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CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY OF BAGHAMSHAH FORMATION IN EASTERN IRAN, LUT BLOCK (BIRG SECTION)

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ABSTRACT – Biostratigraphic studies of the Baghamshah Formation from the Birg section in the northwest of Birjand (Lut Block) are done here for the first time based on the calcareous nannofossils. In the studied section, 82 samples were taken, and smear slides were prepared. The examination of the collected samples resulted in the identification of 65 calcareous nannofossil and 11 didemnid ascidian spicules species belonging to 38 genera corresponding from CC1 to CC4b biozones with the age of early Berriasian to early Hauterivian, according to the Sissingh biozonation. The calcareous nannofossil assemblages are dominated by the following genera: *Watznaueria*, *Nannoconus*, *Conusphaera*, and *Cyclagelosphaera*.

Keywords: Birjand, Baghamshah Formation, biozonation, biostratigraphy, Early Berriasian, Early Hauterivian.

RESUMO – Estudos bioestratigráficos da Formação Baghamshah da seção Birg no noroeste de Birjand (Lut Block) são descritos aqui pela primeira vez com base nos nanofósseis calcários. No setor estudado, foram retiradas 82 amostras e preparadas lâminas de esfregaço. O exame de amostras coletadas resultou na identificação de 65 espécies de nanofósseis calcários e 11 espécies de espículas de ascídia didenídeos pertencentes a 38 gêneros correspondentes às biozonas CC1 a CC4b com a idade do início de Berriasiano ao início de Hauteriviano, de acordo com a biozonação de Sissingh. As associações de nanofósseis calcários são dominadas pelos seguintes gêneros: *Watznaueria*, *Nannoconus*, *Conusphaera* e *Cyclagelosphaera*.

Palavras-chave: Birjand, Formação Baghamshah, biozonação, bioestratigrafia, Berriasiano Inferior, Hauteriviano Inferior.

INTRODUCTION

Calcareous nannofossils biostratigraphy is a powerful tool that gives us instrumental data in the age determination of Jurassic and Lower Cretaceous marine sections. By paying attention to the stratigraphic value of calcareous nannofossils for age determination of sedimentary beds, a sequence of marine strata of the Baghamshah Formation was selected and sampled in eastern Iran for nanno-stratigraphical studies.

Stöcklin (1961) and Stöcklin *et al*. (1965) described the Baghamshah Formation for the first time in the east of Tabas city (in central Iran). Researchers performed several studies on Baghamshah Formation. The investigations on the Baghamshah Formation biostratigraphy belong to Alavi-Naini (1972) and Seyed-Emami *et al*. (1997, 1998, 2002), based on ammonites. In some areas, an age ranging from middle-late the Bathonian to early Callovian was established, reaching middle Callovian. Furthermore, according to recent studies on the Baghmeshah Formation by Kallanxhi *et al*. (2015, 2016) in Damghan area (considering calcareous nannofossils and ammonites), the age of this Formation is determined from lower to middle Callovian. The Baghamshah Formation palynomorphs were investigated by Hashemi-Yazdi *et al*. (2015) which collectively denoted a Middle Jurassic age. Mukherjee & Fürsich (2014) studied the brachiopods of this formation, and the age of the Baghmshah Formation was

determined to be Bathonian to Lower Callovian. Pandey & Fürsich (2003) studied the corals of these sediments. According to this study, the age of this formation is considered to be Bathonian–Middle Callovian.

The above-mentioned studies show nonsynchronous ages for this formation. Some studies were done on the calcareous nannofossils of the Baghamshah Formation in Tabas Block. They show fundamental changes in the age of this formation. Consequently, the Birg section was selected and studied to introduce surveying calcareous nannofossils and age determination of the Baghamshah Formation in this section for the first time. This study aims to investigate the biostratigraphy and the exact age determination of the Baghamshah Formation in eastern Iran (Lut Block) based on calcareous nannofossils.

GEOLOGICAL SETTING

As mentioned above, for the first time, the Baghamshah Formation in the Birg section was measured and investigated based on calcareous nannofossils. The studied section is located in the eastern part of Lut block (Iran), and northwest of Birg Mountain (Figures 1 and 2). The Lut block is an important structural unit of Central Iran and eastern Iran (Figure 1).

Lut block is located in the west of the Zabol-Baluch Zone. This block has 900 km long from north to south. It is surrounded by the fault of Dorooneh from the north and by Jazmourian's pit in the south, which is located in the west of Baluchistan. It is also separated from the Flysch Zone by the Nehbandan fault in the east, whereas the western boundary

