# Early Cretaceous radiolarian assemblages from radiolarites in the Sistan Suture (eastern Iran)

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**ABSTRACT**
A well preserved Cretaceous radiolarian fauna was recovered from the Sistan Suture zone (eastern Iran). This radiolarian fauna was obtained from the red argilaceous cherts and green-grey cherts that distributed in the ophiolite unit. It is regarded as representative of the Early Cretaceous assemblage in the oceanic basin created by the opening of the two blocks (Afghan and Lut) during the Cretaceous time. During the Early Cretaceous, an extensive sedimentation of radiolarian-rich facies occured in this region. Two radiolarian assemblages are determined: Assemblage I (composed of about 15 species which represent the early Aptian), and Assemblage II (characterized by the occurrence of about 32 species). The cryptothoracic Nassellaria correspond to *Holocryptocanium barbui* Dumitrica, 1970, *Dorypyle communis* (Squinabol, 1903), etc. The cryptocephalic Nasselaria is only confined to *Diacanthocapsa* cf. *ovoidea* Dumitrica, 1970. The spumellarian genera are *Dactyliodiscus* cf. *lenticulatus* (Jud, 1994), *Pseudoaulophacus* sp., etc. The study of the radiolarites provides new data for dating the primary opening between two blocks. It is proposed that the oceanic opening of the two blocks occurred prior to the early Aptian.

**KEY WORDS**
Radiolarian assemblages,
Early Cretaceous,
eastern Iran,
Sistan Suture,
Gazik Province.

  

**RÉSUMÉ**

*Assemblages de radiolaires du Crétacé inférieur des radiolarites de la suture de Sistan (Iran oriental).*

Une faune bien préservée de radiolaires d'âge crétacé a été découverte dans la zone de suture de Sistan (Iran oriental). Cette faune extraite de cherts argileux rouges et de cherts vert-gris est incluse dans l'unité ophiolitique. Elle est considérée comme représentative de l'assemblage d'âge crétacé inférieur du bassin océanique formé lors de la séparation des deux blocs (Afghan et Lut) pendant le Crétacé. Durant le Crétacé inférieur, un dépôt important de faciès riche en radiolaires a eu lieu dans cette région. Deux assemblages à radiolaires sont distingués : l'Assemblage I (composé d'environ 15 espèces d'âge aptien inférieur) et l'Assemblage II (caractérisé par la présence d'environ 32 espèces). Les Nasselaria cryptothoraciques correspondent à *Holocryptocanium barbui* Dumitrica, 1970, *Dorypyle communis* (Squinabol, 1903), etc. Le Nasselaria cryptocéphalique est limité à *Diacanthocapsa* cf. *ovoidea* Dumitrica, 1970. Des genres spumellaires sont rapportés à *Dactyliodiscus* cf. *lenticulatus* (Jud, 1994), *Pseudoaulophacus* sp., etc. L'étude des radiolarites fournit de nouvelles données sur l'âge de la première phase d'ouverture entre les deux blocs. Cette ouverture a donc eu lieu avant l'Aptien inférieur.

**MOTS CLÉS**
Assemblages de radiolaires,
Crétacé inférieur,
Iran oriental,
suture de Sistan,
province de Gazik.

## INTRODUCTION

During the Early Cretaceous, widespread sediment of radiolarian-rich facies occured in the Sistan Suture zone. This zone is located between two blocks, Afghan and Lut, in the eastern Iran. The radiolarian faunas were extracted from the radiolarian cherts in the Soulabest region at the Gazik Province in the Sistan Suture zone (Fig. 1). Deposition of these sediments coincides with the opening of two represented blocks before early Aptian (Babazadeh & De Wever in press). This phenomenon records a significant paleogeographic event in the Neo-Tethys in this area. The Soulabest radiolarites in the Sistan oceanic basin represent one of the best exposed portions of the Iranian Early Cretaceous (early Aptian-late Albian) depositional event. This deep marine sediment was deposited in the oceanic basin and is similar to the known Tethyan radiolarites in Samail radiolarites (Sultanat of Oman) (Beurrier *et al.* 1987). This paper presents the first taxonomic description of found radiolarian fauna in the Gazik Province (Soulabest region). The studied area is limited by 60°17' to 60°20'E and 32°30' to 32°33'N (Fig. 2).

## REGIONAL SETTING

Iranian territory is an assemblage of marginal Gondwana fragments that detached from the Gondwanian-Arabian plate during the Late Paleozoic (Permian), or Early Triassic (Stöcklin 1977). Central Iran is a continental fragment with the same Paleozoic history as typical Gondwanian areas such as Arabia or India, in sharp contrast with the coeval history of south Eurasia (Stöcklin 1977). Therefore, central Iran detached from Gondwana and migrated northwards through the opening of a southern ocean and closure of a northern one before it collided with Eurasia. The subsequent consumption of a younger ocean basin (in the south of Iran), the Neo-Tethys, beneath the southern margin of central Iran led to collision with the Arabian plate along the Main Zagros Thrust (Stöcklin 1977). There are some inconsistencies about the time of collision along the Main Zagros Thrust which is interpreted to be either late Campanian-Maastrichtian (Ricou 1971; Berberian & King 1981) or a Miocene event (Bird *et al.* 1975; Sengor & Kidd 1979; Stoneley 1974). Nevertheless, in the Late Cretaceous, Iran was

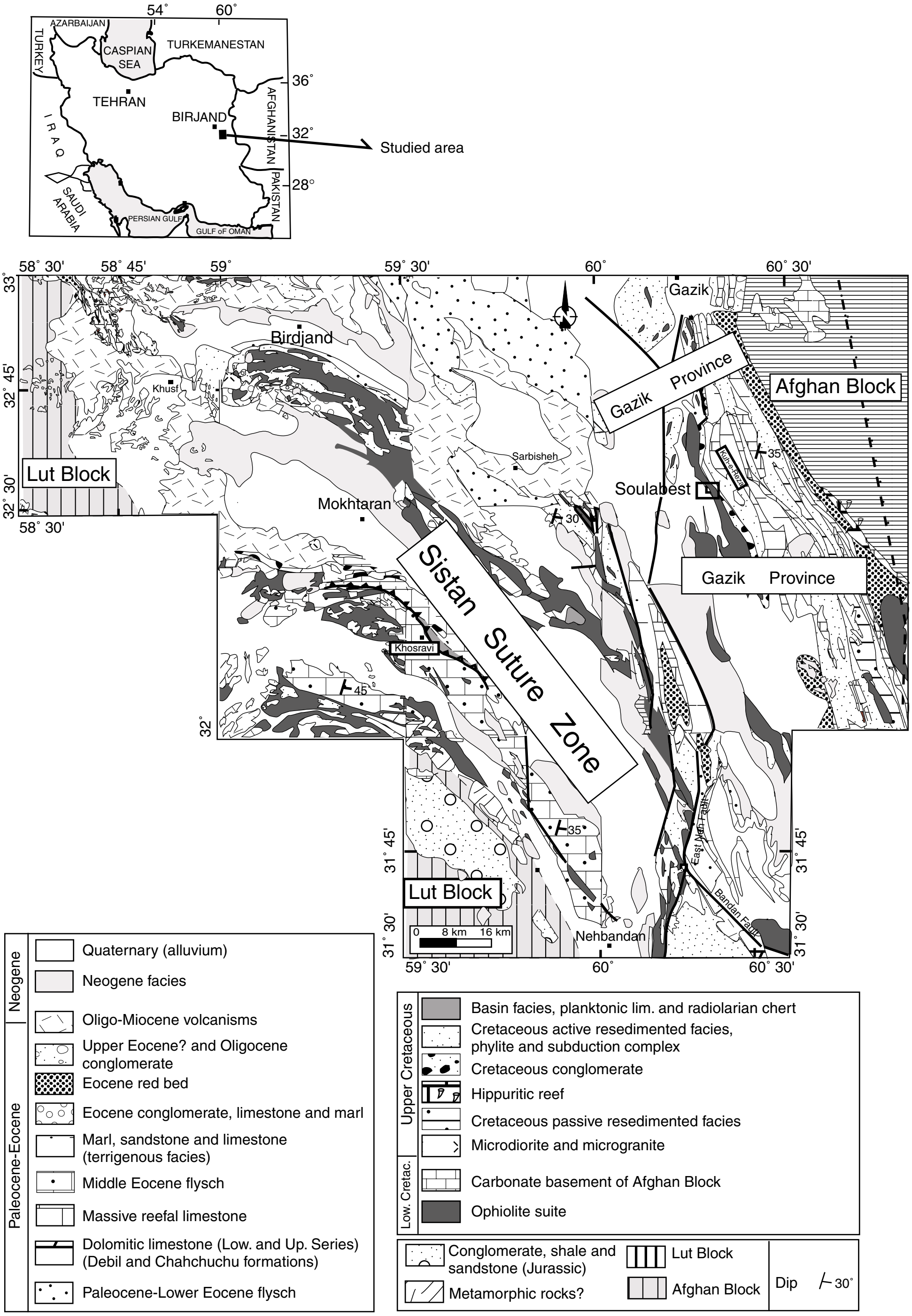


FIG. 1. — Sketch structural map showing Lut and Afghan blocks and Sistan Suture zone (in this study).

