MICROFACIES AND PALAEOENVIRONMENTS OF THE LOWER CARBONIFEROUS MOBARAK FORMATION IN THE KIYASAR SECTION, NORTHERN IRAN

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Abstract: Carboniferous rocks outcrop over vast areas in the Alborz Mountains. The Mobarak Formation outcrops in the studied area near the Kiyasar town, south-east of Sari, Northern Iran. The petrographic study produced the recognition of fifteen different microfacies types. Based on microscopic studies, four facies belts have been characterized: (1) an intertidal facies belt, (2) a lagoonal facies belt, (3) a barrier (shoal) facies belt and (4) an open-marine facies belt. They are respectively interpreted as inner, middle and outer-ramp carbonates developed in a shallowing-upward sequence.

Key-words: Lower Carboniferous, Microfacies, Mobarak Formation, Northern Iran.

Resumen: ***Microfacies y paleoambientes de la Formación Mobarak, Carbonífero Inferior, en la sección de Kiyasar, Norte de Irán***. En vastas áreas de las Montes Alborz afloran rocas Carboníferas. La Formación Mobarak aflora en el área estudiada en las cercanías de la cuidad Kiyasar al Sudeste de Sari (Norte de Irán). El estudio petrográfico realizado, cuyos resultados se informan en este trabajo, produjo el reconomiento de quince diferentes tipos de microfacies. Sobre la base de estudios microscópicos han podido caracterizarse cuatro franjas faciales: (1) una franja de facies intertidal, (2) una franja de facies lagunar (lagoon), (3) una franja de facies de barrera, y (4) una franja de facies de mar abierto. Estas franjas faciales son respectivamente interpretadas como carbonatos de rampa circal, media y distal, desarrollados en una secuencia de somerización progresiva.

Palabras clave: Carbonífero Inferior, Microfacies, Formación Mobarak, Norte de Iran.

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INTRODUCTION

Assereto (1963) introduced the Mobarak Formation for outcrops of the Mobarakabad valley near to Ab-Ali village, Northeast of Tehran. Bozorgnia (1973) carried out detailed biostratigraphic studies on different outcrops of the Mobarak Formation in the central and eastern Alborz. Other important studies on the outcrops and their faunas were subsequently published (e.g., Gaetani 1968, Vachard 1996, Mosaddegh 2003, Brenckle et al. 2009). Nevertheless the Mobarak Fm carbonate microfacies remained poorly known. The biostratigraphy and sedimentology of the Mobarak Fm have been studied in several areas of the eastern and central Alborz. Mahari (1992) examined the Mobarak Fm sedimentary environment in Aruh and Jaban areas and concluded that its sedimentary environment is consistent with the Persian Gulf model. Mossadegh (2000) focused on micropalaeontology and sedimentary environment studies in northern-central Alborz (Zanus and Lashk) and southern-central Alborz (Shahmirzad, Aruh and Mobarakabad) and interpreted the sedimentary environment model of this formation in those areas as a distally steepened carbonate ramp. Later, Mosaddegh et al. (2006) have analyzed the Mobarak Fm facies in several sectors of the eastern and central Alborz and have identified five facies belts. Those belts contain basin plain facies, ramp slope facies, deep ramp facies, ooid barrier (shoal) facies and peritidal facies. Lasemi & Ghouchi-Asli (2006) have studied the sedimentary environment of the Mobarak Fm at the Touyeh region in the eastern Alborz Mountains and considered it as an area with a distally steepened ramp. Biostratigraphical studies based on foraminifers such as *Earlandia minor*, *Earlandia vulgaris*, *Septabrunsiina kingirica*, *Eoforschia moelleri*, *Brunsia spirillinoides*, *Eoparastaffella simplex*, *Endothyra bowmani*, *Lapparentidiscus bokanensis* and *Glomodiscus biarmicus* (Falahatgar 2008) show that the age of the Mobarak Fm in the Kiaysar section ranges from lower Tournaisian to early Middle Visean. The present paper aims to report the results of the microfacies analysis of this succession at Kiyasar.

GEOLOGICAL SETTING AND STRATIGRAPHY

The Kiyasar section is located in northern Iran (Fig. 1) in the eastern limit of the Alborz Mountains. The Alborz Mountains are part of the Alpine-Himalayan orogenic belt. The Lower Carboniferous succession in the studied area is exposed near the Kiyasar town (Fig. 2) and along the main road between Sari and Damghan (36°14'18"N, 53°32'57"E). The distance to Sari is 75 km and to Tehran 375 km. The Mobarak Fm thickness in the Kiyasar section is approximately 250 m. Regionally the Mobarak Fm has been subdivided in four informal units (Fig. 3). In this area the Mobarak Fm conformably overlays the Upper Devonian Geirud Fm (Fig. 4A) and shows, in its upper boundary, an erosive disconformity with the Dorud Fm (Lower Permian). The thickness of the first (lowermost) unit (Fig. 4B) is 34 m, containing black thin to medium-bedded limestone and brown medium-bedded dolomitic limestone, with intercalated shale and marl layers. The base of the section is recognized by a thin bedded limestone. On the top of this unit, thick shale layers with medium bedded dolomitic limestone can be observed. The thickness of the second unit (Fig. 4C) is 60 m, containing a medium-bedded limestone with interbedded shale and marl. On the top of this unit, medium bedded limestones with medium layers of shale have been deposited. The Tournaisian/Visean boundary (Fig. 4D) can be recognized near the top of this unit by the occurrence of the foraminifer *Eoparastaffella simplex* which appears in the lowermost Viséan (Devuyst et al. 2003). The thickness of the third unit (Fig. 4E) is 106 m, beginning with thick-bedded limestone followed by alternating medium-bedded limestone with black shales and dark marls. A coral horizon (Fig. 4F-G) occurs in the middle part of this unit and brachiopods at top. The thickness of fourth unit is 50 m, beginning with dark marl and medium-bedded dolomitic limestone followed by a medium-bedded limestone and medium layers of shale. On the top (Fig. 4H) have been observed yellow to brown, thick layers of shales with alternating thin-bedded limestone. Brachiopods and corals are common at this unit (Fig. 4I). This unit is covered by sandstone of the Lower Permain Dorud Fm (Fig. 4J).