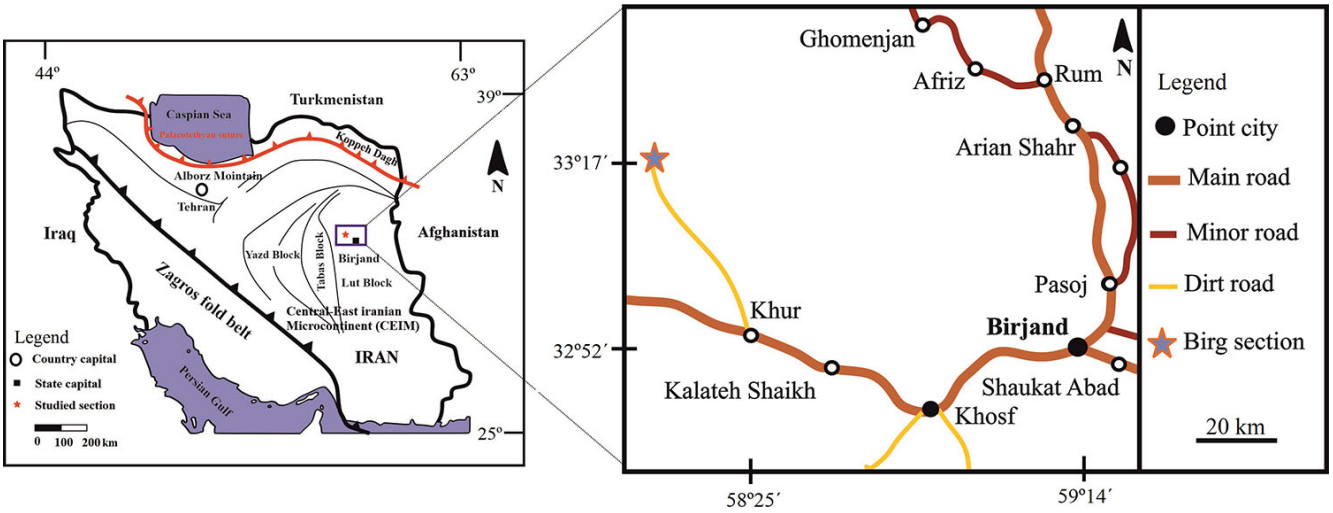

Figure 1. General map of Iran including main tectonic units and the location of the studied area.

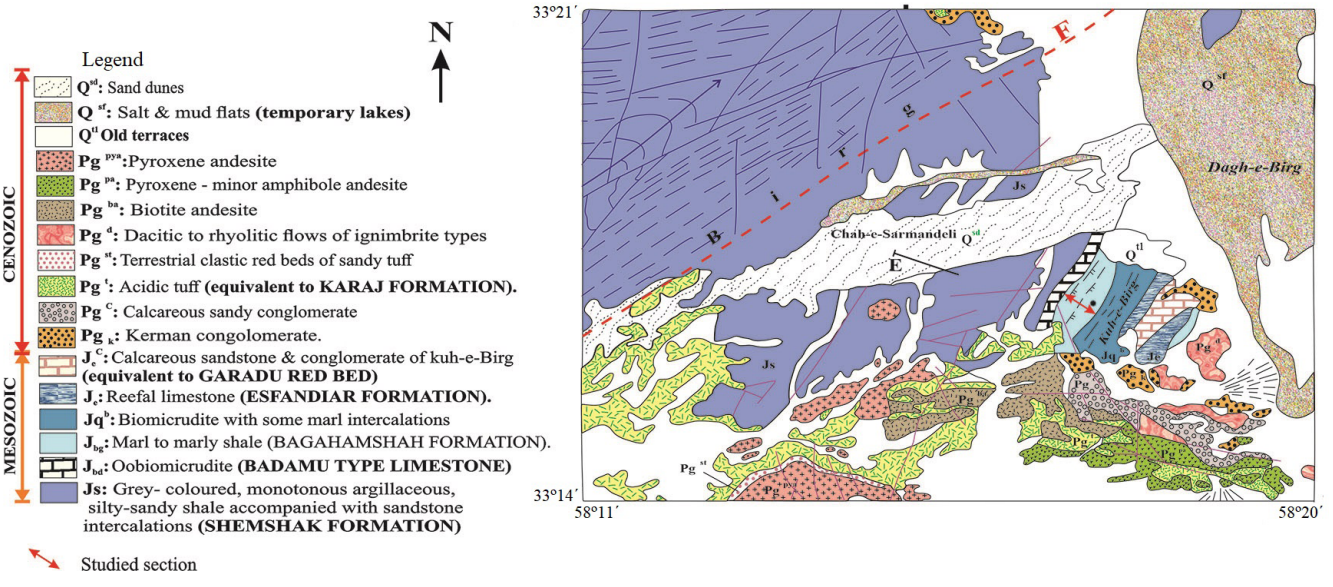

Figure 2. Geological map of the area (part of the geological map 1:100 000 Sarghanj; Lotfi, 1995. Redrawn after Geological Survey of Iran).

with Central Iran is the Nayband fault and Shotori Mountains (Ghorbani, 2013).

The studied section is located in 33º17'N and 58º18'E coordinates, northwest of Khur village, about 85 km from northwest of Birjand city, east of Iran (Figure 1). The Baghamshah Formation is about 830 m thick in this region which consists of gray argillaceous limestone, calcareous shale, pale-green marl, and sandy limestone. The Baghamshah Formation overlies the Badamu Formation which is conformably by the Qal,eh Dokhtar Formation (Figure 3).

MATERIAL AND METHODS

A total of 82 samples were collected from different exposures of the Baghamshah Formation in Birg section (formed from gray argillaceous limestone, calcareous shale, pale- green marl, and sandy limestone) (Figure 4). Calcareous nannofossils were prepared in 82 smear slides using standard techniques described by Bown & Young (1998). They were analyzed under crossed Nicols equipped with gypsum plate by Olympus BX50 light microscopy at 1250x magnification. Digital images of nannofossil specimens were taken with a Sony digital camera. All calcareous nannofossil specimens were identified by taxonomic criteria of Thierstein (1976), Perch-Nielsen (1985), Crux (1989), Bown (1998), Varol (2006), Young (2008). Images of some important nannofossils are illustrated in Figures 5 and 6. Biostratigraphic data were interpreted by Sissingh's zonation scheme commonly used for the lower and upper Cretaceous in the Tethyan area (Table 1). Rock samples and smear slides are stored at the Paleontology Laboratory of Geology Department, Faculty of Science in Ferdowsi University, Mashhad City (Iran).

