sarchahanensis																															
A. zakeenensis																															
A. zagrosensis																															
Cingulochitina sp																															
A. iranensis																															
A. florentini																															
A. vikiensis																															
A. faraghanensis																															
C. aff. clathrata																															
A. cf parafragilis																															
P. kazhdumiensis																															
P. cf carminae																															

Fig. 10. (above and opposite) Distribution chart of number of chitinozoan specimens recovered from all samples in the section, with total number of specimens for each species listed opposite in far right column.

Algerian Sahara (Taugourdeau, 1962, 1963) and southern Iran (Ghavidel-syooki, 2000). Cramer (1967) illustrated a similar species, *P.* sp. 1 (plate 2, figs 2, 9 & 12), from the lower Silurian of Florida. Verniers *et al.*, (1995) indicate that this species is restricted to middle-upper Llandovery (Rhuddanian-Aeronian) strata.

Plectochitina ralphi Nestor 1994

1984 *Ancyrochitina* sp. B; Nestor, pl. 2, figs 8-10
1994 *Plectochitina ralphi* n. sp.; Nestor, p. 75-76, pl. 5, figs 3-6

Material. 327 specimens from samples MG8054 (48 m above the base of section) to MG8075 (81.6 m above the base of section).

Remarks. Plectochitina ralphi has previously been reported from the lower part of the Adavere Stage, from the middle Llandovery, in Estonia (Nestor, 1994).

Plectochitina saharica (Taugourdeau, 1962) (Fig. 8C-E)

1962 *Ancyrochitina saharica* n. sp.; Taugourdeau, pl. 1, fig. 7
1973 *Plectochitina saharica*; Cramer, pl. 1, fig. 29

Material: 258 specimens from samples MG8054 (48 m above the base of section) to MG8078 (86.4 m above the base of section).

Description. This species is characterised by a cylindro-conical vesicle and 12-15 spongy processes on the basal margin. The processes are short, flexible and their tips 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.

Remarks. This species has been recorded from lower Silurian strata of Algerian Sahara (Taugourdeau,1963; Taugourdeau *et al.*, 1967), middle-upper Silurian subsurface material of Florida (Cramer,1973) and lower Silurian of Sarchahan Formation of Iran (Ghavidel-syooki, 2000). In general, based on global biozonation chitinozoan taxa, this species is restricted to middle and upper Llandovery (Aeronian-Telychian) strata (Verniers *et al.*, 1995).

Dimensions. Taken from 72 specimens: L=90-128; Ln=40-99; D=62-84; dcoll=32-49; L/D=1.5-3.3; L/

Thickness(m)	49.6	51.2	52.8	54.4	56.0	57.6	59.2	60.8	62.4	64.0	65.6	67.2	68.8	70.4	72.0	73.6	75.2	76.8	78.4	80.0	81.6	83.2	84.8	86.4	88.0	89.6	Total number of each species
Sample No. / Chitinozoans	MG-8055	MG-8056	MG-8057	MG-8058	MG-8059	MG-8060	MG-8061	MG-8062	MG-8063	MG-8064	MG-8065	MG-8066	MG-8067	MG-8068	MG-8069	MG-8070	MG-8071	MG-8072	MG-8073	MG-8074	MG-8075	MG-8076	MG-8077	MG-8078	MG-8079	MG-8079c	
S. fragilis																											152
A. aff. ancyrea	19	20	10	12	23	20	8	4	7	3	5	5	6	4	3	2	2	3	2	3	3	4	2	3	2	3	742
C. caputoi	70	55	53	51	49	30	35	25	20	17	18	10	9	8	10	9	8	7	7	8	6	5	3	3	3	3	1251
A. udayanensis																											1360
P. nodifera	6	2	3	4	3	4	2	2	2	3	3	4	5	4	3	2	2	2	2	1							327
P. deichai	1	1	1	2	2	2	2	2	3	3	3	3	4	4	3	2	2	2	2	2	2	2	2	1	2	1	103
P. paraguayensis	35	40	40	45	50	60	70	75	75	78	80	85	85	75	80	80	80	80	35	20	20	10	10	10	5	3	1490
C. alargada	15	10	10	9	8																						390
A. convexa																											533
P. pseudoagglutinans	10	10	20	25	30	50	65	70	80	85	85	90	90	93	60	50	50	20	10	5	5						1008
P. saharica	5	5	10	15	15	15	20	15	15	12	12	14	14	10	10	10	10	10	8	8	7	6	5	5			258
P. ralphi	2	2	3	3	4	5	10	10	15	20	25	30	35	39	42	45	25	5	3	2	1						327
P. khosravii	4	4	5	6	10	15	20	20	26	30	30	35	40	40	30	15	5	5	3	2	1						348
A. macclurei	5	5	8	8	12	12	15	15	18	10	10	15	20	22	25	25	35	30	35	25	20	15	10	10	7	5	419
C. acollaris																	25	45	50	55	50	40	35	15	5	5	325
H. sarchahanensis																	45	50	55	60	65	55	45	35	25	8	443
A. zakeenensis																	35	35	40	45	55	40	35	25	20	15	345
A. zagrosensis																	35	40	45	50	55	50	45	40	30	8	398
Cingulochitina sp																	55	70	85	65	55	50	25	14	5	2	426
A. iranensis																	25	30	35	40	45	55	55	53	35	10	383
A. florentini																	25	30	35	40	45	55	45	26	20	10	331
A. vikiensis																	35	40	45	50	56	45	25	20			316
A. faraghanensis																	40	40	45	55	35	35	30	25	10	5	320
C. aff. clathrata																	35	35	40	45	60	45	40	30	15	5	350
A. cf parafragilis																	30	40	45	55	67	45	20	6	8	3	319
P. kazhdumiensis																	20	30	27	48	55	25	15	10	8	9	247
P. cf carminae																	45	50	55	60	65	40	25	20	15	9	384