MATERIAL AND METHOD

Nearly 150 thin sections from carbonate samples were prepared for studying the Mobarak Fm microfacies in the Kiyasar area and for identifying its calcareous microfossils. Nomenclature and interpretation of the microfacies are based on Dunham (1962), Embry & Klovan (1972), Wilson (1975),

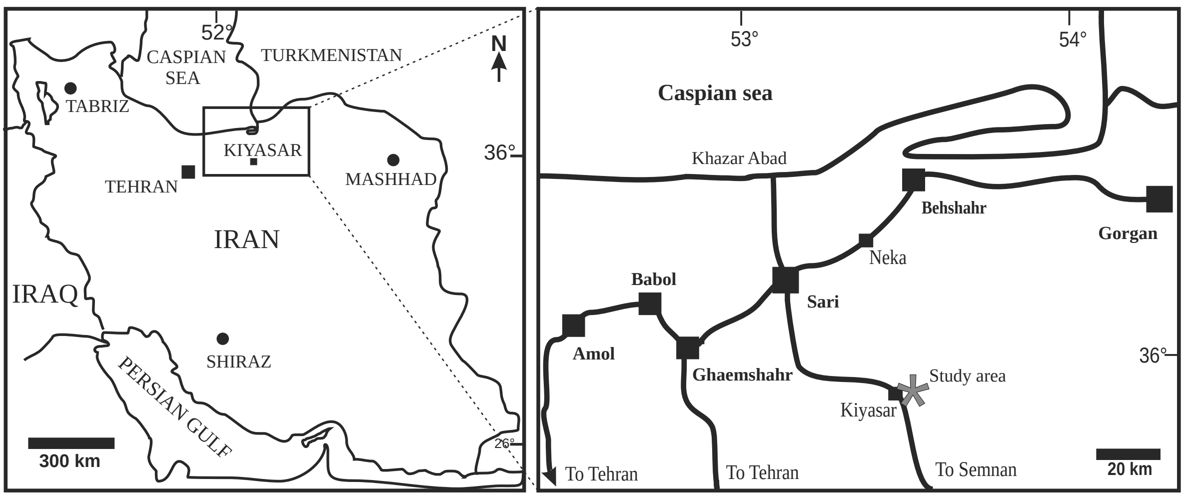

Figure 1. Location map of the study area.

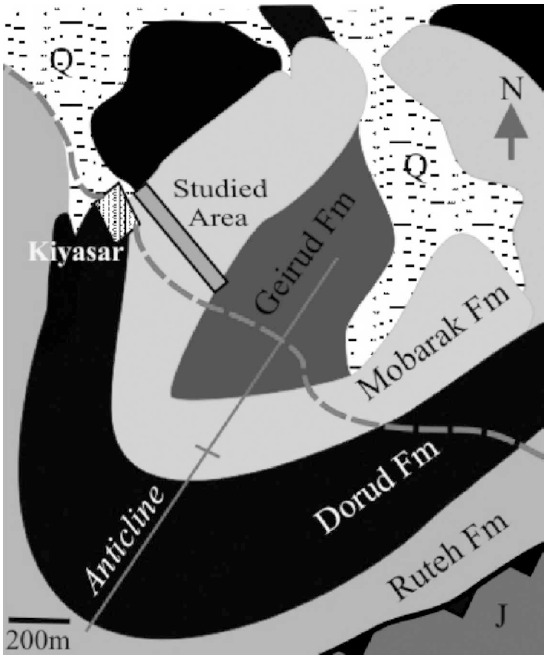

Figure 2. Geological map of the study area. J: Jurassic, Q: Quaternary.

Tucker & Wright (1990), and Flügel (2004). The sedimentary processes have been modelled on the basis of the changes in the distribution of orthochems and allochems, especially the microorganisms. Based on microscopic studies and analysis of carbonates samples, we have been identified 15 microfacies types (Fig. 3, 5-6). The microfacies are arranged in four facies belts depending on its distance from the shore.

RESULTS AND DISCUSSION

Intertidal flat facies

Peloidal packstone (A).- In this microfacies, with pelloids in a matrix of microsparite, sparse amounts of siliciclastic particles, including quartz, can be observed. Organic matter is not apparent in this facies. Therefore, this facies is interpreted as formed in the basal part of an intertidal belt (Fig. 5A).

Lagoonal facies

Bioturbated bioclastic wackestone /packstone (B1).- The allochems scattered in the matrix are composed of pelloids and bioclasts, including algal debris (green algae), and calcitarcha (= calcispheres sensu Versteegh et al. 2009). Rare foraminifers with microgranular tests, including *Earlandia* are seen in this facies. *Earlandia* is generally common in the Lower Carboniferous deposits; however, some of its species have been recorded in the Permian of Iran (e.g. Gaillot & Vachard 2007). *Earlandia* has a simple test without septa, and a microgranular wall with a simple aperture. Probably, due to its "primitive" organization, it has adapted successfully to a wide range of subtidal facies, either in high energy or low energy regimes. This taxon has been positioned in such a way that its aperture is upward facing and the sharp test has entered into the sediments. Gallagher (1998) suggests that this taxon has been adapted, in wackestone facies, to low energy and a depth lower than 2 m. The micritic matrix is affected by an intense bioturbation produced by suspensivore organisms. This bioturbation leads to a mottled fabric (Flügel 2004). Rare silt particles are scattered in the matrix (Fig. 5B).

Green algal packstone (B2).- Large amounts of problematic algae (algospongia sensu Vachard and Cózar 2010) including *Kamaena tenuisepta* Mamet & Rudloff, 1972, associated with few foraminifer tests and thick-walled ostracod shells (Fig. 5C). *Kamaena* is an important contributor to the algal microflora in the Lower Carboniferous succession in Iran. Species of this genus have been already reported in areas of Gaduk, Aruh and Shahmirzad (Mosaddegh 2000). The orthochems are microsparitic cements. The abundance of green algae indicates typically an environment located within the photic zone.

Gastropod bioclastic wackestone/packstone (B3).- Skeleton remains in this microfacies include gastropods, green algae, ostracods, foraminifers *Mediocris* and *Earlandia*, and calcitarcha (Fig. 5D). Pelloids are scattered in the matrix. The orthochems are composed of micrite transformed into microsparite.

Dolomitic bioclastic packstone (B4).- The bioclasts are represented by foraminifers, large ostracods, algae and crinoid fragments (Fig 5E). The surrounding microsparite generally become dolomitic. Similarly, the space situated between the connected ostracod shells can be filled by secondary dolomite.

Foraminifer packstone (B5).- The main allochems of this facies belong to the typical assemblages of the lagoons such as foraminifers, especially of the family Endothyridae, and green algae (Fig. 5F-G). The Endothyridae have a characteristic streptospiral coiling with a microgranular test. Based on the interpretation by Gallagher (1998) this taxon can be considered as adapted to a wide range of depths. The species of *Endothyra* are peculiarly diverse in our samples, although the genus *Paraarchaediscus* predominates by the number of individuals. *Paraarchaediscus* is indeed the most abundant taxon in the Mobarak Fm in this area. The abundance of this genus has been already reported by Mosaddegh (2000) in other areas of the eastern and central Alborz Mountains. These undivided, tubular, diversely coiled tests vary from discoidal to lenticular in shape. Its outer wall is pseudofibrous and its internal wall is microgranular. Gallagher (1998) believes that this taxon has been adapted to various environments where *Tetrataxis* and *Lapparentidiscus* are also relatively abundant, and *Earlandia* is sporadic. The associated bioclasts are large thick-walled ostracods and calcitarcha. Some forms of deeper environments are observed, such as broken pieces of crinoids and brachiopod spines. Microsparite is the principal orthochem. The algal flora (Fig. 7A, C, F) includes *Fourstonella fusiformis* (Brady 1876), *Nanopora anglica* Wood, 1964, *Palaeoberesella* cf. *lahuseni* (Möller, 1879) and *Evlania scabrosa* Vachard, 1981. Palaeoberesellids are small, cylindrical, scalariform calcareous algae. Horbury (1992) found abundant foraminifers in palaeoberesellid-rich buildup facies. Gallagher (1998) found that palaeoberesellid-rich limestones generally yield diverse foraminiferal assemblages containing abundant endothyrids.