RESULTS AND DISCUSSION

This study discusses the biostratigraphy of the calcareous nannofossils of the Baghamshah Formation in the Birg section in eastern Iran. In the studied samples, most of the calcareous nannofossils had a low abundance and preservation. In total, 76 species were identified with 11 species belonging to didemnid ascidian spicules. According to the identified calcareous nannofossils in Birg section, dominant nannofossil assemblages included *Nannoconus*, *Conusphaera*, and *Cyclagelosphaera* genera, and Didemnid ascidian spicules. These genera observed through studying section (Figure 4). The most common and diverse genera within the assemblage are *Nannoconus* spp. (21 species of one genus). Also, some species are present in assemblage which sporadically occurred with a relatively low percentage.

The other identified nannofossils in the studied samples are: *Faviconus multicolumnatus*, *Palaeomicula maltica*, *Diazomatolithus lehmanii*, *Polycostella beckmannii*, *P. senaria*, *Hexalithus noeliae*, *Rotelapillus crenulatus*, *Helenea chiastia, Ethmorhabdus hauterivianus*, *Lithraphidites carniolensis*, *Assipetra infracretacea*, *Cruciellipsis cuvillieri*, *Micrantholithus hoschulzii*, *Rucinolithus wisei*, *Diadorhombus rectus*, *Tubodiscus jurapelagicus*, *Haquius circumradiatus*, *Speetonia colligata*, *Discorhabdus biradiatus*, *Eiffellithus striatus*, *Lithraphidites bollii*, *Zeughrabdothus rectus*, *Kokia borealis*, *Cretarhabdus loriei, Calcicalatina oblongata* and *Retecapsa angustiforata*.

We also identified some species that were reworked from older deposits. These species include *Pseudoconus enigma*, *Nannoconus compressus*, and *Ansulasphaera covingtonii*. Eleven didemnid ascidian spicules of eight genera were found in studying samples. These species include: *Velasquezia praegothica*, *Acinodidemnum lineola*, *Fusellinus insolitus*, *Fusellinus elongatus*, *Paleodidemnum metaxy*, *P. pseudoacutus*, *P. procerus*, *Bactrolithus delicarus*, *Cephalodidemnum carenon*, *Disechinatus carinatus and Geminitrabalis depressus*.

Among the identified species in Birg section, *Nannoconus steinmannii*, *Retecapsa angustiforata*, *Calcicalathina oblongata*, *Cretarhabdus loriei*, and *Lithraphidites bollii* are biostratigraphical markers of the calcareous nannofossils zonation. Considering the first appearance of marker and associated nannofossils, CC1–CC4b biozones were recognized based on Sissingh (1977) nannofossil biozonation scheme. Early Berriasian to Early Hauterivian agewas assigned to the studied deposits based on Tethyan calcareous nannofossil zonations. The Figure 4 shows the biostratigraphy and lithostratigraphy of the Baghamshah Formation in Birg section, while the biozonation scheme for the Early Berriasian–Late Hauterivian interval is illustrated in Table 1.

BIOSTRATIGRAPHY

According to Brönnimann (2003), both coccoliths and nannoliths are useful and reliable zonal markers for biostratigraphic schemes, allowing detailed zonations for

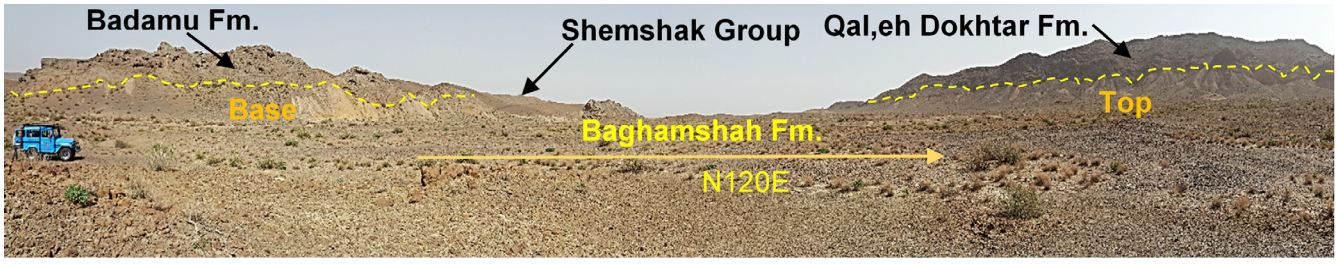

Figure 3. Overview of the studied area.

Table 1. The nannofossil zonation and events identified for the Baghmshah Formation in the Birg section.