Ln=1.2-2.5

Subfamily CYATHOCHITININAE Paris, 1981

Cyathochitina Eisenack, 1931

Type species. Cyathochitina campanulaeformis Eisenack, 1931

Cyathochitina caputoi Costa, 1971 (Fig. 8F-G)

1970 *Cyathochitina* sp.; Costa, p.223, fig. 43
1971 *Cyathochitina caputoi*; Costa, p. 238, fig. 43
1995 *Cyathochitina caputoi*; Paris *et al.*, pl. 1, fig. 2

Material. 1251 specimens from samples MG8027 (4.8 m above the base of section) to MG8079c (89.6 m above the base of section).

Remarks. This species is abundant in the Sarchahan Formation of Kuh Faraghan and Kuh Gahkum, as well as in the G-3 well in the Persian Gulf. Specimens of *Cyathochitina caputoi* in the present study are similar to those elsewhere, but are slightly larger than those described by Costa from the Amazon. The vesicle surface is granular and the carina displays ribs.

This species shows a slightly more extended range than that listed by Paris *et al.*, (1995).

Dimensions. Taken from 101 specimen: L=194-223; Ln=52-84; D=125-206; dcoll=54-83; width of carina =10-20; L/D=1.2-2.7; L/Ln=2.4-3.4

BIOSTRATIGRAPHY

A total of 28 species belonging to nine genera has been identified in the Llandovery material (Figs. 3-8). Stratigraphic distribution is plotted on Figure 9, while Figure 10 shows the distribution of specimens recovered. Five local biozones are established through the Sarchahan Formation, and the age ranges of these biozones are supported at all levels by acritarch and graptolite data.

Spinachitina fragilis biozone

The index species *Spinachitina fragilis* appears at the base of the Sarchahan Formation and extends through a thickness of 9.6 metres (MG8024 to MG8030). Associated, but longer ranging chitinozoan species of this biozone are *Ancyrochitina ancyrea* and *Cyathochitina caputoi*. The *Spinachitina fragilis* biozone has been recorded from the basal part of the Qusaiba member of the Qalibah Formation in Saudi Arabia (Paris *et al.*, 1995), the Puikule member of the Ohne Formation in Estonia (Nestor, 1980a; 1994) and the lowermost part of Sarchahan Formation (Ghavidel-syooki, 2000). Graptolites are also found in the basal part of the Sarchahan Formation, but Rickards *et al.* (2000) recorded no diagnostic graptolites. Based on the global chitinozoan

biozonation for the Silurian, the *Spinachitina fragilis* biozone corresponds to the *acuminatus* graptolite zone. Therefore, the basal part of Sarchahan Formation is assigned to the Early Llandovery (Rhuddanian).

***Ancyrochitina udayanensis - Pterochitina deichai* biozone**

This biozone is defined by first appearance *Ancyrochitina udayanensis* Paris & Al-Hajri and *Pterochitina dechai* Taugourdeau. *Ancyrochitina udayanensis* Paris & Al-Hajri extends slightly into the succeeding biozone. Accompanying species include *Plectochitina nodifera* Nestor and the long ranging *Ancyrochitina* aff. *anycrea* Eisenack and *C. caputoi* Costa from the previous biozone.