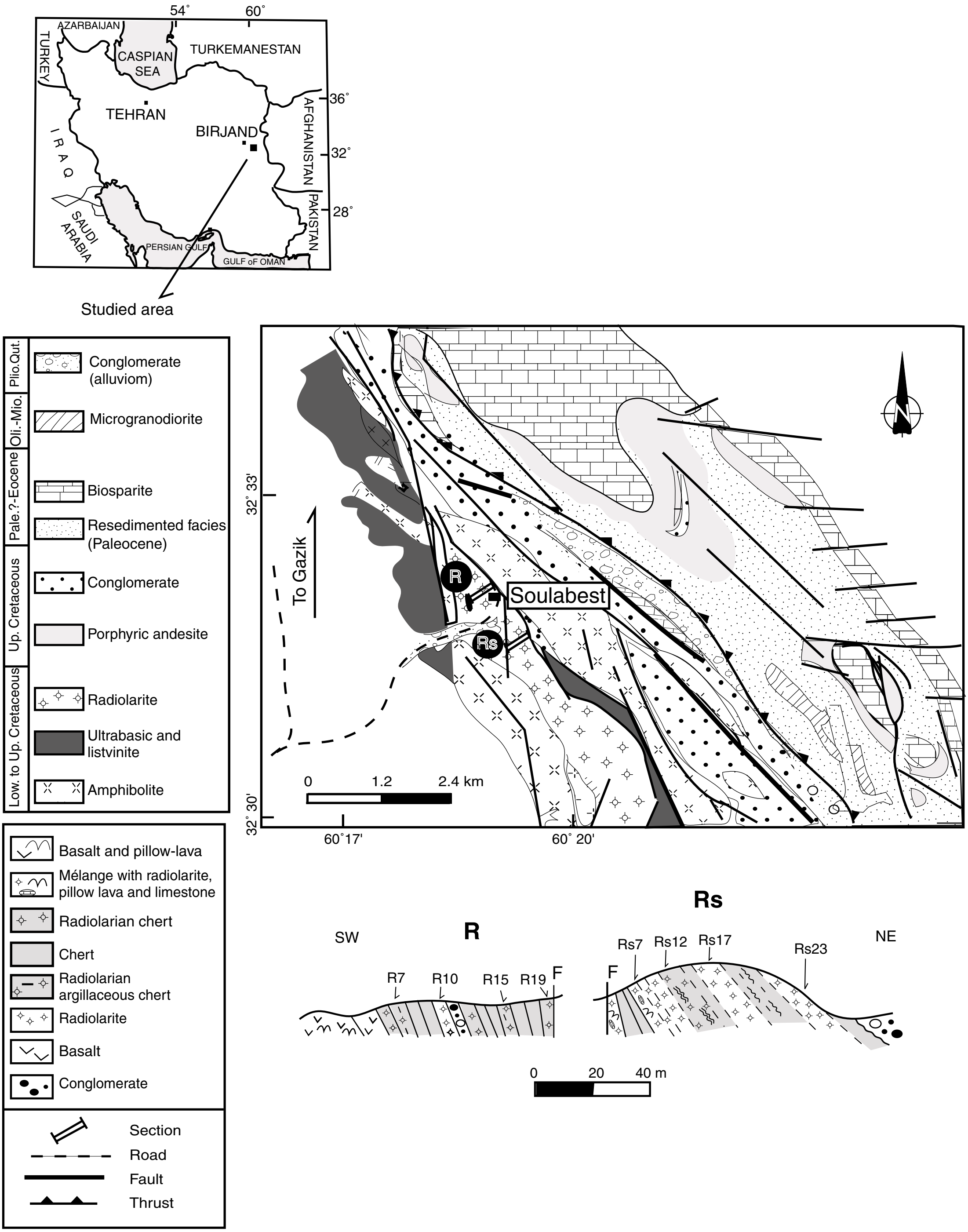


FIG. 2. — Location of the two studied sections (R and Rs) in the Soulabest area and their cross-sections, geological map of Gazik (Alavi Naini & Behruzi 1981) (simplified).

colliding with the Gondwanian Afro-Arabia plate, but the oceanic area was not completely closed as evidenced by the presence of Cretaceous-Tertiary flysch deposits in eastern Iran.

Three major tectonic units (Turanian, Iranian and Arabian plates) recognized by Lensch *et al.* (1984) in Iran are separated from each other by ophiolitic complexes (Stöcklin 1977). Central Iran comprises Sanandaj-Sirjan belt, Orumiyeh-Dokhtar belt, central-East Iran microplate (Davoudzadeh & Schmidt 1981), this latter subdivided into Yazd, Tabas and Lut blocks (Fig. 3). The three components of the inner microcontinental nucleus (formerly termed the Lut block by Stöcklin 1968), the Yazd, Tabas, and Lut blocks are separated by fracture zones and have been rearranged from their original position (Sengor *et al.* 1988).

In central Iran, there are two ophiolite belts including mélanges and deep water marine sedimentary rocks: 1) one of these ophiolite complexes extends from Esfandagheh to the Nain area and along the Great Kavir Fault to the extensive ophiolitic mélange exposures around Sabzevar; 2) the second major belt, the Sistan Suture zone (Sistan Ocean), branches from the central Makran Ranges northward to the Birjand area, but does not join the mélange of the Sabzevar zone (Stöcklin 1977) (Fig. 3). Tirrul *et al.* (1983) suggested the found oldest rocks within flysch-ophiolitic range in Sistan Suture are attributed to Upper Cretaceous. The studied area is situated within this suture zone, in the Gazik Province of the ophiolite unit (Fig. 1).

## LITHOLOGY AND LOCATION OF SAMPLES

Two studied outcrops located at the North and South of the Soulabest village were examined (respectively R and Rs in Fig. 2). The radiolarites of the northern side of the village so-called northern unit consist in stratified basalts, radiolarian cherts, red radiolarian argilaceous cherts, green-gray to black cherts without Radiolaria, radiolarites and conglomerates containing the fragments of basalt, patched limestone and dolomites in different colors of red, green and black, contain moderately preserved radiolarian skeletons. The true thickness is 60 m. Radiolarites of the southern side of the village is called southern unit. The lower part of the southern unit shows a body of mélange containing the radiolarites, the pillow-lavas and the patched limestones with the intercalation of the cherts. It is covered by the disorganized complex containing red radiolarites, red radiolarian argilaceous cherts showing weak metamorphism and bedded gray cherts without Radiolaria. In contrast with the northern location, these radiolarians are well preserved. The thickness of this body reaches 100 m. The contact between these two units is faulted. On the basis of radiolarian assemblage, the southern unit appears to be younger than the northern one. The lower part of the section overlies conformably massive and pillowed basalts, the upper part is unconformably overlain by Maastrichtian conglomerates containing the cherts, the basalts and the limestones (Fig. 4).

## RADIOLARIAN FAUNA AND AGE

We report two radiolarian assemblages from two outcrops located at the North and South of the Soulabest village (respectively R and Rs in Fig. 2). The ages of the two radiolarian assemblages of the studied materials are different. Both of these radiolarian assemblages consist mainly of nassellarians, but spumellarians are minor components.

Assemblage I consists of the following radiolarian association: *Dictyomitra excellens* (Tan, 1927); *Archaeodictyomitra* aff. *vulgaris* Pessagno, 1977; *A. apiarium* (Rüst, 1885); *A.* sp.; *Podobursa* aff. *typica* (Rüst, 1898); *Stichomitra communis* Squinabol, 1903; *S.* cf. *japonica* Nakaseko & Nishimura, 1979; *S.* sp.; *Thanarla pacifica* Nakaseko & Nishimura, 1981; *T.* aff. *brouweri* (Tan, 1927); *Xitus elegans* (Squinabol, 1903); *Dactyliodiscus* cf. *lenticulatus* (Jud, 1994); *Stichocapsa* cf. *robusta* Matsuoka, 1984;

