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THE BIOSTRATIGRAPHICAL ASPECTS OF GADVAN FORMATION (BARREMIAN-APTIAN) OF SOUTHWEST IRAN

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Key-words: Gadvan Formation, Benthonic and Planktonic Foraminifera, Barremian-Aptian, Southwestern Iran.

Riassunto. Un'eccellente esposizione ha permesso di condurre studi dettagliati sulla Formazione Gadvan del Cretacico inferiore della regione di Banish, Iran sud-occidentale. 150 campioni sono stati esaminati, di cui 50 in sezione sottile ed i rimanenti su residui di lavaggio. Le associazioni a Foraminiferi sono state studiate quantitativamente. Lo studio delle sezioni sottili, inutilizzabili da un punto di vista quantitativo, ha permesso di meglio definire la distribuzione stratigrafica dei singoli taxa e di chiarire i rapporti tra facies e faune. Sono state identificate 40 specie e sottospecie, di cui una nuova, *Gaudryina barnardi.* Sono state inoltre distinte due associazioni faunistiche a *Choffatella decipiens* e a *Leupoldina cabri.* Le due zone di associazioni, suddivise in quattro sottozone, sono riconoscibili su gran parte dell'Iran sudoccidentale.

Abstract. Detailed investigation of Lower Cretaceous of the Banish area, Southwest Iran, has been made possible by excellent exposure. One hundred and fifty samples from the Gadvan Formation were analysed, fifty of which in thin sections and the remainder as washed residues. Foraminiferal assemblages were picked and counted. Thin sections were of any use for quantitative analyses, however, they were important for defining the stratigraphic distribution of the single taxa and for correlation between facies and faunal distribution. A total of 40 species and subspecies of foraminifera were recognized, one of which, *Gaudryina barnardi,* is considered to be a new species. Two assemblage zones, the *Choffatella decipiens* and the younger *Leupoldina cabri* zones, are proposed. These zones, subdivided into four subzones, can be identified across most of southwestern Iran.

Introduction.

The literature dealing with the micropaleontological biostratigraphy of the Lower Cretaceous succession of the Middle East in general, and in particularly of Iran, is meagre. Published papers are mainly focused on lithostratigraphic description of bore-hole sequences, occasionally complemented by fossil lists (e. g. Setudehnia, 1971; Kalantari, 1976). Detailed paleontological, biostratigraphic or microfacies investigations were not attempted. For this reason, those aspects of the Lower Cretaceous from the Banish area,

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Soutwestern Iran, are the aim of the present paper. A geological reconnaissance carried out on the region mentioned above showed that rocks belonging to an interval spanning from Late Jurassic to Early Cretaceous were exposed in a relatively small area (Fig. 1). Those rocks include the Gadvan Formation, previously called "Aptian-Barremian Marl", whose paleontological content is described in the present paper.

The Gadvan Formation was named by James & Wynd (1965). It belongs to the Khami Group which consists of the following formations in ascending order:

Surmeh Formation (Early to Late Jurassic),
Fahliyan Formation (Tithonian-Hauterivian),
Gadvan Formation (Barremian-Aptian), and
Dariyan Formation (Aptian).

The number of outcrops, in which the entire Lower Cretaceous sequence is exposed, is very limited and confined to the area southwest of the Crush zone (Fig. 1). It is worth mentioning that in the last decade, increasing attention has been paied by Oil

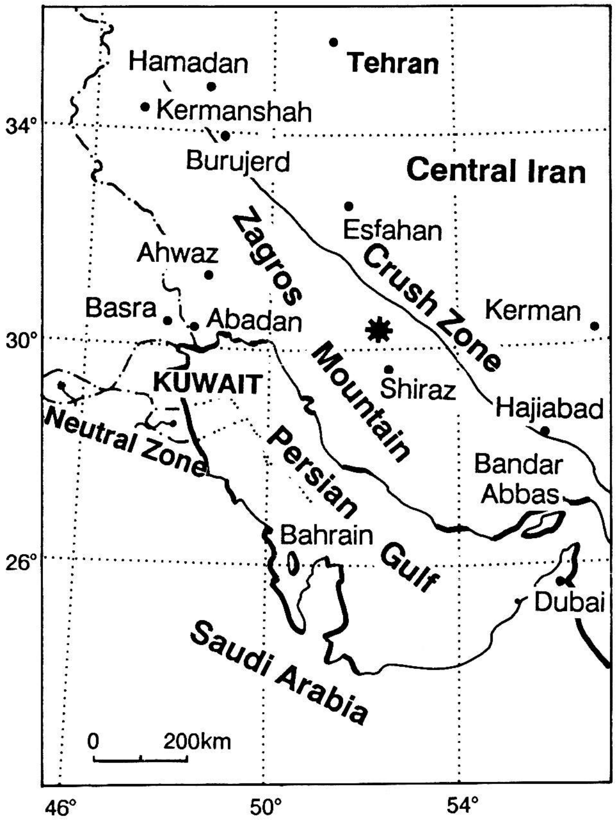


Fig. 1 - Location map showing the position of the Banish area in relation to the Zagros Suture.

Companies operating in southwestern Iran to explore deeper and older reservoirs for hydrocarbons.

Stratigraphy.

The Gadvan Formation forms a low weathering unit below the Dariyan Formation within the Khami Group (Shakib, 1987). In Khuzestan and northwestern Fars province, the Gadvan Formation consists of dark argillaceous limestones. From Khuzestan towards Lurestan, this formation grades into dark-grey to black limestones of the Garau Formation (Setudehnia, 1971).