Barrier facies (Shoal)

Red algae (?) bioclastic packstone (C1).- This microfacies

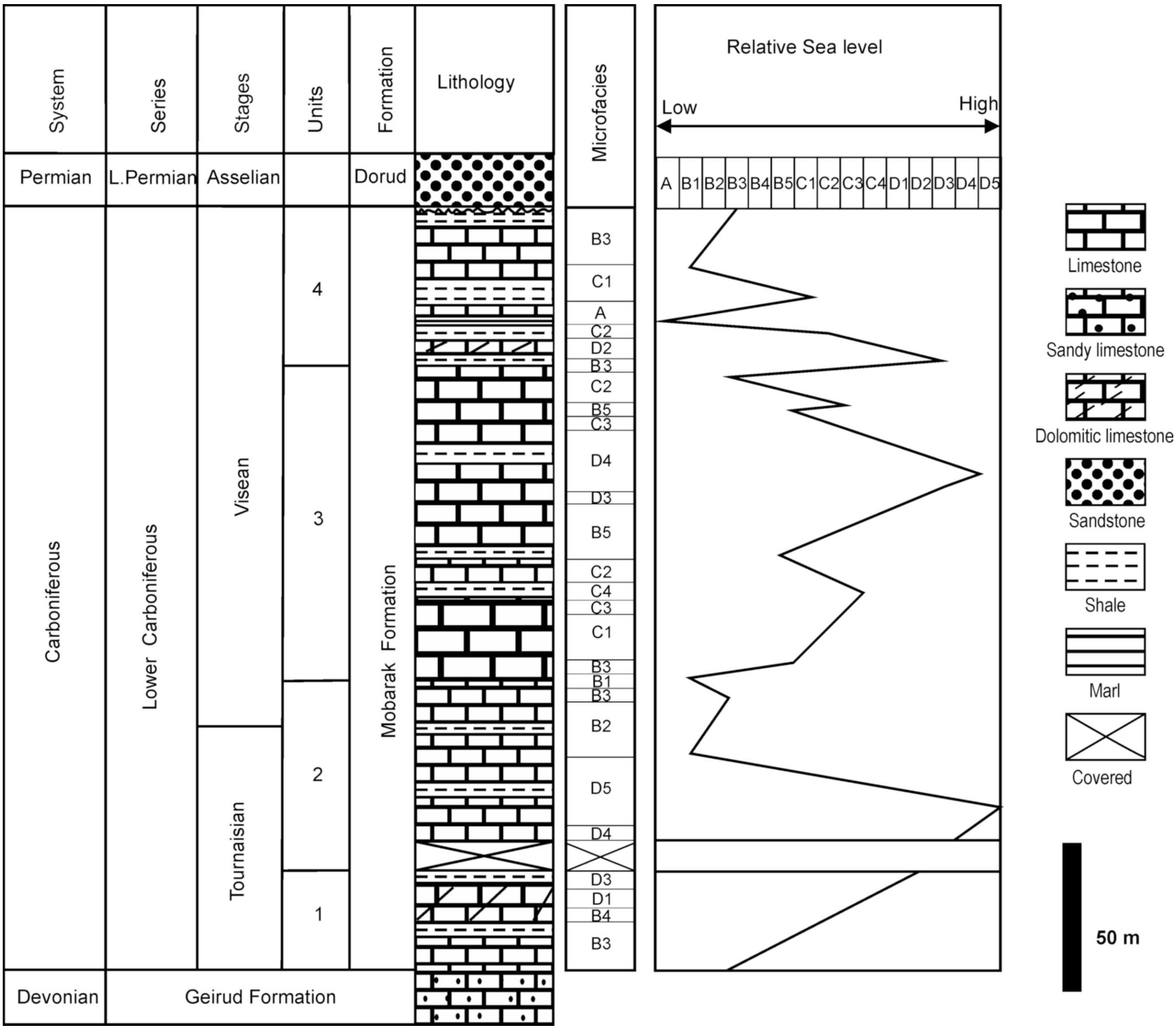

Figure 3. Stratigraphic column of the Mobarak Formation in the Kiyasar section with indication of the age, the associated microfacies and the estimated sea-level changes. The codification of the microfacies is explained in the text.

contains red algae(?), crinoid fragments, bryozoan fragments, brachiopod debris, and fewer amounts of foraminifera with pseudofibrous and microgranular tests (Fig. 5H). The most common problematic red alga(?), scattered in the matrix (Fig. 7E) belongs to the species *Aoujgalia skimoensis* (Mamet & Rudloff, 1972, = *Stacheia* pars, = *Mametella* pars). In fact, *Aoujgalia* is currently interpreted as an *incertae sedis* alga (Vachard & Cózar 2010). Generally, the red algae are observed in middle ramp areas and deeper areas than lagoonal areas. Madi et al. (1996) indicated that algal flora has a determinant role in determining the depths of the palaeoenvironments. There are some green algae specimens in this facies such as *Koninckopora inflata* (Koninck, 1842) (Fig. 7G) and *Atractyliopsis minima* Mamet & Roux, 1978 (Fig. 7H). The wall of *Koninckopora* is bilayered (e.g., Gallagher 1998). This taxon is considered a dasycladacean by many authors (e.g., Wray 1977, Skompski 1986, Madi et al. 1996). This taxon occurs at the top of shallowing upward minor cycles in low amounts (Gallagher 1998). The matrix of this facies contains some microsparite patches where pelloid particles are scattered.

Crinoidal packstone (C2).- The allochems in the microsparite matrix are constituted by abundant crinoid debris, shells of brachiopods, bryozoans and subordinate red(?) and green(?) algae, ostracod shells and foraminifera such as *Tetrataxis* and *Earlandia* (Fig. 5I-J). Syntaxial cements are conspicuous on some crinoid ossicles.

Coral framestone (C3).- In this facies, rugose corals have constructed a patch reef (Fig. 6A). Many Palaeozoic coral reefs are formed in the margin of the shoals and under high energetic conditions. The facies matrix contains microsparite locally transformed into sparite.

Bioclastic rudstone (C4).- This facies contains allochems, such as crinoid debris (longer than 2 mm) and fewer brachiopod shells, bryozoans and ostracod shells (Fig. 6B-C). The orthochems are microsparitic. The foraminifers previously encountered in the microfacies C2, occur also here. This facies is located below the fair weather wave base (Fig. 9).