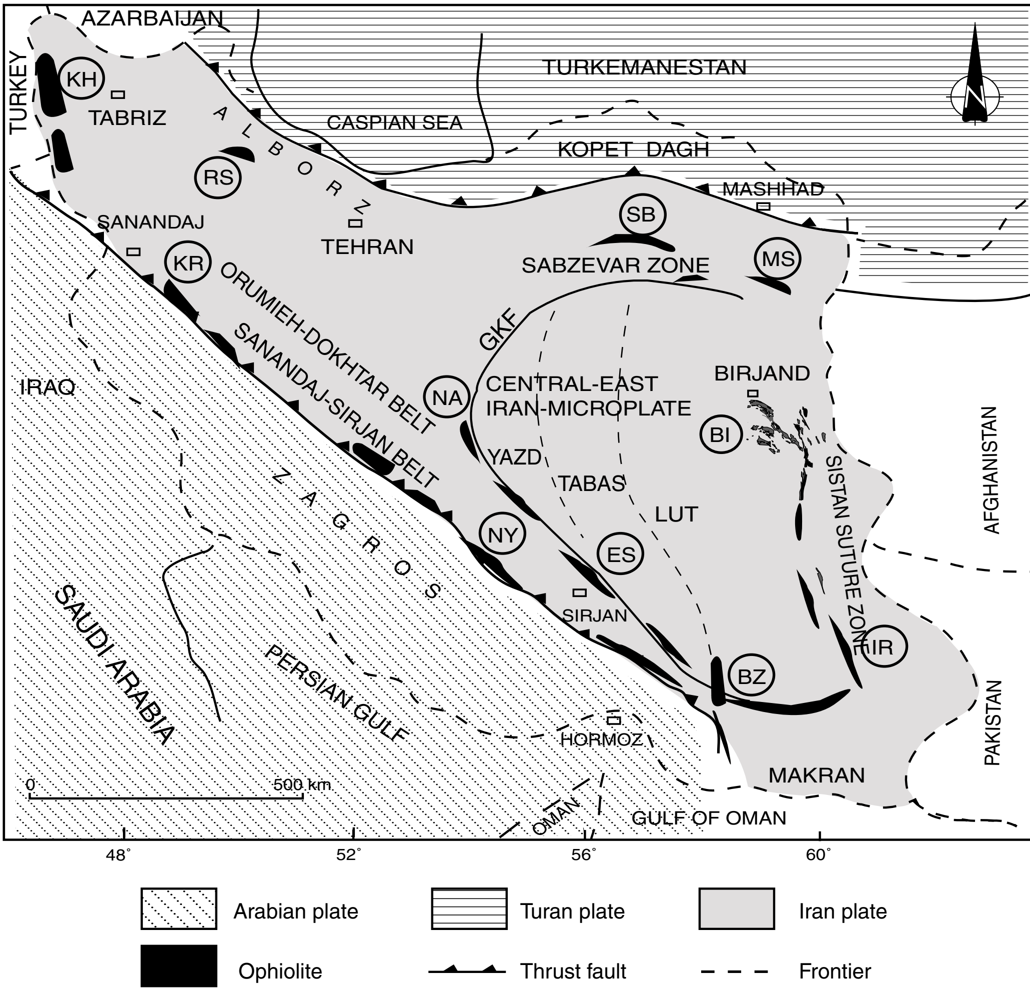


FIG. 3. — Modified sketch map of Iran showing the major tectonic units (Lensch *et al.* 1984), the inner microcontinental nucleus (Yazd, Tabas and Lut blocks) (Sengor *et al.* 1988), the positions of the main ophiolites (Stöcklin 1977; Dilek & Delaloye 1992). Abbreviations: **BI**, Birjand; **Bz**, Band Ziarat; **ES**, Esphandagheh; **GKF**, Great Kavir Fault; **IR**, Iranshahr; **KH**, Khoy; **KR**, Kermanshah; **MS**, Mashhad; **NA**, Nain; **NY**, Neyriz; **RS**, Rasht; **SB**, Sabzevar.

*Cryptamphorella* cf. *conara* (Foreman, 1968); *Hiscocapsa* cf. *asseni* (Tan, 1927) and *Parvicingula* sp. This assemblage can be compared with *Hiscocapsa asseni* Zone and *Turbocapsula verbeeki* Zone of O'Dogherty (1994).

This association allows to assign an early Aptian age (Fig. 5).

Assemblage II yields the following radiolarian association: *Thanarla pulchra* (Squinabol, 1904); *Thanarla* sp. aff. *brouweri*; *Thanarla* aff. *veneta* (Squinabol, 1903); *T.* sp.; *Archaeodictyomitra* aff. *vulgaris*; *A.* sp.; *Dictyomitra gracilis* (Squinabol, 1903); *D. montisserei* (Squinabol, 1903); *Pseudodictyomitra pseudomacrocephala* (Squinabol, 1903); *P. paronai* (Aliev, 1965); *Rhopalosyringium solivagum* O'Dogherty, 1994; *R. mosquense* (Smirnova & Aliev, 1969); *R. perforaculum* O'Dogherty, 1994; *R. adriaticum* O'Dogherty, 1994; *R. scissum* O'Dogherty, 1994; *R. hispidum* O'Dogherty, 1994; *R.* sp. 1; *R.* sp. 2; *Stichomitra*

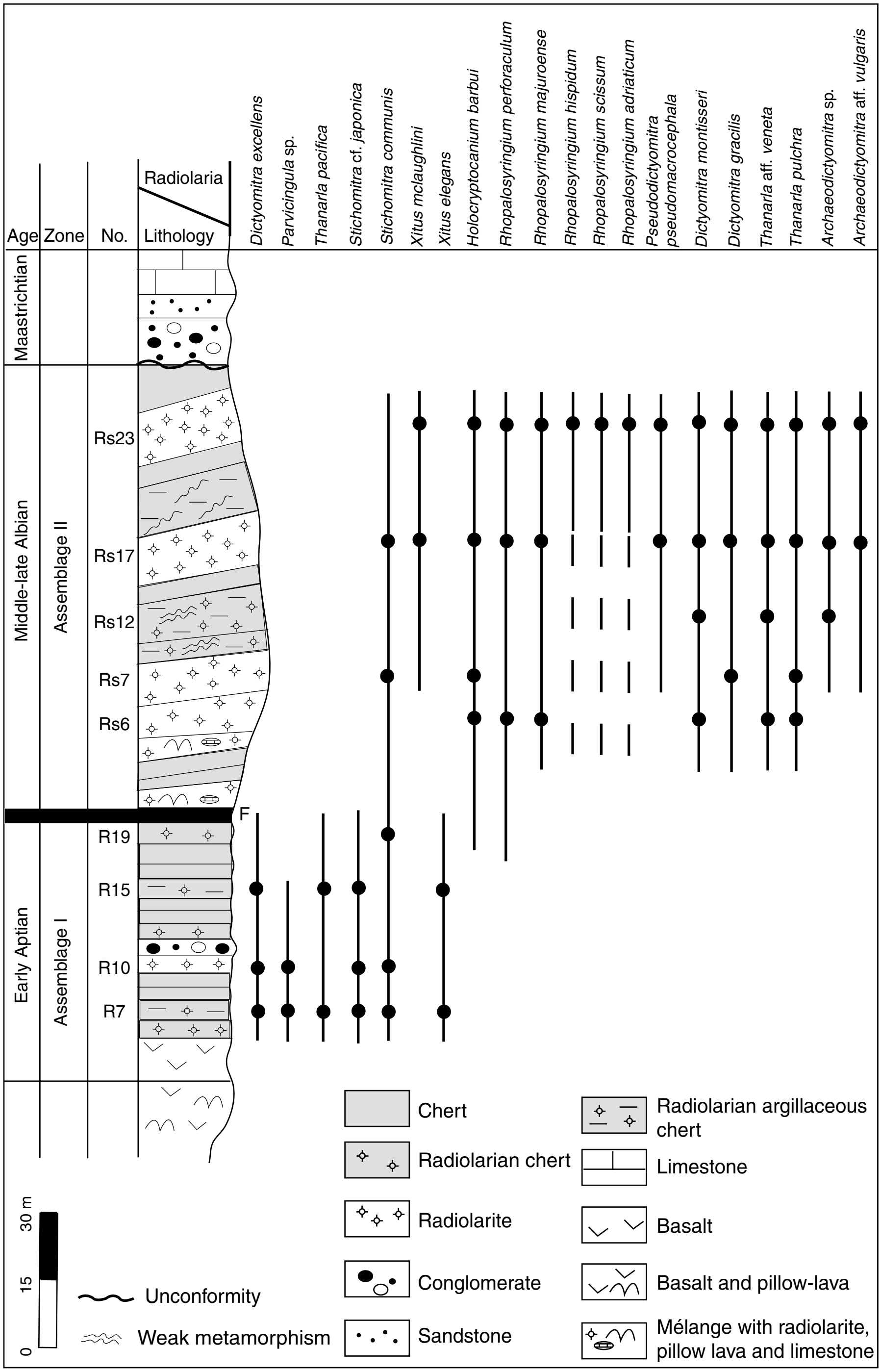


FIG. 4. — Succession of microfauna of Soulabest radiolarite.