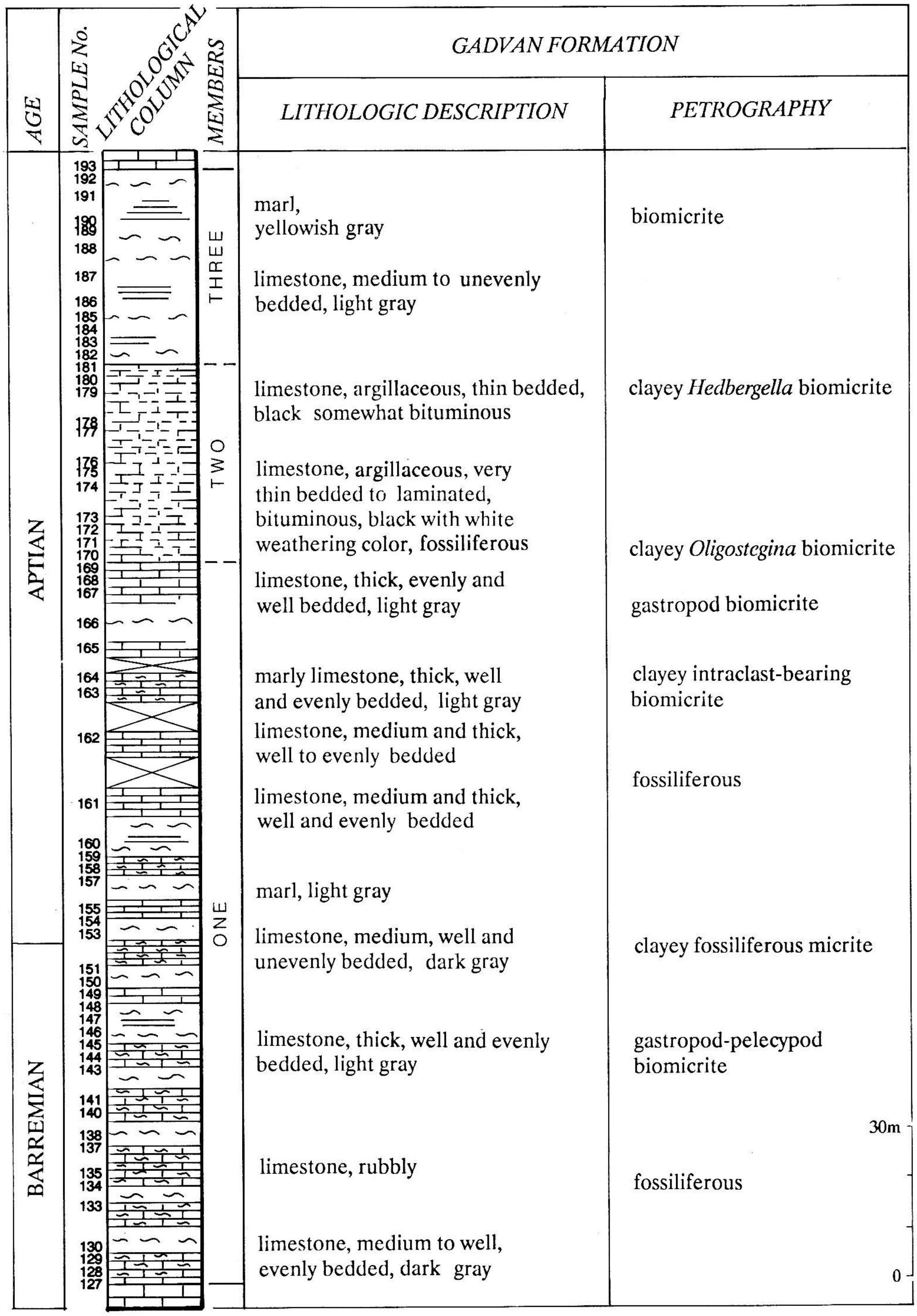
The Gadvan Formation in the Banish area is 218 m thick and overlies the Fahliyan Formation. The contact between the two formations is marked by a horizon with abundant iron oxide nodules. The Gadvan Formation is characterized by marls and marlstones, intercalated with limestones, in strata thin to medium bedded, light-gray to white, and yellowish gray in coulour. The Gadvan Formation is frequently covered by slump blocks and scree material from the overlying Dariyan Formation. Megafossil content includes *Spondylus* spp., *Exogyra*, corals in the lower portion of the formation, and small pelecypods and echinoids in the upper portion. Shakib (1983) recognized three lithologic members in the Gadvan Formation, characterized by an alternation of light-gray marls and light gray, occasionally dark gray, limestones (Members 1), by black limestones (Member 2), and dominantly yellowish gray marls (Member 3), respectively (Fig. 2).

Biostratigraphy.

Gollestaneh (1965) recognized ten distinctive microfossil zonal assemblages from the Khami Group of Southern Iran. These zonal assemblages, whose boundaries were marked by changes in fossil content, are restricted to a relatively short intervals. Three of these assemblage-zones fall in the Berriasian-Aptian time interval. These zones can be recognized in portions of the Zagros Mountain Belt inside the previously called Oil Consortium Agreement Area, where Gollestaneh (1965) worked, but they do not apply to the Banish area.

Portions of the Zagros Mountains were explored by AGIP geologists and the stratigraphic results were published by Sampò (1969). This author studied both larger and smaller foraminifera mainly in thin sections. Kalantari (1976) described the biostratigraphic succession of the Sarvestan area (Southern Iran) and recognized three zones attributable to the Neocomian-Aptian interval (Fig. 3).

The entire foraminiferal faunas recovered from the studied lithologic units were analysed for correlating the Lower Cretaceous sequences. Some species exhibited different stratigraphic range in respect to that reported by other authors and areas.


AGE
SAMPLE No.
LITHOLOGICAL COLUMN
MEMBERS
GADVAN FORMATION
LITHOLOGIC DESCRIPTION
PETROGRAPHY
APTIAN
BARREMIAN
THREE
TWO
ONE
marl, yellowish gray
biomicrite
limestone, medium to unevenly bedded, light gray
limestone, argillaceous, thin bedded, black somewhat bituminous
clayey Hedbergella biomicrite
limestone, argillaceous, very thin bedded to laminated, bituminous, black with white weathering color, fossiliferous
clayey Oligostegina biomicrite
limestone, thick, evenly and well bedded, light gray
gastropod biomicrite
marly limestone, thick, well and evenly bedded, light gray
clayey intraclast-bearing biomicrite
limestone, medium and thick, well to evenly bedded
fossiliferous
limestone, medium and thick, well and evenly bedded
marl, light gray
limestone, medium, well and unevenly bedded, dark gray
clayey fossiliferous micrite
limestone, thick, well and evenly bedded, light gray
gastropod-pelecypod biomicrite
limestone, rubbly
fossiliferous
limestone, medium to well, evenly bedded, dark gray
30m
0

BARREMIAN	APTIAN	GOLLESTANEH (1965) S. Iran
Orbitolina / Choffatella / Salpingoporella dinarica		

BARREMIAN	APTIAN	SAMPO' (1969) SW.Iran
Dictyoconus arabicus	*Choffatella decipiens*	

NEOCOMIAN	APTIAN	ALBIAN	KALANTARI (1976) SW. Iran
Pseudocyclammina lituus & *Pseudochrysalidina arabica*	*Choffatella decipiens* & *Pseudocyclammina rugosa*	*Orbitolina discoidea/conoidea* & *O. lenticularis*	

BARREMIAN		APTIAN					PRESENT WORK & SHAKIB (1987)
Choffatella decipiens		*Leupoldina cabri*		*Globigerinelloides* cf. *texanensis*			
Lenticulina nodosa	*Gavelinella barremiana*	*Quasispiropl. alexanderi*	*Saracenaria frankei*	*Gls.barri*	*Marssonella subtrochus*	*Frondicularia filocenta*	

Fig. 3 - Biostratigraphic schemes of Lower Cretaceous according to different investigators.

A zonal scheme is proposed below (Fig. 3). Each zone is defined by more than one index species in order to overcome the patchyness of foraminiferal record due to paleoecological factors (Shakib, 1983, 1987). Zonal schemes based upon stratigraphic range of higher taxonomic categories such as families or superfamilies are too coarse and less reliable than a scheme based upon selected species or subspecies, which display a shorter range. However, changes in abundance of the higher hierarchical taxonomic units may be stratigraphically useful at a local scale.

The Lower Cretaceous benthonic foraminiferal faunas from the Banish area are essentially composed of representatives of eight superfamilies: *Ammodiscacea*, *Lituolacea*, *Nodosariacea*, *Buliminacea*, *Spirillinacea*, *Robertinacea*, and *Cassidulinacea*. Of these, *Lituolacea* and *Nodosariacea* are quantitatively the most important through the Lower Cretaceous of the studied area (Fig. 4). Of the 13 benthonic families recorded in the Aptian assemblages, *Lituolidae*, *Orbitolinidae*, *Nodosariidae*, *Ataxophragmiidae* are dominant

Fig. 2 - Composite stratigraphic section of Gadvan Formation in the Banish area.