Series	Stage		Sissingh (1977)	Applegate & Bergen (1988)		Bralower *et al*. (1989)		This study
Lower Cretaceous	Hauterivian	late	CC5 *Lithraphidites bollii*			Lo *Crucicllipsis cuvillieri*	NC5a *N. bucheri*	CC4 *Cretarhabdus loriei*
			Lo *Speetonia colligata*	Lo *Speetonia colligata*	CC4b *Speetonia colligata* Fo *L. bollii*			CC4b Fo *L. bollii*
		early	CC4 *Cretarhabdus loriei* Fo *Cretarhabdus loriei*	CC4 *Cretarhabdus loriei* Fo *Eiffellithus striatus*	CC4a *E. striatus*	NC4 *Crucicllipsis cuvillieri*	NC4b *L. bollii* NC4a *Calcicalathina oblongata*	CC4a Fo *Cretarhabdus loriei*
	Valanginian	late	CC3 *Calcicalathina oblongata*	CC3 *Calcicalathina oblongata*	CC3 *E. windii* Fo *E. windii*	Lo *Tubodiscus vereneae*		CC3 *Calcicalathina oblongata*
		early	Fo *Calcicalathina oblongata*	Fo *Calcicalathina oblongata*	CC3a *T. verenae*	NK-3 *Calcicalathina oblongata* Fo *Calcicalathina oblongata*	NK-3B *T. verenae* Lo *R. wisei* NK-3A *R. wisei*	Fo *Calcicalathina oblongata*
	Berriasian	late	CC2 *Stradneria crenulata* Fo *Cretarhabdus crenulatus*	CC2 *Retecapsa angustiforata* Fo *Retecapsa angustiforata*		NK-2 *Cretarhabdus angustiforatus* Fo *Cretarhabdus angustiforatus*	NK-2B *P. fenestrata* Fo *P. fenestrata* NK-2A *A. infracretacea*	CC2 *Stradneria crenulata*
		early	CC1 *Nannoconus steinmannii* Fo *Nannoconus steinmannii*	CC1 *Nannoconus steinmannii* Fo *Nannoconus steinmannii*		NK-1 *N. steinmannii steinmannii* Fo *N. steinmannii steinmannii*		Fo *Retecapsa angustiforata*
						NJK *Microstaurus chiastius*	NJK-D *N. steinmannii minor* Fo *N. steinmannii minor* NJK-C *R. laffittei*	CC1 *Nannoconus steinmannii steinmannii* Fo *Nannoconus steinmannii*

both the Jurassic and Cretaceous. Calcareous nannofossils are usually excellent marine markers to accurate biostratigraphy of the Mesozoic and Cenozoic ages. Indeed, in some studies, the most significant stratigraphic data were obtained by the analysis of calcareous nannofossils (*e.g*., Halásová *et al*., 2012).

In the studied Interval, the CC1 – CC4 calcareous nannofossil zones of Sissingh (1977) were recognized in Birg section in eastern Iran. These biozones cover the Early Berriasian to Early Hauterivian in this section. Species appearance like *Nannoconus colomii*, *N. dolomiticus*, *N. globulus*, *N. steinmannii minor, and N. steinmannii steinmannii with Lithraphidites carniolensis, Polycostella senaria* and *Polycostella beckmannii* at the base of this section was observed, corresponding to the CC1 Calcareous Nannofossil Zone (Sissingh, 1977). *Lithraphidites carniolensis* is a species that appears near the base of the Cretaceous located in the lowest part of Berriasian.

Moreover, the first appearance of species as *Rucinolithus wisei* and *Eiffellithus windii* at the base of CC3 Zone could confirm the Valanginian age of this part of Birg section.

The proposed biozones are arranged from the base to the top, and they are *Nannoconus steinmannii* Zone (CC1), *Cretarhabdus crenulatus* Zone (CC2), *Calcicalathina oblongata* Zone (CC3), *Cretarhabdus loriei* Zone (CC4).

Nannoconus steinmannii Zone (CC1)

Sissingh (1977) proposed the *Nannoconus steinmannii* Zone. This zone was explained as the interval from the first occurrence (**FO**) of *Nannoconus steinmannii steinmannii* to FO of *Cretarhabdus crenulatus* by Worsley (1971), emended by Thierstein (1971) and Sissingh (1977). Its age is Early Berriasian.

This zone is identified in the lower part of the Baghamshah Formation in Birg section. The earliest appearance of *Nannoconus steinmannii* subsp. *steinmannii* in the section is