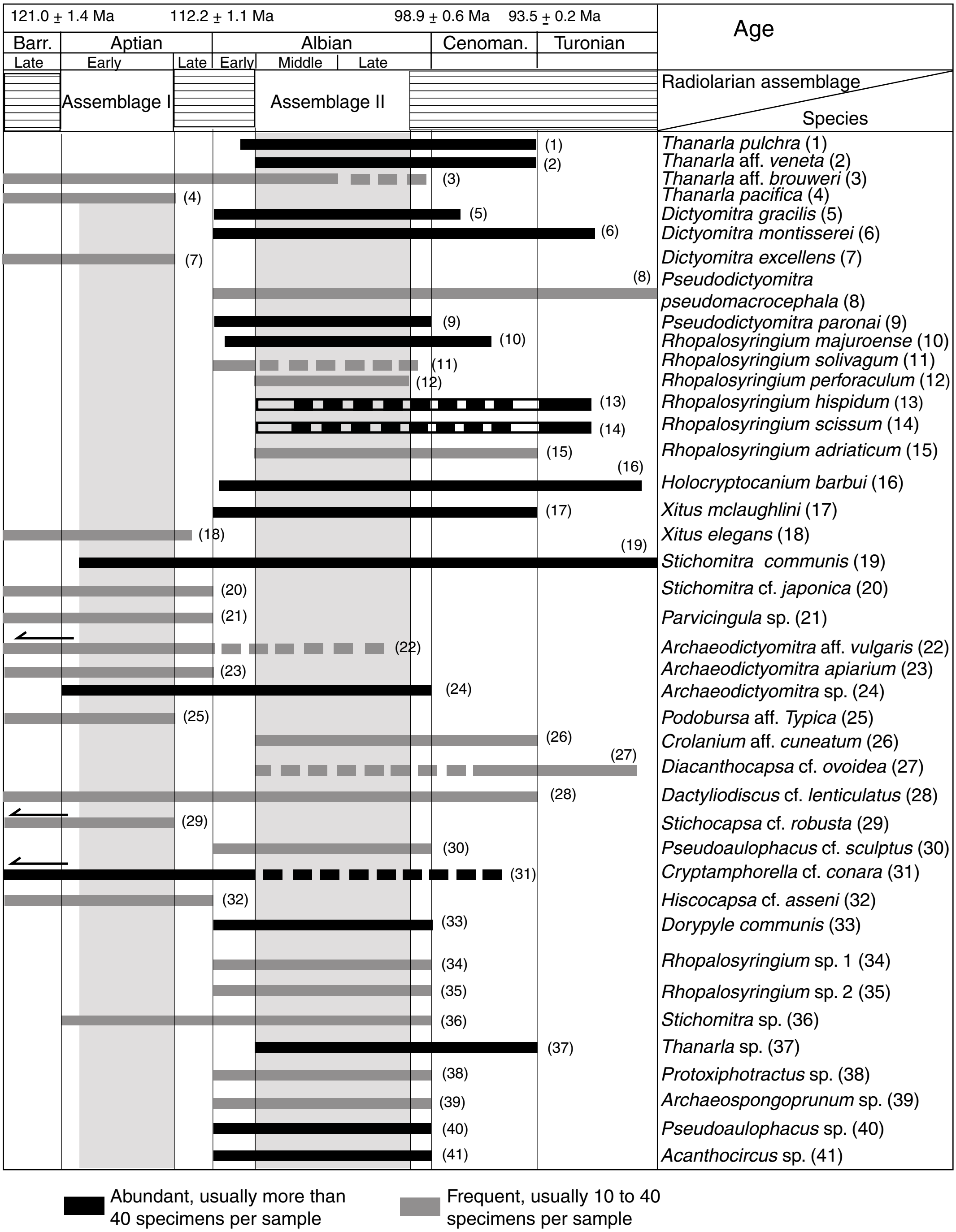


FIG. 5. — Stratigraphic range and faunal assemblage of selected radiolarian taxa in the Soulabest area (age, Robaszynski & Caron 1995). Stratigraphic range for numbers 1 to 9, 12, 15, 17, 18, 20, 23 and 25 to 33 (O'Dogherty 1994); numbers 10 and 19 (Gorican 1994); numbers 13 and 14 (O'Dogherty 1994 and in this study); numbers 11, 21 and 24 (in this study).

*communis*; *S.* sp.; *Xitus mclaughlini* (Pessagno, 1977); *X. elegans*; *Dorypyle communis* (Squinabol, 1903); *Holocryptocanium barbui* Dumitrica, 1970; *Cryptamphorella* cf. *conara*; *Archaeospongoprunum* sp.; *Pseudocrucella* sp.; *Protoxiphotractus* sp.; *Acanthocircus* sp.; *Pseudoaulophacus* cf. *sculptus* (Squinabol, 1904); *Pseudoaulophacus* sp.; *Pseudocrucella* sp.; *Dactyliodiscus* cf. *lenticulatus*; *Diacanthocapsa* cf. *ovoidea* Dumitrica, 1970; *Crolanium* aff. *cuneatum* (Smirnova & Aliev, 1969). This association can be similar to *Pseudodictyomitra psedomacrocephal*a Zone of Vishnevskaya (1993) and *Holocryptocanium barbui* Zone of Bak (1999).
The age of this association ranges from middle-late Albian (Fig. 5).
Remarks: O'Dogherty (1994) suggested that "*Rhopalosyringium scissum*" and "*Rhopalosyringium hispidum*" indicate Turonian age, whereas in this study, they range to middle-late Albian.

## SYSTEMATICS

Subclass RADIOLARIA Müller, 1858
Superorder POLYCYSTINA Ehrenberg, 1875
emend. Riedel, 1967
Order NASSELLARIA Ehrenberg, 1875
Family ARCHAEODICTYOMITRIDAE
Pessagno, 1976
Genus *Thanarla* Pessagno, 1977

### ***Thanarla pulchra*** (Squinabol, 1904)
(Fig. 6A-D)

*Thanarla pulchra* – Pessagno 1977b: 46, pl. 7, figs 7, 21, 26. — O'Dogherty 1994: 91.

OCCURRENCE. — Abundant in samples Rs6, Rs7, Rs12 and Rs23.

AGE. — Middle Albian to Cenomanian.

REMARKS
This species differs from *T. pacifica*, in having a more cylindrical post-abdominal segment with parallel vertical sides in longitudinal section. In Figure 6C, our specimens present, however, a slight constriction of the post-abdominal segment.

### ***Thanarla pacifica*** Nakaseko & Nishimura, 1981
(Fig. 9K)

*Thanarla pacifica* Nakaseko & Nishimura, 1981: 163, pl. 7, figs 3a-b, 6, 9, pl. 15, fig. 14. — O'Dogherty 1994: 84.

OCCURRENCE. — Frequent in samples R7 and R15.

AGE. — Late Barremian to early Aptian.

### ***Thanarla*** sp. aff. ***brouweri*** (Tan, 1927)
(Fig. 7O)

*Thanarla* sp. aff. *T. brouweri* – Nakaseko & Nishimura 1981: 162, pl. 6, fig. 14; pl. 7, figs 1, 2; pl. 15, fig. 13. — O'Dogherty 1994: 86.

OCCURRENCE AND RANGE. — Less than 15 specimens in samples Rs17 and Rs23, late Barremian-middle Albian.

REMARKS
The presentation of the observed specimens is not good enough to fully assign these forms to *T. brouweri*, but they are quite close to the species.

### ***Thanarla*** aff. ***veneta*** (Squinabol, 1903)
(Fig. 6E-G)

*Thanarla* aff. *T. veneta* – Pessagno 1977b: 46, pl. 7, figs 5, 12, 17, 19, 25; pl. 12, fig. 8. — O'Dogherty 1994: 92.

OCCURRENCE AND RANGE. — Abundant in samples Rs12, Rs17 and Rs 23, middle Albian-Cenomanian.

REMARKS
Although it is not well preserved, this specimen presents the characteristic change on the outline of the test between the annular third segment and the long truncated-conical fourth segment.

### ***Thanarla*** sp.
(Fig. 6H)

RANGE. — Middle Albian-Cenomanian.

REMARKS
A single specimen in sample Rs23 which seems to be related to *T. pulchra* group. Unlike *T. pulchra* it has, however, a very short proximal part.

