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Calcareous nannofossil biostratigraphy and paleoecolgy of the Rupelian-Chattian stages (Oligocen) in the Central Iran basin

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Abstract:

Calcareous nannofossils are one group of microfossils that use in biostratigraphy studies since the 1950′s and 1960′s. Recently, because of the potential of nannofossil species for age determination, several authors use this fossil-group in the study of Cenozoic sediments and rocks. Here, we present a nannofossil biozonation based on biostratigraphic information from the Sabzevaran section (Central Iran). The Sabzevaran section mainly consists of marl, limestone, and shaly limestone. Based on index nannofossil species, three nanno-bizones (NP23-NP25) were recognized in this section. According to the identified biozones, the age of the studied deposits in the Sabzevaran section is middle to late Oligocene (Rupelian to Chattian stages). In this section, calcareous nannofossils abundance and diversity are medium to low with a sharp decrease slightly near the conglomerate and sandstone layers and are absence in conglomerate and sandstone beds. Paleoecological data indicate the shallow marine, low latitude and low productivity for the marine deposits of Sabzevaran section.

Keywords: Central Iran; Calcareous nannofossils; Biostratigraphy; Rupelian; Chattian; Paleogene

1. Introduction

In the present research, study of calcareous nannofossil species from marine deposits of sabzevaran section allowed us to determination of nannofossil biozones and reconstruction of paleoecological conditions throughout the Oligocene of the Central Iran basin.

Central Iran is relatively one of the virgin basins in Iran, which is in the form of a triangular shape, continue from the east up to the Lut Block, and from the northern part might up to the Alborz Mountains and from the South up to the Sanandaj-Sirjan Zone (Aghanbati, 2004); (Berberian and King, 1981). However, both tectonic and stratigraphic significances of the Central Iran have been highlighted by several works (e.g. Salehi et al. (2018)). Moreover, due to the presence of micro- and macrofossils, which have been either detected in different dimension or being identified, these tectonic zone has gained an obvious importance. The Sabzevaran section (near Jiroft) is a sequence of marine deposits that was investigated for biostratigraphy and paleoecology. The paleontological investigation of the Jiroft region focused on foraminifera and ostracoda (Fariabi, 1993); (Mostafavi and Hadavi, 2018); (Hoseini-Raviz and Afghah, 2018); (Hoseini-Raviz, 2019); (Hoseini-Raviz et al., 2020) and the reports of nannofossil studies in this area are from Hadavi et al. (2018) and Hoseinzadeh (2018).

Based on calcareous nannofossil, marine deposits of the Sabzevaran section were investigated for biostratigraphy and paleoenvironment reconstructions.

2. Geographical and geological settings

The studied deposits, including those of the Sabzevaran section were deposited around the Jiroft region. This section (about 375 m-thick), with coordinates N: 28° 48′ 51″, E:

57° 37′ 47″ (Fig. 1) consists of alternation of conglomerate, sandstone, limestone, and shale. The lowermost part of the section is distinguished by the alternation of conglomerate and sandstone. Its upper limit is recognized as an erosional surface while the lower part of the section is characterized by 30 meters of conglomerate and sandstone alternation, underlying a limestone and shaly limestone unit of 30 m-thick, then 170 meters of marl and sandstones alternation. There is an erosional surface, of 12 m-thick, composed of conglomerate and sandstone, located between of 235 and 247 m from the base of the section and 40 meters of limestone, sandstone and marl alternation forming the next unit. Finally, the top of the section is composed of 70 m-thick of limestone (Fig. 2).

3. Material and methods

A total of 155 samples were collected and prepared with classical techniques of Bown and Young (1998) for nannofossil analysis. The present nannofossil species in the Sabzevaran section were shown in Figure. 3. All the calcareous nannofossil specimens examined were identified following the taxonomic schemes of Perch-Nielsen (1985) and Bown and Young (1998). In this research, the biostratigraphic zonation scheme used for the studied sediments follows Martini (1967). In Martini (1970) zonation, the NP indicate the nannofossil of Paleogene and the first (FO) and the last (LO) occurrence of species are mainly used for subdivision and zonation. Furthermore, for the purpose of paleoecological studies, all nannofossil species were counted in ten traverses, then the percentages of species were determined.