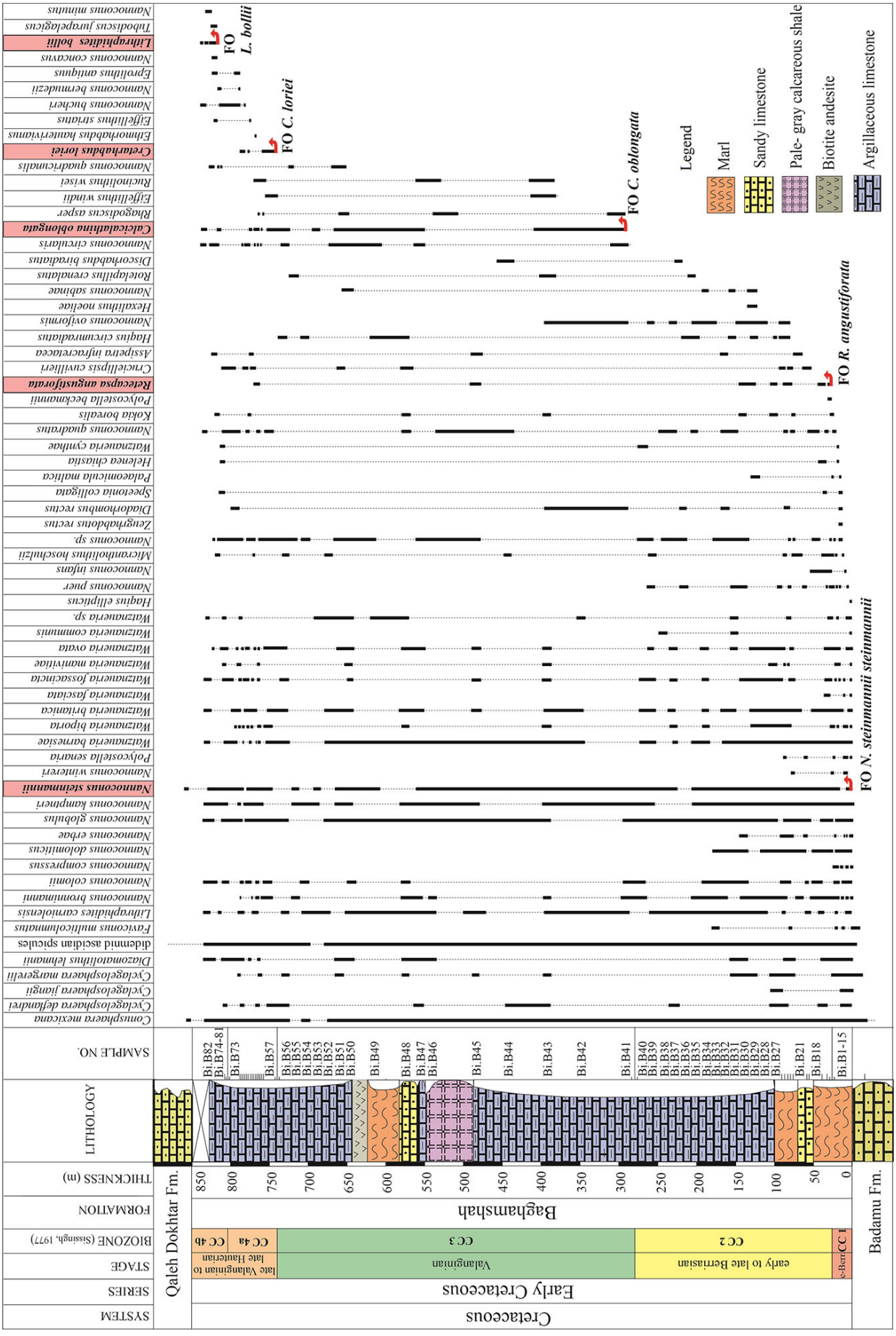

Figure 4. Distribution chart of calcareous nannofossils in the Birg Section.