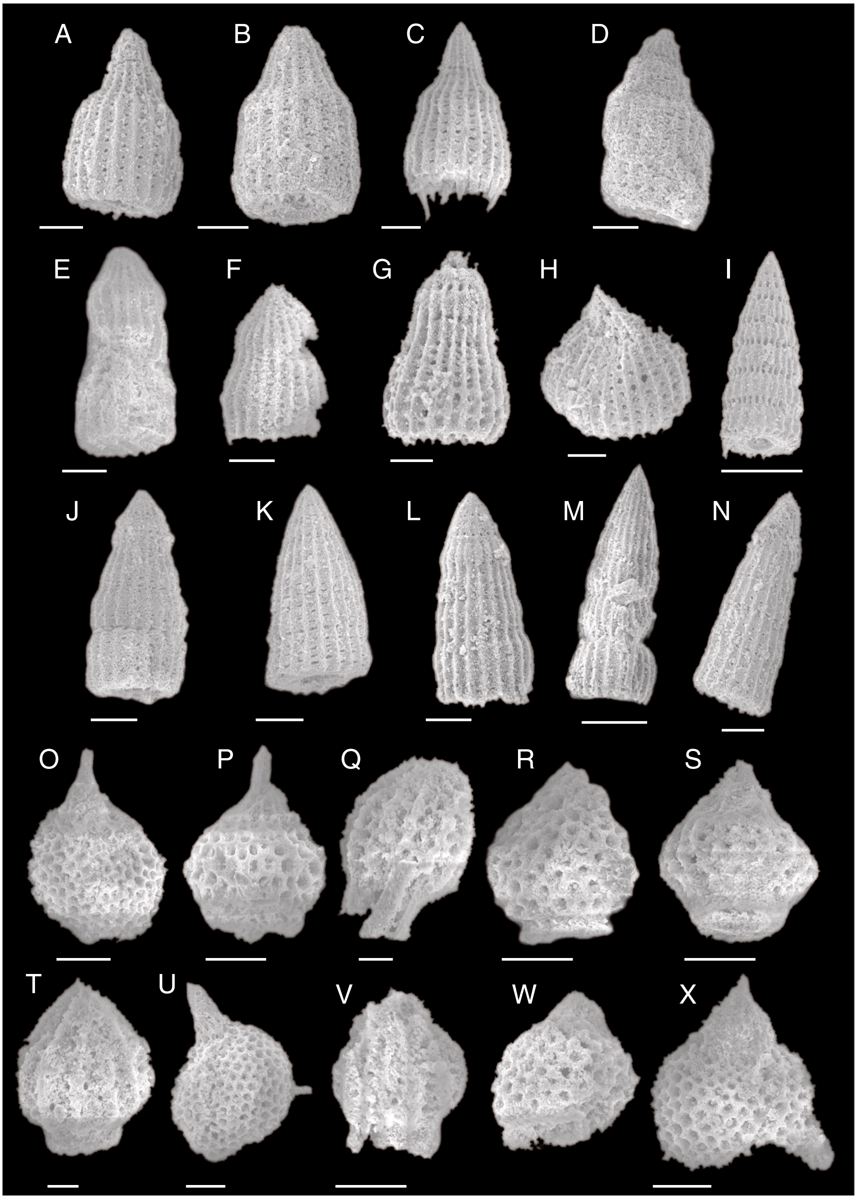


FIG. 6. — Early Cretaceous Radiolaria from eastern Iran; **A**-**D**, *Thanarla pulchra* (Squinabol, 1904), Rs6 (**D**), Rs7 (**B**), Rs12 (**A**) and Rs23 (**C**), middle Albian-Cenomanian; **E**-**G**, *Thanarla* aff. *veneta* (Squinabol, 1903), Rs12 (**E**), Rs17 (**F**) and Rs23 (**G**), middle Albian-Cenomanian; **H**, *Thanarla* sp., Rs23, middle Albian-Cenomanian; **I**-**N**, *Dictyomitra montisserei* (Squinabol, 1903), Rs6 (**J**, **K**), Rs12 (**M**), Rs17 (**I**) and Rs23 (**L**, **N**), Albian-Turonian; **O**, **P**, **X**, *Rhopalosyringium hispidum* O'Dogherty, 1994, Rs23, Albian-Turonian; **Q**, *Rhopalosyringium scissum* O'Dogherty, 1994, Rs23, Albian-Turonian; **R**, *Rhopalosyringium mosquense* (*majuroense*) (Smirnova & Aliev, 1969), Rs17, early Albian-early Cenomanian; **S**, *Rhopalosyringium perforaculum* O'Dogherty, 1994, Rs17, middle-late Albian; **T**, *Rhopalosyringium adriaticum* O'Dogherty, 1994, Rs23, middle Albian-Cenomanian; **U**, *Rhopalosyringium solivagum* O'Dogherty, 1994, Rs23, Albian; **V**, *Rhopalosyringium* sp. 1, Rs23, Albian; **W**, *Rhopalosyringium* sp. 2, Rs17, Albian. All figures are Scanning Electron Micrographs. Scale bars: A, B, D, E, J, K, N-P, R, S, V, W, X, 15 µm; C, F-H, L, U, 30 µm; I, 25 mm; M, 60 µm; Q, T, 6 µm.

Genus *Archaeodictyomitra* Pessagno, 1976

***Archaeodictyomitra vulgaris*** Pessagno, 1977
(Fig. 7G)

*Archaeodictyomitra vulgaris* Pessagno, 1977b: 44, pl. 6, fig. 15.

OCCURRENCE AND RANGE. — Frequent in samples Rs6, Rs7, Rs15, Rs17 and Rs23, Albian (in this study).

REMARKS
It resembles what Origlia-Devos (1983) illustrated as *A. squinaboli* from the upper Albian of Costa Rica and looks like completely *A. vulgaris* of Dumitrica *et al.* (1997). Several specimens of this type (short conical test with strong costae) have been recorded in this area.

***Archaeodictyomitra apiarium*** (Rüst, 1885)
(Fig. 7E, H)

*Archaeodictyomitra apiarium* – Pessagno 1977b: 41, pl. 6, figs 6, 14.

OCCURRENCE AND RANGE. — Frequent in samples R7, Rs17 and Rs23, late Barremian-Aptian.

***Archaeodictyomitra*** sp.
(Fig. 7J, K)

OCCURRENCE AND RANGE. — Abundant in samples R7, Rs17 and Rs23, Aptian-Albian.

REMARKS
It differs from *Archaeodictyomitra vulgaris* by a wider, cylindrical test and with a short rounded cephalis. It differs from *Archaeodictyomitra apiarium* by a narrower, cylindrical test.

Genus *Dictyomitra* Zittel, 1876

***Dictyomitra gracilis*** (Squinabol, 1903)
(Fig. 7A-C)

*Dictyomitra gracilis* – O'Dogherty 1994: 73, pl. 1, figs 12-25.

OCCURRENCE. — Abundant in samples Rs6, Rs17 and Rs23.

RANGE. — Early Albian-Turonian

REMARKS
The specimens observed present variable shapes and outlines. Costae are well preserved and oriented on silicified surface. In the several specimens, cephalis is sharply pointed.

***Dictyomitra excellens*** (Tan, 1927)
(Fig. 9M, N)

*Dictyomitra excellens* – Renz 1974: 791, pl. 8, figs 7, 8; pl. 11, fig. 35. — O'Dogherty 1994: 70.

OCCURRENCE. — Frequent in samples R7, R10 and R15.

RANGE. — Late Barremian-early Aptian.

***Dictyomitra montisserei*** (Squinabol, 1903)
(Figs 6I-N; 7F)

*Dictyomitra montisserei* – O'Dogherty 1994: 77, pl. 3, figs 1-29.

OCCURRENCE. — Abundant in samples Rs6, Rs12, Rs17 and R15.

RANGE. — Albian-Turonian.

REMARKS
Specimens are relatively well preserved, presenting a single row of pores at each stricture. Some of these strictures are well marked.

Family PSEUDODICTYOMITRIDAE Pessagno, 1977
Genus *Pseudodictyomitra* Pessagno, 1977

***Pseudodictyomitra pseudomacrocephala***
(Squinabol, 1903)
(Fig. 7D)

*Pseudodictyomitra pseudomacrocephala* – Pessagno 1977b: 51, pl. 8, figs 10, 11. — O'Dogherty 1994: 108.

OCCURRENCE. — Frequent in samples Rs17 and Rs23.

RANGE. — Middle Albian-early Cenomanian.

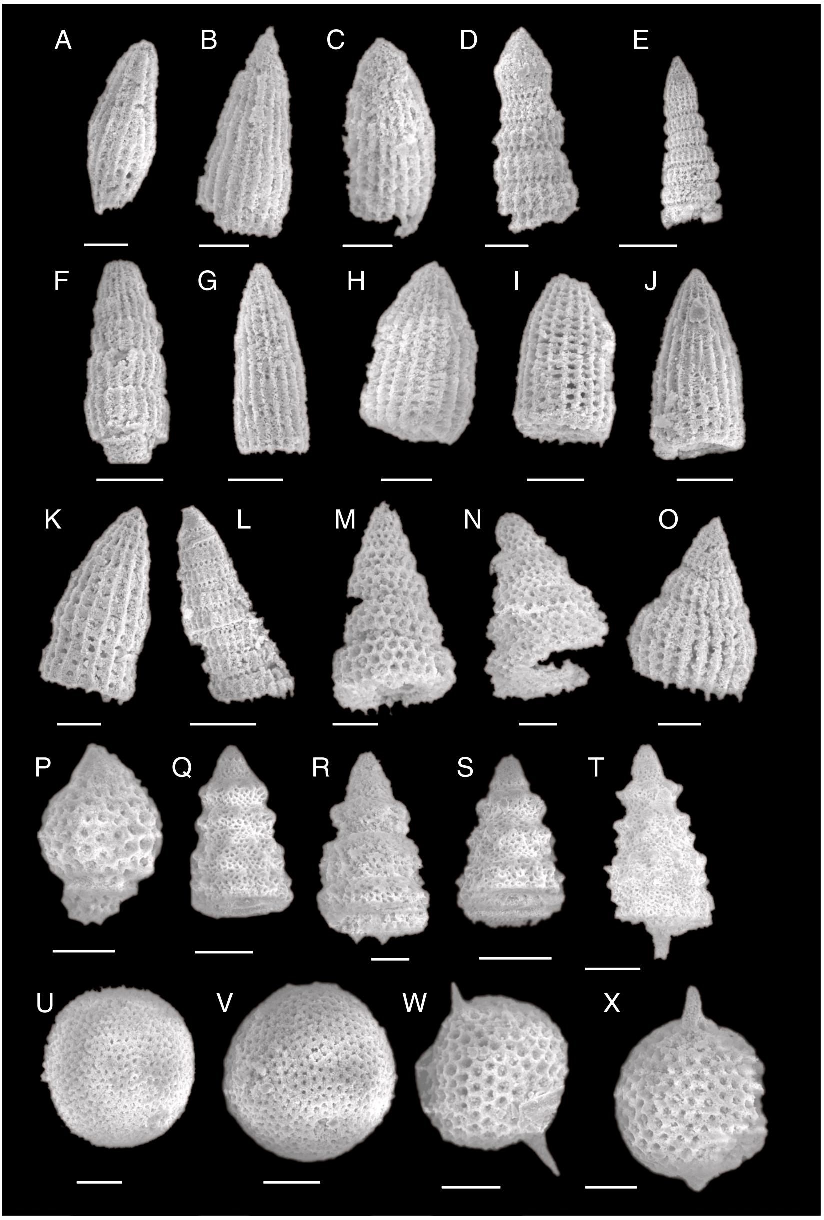


FIG. 7. — Early Cretaceous Radiolaria from eastern Iran; **A**-**C**, *Dictyomitra gracilis* (Squinabol, 1903), Rs6 (**A**), Rs17 (**B**) and Rs23 (**C**), early Albian-Turonian; **D**, *Pseudodictyomitra pseudomacrocephala* (Squinabol, 1903), Rs17, middle Albian-early Cenomanian; **E**, **L**, *Pseudodictyomitra paronai* (Aliev, 1965), Rs17 (**E**) and Rs23 (**L**), Albian; **F**, *Dictyomitra montisserei* (Squinabol, 1903), Rs12, early Albian-early Turonian; **G**, *Archaeodictyomitra vulgaris* Pessagno, 1977, Rs23, Albian (in this study); **H**, **I**, *Archaeodictyomitra apiarium* (Rüst, 1885), R7 (**H**) and R15 (**I**), late Barremian-Aptian; **J**, **K**, *Archaeodictyomitra* sp., R7 (**J**) and Rs17 (**K**), Aptian-Albian; **M**, **N**, *Stichomitra communis* Squinabol, 1903, R7 (**M**) and Rs17 (**N**), Aptian and Albian; **O**, *Thanarla* sp. aff. *brouweri* (Tan, 1927), Rs17, late Barremian-middle Albian; **P**, *Rhopalosyringium mosquense* (Smirnova & Aliev, 1969), Rs6, early Albian-early Cenomanian; **Q**-**T**, *Xitus mclaughlini* (Pessagno, 1977), Rs12 (**R**, **S**), Rs17 (**Q**) and Rs23 (**T**), early Albian-Cenomanian; **U**, **V**, *Holocryptocanium barbui* Dumitrica, 1970, Rs6 (**U**) and Rs23 (**V**), Albian-Turonian; **W**, **X**, *Dorypyle communis* (Squinabol, 1903), Rs17 (**W**), Rs23 (**X**), Albian. All figures are Scanning Electron Micrographs. Scale bars: A-D, F-K, M-O, Q, S, T, 30 µm; E, L, 60 µm; P, R, U-X, 15 µm.