4. Results and discussion

4.1 Calcareous nannofossils.

In this study, 26 species belong to 8 genera were observed from the Sabzevaran section. The identified taxa present low variety and medium abundance, with moderate to well

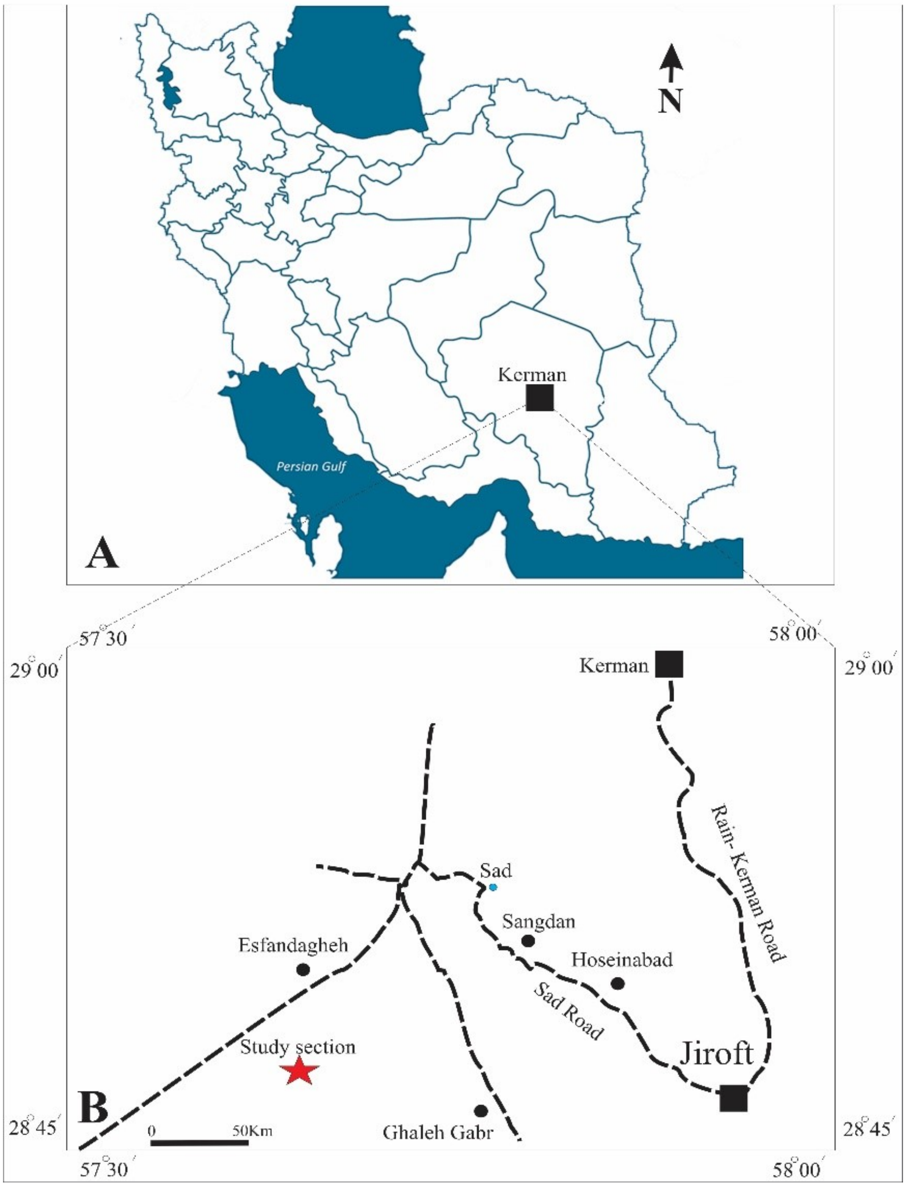

Figure 1. (a) General map of Iran. (b) Location of the study area.