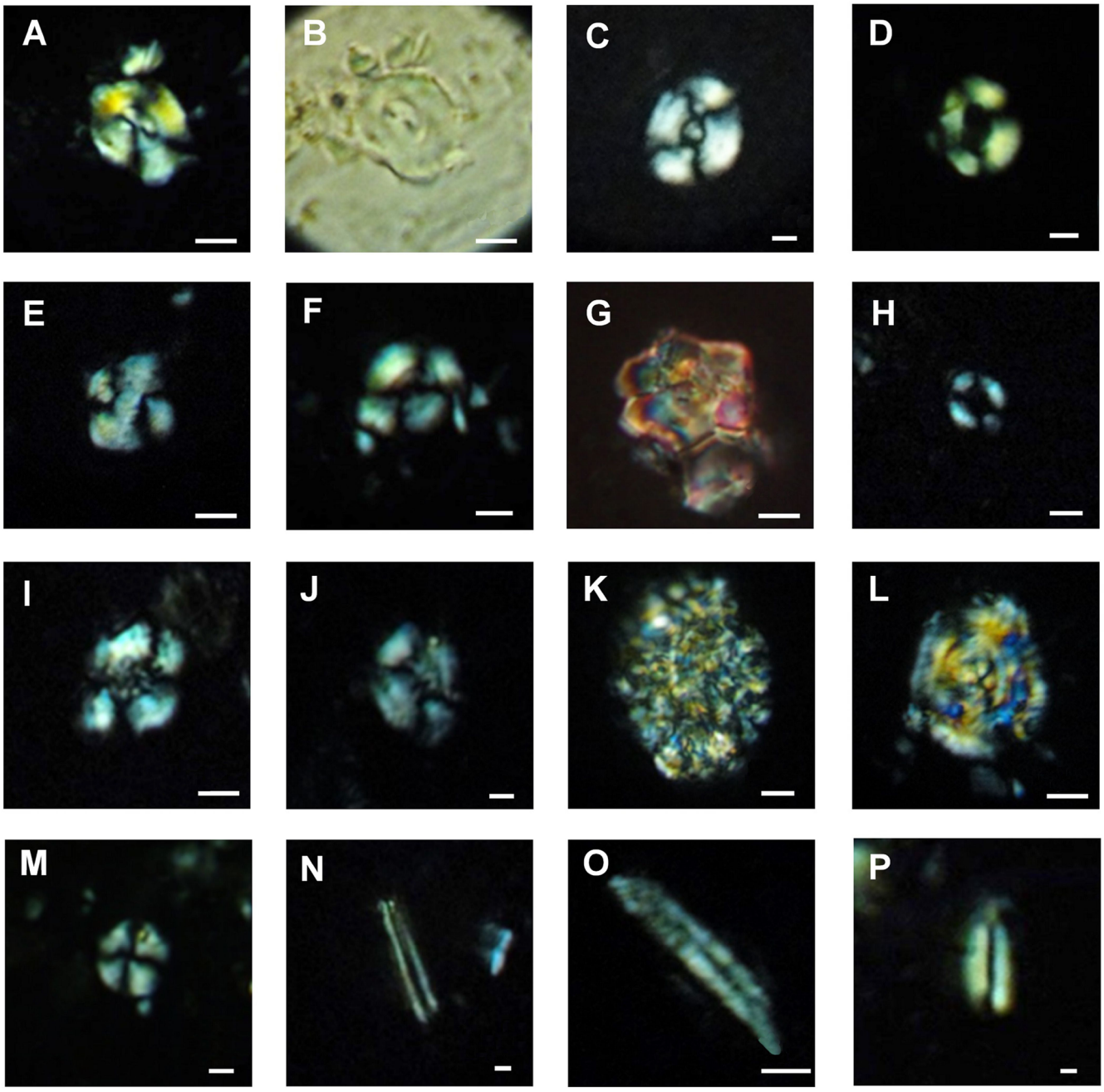

Figure 5. Calcareous nannofossils from the Birg section. **A**, **B**, *Watznaueria barnesiae* Perch-Nielsen, 1968; sample Bi.B12. **C**, *Watznaueria britannica* (Stradner, 1963) Reinhardt, 1964; sample Bi.B17. **D**, *Watznaueria ovata* Bukry, 1969; sample Bi.B5. **E**, *Watznaueria biporta* Bukry, 1969; sample Bi.B57. **F**, *Watznaueria fossacincta* (Black, 1971) Bown *in* Bown & Cooper, 1989; sample Bi.B22. **G**, *Hexalithus noeliae* Loeblich & Tappan, 1966; sample Bi.B29. **H**, *Diazomatolithus lehmanii* Noël, 1965; sample Bi.B72. **I**, *Cretarhabdus loriei* Gartner 1968, according to Verbeek 1977; sample Bi.B57. **J**, *Cruciellipsis cuvillieri* (Manivit, 1966) Thierstein, 1971; sample Bi.B65. **K**, *Calcicalathina oblongata* (Worsley, 1971) Thierstein, 1971; sample Bi.B72. **L**, *Cyclagelosphaera deflandrei* (Manivit, 1966) Roth, 1973; sample Bi.B1. **M**, *Cyclagelosphaera margerelii* Noël, 1965; sample Bi.B6. **N**, *Lithraphidites carniolensis* Deflandre, 1963; sample Bi.B45. **O**, **P**, *Lithraphidites bollii* (Thierstein, 1971) Thierstein, 1973; sample Bi.B81. Scale bars = 2 μm.

in the sample about 1 m from the base, and the last appearance of this species is in the sample 82 at 830 m. In addition to the marker species, it is also dominated by *Watznaueria barnesiae*, *W. britannica*, *W. ovata*, *W. fossacincta*, *Cyclagelosphaera margerelii*, *C. mexicana*, *Nannoconus colomii*, *N. dolomiticus*, *N. globulus*, *N. steinmannii minor*, *N. kamptneri* and with *Lithraphidites carniolensis*. Perch-Nielsen (1985) believes that the first appearance of *Lithraphidites carniolensis* indicates the Cretaceous base and the Berriasian lowest part. Therefore, the earliest appearance of *L. carniolensis* and *N. steinmannii steinmannii* in the first sample of the studied section confirms the Early Berriasian age for the base of Birg section. The FO of *N. steinmannii* and the lower part of this zone is unknown. Therefore, its exact thickness was