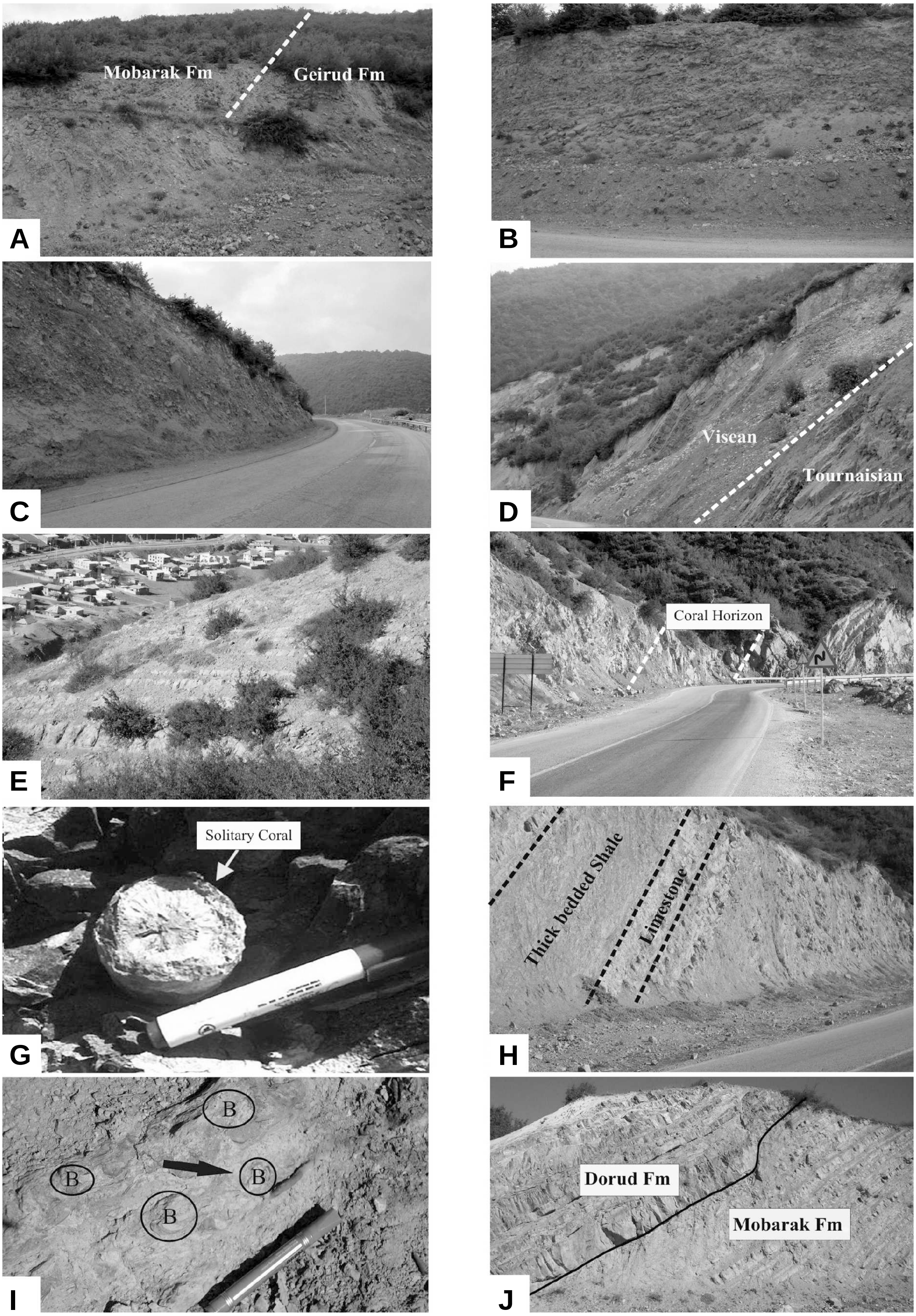

Figure 4. Outcrop views of the Mobarak Formation in the Kiyasar section. **A:** Contact between upper part of the Geirud Fm and lower Mobarak Fm. **B:** Upper part of Unit 1, alternation of dolomitic limestone with thick-bedded shales. **C:** Unit 2, upper part of the Tournaisian succession, medium-bedded limestone with interbedded shales and marls. **D:** Unit 2, Tournaisian-Visean boundary. **E:** Upper part of unit 3, alternation of medium bedded limestone with black shales and dark marls. **F:** Coral horizon in middle part of unit 3. **G:** Solitary coral in middle part of unit 3. **H:** Thick bedded shale in the upper part of the unit 4. **I:** Brachiopods in the upper part of the unit 4. **J:** The boundary of the Mobarak and Dorud formations.