Remarks
The specimens present a very typical arrowhead outline of the proximal portion of the test. It looks quite similar to the species figured by O'Dogherty (1994: pl. 8, fig. 7).

***Pseudodictyomitra paronai*** (Aliev, 1965)
(Fig. 7E, L)

*Pseudodictyomitra paronai* – O'Dogherty 1994: 106, pl. 7, figs 22-28.

Occurrence. — Abundant in samples Rs6, Rs17 and Rs23.

Range. — Albian-early Cenomanian.

Family Amphipyndacidae Riedel, 1967
Genus *Stichomitra* Cayeux, 1897

***Stichomitra communis*** Squinabol, 1903
(Fig. 7M, N)

*Stichomitra communis* Squinabol, 1903: 141, pl. 8, fig. 40. — O'Dogherty 1994: 144.

Occurrence. — Abundant in samples R7, R10, R15, Rs6, Rs17 and Rs23.

Range. — Aptian-Albian.

Remarks
The observed specimens present variable shapes and outlines, as remarked by previous authors (Vishnevskaya 1992; Gorican 1994; O'Dogherty 1994; Wakita *et al.* 1994a, b).

***Stichomitra*** cf. ***japonica***
(Nakaseko & Nishimura, 1979)
(Fig. 9G, H)

*Stichomitra* cf. *S. japonica* – O'Dogherty 1994: 139, pl. 16, figs 1-6.

Occurrence. — Frequent in samples R7, R10, R15, Rs6 and Rs17.

Range. — Late Barremian-Aptian.

Remarks
The fourth segment is missing in all observed specimens. They can not be related to the genus *Trimulus* O'Dogherty, 1994.

***Stichomitra*** sp.
(Fig. 9 I, J)

Occurrence. — Frequent in samples R7, R10, Rs17 and Rs23.

Range. — Aptian-Albian.

Description
Test subconical with four chambers. Cephalis subspherical, without apical horn. Post-abdominal chamber increasing strongly and becoming spherical. Thick-walled test having usually a close-packed layer of pores in hexagonal pore frame. Stricture between abdominal and post abdominal chamber well developed. Test ending in a circular aperture with a short, poreless peristome.

Family Parvicingulidae Pessagno, 1977
Genus *Parvicingula* Pessagno, 1977

***Parvicingula*** sp.
(Fig. 9D)

Occurrence and range. — This specimen is frequent in sample R7, late Barremian-early Aptian.

Remarks
This form differs from *P. cosmoconica* by having small subcylindrical apical portion. This species has weak ridges on each segment.

Genus *Crolanium* Pessagno, 1977

***Crolanium*** aff. ***cuneatum*** (Smirnova & Aliev, 1969)
*in* Aliev & Smirnova, 1969
(Fig. 9E, F)

*Crolanium* aff. *C. cuneatum* – O'Dogherty 1994: 119, pl. 9, figs 7-14.

Occurrence and range. — Frequent in samples Rs17 and Rs23, middle Albian-Cenomanian.

Remarks
This species represents weakly constricted test and short apical horn. The distal post-abdominal chamber is triangular in transverse section and strongly increasing in width towards distal end.

Family SYRINGOCAPSIDAE Foreman, 1973
Genus *Podobursa* Wishinowski, 1889

***Podobursa*** **aff.** ***typica*** (Rüst, 1898)
(Fig. 9L)

*Podobursa* aff. *P. typica* – O'Dogherty 1994: 177, pl. 25, figs 14-17.

OCCURRENCE AND RANGE. — Frequent in sample R7, late Barremian-early Aptian.

REMARKS
Thorax and abdomen are not well preserved due to silicification. Large polygonal pores on fourth chamber are disposed in an oblique arrangement. The large terminal tube has longitudinally aligned tube.

Family RHOPALOSYRINGIIDAE
Empson-Morin, 1981
Genus *Rhopalosyringum*
Campbell & Clark, 1944

***Rhopalosyringium solivagum*** O'Dogherty, 1994
(Fig. 6U)

*Rhopalosyringium solivagum* O'Dogherty, 1994: 163, 164, pl. 21, figs 23, 24.

OCCURRENCE AND RANGE. — Frequent in sample Rs23, Albian (in this study).

REMARKS
The three short radial spines, which are illustrated by O'Dogherty (1994), were not well preserved. Our specimens present a very small cephalis, well developed apical horn, and a thoracic short terminal tube. This terminal tube is circular in cross-section. Thoracic pores are moderately large, hexagonal, and set in regular circular to angular pore-frames.

***Rhopalosyringium mosquense*** (Smirnova & Aliev, 1969) *in* Aliev & Smirnova, 1969
(Figs 6R; 7P)

*Rhopalosyringium mosquense* – O'Dogherty 1994: 165, pl. 22, figs 1-6.

OCCURRENCE AND RANGE. — Abundant in samples Rs6, Rs17 and Rs23, early Albian-early Cenomanian.

REMARKS
Our specimen (Fig. 6R) resembles illustration of Schaaf (1981) as *R. majuroensis* from the Cenomanian-Turonian whereas the specimen on Figure 7P resembles the specimen illustrated by O'Dogherty (1994) as *R. mosquense*. The thick ornamentation of the test and the characteristic inflated apertural ring of the shell are observed.

***Rhopalosyringium perforaculum***
O'Dogherty, 1994
(Fig. 6S)

*Rhopalosyringium perforaculum* O'Dogherty, 1994: 166, pl. 21, figs 25-27.

OCCURRENCE AND RANGE. — Frequent in samples Rs6, Rs17 and Rs23, middle-late Albian.

REMARKS
The robust longitudinal costae that distinguish this form from *R. mosquense* are observed in our specimens.

***Rhopalosyringium adriaticum*** O'Dogherty, 1994
(Fig. 6T)

*Rhopalosyringium adriaticum* O'Dogherty, 1994: 169, 170, pl. 24, figs 1, 2.

OCCURRENCE AND RANGE. — Frequent in sample Rs23, middle Albian-Cenomanian.

REMARKS
No collar stricture is observed.

***Rhopalosyringium scissum*** O'Dogherty, 1994
(Fig. 6Q)

*Rhopalosyringium scissum* O'Dogherty, 1994: 168, pl. 23, figs 12-16.

OCCURRENCE. — Abundant in sample Rs23.

REMARKS
This form looks like true representative of *R. scissum*, but is dated Albian (in this study).

***Rhopalosyringium hispidum*** O'Dogherty, 1994
(Fig. 6O, P, X)

*Rhopalosyringium hispidum* O'Dogherty, 1994: 167, pl. 23, figs 7-11.

OCCURRENCE. — Abundant in sample Rs23.

DESCRIPTION
Cephalis hemispherical, bearing a stout three-bladed apical horn. Collar stricture indistinct or weakly marked. Thorax annular to subglobose, with large hexagonal pores set in regular circular to angular pore frames. This form is dated of an Albian age in this study.

***Rhopalosyringium*** sp. 1
(Fig. 6V)

OCCURRENCE AND RANGE. — Frequent in samples Rs7 and Rs23, Albian.

DESCRIPTION
Cephalis round, without apical horn. Cephalis and thorax separated by a collar stricture. Thorax globose to annular. Costate throughout and five to six costae visible in lateral view. Distally costae develop longitudinally lamelar feet. Lumbar stricture well marked, without circumferential apertural ring. Pores are irregular, tending to form longitudinal row between the costae.

***Rhopalosyringium*** sp. 2
(Fig. 6W)

OCCURRENCE AND RANGE. — Frequent in samples Rs6, Rs17 and Rs23, Albian.

REMARKS
Cephalis is round without apical horn. Collar stricture is weakly marked. It differs from *Rhopalosyringium* sp. 1 by having large pores, which set in regular circular to angular pore frame, without costae and rectangular aperture.

Family EUCYRTIDIIDAE Ehrenberg, 1847
Genus *Stichocapsa* Haeckel, 1881

***Stichocapsa*** cf. ***robusta*** Matsuoka, 1984
(Fig. 8O)

*Stichocapsa* cf. *S. robusta* Matsuoka, 1984: 146, pl. 1, figs 6-13; pl. 2, figs 7-12.

OCCURRENCE AND RANGE. — Frequent in samples R10 and Rs17, late Barremian-Aptian.

REMARKS
This specimen is represented by a four-segmented, drop-like shaped shell. It is close to that of *S. robusta*. Shell is thick and porous, the pores are densely spaced.

Family XITIDAE Pessagno, 1977
Genus *Xitus* Pessagno, 1977

***Xitus mclaughlini*** (Pessagno, 1977)
(Fig. 7Q-T)

*Xitus mclaughlini* – O'Dogherty 1994: 130, pl. 12, figs 14-21.

OCCURRENCE AND RANGE. — Abundant in samples Rs17 and Rs23, Albian-Cenomanian.

REMARKS
This species has relatively wide single row of large tubercles on its abdominal chamber. The thoracic transverse row of pores is well marked.