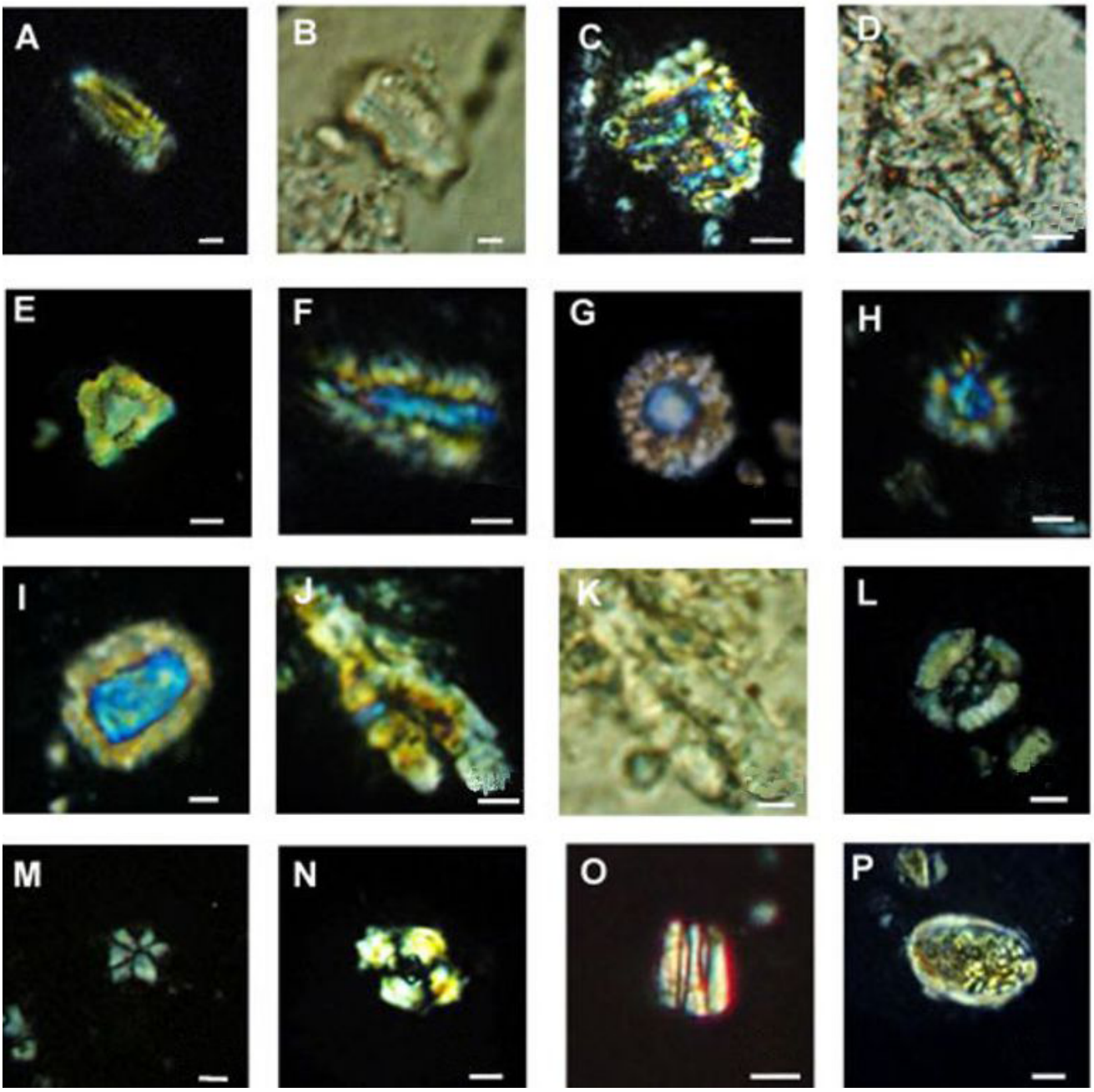

Figure 6. Calcareous nannofossils from the Birg section. **A**, **B**, *Nannoconus steinmannii* subsp. *minor* (Kamptner, 1931) Deres & Achéritéguy, 1980; **A**, sample Bi.B27; **B**, sample Bi.B20. **C**, **D**, *Nannoconus steinmannii* subsp. *steinmannii* Kamptner, 1931; **C**, **D**, sample Bi.B64. **E**, *Nannoconus wintereri* Bralower & Thierstein *in* Bralower *et al*., 1989; sample Bi.B23. **F**, *Nannoconus kamptneri* subsp. *kamptneri* Brönnimann, 1955; sample Bi.B46. **G**, *Nannoconus globulus* subsp. *globulus* Brönnimann, 1955; sample Bi.B15. **H**, *Nannovonus bucheri* Brönnimann, 1955; sample Bi.B82. **I**, **J**, *Nannoconus bermudezii* Brönnimann, 1955; **I**, **J**, sample Bi.B70. **K**, **L**, *Retecapsa angustiforata* Black, 1971; **K**, sample 15; **L**, sample Bi.B17. **M**, *Rucinolithus wisei* Thierstein, 1971; sample Bi.B47. **N**, *Helenea chiastia* Worsley, 1971; sample Bi.B17. **O**, *Conusphaera mexicana* subsp. *Minor* Bown & Cooper, 1989; sample Bi.B29. **P**, *Rhagodiscus asper* (Stradner, 1963) Reinhardt, 1967; sample Bi.B46. Scale bars: A–I, L–P = 2 µm; J–K = 3 µm.

not determined. *Cretarhabdus crenulatus* species was not observed, hence according to Thierstein (1976) and Applegate & Bergen (1988), the FO of *Cretarhabdus crenulatus* was replaced by the FO of *Retecapsa angustiforata*. *Retecapsa angustiforata* range is from sample 15 (15 m) to sample 57 (~ 740 m). This zone is relatively equivalent to the CC1 zone from Applegate and Bergen 's zonation scheme (1988) (Table 1).

***Cretarhabdus crenulatus* Zone (CC2)**

Sissingh (1977) proposed the *Cretarhabdus crenulatus* Zone. The age of this zone is Late Berriasian to Early Valanginian (Perch-Nielsen, 1985). based on the Geological Time Scale (2012), the age of CC2 zone is Early to Late Berriasian (Ogg & Hinnov, 2012). This zone is the interval from the FO of *Cretarhabdus crenulatus* to the FO of *Calcicalathina oblongata*. The base of CC2 Zone is

determined by the FO of *Retecapsa angustiforata* (sample 14 at about 165 m) in this research. The FO of *Calcicalathina oblongata* species is recorded at about 280 m from the base of this section; thus, the thickness of this zone is around of 265 m. The most dominant species in this zone, besides the marker species, are *Watznaueria barnesiae*, *W. britannica*, *W. ovata*, *W. fossacincta*, *Cyclagelosphaera margerelii*, *C. mexicana*, *Nannoconus dolomiticus*, *N. broennimannii*, *N. colomii*, *N. globulus*, *N. kamptneri*, *N. steinmannii minor*, *N. steinmannii and with Lithraphidites carniolensis*. This zone is relatively equivalent to the CC2 zone from Applegate & Bergen (1988) zonation scheme (Table 1).