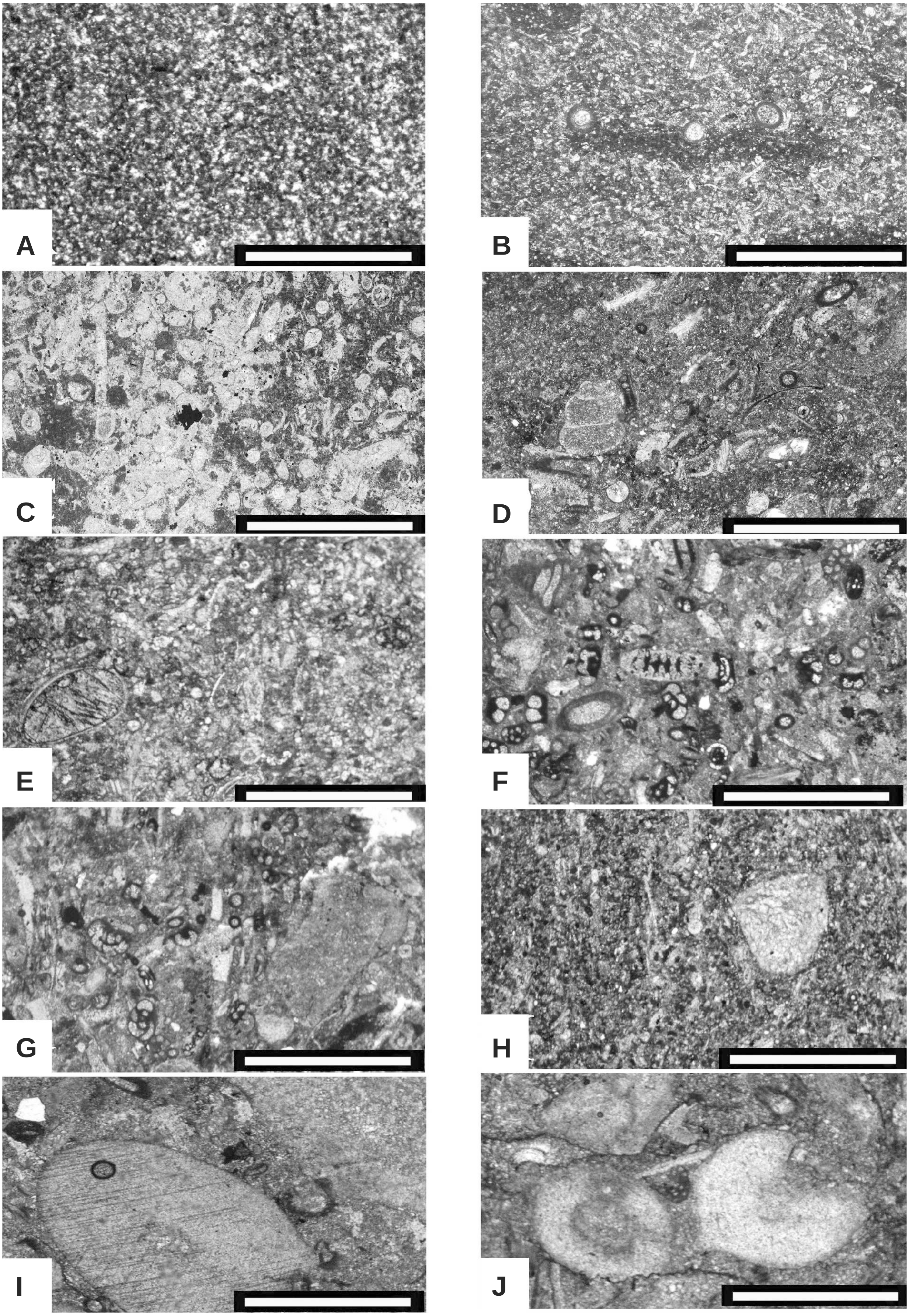

Figure 5. Thin-section images of the Mobarak Fm facies. **A:** Peloidal packstone. **B:** Bioturbated bioclastic wackestone/packstone. **C:** Green algal packstone. **D:** Gastropod bioclastic wackestone/packstone. **E:** Dolomitic bioclastic packstone. **F-G:** *Endothyra* packstone. **H:** Red algae(?) bioclastic packstone. **I-J:** Crinoidal packstone. Scale bar: 1 mm.

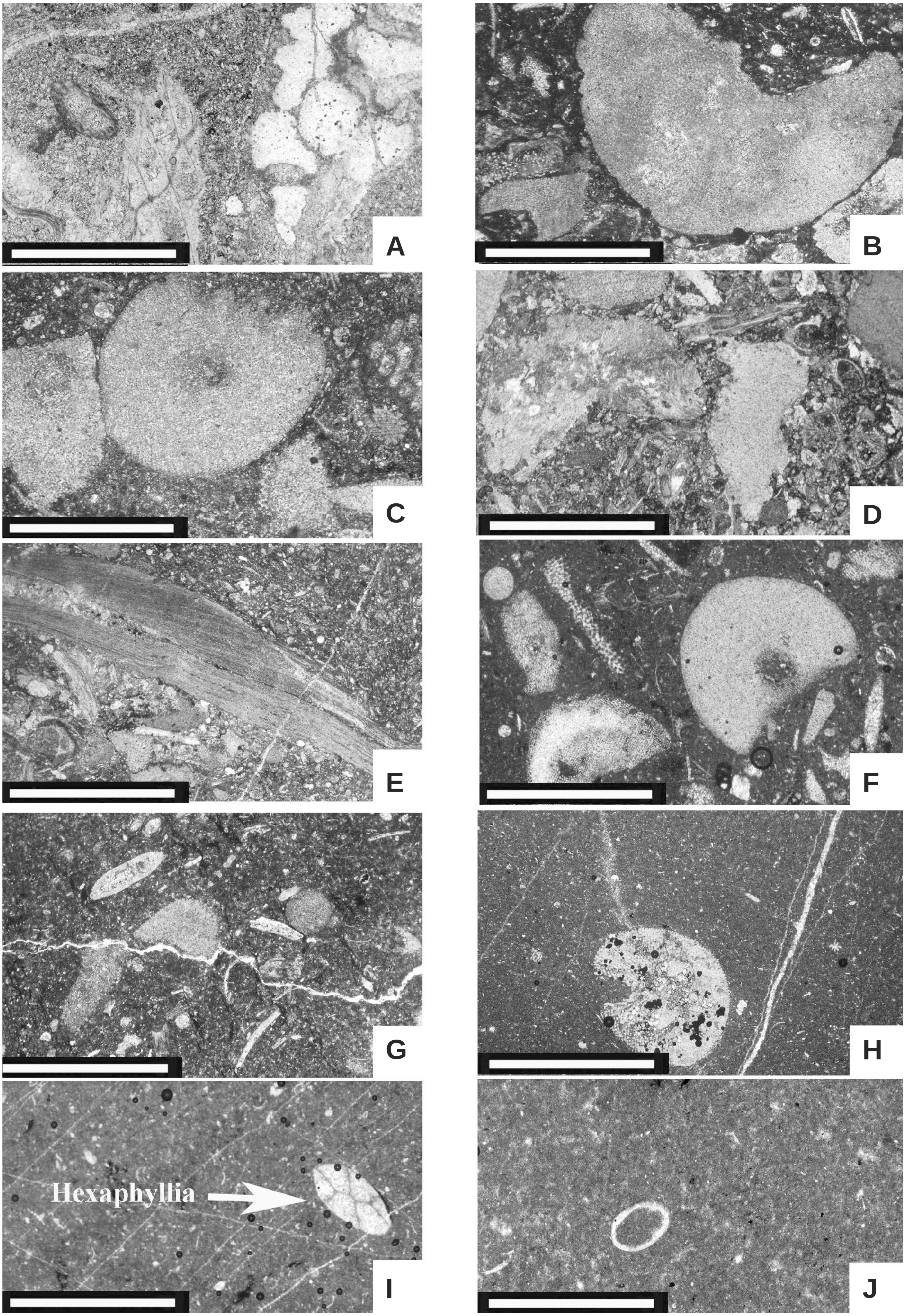

Figure 6. Thin-section images of the Mobarak Fm facies. **A:** Coral framestone. **B-C:** Bioclastic rudstone. **D-E:** Brachiopod bioclastic wackestone/packstone. **F:** Dolomitic bioclastic wackestone. **G:** Biolastic wackstone. **H-I:** Bioclastic mudstone/wackestone. **J:** Lime mudstone. Scale bar: 1 mm.