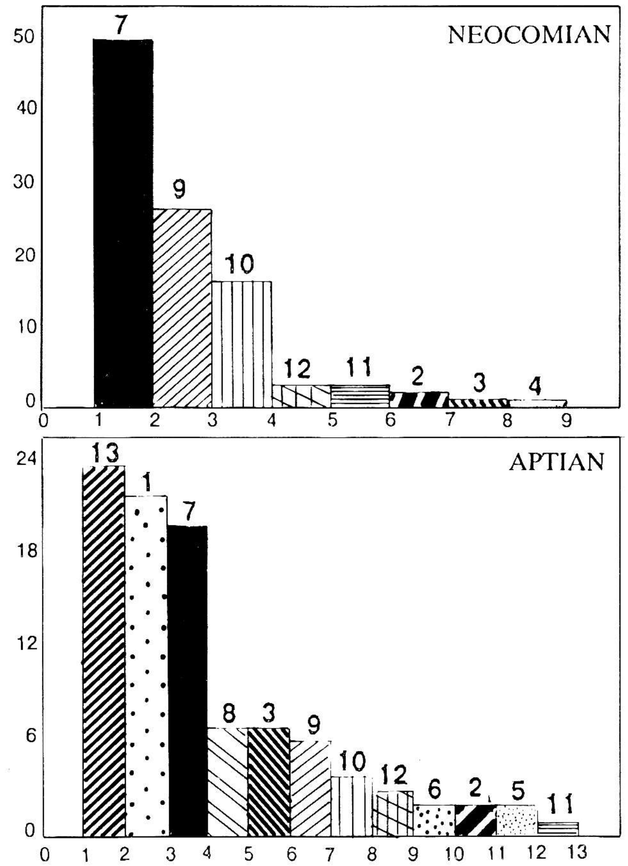


Fig. 4 - Average composition of foraminiferal assemblages in the Early Cretaceous of SW Iran. Vertical axis = family %.
1) *Globigerinelloididae*; 2) *Spirillinidae*; 3) *Polymorphinidae*; 4) *Miliolidae*; 5) *Schackoinidae*; 6) *Anomalinidae*; 7) *Ataxophragmiidae*; 8) *Hedbergellidae*; 9) *Lituolidae*; 10) *Nodosariidae*; 11) *Saccamminidae*; 12) *Ammodiscidae*; 13) *Orbitolinidae*.

throughout, whereas *Miliolidae*, *Trochamminidae*, *Glandulinidae*, and *Anomalinidae* are represented in low percentages.

Five planktonic foraminiferal families are represented in the studied assemblages, of which the *Hedbergellidae* constitute the dominant component in the Aptian-Albian interval. The *Globigerinelloididae* are also quantitatively important in the Aptian, whereas the *Schackoinidae* are subordinate throughout.

Proposed zonal scheme.

The zonal scheme here proposed is based upon the distribution of thirty selected foraminiferal species out of the 40 taxa identified in the Barremian-Aptian interval (Fig. 5).

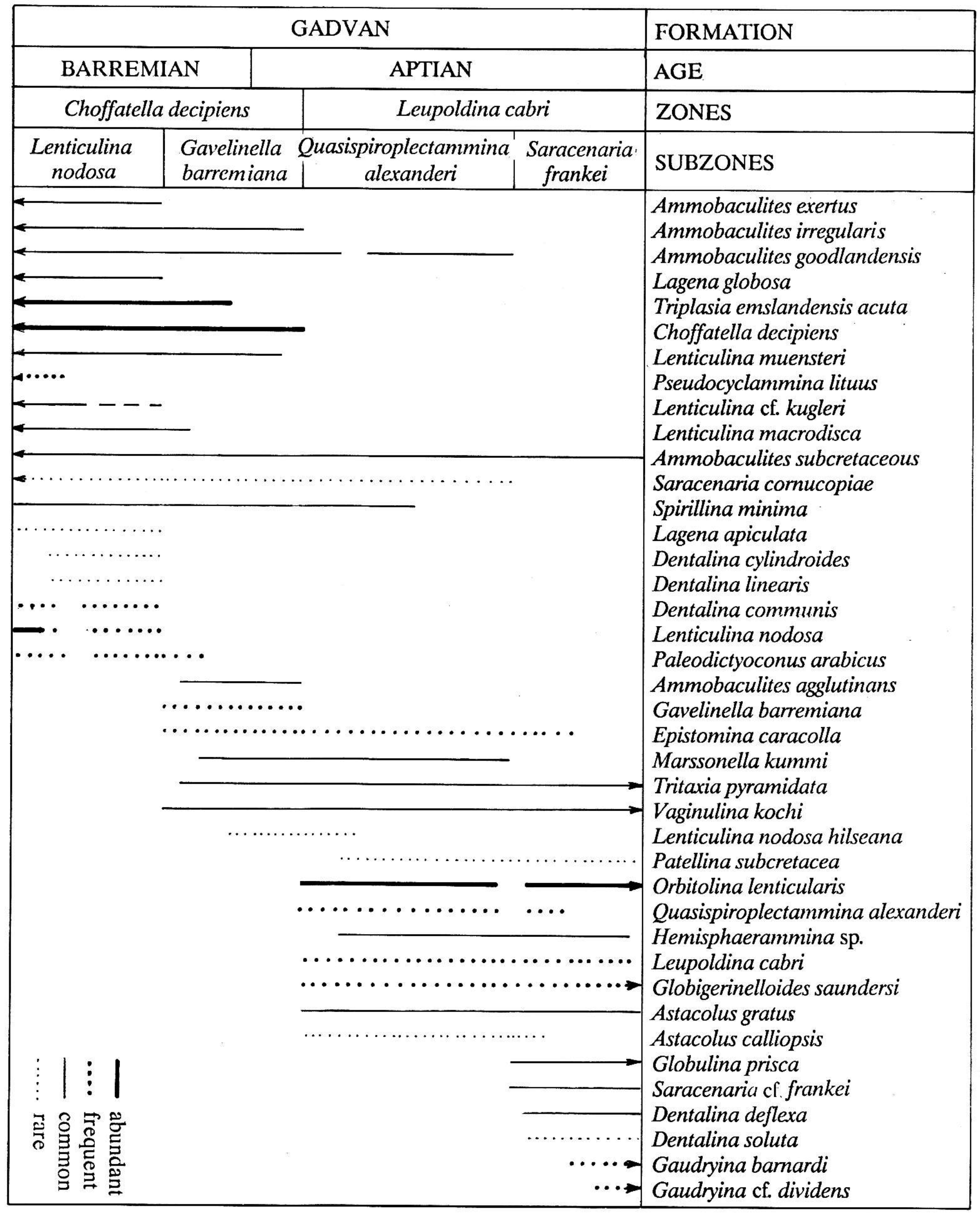


Fig. 5 - Vertical distribution and abundance of selected foraminiferal species from the Gadvan Formation, Banish area, SW Iran.

Zone 1 - *Choffatella decipiens* zone.

Author. The *Choffatella decipiens* zone was defined by Kalantari (1976), which, however, according to this author, is identified also by *Pseudocyclammina rugosa.*

Definition. Interval from the appearance of *Paleodictyoconus arabicus* to the extinction of *Choffatella decipiens.*

Age. This zone is dated as Barremian to earliest Aptian in age. This age is based on the appearance of *P. arabicus* described by Henson (1948) from the Barremian of Qatar Peninsula (Arabia) and other associated microfossils. In central Iran (Isfahan region) this species was reported by Seyed-Emami et al. (1971) from the lower "Orbitolina Limestone" (Upper Barremian), which also contains "*Orbitolina lenticularis*". *P. arabicus* also occurs in the Lower Barremian of Kopet Dagh (Turkmenistan, USSR), where it has been described as *Dictyoconus arabicus* and *D. walnutensis* (Carsey) by Mamontova (1961). This species is also present in the Iranian side of Kopet Dagh in Barremian strata (Kalantari, 1969). In the western Mediterranean region, *P. arabicus* was recorded by Schroeder et al. (1978) from various localities of northeastern Algeria (Barremian-Lower Aptian). Later Schroeder (1979) found this species in the Upper Barremian of the Grand Bank Continental Rise in the northwestern Atlantic.

The relatively short stratigraphic range and the world-wide geographical distribution of *Choffatella decipiens* enhances the value of this species for correlation (Fig. 6).