***Xitus elegans*** (Squinabol, 1903)
(Fig. 9A-C)

*Xitus elegans* – O'Dogherty 1994: 126, pl. 1, figs 9-14.

OCCURRENCE AND RANGE. — Frequent in samples R7 and R15, late Barremian-early Aptian.

REMARKS
The specimens present less prominent circumferential ridges than those observed by O'Dogherty (1994). A single transversal row of pores is observed on thorax.

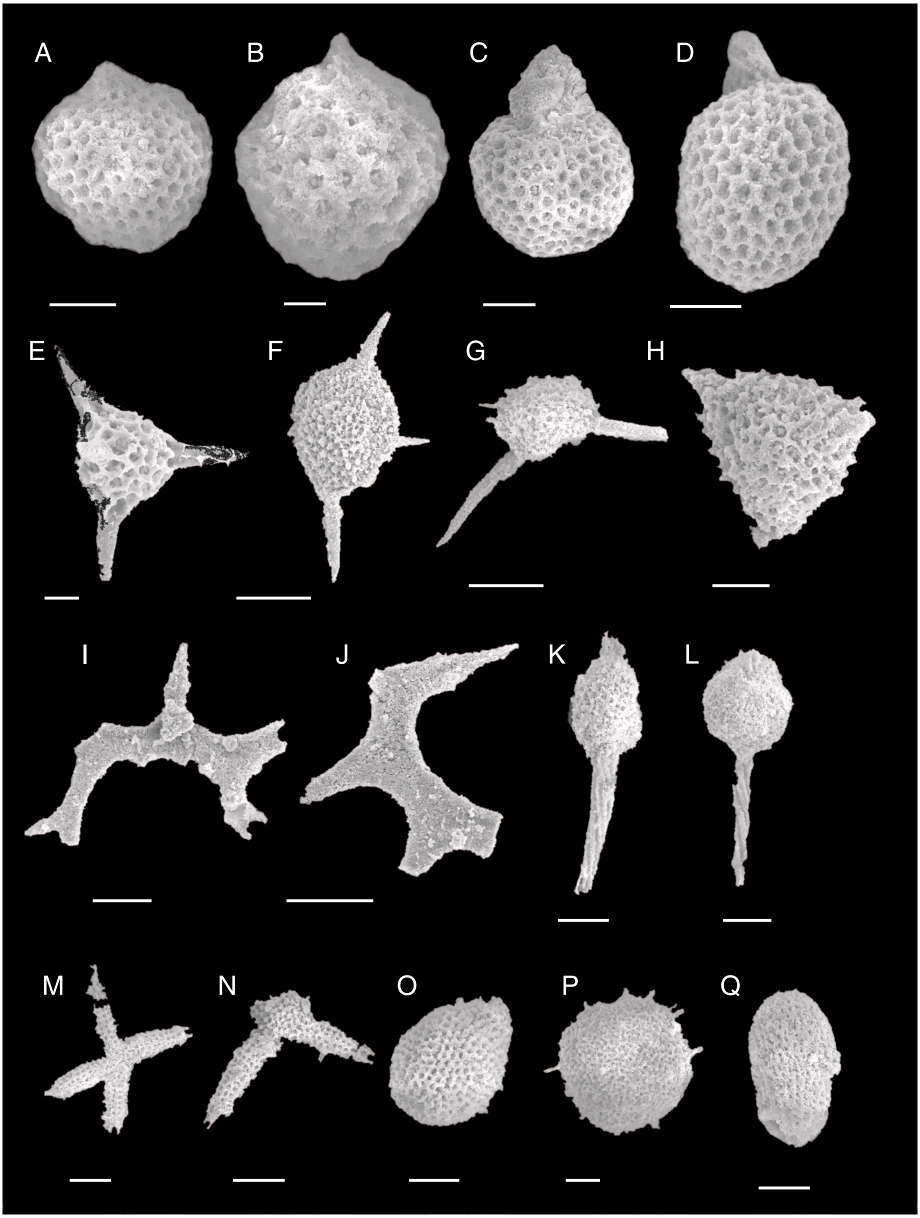


FIG. 8. — Early Cretaceous Radiolaria from eastern Iran; **A**, **B**, *Cryptamphorella* cf. *conara* (Foreman, 1968), Rs12 (**A**) and Rs23 (**B**), late Barremian-Albian; **C**, **D**, *Hiscocapsa* cf. *asseni* (Tan, 1927), R7 (**C**) and R15 (**D**), late Barremian-early Aptian; **E**, *Protoxiphotractus* sp., Rs23, Albian; **F**, **G**, *Pseudoaulophacus* sp., Rs12 (**G**) and Rs23 (**F**), Albian; **H**, *Pseudoaulophacus* cf. *sculptus* (Squinabol, 1904), Rs23, Albian; **I**, **J**, *Acanthocircus* sp., Rs23, Albian (**J**, broken); **K**, **L**, *Archaeospongoprunum* sp., Rs17 (**K**) and Rs23 (**L**), Albian; **M**, **N**, *Pseudocrucella* sp., Rs23 (**M**) and Rs17 (**N**), Albian; **O**, *Stichocapsa* cf. *robusta* Matsuoka, 1984, R10, late Barremian-early Aptian; **P**, *Dactyliodiscus* cf. *lenticulatus* (Jud, 1994), Rs23, late Barremian-Cenomanian; **Q**, *Diacanthocapsa* cf. *ovoidea* Dumitrica, 1970, Rs23, middle Albian-early Cenomanian. All figures are Scanning Electron Micrographs. Scale bars: A, 15 µm; B, E, 6 µm; C, D, H-L, 35 µm; F, N, 50 µm; G, M, 70 µm; O-Q, 25 µm.

Family DORYPYLIDAE O'Dogherty, 1994
Genus *Dorypyle* Squinabol, 1904

***Dorypyle communis*** (Squinabol, 1903)

*Dorypyle communis* – O'Dogherty 1994: 204, pl. 32, figs 11-19.

OCCURRENCE AND RANGE. — Abundant in samples Rs6, Rs17 and Rs23, Albian.

REMARKS
Cephalis and thorax are deeply depressed inside the abdominal segment that represents the circular pores with hexagonal frames.

Genus *Hiscocapsa* O'Dogherty, 1994
***Hiscocapsa*** cf. ***asseni*** (Tan, 1927)
(Fig. 8C, D)

*Hiscocapsa* cf. *H. asseni* – O'Dogherty 1994: 200, pl. 31, figs 7-13.

OCCURRENCE AND RANGE. — Frequent in samples R7 and R15, late Barremian-early Aptien.

REMARKS
Owing to its poor preservation, this form is tentatively assigned to *H. asseni*. It resembles *H. asseni* by the subconical outline of the cephalis, thorax and abdomen. The post-abdominal segment is longly inflated.

Family WILLIRIEDELLIDAE Dumitrica, 1970
Genus *Cryptamphorella* Dumitrica, 1970

***Cryptamphorella*** cf. ***conara*** (Foreman, 1968)
(Fig. 8A, B)

*Cryptamphorella* cf. *conara* – Dumitrica 1970: 80, pl. 11, figs 66a-c.

OCCURRENCE AND RANGE. — Abundant in samples R7, R10, Rs12, Rs17 and Rs23, late Barremian-Albian (in this study).

Genus *Holocryptocanium* Dumitrica, 1970

***Holocryptocanium barbui*** Dumitrica, 1970
(Fig. 7U, V)

*Holocryptocanium barbui* Dumitrica, 1970: 76, pl. 17, figs 105-108a, b; pl. 21, fig. 136.

OCCURRENCE AND RANGE. — Abundant in samples Rs6, Rs12, Rs17 and Rs23, Albian-Turonian.

REMARKS
Although the thorax and cephalis are depressed into the abdomen, the external surface of the abdomen is smooth. The pores usually set in regular rows.

Order SPUMELLARIA Ehrenberg, 1875
emend. De Wever *et al.*, 2001
Family ARCHAEOSPONGOPRUNIDAE
Pessagno, 1973
Genus *Archeospongoprunum* Pessagno, 1973

***Archaeospongoprunum*** sp.
(Fig. 8K, L)

OCCURRENCE AND RANGE. — Frequent in samples Rs17 and Rs23, Albian.

REMARKS
These specimens present the main characteristics of the representatives of *Archaeospongoprunum.* They have ellipsoidal, ovoid to spherical spongy test and two opposite polar spines. Spongy fabric are arranged irregularly. Polar spines have longitudinally or spirally arranged ridges alternating with grooves.

Family QUINQUECAPSULARIIDAE Dumitrica, 1994
Genus *Protoxiphotractus* Pessagno, 1973

***Protoxiphotractus*** sp.
(Fig. 8E)

OCCURRENCE AND RANGE. — Frequent in sample Rs23, Albian.