***Calcicalathina oblongata* Zone (CC3)**

Thierstein (1971) proposed this zone and emended by Sissingh (1977). The age of this zone is Late Valanginian (Perch- Nielsen, 1985). Its age in the Geological Time Scale (2012) is Valanginian (Ogg & Hinnov, 2012). It includes the Interval from the FO of *Calcicalathina oblongata* to the FO of *Cretarhabdus loriei*. In addition to the marker species, the most dominant species in this zone are *Watznaueria barnesiae*, *W. britannica*, *W. fossacincta*, *Cyclagelosphaera mexicana*, *Nannoconus kamptneri*, *N. steinmannii*, *L. carniolensis*. *Calcicalatina oblongata* appeared at sample 41 at about 280 m from the base of studied section. The FO of *C. loriei* is at sample 57 at about 740 m from the base and marks the end of this zone. Therefore, the thickness of this biozone is 460 m.

Applegate & Bergen (1988) believe that the first appearance of *Eiffellithus windii* indicates the base of the CC3b nannofossil subzone. Also, another bioevent, as the Last Occurrence (**LO**) of *Rucinolithus wisei* subdivides the NK3a/NK3b in the Bralower's (1989) scheme (Table 1). The FO of *E. windii* at sample 43 at 400 m from the base and LO of *R. wisei* at sample 64 at 775 m from the base could confirm Valanginian age for this part of section. This zone is relatively equivalent to the CC3 zone from Applegate & Bergen (1988) zonation scheme (Table 1).

***Cretarhabdus loriei* Zone (CC4)**

Sissingh (1977) proposed the *Cretarhabdus loriei* Zone. This age of this zone is Early Hauterivian (Perch-Nielsen, 1985), in the Geological Time Scale (2012) is Late Valanginian to Late Hauterivian (Ogg & Hinnov, 2012). This zone is identified from the FO of *Cretarhabdus loriei* to the LO of *Speetonia colligata* by Sissingh (1977). Thierstein (1976) has used the first occurrence of *Lithraphidites bollii* for this zone's subdivisions in Tethyan Realm. Applegate & Bergen (1988) represented that the FO of *L. bollii* divides this biozone into two subzones of CC4a and CC4b. By *L. bollii* appearance at 804 m, Early Hauteivian age was suggested for this part of section. So, this zone includes two subzones of CC4a and CC4b. This zone is relatively equivalent to the CC4 zone from Applegate & Bergen (1988) zonation scheme (Table 1).

CC4a Subzone. This subzone is identified from the FO of *Cretarhabdus loriei* to the FO of *Lithraphidites bollii*. The thickness of this subzone is 64 m.

CC4b Subzone. This subzone is identified from the FO of *Lithraphidites bollii* to the LO of *Speetonia colligata*. In this research, the LO of *Speetonia colligata* and the upper part of this subzone is unknown. Therefore, the thickness of this subzone was not determined.

Indicative bioevents of this biozone include: FO of *Eiffellithus striatus* (sample 62 at about 775 m) that defines the base of the CC4a nannofossil subzone by Applegate & Bergen (1988) and the FO of *N. bucheri* (sample 69 at about 790 m), which is recognized in numerous sections close to the boundary between Zones CC3/CC4, as well as in the studied section.

In this research, based on the identified biozones (CC1–the lower part of CC4b). Considering the distinguished biozones, the age of the Baghamshah Formation in Birg section is Early Berriasian to Early Hauterivian. This contradicts the previous studies that suggested the age Bathonian–Callovian for this formation. Thus, other studies in other sections of this Formation are recommended to complete the studies.

It is worth noting that more paleontological studies have been carried out on the Baghamshah Formation, most of them are based on ammonites, as well as corals, brachiopods, and miospores. The only study based on calcareous nannofossils was by Kallanxhi *et al*. (2016), which, due to the lack of index species of nannofossils for age determining, ultimately studied ammonite content, and lower to middle Callovian age was determined for this Formation.

CONCLUSIONS

The Birg section in eastern Iran (Lut block) contains moderately preserved calcareous nannofossil assemblages; 38 genera and 76 species of calcareous nannofossils and didemnid ascidian spicules were determined in the Baghamshah Formation in Birg section. Tethyan forms dominate the assemblages recorded in this study. The dominant species in calcareous nannofossil assemblages of this section are *Watznaueria*, *Cyclagelosphaera*, *Nannoconus*, *Conusphaera*. We used nannofossil zonations of Sissingh (1977) and detected several bioevents, including FOs of *Nannoconus steinmannii steinmannii*, *Retecapsa angustiforata*, *Calcicalathina oblongata*, *Cretarhabdus loriei* and *Lithraphidites bollii*. These species correspond to the CC1–CC4b biozones. Considering the distinguished biozones, the age of the Baghamshah Formation in this section is early Berriasian to early Hauterivian.

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