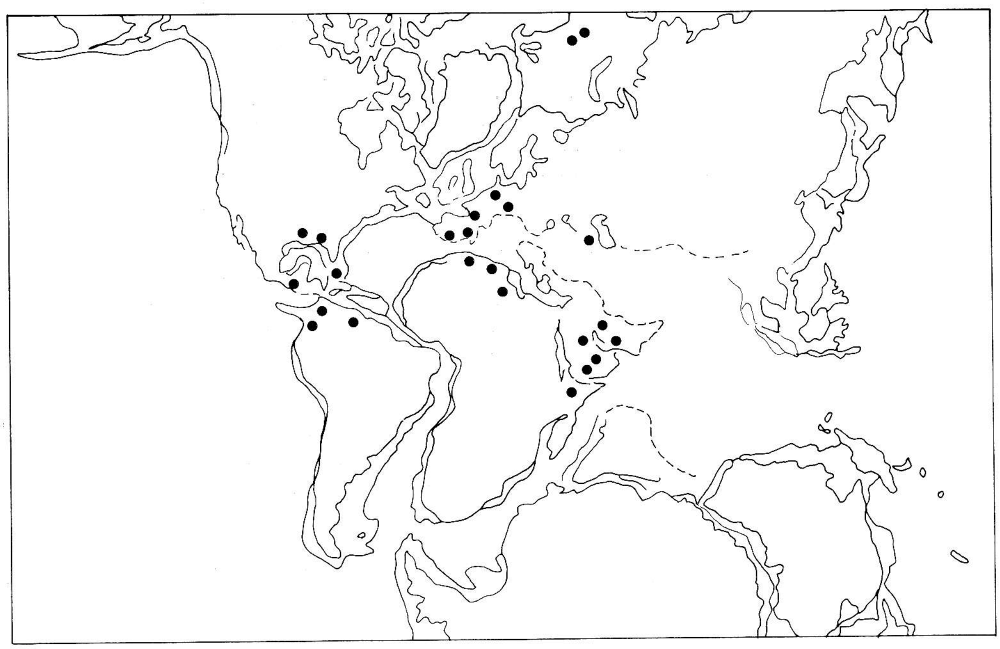


Fig. 6 - Geographical distribution of *Choffatella decipiens* plotted from published and unpublished occurrences.

The type locations from which *C. decipiens* was described are in Portugal and France and are Aptian in age (Schlumberger, 1905). In Spain, it was reported by Gomez Llueca (1929) and Colom (1934) in the Aptian stage. Fichter (1934) recorded this species in the Aptian of central Switzerland. Moullade (1966) described this species from the Barremian of the Vocontian Trough (Southern France). In Syria and Lebanon, *C. decipiens* is common in Aptian limestones. Henson (1948) reported it in the Lower Aptian from southern Iran (Kuh-e-Kartage). This species along with the *Psedocyclammina* assemblage has been observed in Barremian-Aptian beds of the Zagros Range of Iran by Furon (1941). Blumenthal (1949) informed in a personal letter to Maync (1950) about the occurrence of *C. decipiens* in the Barremian of Turkey. Maync (1950) recorded this species in the Lower Aptian of Mexico, eastern Venezuela, Cuba, and Florida. In Trinidad this species has been reported from the Barremian-Aptian by Bartenstein & Bolli (1977). Colin et al. (1981) described this species from the Aptian of the North Celtic sea Basin and offshore southern Ireland. *C. decipiens* was not recorded in the Far East, USSR, New Zealand, Australia, and Madagascar. Its absence in the last areas may be not real but due to poor record. No evidence of this species was found in the Alborz Mountains, northern Iran. However, Kalantari (1969) observed some *Choffatella maynci* n. sp. of supposedly Bajocian age. According to his author, *C. maynci* differs from *C. decipiens* in having fewer chambers, a small test and a small initial whorl. Kalantari's species is probably a juvenile of *C. decipiens.* If this interpretation is correct, then the Bajocian age needs to be reconsidered.

The *Choffatella decipiens* zone from the studied area correlates with the "*Orbitolina-Choffatella* and *Salpingoporella*" zone of Gollestaneh (1965), and with the "*Dictyoconus arabicus*" and "*C. decipiens*" (partim) zones of Sampò (1969).

The zone may be subdivided into two subzones as follows:

Subzone 1.1 - *Lenticulina nodosa* subzone.

Author. Kalantari (1969).

Definition. Interval from the appearance of *Lenticulina nodosa*, *Dentalina communis*, *D. cylindroides*, *D. linearis*, *Lagena apiculata*, *Pseudonodosaria humilis*, and *Paleodictyoconus arabicus.* Of the mentioned species only *P. arabicus* continues into the next subzone, whereas the remainder of the species disappear at the top of this subzone.

Subzone 1.2 - *Gavelinella barremiana* subzone.

Author. New subzone, erected herein.

Definition. Interval from the appearance of *Gavelinella barremiana* and *Vaginulina kochi. G. barremiana* was also utilized as index species for the Upper Barremian-Lower Aptian by Moullade (1966), Neagu (1972), and Bartenstein & Bolli (1977).

Zone 2 - *Leupoldina cabri* zone.

Author. New zone, erected herein.

Definition. Interval from the appearance of abundant *Leupoldina cabri* and *Orbitolina lenticularis* to the extinction level of *Astacolus gratus* and *Patellina subcretacea.*

Age. Kalantari (1969) attributed this interval to the *Schackoina gandolfii* zone, but the identification of the taxon was uncorrect. Based on its total range *Leupoldina cabri* is also used for defining the homonymus zone, which, according to Sigal (1977), straddles the lower to upper Aptian boundary. It is recorded from numerous localities of Europe, Central and North America, and Asia (i. e. Bolli, 1959; Kalantari, 1969). It is considered to be Early to early Late Aptian in age. Most of the *Orbitolina* species are reported from the northern hemisphere with the exception of one occurrence in Tanganyka (Africa) (Douglass, 1960). In general, *Orbitolina lenticularis* is known from rocks of Barremian to Cenomanian age in the Banish area (Shakib, 1983). Hofker (1966) records *Orbitolina daviesi* from the Paleocene of Pakistan. Schroeder (1975), however, believes that the embryonic structures of this species are completely different and cannot be derived from those of *Orbitolina.* Thus, Hofker's generic attribution must be rejected.

This zone, partially overlapping with the *Leupoldina cabri* zone of the standard biozonal schemes (Sigal, 1977), is equivalent to the "*Orbitolina discoidea/conoidea* and *O. lenticularis*" zone of Kalantari (1976).

The zone may be subdivided into two subzones as follows:

Subzone 2.1 - *Quasispiroplectammina alexanderi* subzone.

Author. New subzone, erected herein.

Definition. Interval from the appearance of *Quasispiroplectammina alexanderi, Hemisphaerammina* sp., *Astacolus gratus, A. calliopsis,* and *Globigerinelloides saundersi.* Longoria (1974) located the first occurrence of *G. saundersi* in the Lower Aptian of Mexico.

Subzone 2.2 - *Saracenaria frankei* subzones.

Author. New subzone, erected herein.

Definition. Interval from the appearance of *S. frankei* to the extinction level of *Astacolus gratus* and *Patellina subcretacea.* This subzone is characterized by the concurrence of *Dentalina deflexa, D. soluta,* and *Globulina prisca. Astacolus calliopsis* disappears in the middle part of the subzone. Bartenstein, Bettenstaedt & Bolli (1966) and Scheibnerova (1974) recorded *D. deflexa* in the Aptian from Trinidad and eastern Indian Ocean, respectively.