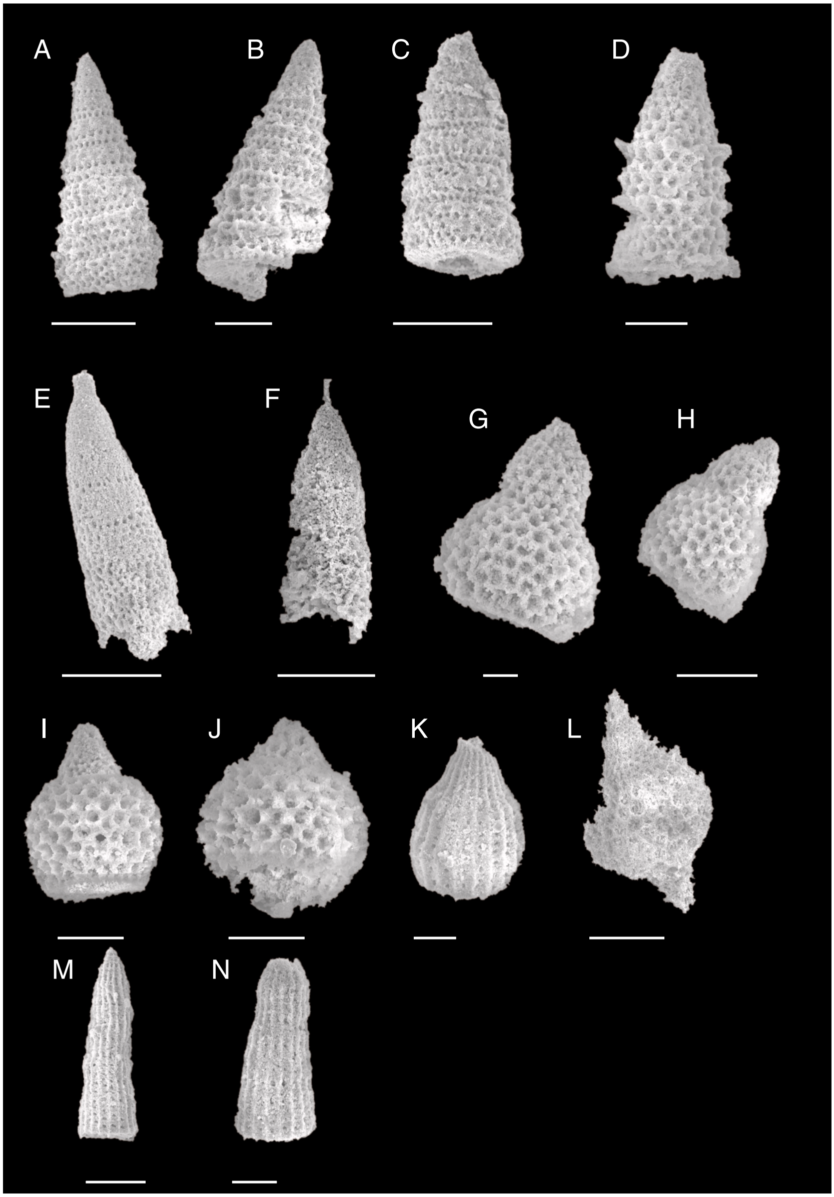


FIG. 9. — Early Cretaceous Radiolaria from eastern Iran; **A**, **B**, *Xitus elegans* (Squinabol, 1903), R7 (**A**) and R15 (**B**), late Barremian-Aptian; **C**, *Xitus elegans*, R7, late Barremian-early Aptian; **D**, *Parvicingula* sp., R7, late Barremian-early Aptian; **E**, **F**, *Crolanium* aff. *cuneatum* (Smirnova & Aliev, 1969), Rs17 (**E**) and Rs23 (**F**), middle Albian-Cenomanian; **G**, **H**, *Stichomitra* cf. *japonica* (Nakaseko & Nishimura, 1979), R7 (**G**) and R10 (**H**), late Barremian-Aptian; **I**, **J**, *Stichomitra* sp., R7 (**I**) and Rs17 (**J**), Aptian-Albian; **K**, *Thanarla pacifica* Nakaseko & Nishimura, 1981, R15, late Barremian-early Aptian; **L**, *Podobursa* aff. *typica* (Rüst, 1898), R7, late Barremian-early Aptian; **M**, **N**, *Dictyomitra excellens* (Tan, 1927), R7 (**M**), R15 (**N**), late Barremian-early Aptian. All figures are Scanning Electron Micrographs. Scale bars: A, 70 µm; B, D, 35 µm; C, 100 µm; E, 40 µm; F, 20 µm; G, 14 µm; H-J, 15 µm; K, N, 25 µm; L, 30 µm; M, 50 µm.

REMARKS
Cortical test is nearly spherical with four spines. It has coarse meshwork, which comprised large hexagonal pore frame. Spines are quite robust and circular in cross-section. This species is tentatively assigned to *Protoxiphotractus*.

Family PSEUDOAULOPHACIDAE Riedel, 1967
Genus *Pseudoaulophacus* Pessagno, 1963

***Pseudoaulophacus*** cf. ***sculptus*** (Squinabol, 1904)
(Fig. 8H)

*Pseudoaulophacus* cf. *sculptus* – O'Dogherty 1994: 319, pl. 59, figs 1-4.

OCCURRENCE AND RANGE. — Frequent in samples Rs12, Rs17 and Rs23, Albian.

REMARKS
This specimen is tentatively assigned to *P. sculptus* owing to its triangular outline, meshwork cortical shell and a raised central area.

***Pseudoaulophacus*** sp.
(Fig. 8F, G)

OCCURRENCE AND RANGE. — Abundant in samples Rs12 and Rs23, Albian.

REMARKS
Test is lenticular in cross-section and subcircular in outline, with three sturdy rounded spines. The spines are not equal in length. Variable number of short secondary spines occuring radially at the periphery of the test. Spongy meshwork composed of small polygonal pore frames comprises small nodes at the pore vertices. Upper and lower surfaces are convex and have slightly raised central area.

Family HAGIASTRIDAE Riedel, 1971
Genus *Pseudocrucella* Baumgartner, 1980

***Pseudocrucella*** sp.
(Fig. 8M, N)

OCCURRENCE AND RANGE. — Abundant in samples Rs17 and Rs23, middle Albian-early Cenomanian.

DESCRIPTION
Test composed of four rays at right angles, with tapering tips and long triradiate central spines. Median external beams on each side connected by transverse bars with more or less developed nodes at intersections. Central area with irregular meshwork, nodose with smaller pores and with a depression. Lateral sides exposing the rays with two paired rows of circular to rectangular pores.

Family ACTINOMMIDAE Haeckel, 1881
emend. Riedel, 1967
Genus *Acanthocircus* Squinabol, 1903
emend. Donofrio & Mostler, 1978

***Acanthocircus*** sp.
(Fig. 8I, J)

OCCURRENCE AND RANGE. — Abundant in sample Rs23, Albian.

REMARKS
The size and shape of the shell are not known because all the specimens we observed are broken.

Family DACTYLIOSPHAERIDAE
Squinabol, 1904
Genus *Dactyliodiscus* Squinabol, 1903

***Dactyliodiscus*** cf. ***lenticulatus*** (Jud, 1994)
(Fig. 8P)

*Dactyliodiscus* cf. *D. lenticulatus* – O'Dogherty 1994: 331, pl. 61, figs 12-15.

OCCURRENCE AND RANGE. — Frequent in samples Rs17 and Rs23, late Barremian-Cenomanian.

REMARKS
This specimen is tentatively assigned to *D. lenticulatus* owing to its rounded periphery outline, flated form and covered by minute spines.

Family DIACANTHOCAPSIDAE O'Dogherty, 1994
Genus *Diacanthocapsa* Squinabol, 1903

***Diacanthocapsa* cf. *ovoidea* Dumitrica, 1970**
(Fig. 8Q)

*Diacanthocapsa* cf. *D. ovoidea* – O'Dogherty 1994: 220, pl. 37, figs 1-6.

OCCURRENCE AND RANGE. — Frequent in samples Rs17 and Rs23, middle Albian-early Cenomanian.

REMARKS
The crytocephalic test lacks apical horn. The circular pores of thorax and abdomen are longitudinally arranged. Abdomen is cylindrical, slightly constricted in the lumbar with semi-circular aperture.

## CONCLUSION

A systematic research of the different radiolarian morphotypes in the samples allows to have an idea of the diversity of radiolarian fauna.
The radiolarian assemblages allow to assign the age of Soulabest radiolarite. In the Assemblage I, the well diagnostic taxa, including *Dictyomitra excellens*, *Thanarla pacifica*, *Hiscocapsa* cf. *asseni* and *Parvicingula* sp., suggest an age early Aptian, equivalent to the *Hiscocapsa asseni* Zone and *Turbocapsula verbeeki* Zone of O'Dogherty (1994).
The Assemblage II includes the following taxa: *Thanarla pulchra*, *Dictyomitra gracilis*, *Pseudodictyomitra pseudomacrocephala*, etc. This association can be equivalent with *Pseudodictyomitra psedomacrocephala* Zone of Vishnevskaya (1993) and *Holocryptocanium barbui* Zone of Bak (1999). The age of this assemblage is attributed to middle Albian-early Cenomanian.
In the studied area (Sistan Suture zone, Gazik Province), Tirrul *et al.* (1983) stated that the oldest rocks separating the Lut block from the Afghan block are attributed to Upper Cretaceous. However, the above results of the radiolarites within the ophiolite unit, indicate that the oldest rocks in the ophiolite belong to an Early Cretaceous (early Aptian and middle-late Albian) oceanic crust, and the oceanic opening took place in pre-early Aptian. Moreover, the middle-late Albian radiolarites with the Assemblage II in this region could be correlated with the Samail radiolarites containing *Pseudodictyomitra pseudomacrocephala*, *Thanarla veneta*, etc. (Beurrier *et al.* 1987). The oceanic crust was later disrupted and incorporated in the mélange and tectonically emplaced before the presence of unconformable Maastrichtian conglomerates. It implies that the age of ophiolite emplacement is pre-Maastrichtian. Then, in the basis of the faunal assemblage and the age of ophiolite emplacement, it seems that the paleogeographic history of this ophiolite branch (Gazik Province) can be similar to the High-Zagros-Oman in the south of Iran during Early-Late Cretaceous.

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