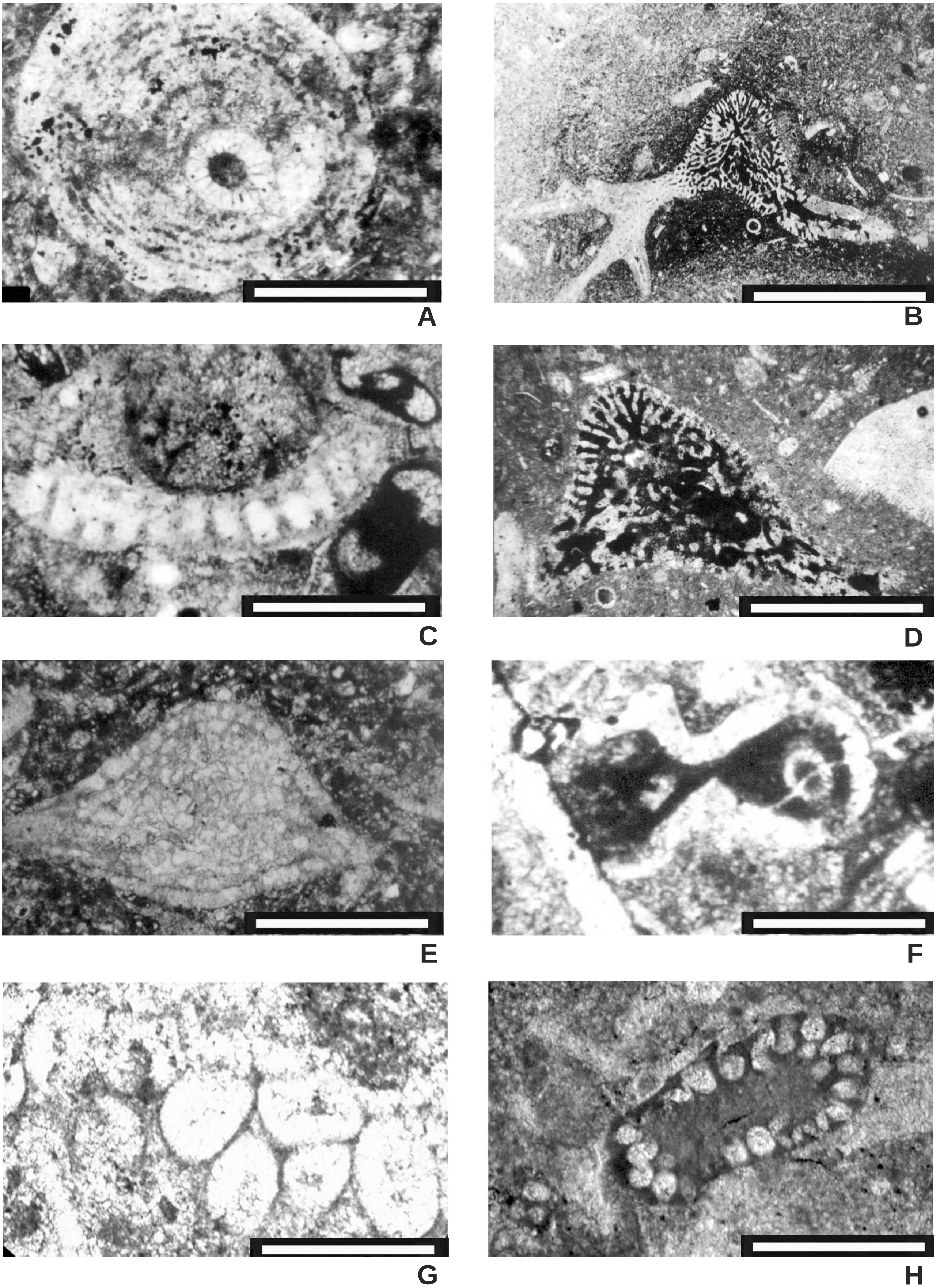

Figure 7. Calcareous algae fossils from the Mobarak Fm in the Kiyasar section. **A:** *Fourstonella fusiformis* with *Nanopora anglica* (center). **B-D:** *Epistacheoides* cf. *nephroformis.* **C:** *Palaeoberesella* cf. *lahuseni.* **E:** *Aoujgalia skimoensis.* **F:** *Evlania scabrosa.* **G:** *Koninckopora inflata.* **H:** *Atractyliopsis minima.*Scale bar: 1 mm.

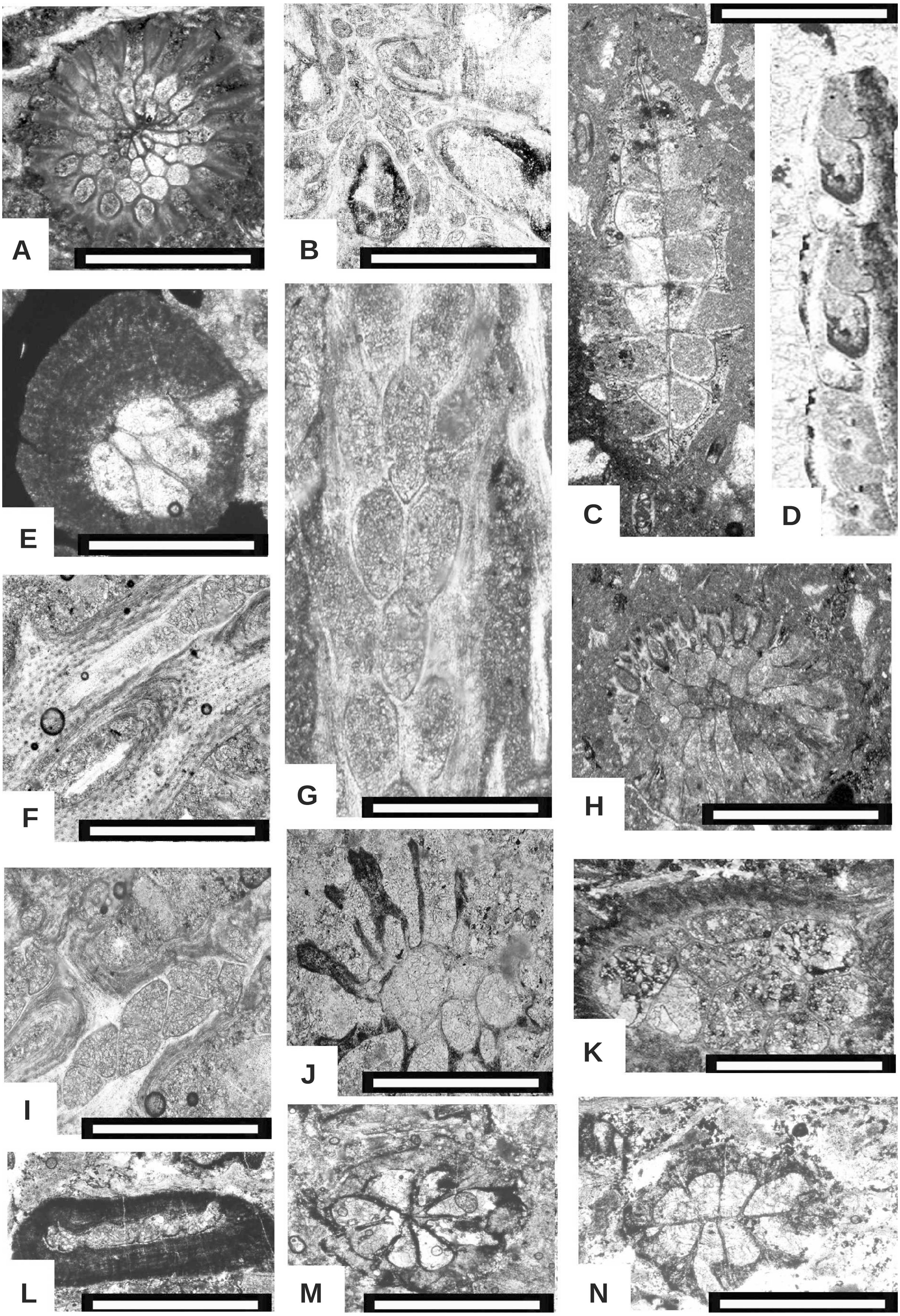

Figure 8. Bryozoan fauna from the Mobarak Fm in the Kiyasar section. **A:** *Nikiforovella* sp. **B, F, I, L:** *Spinofenestella subspeciosa.* **C:** *Sulcoretepora lophodes*. **D:** Fenestrata, longitudinal section along a branch cutting through short parallelogram-shape chambers. **E, G:** *Polypora remota.* **H:** *Streblotrypa (Streblotrypa)* sp. **J:** *Dyscritella* sp. **K:** *Admiranda ramosa.* **M, N:** *Pseudonematopora planatus.* Scale bar: 1 mm.