Taxonomic Notes

A brief discussion of the taxonomy and distribution of few biostratigraphically and/or paleoecologically important species is presented as a basis for the conclusions reached in the present paper.

Tritaxia pyramidata Reuss, 1860

Pl. 16, fig. 12

1860 *Tritaxia pyramidata* Reuss, p. 228, pl. 12, fig. 2a,b.
1975 *Tritaxia pyramidata* - Luterbacher, fig. 2,3.
1977 *Tritaxia pyramidata* - Bartenstein & Bolli, p. 546.

Remarks.

The small intraspecific variability is mostly expressed in a variable inclination of the chambers to the vertically axis of the test and in different concavity of the test's sides. *Tritaxia tricarinata* (Reuss) differs from *T. pyramidata* by lacking last uniserial chamber and in having angular periphery and much more concave sides. The species ranges in Tethys from Upper Valanginian to Albian, but in the Boreal areas from Upper Albian into Upper Cretaceous. *T. pyramidata* is known from Upper Albian and Cenomanian of Poland, Barremian of Rumania, Lower Cretaceous of the Netherland, Bulgaria and Trinidad, Albian of SE England, and Barremian of NE Iran.

Marssonella kummi Zedler, 1961

Pl. 16, fig. 13

1961 *Marssonella kummi* Zedler, p. 31, pl. 7, fig. 1.
1966 *Marssonella kummi* - Geroch, p. 471, fig. 12.

Remarks.

Zedler (1961) gave the name of *M. kummi* to those Lower Cretaceous forms which are smaller and thinner than *M. oxycona* (Reuss) and have slightly narrower chambers. Maync (1973) distinguished these two species because of their different length/breadth ratio. He stated that the ratio of the broadly flaring Upper Cretaceous forms of *M. oxycona* is 1.3:1 to 2:1, whereas in *M. kummi* it varies between 0.8:1 to 2.4:1. Size measure-

Species	Author & Year	Length/Breadth ratio
M. kummi	Zedler, 1961	0.8:1 to 2.4:1
M. hauteriviana	Moullade, 1961	2.5:1 to 3:1
M. praehauteriviana	Dieni & Massari, 1966	1.3:1 to 2.8:1
M. oxycona	Reuss, 1860	1.3:1 to 2:1
M. ellissorae	Cushman, 1946	3.7:1

Table 1 - Degree of variability of Length/Breadth ratio in species of *Marssonella*.

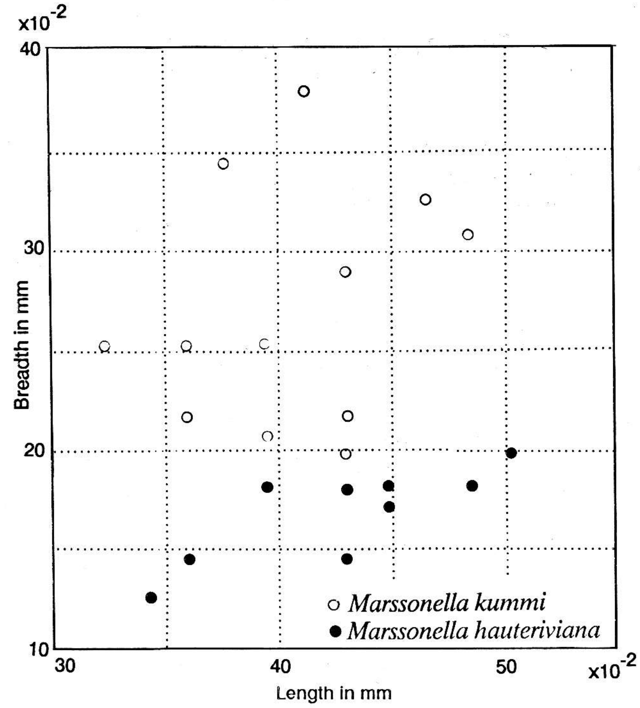


Fig. 7 - Comparison of Length/Breadth ratio in *Marssonella kummi* and *M. hauteriviana*.

ments of some specimens of *M. kummi* and *M. hauteriviana* Moullade obtained the same results reported by Maync (Fig. 7 and Tab. 1).

According to previous records, this species seems to range from Valanginian through Albian.

Saracenaria cf. **frankei** ten Dam, 1946

Pl. 17, fig. 12, 13

non 1969 *Saracenaria frankei* Kalantari, p. 158, pl. 14, fig. 15.
1972 *Saracenaria frankei* - Neagu, p. 212, pl. 4, fig. 36.

Remarks.

This species differs from *Saracenaria frankei* ten Dam in having a very elongate, slender and straight test, and more depressed sutures. Small intraspecific variability, mostly concerning the degree of convexity, the number of chambers in the rectilinear part and test size, was observed.

This species has been reported from Aptian of Rumania. In SW Iran *S. frankei* occurs commonly in the upper part of Gadvan Formation.

Astacolus calliopsis (Reuss, 1863)

Pl. 17, fig. 14, 15

1951 *Lenticulina* (*Astacolus*) *calliopsis* - Bartenstein & Brand, p. 286, pl. 5, fig. 120-122.
1966 *Lenticulina* (*Astacolus*) *calliopsis* - Bartenstein, Bettenstaedt & Bolli, p. 149, pl. 2, fig. 151-154, 169-173.
1973 *Astacolus* cf. *A. calliopsis* Dailey, p. 60, pl. 8, fig. 5.

Remarks.

The morphological group into which *A. calliopsis* belong is characterized by narrow slender forms displaying a poorly developed spire and depressed sutures. Michael (1967) interprets this species as junior synonim of *Astacolus compressus* (d'Orbigny). On the other hand Maync (1973) defines this species as belonging to a highly variable plexus of different intergrading morphotypes, which have been given different specific names, partly reflecting more dimorphism. Iranian specimens are very close to Bartenstein & Brand's material (1951), differing only in their smaller width and slightly inflated coiled part.

Astacolus calliopsis seems to range from Valanginian through Albian. This species occurs rarely in the upper part of Gadvan Formation.

Epistomina caracolla (Roemer, 1841)

Pl. 18, fig. 19, 20

1969 *Epistomina caracolla caracolla* - Kalantari, p. 167, pl. 18, fig. 4.
1972 *Epistomina caracolla* - Gawor-Biedowa, p. 134, pl. 19, fig. 1-6.

Remarks.

In the studied area, this species is represented almost exclusively by large specimens (0.55 mm in diameter) composed of three whorls with 9 chambers in the last whorl with a considerably more convex ventral side. Our specimens are very similar to *E. caracolla caracolla* of Kalantari (1969). This species is widely distributed, having been reported from several areas of Western Europe, as well as from Poland, North America, Australia, Trinidad, Madagascar, and California. Its range in Europe is considered to be Late Valanginian-Early Barremian in age (Michael, 1967), but to extend upward into Middle Barremian in Trinidad and Upper Aptian in NE Iran. This species occurs frequently in the upper part of Gadvan Formation.

Gaudryina barnardi n. sp.

Pl. 18, fig. 13-15

Derivation of name. This species is named from Prof. T. Barnard, in honour of his contribution to the study of the Cretaceous of England.

Holotype. Pl. 18, fig. 15.
Type Locality. Outcrop in the Banish area, 60 km north of Shiraz, SW Iran.
Type Level. Uppermost part of Gadvan Formation, Member 3, Sample 183. Middle Aptian.

Diagnosis.

A species of *Gaudryina* characterized by a small test, wedge-shaped triserial part, and twisted biserial part. Sutures depressed and distinct. Aperture interiomarginal, semicircular.

Description.