Based on the presence of *P. deichai* the *A. udayanensis-P. dechai* biozone is equivalent to the *electa* and *maennili* global biozones of Verniers *et al.* (1995). There is no indication in this study of the presence of the *postrobusta* global biozone that occurs between the *fragilis* and *electa* global biozones. *Ancyrochitina udayanensis* is found in the *L. nuayyimensis* and *A. quasibaensis* biozones from central Saudi Arabia (Paris *et al.*, 1995), along with *P. deichai,* confirming a correlation between the Iranian and Saudi biozones.

***Conochitina alargada – Ancyrochitina convexa* biozone**

The base of this biozone is defined by the first appearance of *C. alargada* and *A. convexa.* Accompanying species include *P. paraguayensis, P. nodifera* and *P. dechai.*

The lower part of the *alargada* global biozone of Verniers *et al.* (1995) correlates with the *C. alargada-A. convexa* biozone in Iran. The biozone from the Sarchahan Formation is equivalent to the *C. alargada/ P. paraguayensis* biozone from Saudi Arabia (Paris *et al.*, 1995), and to the *A. convexa* biozone from Estonia (Nestor 1994).

Graptolite biozones, including the *leptotheca, convolutus* and *sedgwickii* biozones, were established in the Sarchahan Formation by Rickards *et al.* (2000), confirming a middle Llandovery age for this part of the formation.

***Angochitina macclurei* biozone**

The base of this biozone is defined by the first appearance of *Angochitina macclurei.* Several other species also appear at the same time, including *Plectochitina pseudoagglutinans, P. saharica, P. ralphi* and *P. khosravii.* The biozone extends through 37.2 metres of the Sarchahan Formation, from MG8054 to MG8070 (see Fig. 9).

This biozone can be correlated with the *A. macclurei* biozone from the Telychian of Saudi Arabia (Paris *et al.*, 1995), which is there defined as an acme range; in both Iran and Saudi, the base of the biozone coincides with the first appearance of *A. macclurei.* Verniers *et al.* (1995) nominate *A. macclurei* as a diagnostic species of the *Angochitina longicollis* global biozone. This suggests that the global *dolioformis* biozone that occurs between the *alargada* and *longicollis* biozones is not represented in the Sarchahan Formation. However, the presence of *P. pseudoagglutinans* and *P. saharica* may indicate the presence of this zone. No diagnostic graptolites have been recovered from this part of the section.

***Ancyrochitina vikiensis – Plectochitina kazhdumiensis* biozone**

The highest biozone in the Sarchahan Formation is defined by the first appearance of *A. vikiensis* Nestor and *P. kazhdumiensis* n. sp., and extends through 16 m of the section (MG8071-MG8079). Many of the species from underlying biozones extend into this biozone, and a suite of species appear, e.g. *Calpichitina acollaris* and several new species of *Ancyrochitina.*

Ancyrochitina vikiensis also occurs in the *C. proboscifera* biozone of Estonia and northern Latvia (Nestor, 1994). The *C. proboscifera* biozone is regarded as equivalent to the *longicollis* biozone (Verniers *et al.*, 1995), in the uppermost Telychian in most locations, but there are some cases of diachronous first appearances.

Hence, based on chitinozoan data, the upper Sarchahan Formation is assigned a late Llandovery (Telychian) age. No diagnostic graptolites have been recovered from this part of the section.

CONCLUSIONS

Investigation of surface samples of Llandovery age from the Zagros Basin, southern Iran, allows the following conclusions to be drawn:

1) Based on stratigraphic information from chitinozoan taxa, the Sarchahan Formation is early-late Llandovery in age (Rhuddanian-Telychian).

2) Eight new species are defined, viz. *Ancyrochitina faraghanensis, A. florentini, A. iranensis, A. zagrosiensis, A. zakeenensis, Plectochitina kazhdumiensis* and *Hyalochitina sarchahanensis.*

3) Several local biozones have been defined and correlated with other local biozones from the same region and with global biozones erected by Verniers *et al.* (1995).

4) Palaeontological and lithological data of the Sarchahan Formation suggest a close correlation with the Qalibah Formation in Saudi Arabia, suggesting a similar environment existed on both

the southern and northern shores of the Persian Gulf.

5) The most abundant chitinozoan taxa of the Sarchahan Formation are *Plectochitina pseudoagglutinans, P. saharica, P. paraguayensis, P. nodifera, Pterochitina deichai* and *Ancyrochitina macclurei* which are obvious elements of the North Gondwana Domain. This confirms the contention that the Zagros Basin of Iran was part of the Gondwana landmass during the Silurian.

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