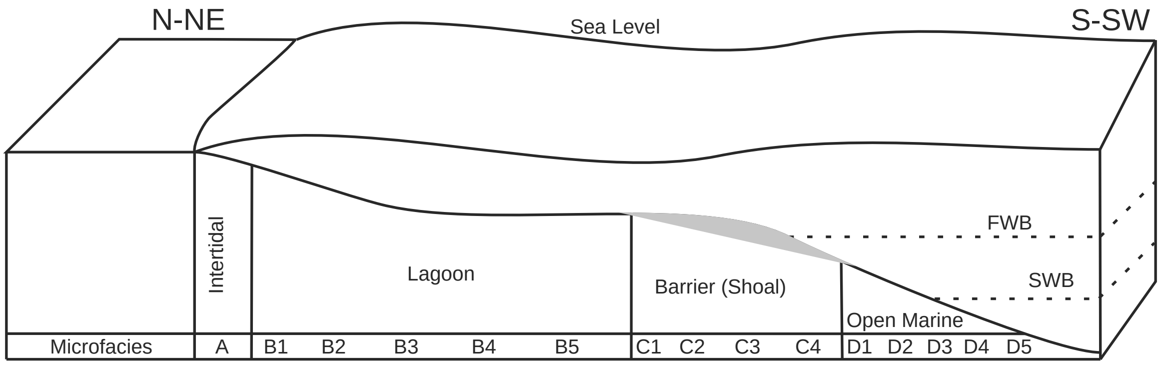

Figure 9. Depositional model for the Mobarak Fm carbonate platform in the Kiyasar area based on the results of the present paper.

Open marine facies

Brachiopod bioclastic wackestone/packstone (D1).- The skeleton fragments, especially of brachiopods and bryozoans, are numerous. There are also ostracods, which have delicate shells and fewer amounts of red algae(?) and foraminifera, the environmental energy lead to the collapse of small skeleton pieces and thereby mixing with bigger ones (Fig. 6D-E).

Dolomitic bioclastic wackestone (D2).- This facies contains allochems such as brachiopod shells, bryozoans and ostracod shells, in a matrix of microsparite (Fig. 6F). The orthochems and the margins of allochem pieces have been replaced by secondary dolomite. In this facies occur red algae(?), such as *Epistacheoides* cf. *nephroformis* Petryk & Mamet, 1972 (Figs. 7B, D). The following bryozoans were identified (Fig. 8): *Sulcoretepora lophodes* (Condra, 1902), *Streblotrypa* (*Streblotrypa*) sp., *Admiranda ramosa* Ariunchimeg, 1996, *Dyscritella* sp., *Polypora remota* Condra, 1902, *Spinofenestella subspeciosa* (Shulga-Nesterenko, 1955), *Pseudonematopora planatus* Wyse-Jackson, 1996, *Nikiforovella* sp. and *Stenophragmidium sparsitabulata* (Lee, 1912).

Bioclastic wackstone (D3).- In this microfacies, are present few crinoid fragments, brachiopods and fewer amounts of foraminiferal tests along with red algae(?) (Fig. 6 G). The orthochems are microsparitic. This facies should have been located below the storm wave base (Fig. 9).

Bioclastic mudstone/ wackestone (D4).- Allochems of this facies constitute less than 10% of the rock volume; they include crinoid debris, brachiopod shells and sponge spicules (Fig. 6H-I). The occurrence of the coral *Hexaphyllia* is conspicuous, and could be assumed it has been transported to the barrier environment by marine flows due to their small size. The orthochems are constituted of micrite which have been transformed into microsparite in some parts. This microfacies has been deposited in an outer ramp environment. The anaerobic conditions are characteristic of this environment.

Lime mudstone (D5).- This microfacies is poor in allochems, sponge spicules and ostracod shells float in the micritic matrix of micrite (Fig. 6J). This facies should have been deposited in a deeper environment than that of the facies D4, and has the same characteristics, including the dominant anaerobic conditions.

CONCLUSION

Based on the microscopic analysis, four facies belts have been recognized: (1) an intertidal facies belt, (2) a lagoonal facies belt, (3) a barrier (shoal) facies belt and (4) an open-marine facies belt (Fig. 9). The Lower Carboniferous succession can be interpreted as deposited in the form of a shallowing upward sequence on the carbonate ramp platform, in the passive margin of the Southern Palaeo-Tethys Ocean. The microfacies and depositional setting of the Lower Carboniferous carbonate platform represented by the Mobarak Fm in the Kiyasar section are described in detail for the first time. Field observations and laboratory investigation of the Lower Carboniferous succession in the Kiyasar section indicate similarities and differences with other sections of the Mobarak Fm which are located in the eastern and central Alborz Mountains. Generally, the Lower Carboniferous sequence in the Kiyasar section consists of thin to medium bedded limestone, dolomitic limestone, shaly and marly layers. There are differences between this section and other outcrops of the Mobarak Fm from the central and eastern Alborz Mountains which can be referred to the existence of thick-bedded oolitic limestones in those sections, but in the studied section, this facies was not observed. The peritidal facies have a limited extension in the Kiyasar section in respect to the central Alborz. Moreover, some sub-facies of open marine conditions which contain mud mounds and turbidite deposits that are dominant in eastern Alborz (Mosaddegh 2000) have not observed in the Kiyasar section. The lagoonal facies of this area are more similar to those of other otucrops of the Mobarak Fm in the eastern and Central Alborz.

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REFERENCES

Ariunchimeg Y., 1996. New Lower Carboniferous Bryozoans from Mongolia. *Paleontological Journal* **30**: 191-197.

Assereto R., 1963. The Paleozoic formations in Central Elburz (Iran). (preliminary note). *Rivista Italiana di Paleontologia e* Stratigrafia **69**: 503–543.

Bozorgnia F., 1973. Paleozoic foraminiferal biostratigraphy of central and east Alborz Mountains, Iran. *Publication* of *national Iranian Oil Company (*geological Laboratory*)* **4**: 1-185.

Brady H.B., 1876. A Monograph of Carboniferous and Permian Foraminifera (The genus *Fusulina* excepted). *Palaeontographical Society* **30**: 1-166.