Test finely angular, elongate, somewhat twisted in respect to the vertical axis in biserial part. Early chambers triserially arranged, wedge-shaped, occupying half of the length of the test; 4-5 nearly inflated chambers, slightly concave. Biserial part straight, wider, consisting of 2-3 oval chambers. Periphery strongly lobulate. Sutures in the triserial part not perfectly distinct, straight, depressed, perpendicular to the vertical axis of test; in the biserial part sutures are depressed and distinct. Aperture interiomarginal, large and semicircular.

Dimension of figured specimens:
Length 0.36-0.40 mm; width 0.18-0.22 mm.

Remarks.

This species resembles *Gaudryina dividens* Grabert but it differs in lack of uniserial part and considerably larger triserial part. It is marked by less inflated and fewer chambers particularly in the biserial part. Intraspecific variability expresses in the degree of convexity of both part of the test, in varying number of chambers, the shape of biserial part and the degree of lobulation of test.

This species occurs frequently in the upper part of Gadvan Formation (Member 3, samples 183-192) of studied area.

Conclusions.

According to the present study, the Gadvan Formation may be subdivided in three members on the basis of petrological and lithological characteristics. The analysis revealed that the Gadvan Formation is somewhat argillaceous, consisting of marl and marly limestone. The lithology, sedimentary structures and fossil content allow us to suggest that 1) the lower part of the formation, Barremian in age, was deposited in an inner shelf environment in a water depth of about 50 m, as corroborated by the occurrence of larger Foraminifera (e. g. *Choffatella decipiens* and *Paleodictyoconus arabicus*); and 2) the upper part was deposited in an outer shelf environment in a water depth of about 150 m. The Gadvan Formation initiated at a slow rate of deposition which is considered responsible for the oxidation of the formerly deposited sediments. Overall, the Gadvan

Formation sedimented in a low energy environment, characteristically much deeper than that of the underlying Fahliyan Formation (Tithonian- Hauterivian).

The occurrence of calcareous forms belonging to the *Nodosariidae* and *Buliminidae* indicates that water turbidity decreased and salinity increased through the formation, with sediments alternatively enriched in microcrystalline calcite ooze and clay particles (Shakib, 1983).

Finally, the recognized microfossil assemblages have been proved to be biostratigraphically useful either for age determination or spacial correlations.

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PLATE 16

Fig. 1 - *Ammobaculites exertus* Crespin. Gadvan Formation, sample 127. Spiral view; x 65.

Fig. 2 - *Ammobaculites goodlandensis* Cushman & Alexander. Gadvan Formation, sample 140. Spiral view; x 58.

Fig. 3,4 - *Ammobaculites subcretaceous* Cushman & Alexander. Gadvan Formation, sample 160. Spiral views; x 37.

Fig. 5 - *Ammobaculites irregularis* Bartenstein & Brand. Gadvan Formation, sample 132. Spiral view; x 25.

Fig. 6 - *Ammobaculites agglutinans* d'Orbigny. Gadvan Formation, sample 151. Spiral view; x 25.

Fig. 7 - *Triplasia emslandensis acuta* Bartenstein & Brand. Gadvan Formation, sample 136. Side view; x 65.

Fig. 8-11 - *Choffatella decipiens* Schlumberger. Gadvan Formation, sample 132.
8) Dorsal view; x 15; 9) ventral view; x 29; 10) side view; x 90; 11) dorsal view; x 115.

Fig. 12 - *Tritaxia pyramidata* Reuss. Gadvan Formation, sample 180. Side view; x 33.
Fig. 13 - *Marssonella kummi* Zedler. Gadvan Formation, sample 163. Side view; x 170.
Fig. 14 - *Paleodictyoconus arabicus* Henson. Gadvan Formation, sample 136. Dorsal view; x 103.
Fig. 15 - *Lenticulina muensteri* Roemer. Gadvan Formation, sample 144. Spiral view; x 83.

PLATE 17

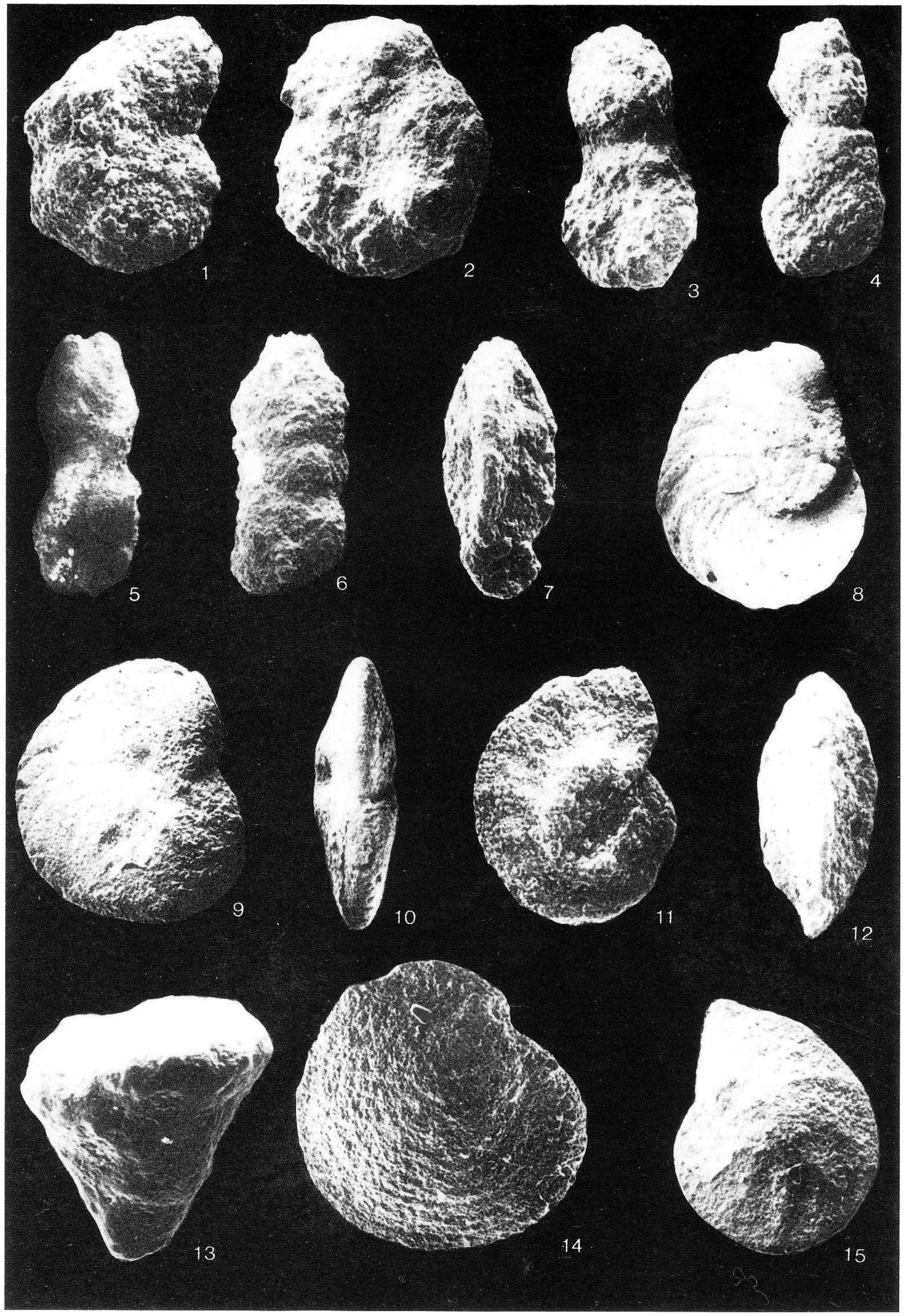
Fig. 1-3 - *Lenticulina nodosa* (Reuss). Gadvan Formation, sample 134. 1) Spiral view; x 100; 2) side view; x 62; 3) spiral view; x 37.
Fig. 4 - *Lenticulina nodosa hilseana* Bartenstein. Gadvan Formation, sample 144. Apertural view; x 75.
Fig. 5,6 - *Lenticulina macrodisca* (Reuss). Gadvan Formation, sample 132. Spiral and side views; x 83.
Fig. 7,8 - *Lenticulina* cf. *kugleri* Bartenstein, Bettenstaedt & Brand. Gadvan Formation, sample 132. 7) Spiral view; x 12; 8) side view; x 115.
Fig. 9-11 - *Saracenaria cornucopiae* (Schwager). Gadvan Formation, sample 160. 9) Side view; x 107; 10) face view; x 107; 11) side view; x 90.
Fig. 12,13 -*Saracenaria* cf. *frankei* ten Dam. Gadvan Formation, sample 174. Side and face views; x 65.
Fig. 14,15 -*Astacolus calliopsis* (Reuss). Gadvan Formation, sample 162. Spiral views. 14) x 106; 15) x 90.
Fig. 16,17 -*Astacolus gratus* (Reuss). Gadvan Formation, sample 174. Spiral views. 16) x 106; 17) x 95.

PLATE 18

Fig. 1,2 - *Dentalina communis* d'Orbigny. Gadvan Formation, sample 136. 1) x 75; 2) x 100.
Fig. 3 - *Dentalina cylindroides* Reuss. Gadvan Formation, sample 130; x 75.
Fig. 4 - *Dentalina linearis* (Roemer). Gadvan Formation, sample 130; x 83.
Fig. 5 - *Dentalina* cf. *deflexa* Reuss. Gadvan Formation, sample 180; x 75.
Fig. 6,7 - *Dentalina soluta* Reuss. Gadvan Formation, sample 181. 6) x 90; 7) x 78.
Fig. 8,9 - *Lagena apiculata emaciata* Reuss. Gadvan Formation, sample 129. 8) x 185; 9) x 230.
Fig. 10 - *Lagena globosa ovalis* Reuss. Gadvan Formation, sample 131; x 180.
Fig. 11,12 -*Patellina subcretacea* Cushman & Alexander. Gadvan Formation, sample 164. Top and side views. 11) x 103; 12) x 124.
Fig. 13-15 -*Gaudryina barnardi* n. sp. Gadvan Formation, sample 183. 13) Paratype, side view; x 87; 14) paratype, apertural view; x 223; 15) holotype, side view; x 87.
Fig. 16-18 -*Leupoldina cabri* (Sigal). Gadvan Formation, sample 172. Spiral views. 16 and 17) x 107; 18) x 124.
Fig. 19,20 -*Epistomina caracolla* (Roemer). Gadvan Formation, sample 169. Dorsal view; x 65.