Brenckle P.L., Gaetani M., Angiolini, L. & Bahrammanesh M., 2009. Refinements in biostratigraphy ,chronostratigraphy, and paleogeography of the Mississippian (Lower Carboniferous) Mobarak Formation, Alborz Mountains, Iran. *GeoArabia* **14**: 43-78.

Condra G. E., 1902. New Bryozoa from the Coal Measures of Nebraska. *The American Geologist* **30**: 337-359.

Devuyst F.X., Hance L., Hou H., Wu X., Tian S., Coen M. & Sevastopulo G., 2003. A proposed Global Stratotype Section and Point for the base of the Viséan Stage (Carboniferous): the Pengchong section, Guangxi, South China. *Episodes* **26**: 105-115.

Dunham R.J., 1962. Classification of carbonate rocks according to depositional texture. *American Association of Petroleum Geologists Memoir* **1**: 108-121.

Embry A. F. & Klovan J. E., 1972. Absolute water depth limits of late Devonian paleoecological zones. *Gologische Rundschau* **61**: 672–686.

Falahatgar M., 2008. Microbiostratigraphy and microfacies of the Mobarak Formation (Lower Carboniferous) in Kiyasar section, South-East of Sari, Northern Iran. Unpublished MSc. thesis, 123 p. *Payame Noor University of Shiraz*, Iran.

Flügel E., 2004. Microfacies analysis of limestones, analysis interpretation and application. Berlin. Springer-Verlag, 976 p.

Gaetani M., 1968. The geology of the upper Djadjerud and Lar Valleys (North Iran) II. Palaeontology. Lower Carboniferous brachiopods from Central Elburz, Iran. *Rivista Italiana di Paleontologia e Stratigrafia* **74:** 665-744.

Gaillot J. & Vachard D., 2007. The Khuff Formation (Middle East) and time-equivalents in Turkey and South China*:* biostratigraphy from Capitanian to Changhsingian times (Permian), new foraminiferal taxa, and palaeogeographical implications. *Coloquios de Paleontología* **57**: 37–223.

Gallagher S., 1998. Controls on the distribution of calcareous Foraminifera in the Lower Carboniferous of Ireland. *Marine Micropaleontology* **34**: 187–211.

Horbury A.D., 1992. A late Dinantian Peloid cementstone-palaeoberesellid buildup from North Lancashire, England. *Sedimentary Geology* **79**: 117-137.

Koninck L.G. de, 1842. Description des animaux fossiles qui se trouvent dans le terrain Carbonifere de Belgique. Dessain Liege **3**: 650 p.

Lasemi Y. & Ghouchi-Asli E. 2006 Carbonate and siliciclastic storm deposits within the Upper Devonian Geyrud Formation in Touyeh area, eastern Alborz, northern Iran. *Abstracts of the Carboniferous Conference Cologne*, Cologne, p. 5.

Lee G.W., 1912. The British Carboniferous Trepostomata. *Memoirs of the Geological Survey of Great Britain* **1**: 135-195.

Madi A., Bourque P.A. & Mamet B., 1996. Depth-related ecological zonation of a Carboniferous carbonate ramp, Upper Visean of Bechar Basin, Western Algeria. *Facies* **35**: 59–80.

Mahari R., 1992. Microfacies and sedimentary environment of the Mobarak Formation (Eastern Tehran), Unpublished MSc. Thesis, 123 p., *Islamic Azad University, Tehran branch*, Iran.

Mamet B. & Roux A., 1978. Algues viseennes et namuriennes du Tennessee (Etats-Unis): *Revue de Micropaleontologie* **21**: 68-97.

Mamet B. & Rudloff B., 1972. Algues carbonifères de la partie septentrionale de l'Amerique du Nord. *Revue de Micropaleontologie,* **15**: 75-114.

Möller V.von., 1879. Die Foraminiferen der russischen Kohlenkalk. *Memoires de l'Academie Imperiale des Sciences de Saint-Petersbourg* **27**: 1-131.

Mosaddegh H., 2000. Microfossils, Microfacies, Sedimentary Environment and Sequence Stratigraphy of the Mobarak Formation in Central Alborz. Unpublished Ph.D. thesis, 269 p., *Tehran Teacher Training University*, Iran.

Mosaddegh H., 2003. Microbiostratigraphy of Mississippian (Lower Carboniferous) strata (Mobarak Formation) in Central Alborz, North of Iran. *Abstracts of the Fifteen International Congress on Carboniferous and Permian Stratigraphy*, Utrecht, p. 360-361.

Mosaddegh H., Rahimi B. & Aharipour R., 2006. Sequence Stratigraphy and Depositional Environment of the Lower to Middle Carboniferous Strata (Mobarak and Ghesel-Ghal'eh formations) in Central and East Alborz, North of Iran. *Abstracts of the Carboniferous Conference Cologne,* Cologne, p. 89-90.

Petryk A.A. & Mamet B., 1972. Lower Carboniferous algal microflora, southwestern Alberta. *Canadian Journal of Earth Sciences* **9**: 767-802.

Shulga-Nesterenko M.I., 1955. Kamennougolnye mshanki Russkoi Platformy [Carboniferous Bryozoa of the Russian Platform]. *Trudy paleontologicheskogo Instituta Akademii Nauk SSSR* **57**: 1-157.

Skompski S., 1986. Upper Viséan calcareous algae from the Lublin Coal Basin. *Acta Geologica Polonica* **36**: 251-280.

Tucker M.E. & Wright V.P., 1990. Carbonate sedimentology. Oxford, Blackwell Scientific Publications. 482 p.

Vachard D., 1981. Tethys et Gondwana au Paléozoïque supérieur, les données afghanes: biostratigraphie , micropaléontologie, paléogéographie. *Documents et Travaux de l'Institut Géologique Albert de Lapparent* **2**: 1-463.

Vachard D., 1996. Iran. *In* R.H. Wagner, C.F. Winkler Prins, & L.F. Granados (*eds.*): Carboniferous of the World **3**: 491-513.

Vachard D. & Cózar P., 2010. An attempt of classification of the Palaeozoic *incertae sedis* Algospongia. *Revista Española de Micropaleontología* **42**: 129-241.

Versteegh G. J. M., Servais T., Streng M., Munnecke A. & Vachard D., 2009. A discussion and proposal concerning the use of the term calcispheres. *Palaeontology* **52**: 343-348.

Wilson J. L., 1975. Carbonate Facies in Geologic History. Springer-Verlag, New York. 471 p.

Wood A., 1964. A new Dasycladacean alga, *Nanopora,* from the Lower Carboniferous of England and Kazakhstan. *Palaeontology* **7**: 181-185.

Wray J. L., 1977. Calcareous Algae. Developments in Paleontology and Stratigraphy. Amsterdam: Elsevier **4**: 185 p.

Wyse-Jackson P.N., 1996. Bryozoa from the Lower Carboniferous (Visean) of County Fermanagh, Ireland. *Bulletin of the Natural History Museum, Geology Series* **52**: 119-171.