PLATE 19

Fig. 1 - Fossiliferous micrite with *Choffatella decipiens* Schlumberger. Gadvan Formation, sample 133. Axial section; x 33.
Fig. 2 - Biomicrite with *Choffatella decipiens* Schlumberger. Gadvan Formation, sample 132. Oblique section; x 33.
Fig. 3-5 - *Orbitolina* sp. Gadvan Formation, sample 129. Oblique axial sections; 3 and 4) x 48; 5) x 30.
Fig. 6 - Miliolid intrasparite with *Paleodictyoconus arabicus* (Henson). Gadvan Formation, sample 128. Axial section; x 23.
Fig. 7 - *Hedbergella*-bearing biomicrite. Gadvan Formation, sample 183; x 33.
Fig. 8 - Radiolarian-bearing biomicrite. Gadvan Formation, sample 190; x 33.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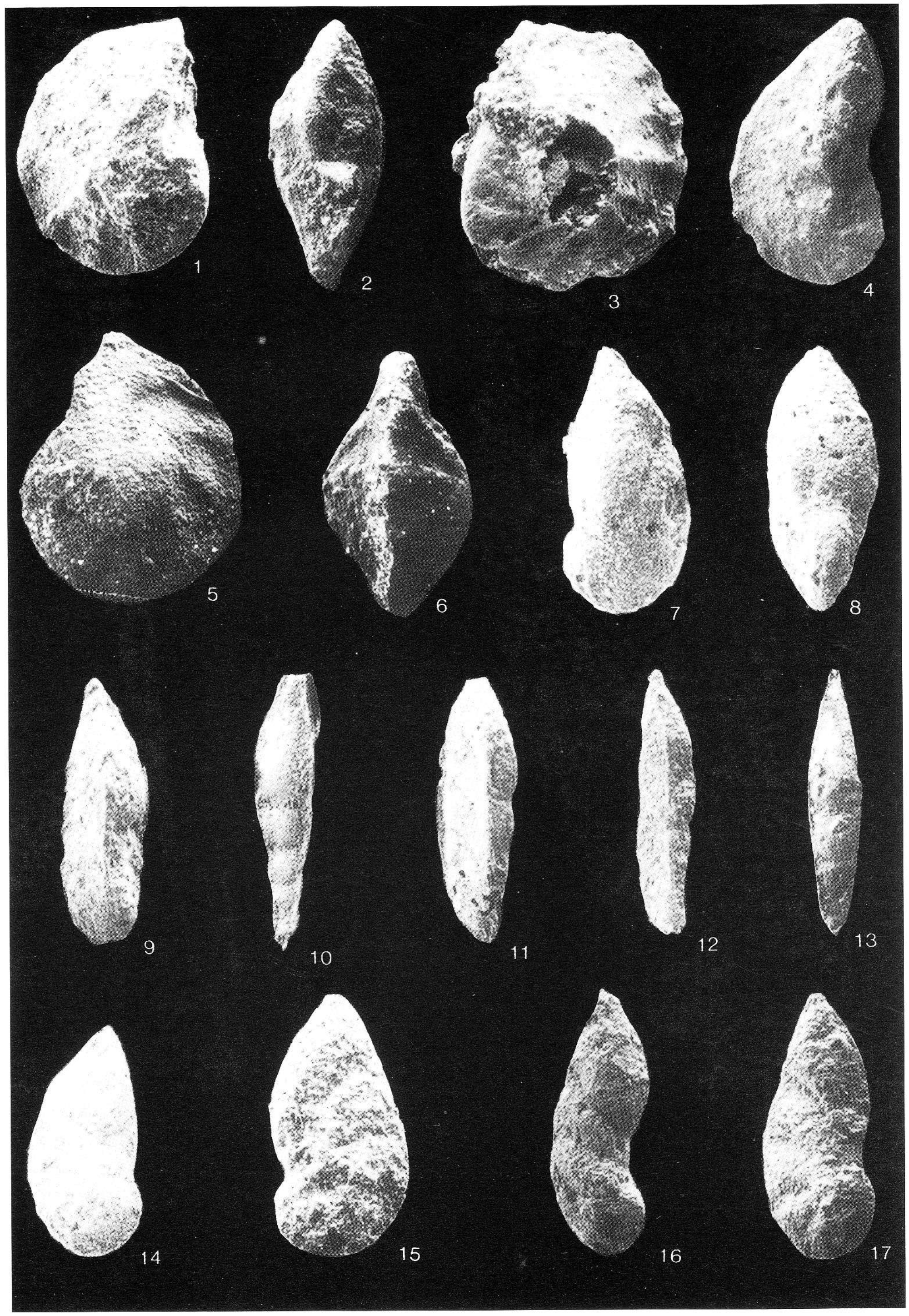
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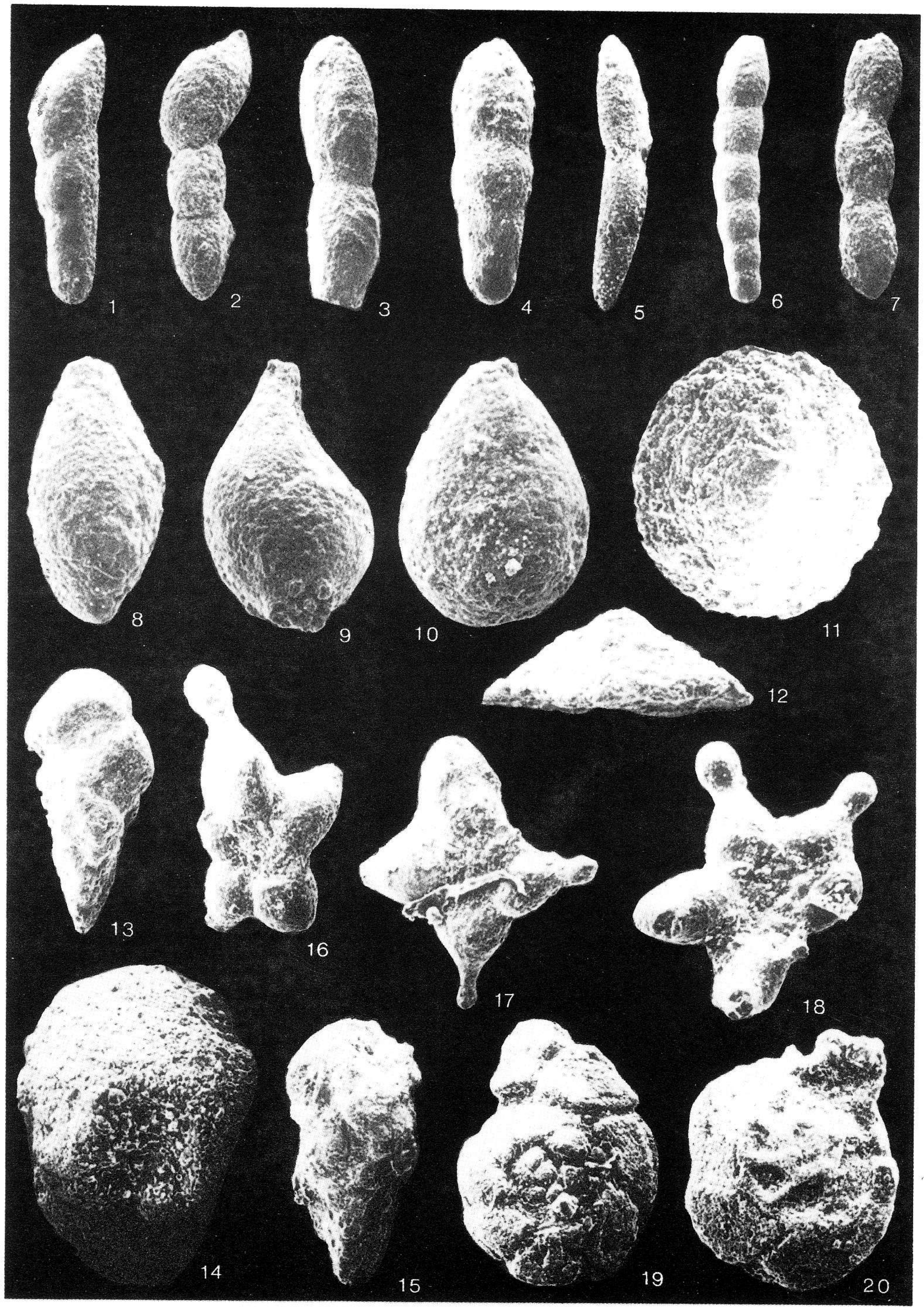
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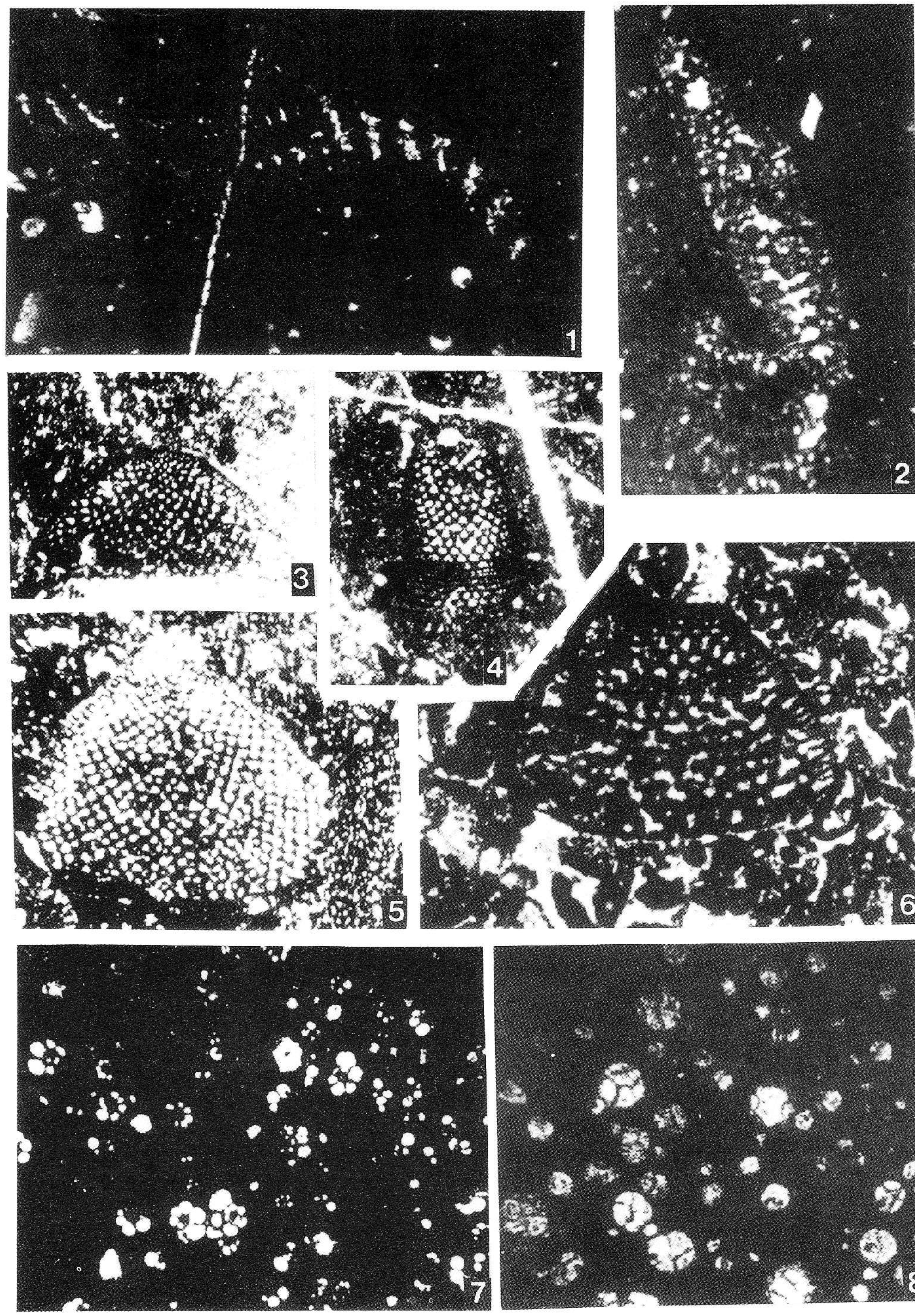
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