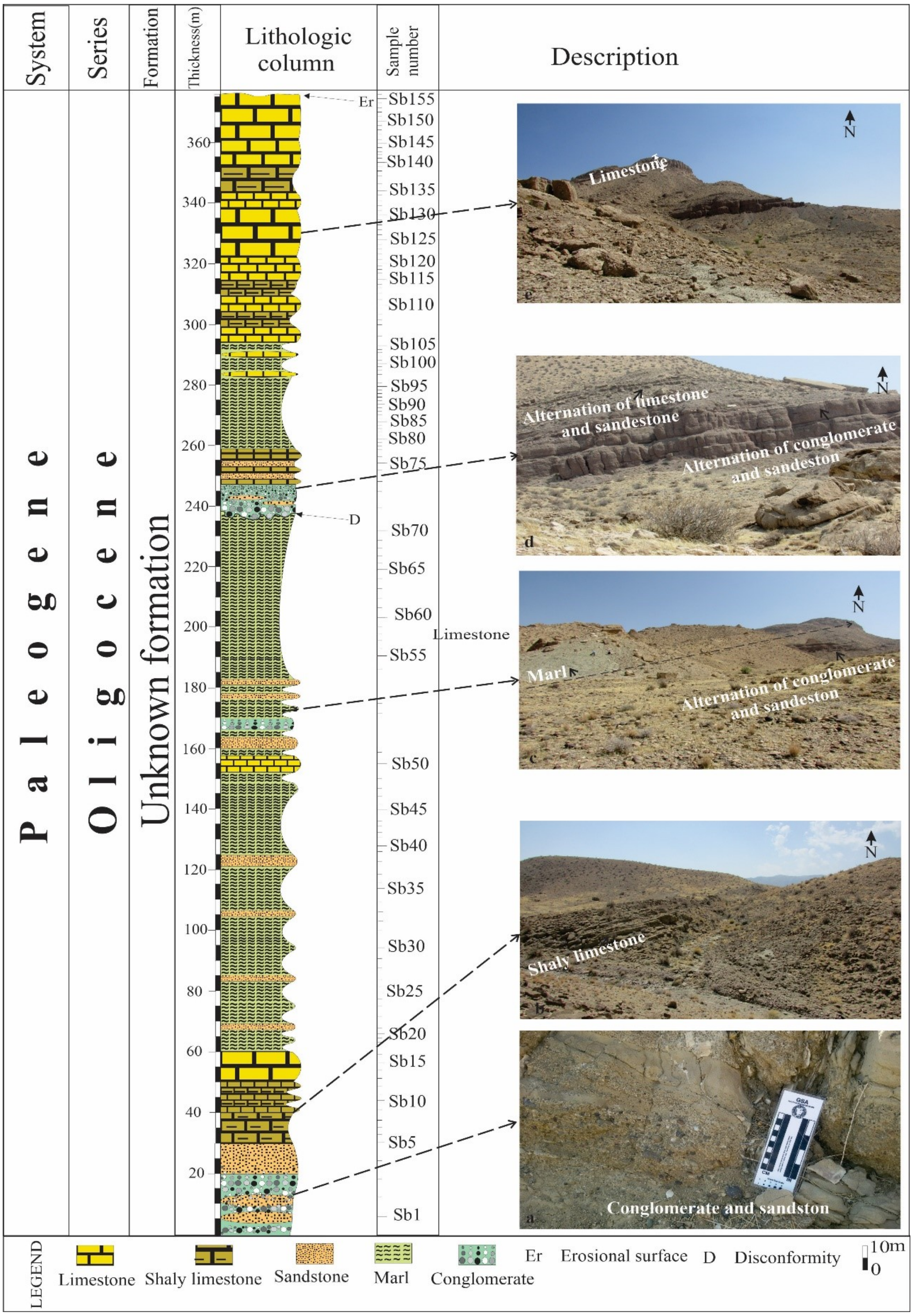

Figure 2. Lithostratigraphic column of the Sabzevaran section.

preservation specimens. In the marl layers, all specimens are relatively well preserved, such as the arms and knobs, the central stem of the genus *Discoaster*, and the central area of *Coccolithus*, *Sphenolithus*, *Helicosphaera*, *Reticulofenestra*. It should be noted that some species have lost their delicate structures due to the dissolution or during the preparation of the specimens. The identified species of nannofossils belong to the genera *Coccolithus*, *Sphenolithus*, *Reticulofenestra* and *Helicosphaera* that are present in the most samples studied. But species of *Discoaster* are present in the few samples (Fig. 4). The abundance of species in the studied samples is different and relative to change in the lithology. The most dominant calcareous nannofossils species are *Reticulofenestra* spp. (average of 45.17%), *Sphenolithus* spp. (average of 32.12%,) *Helicosphaera* spp. (average of 6.03%), and *Coccolothus pelagicus* (average of 5.01%). Some Paleogene nannofossil genera like *Discoaster* spp. and *Zygrhablithus* are present but occur spo-

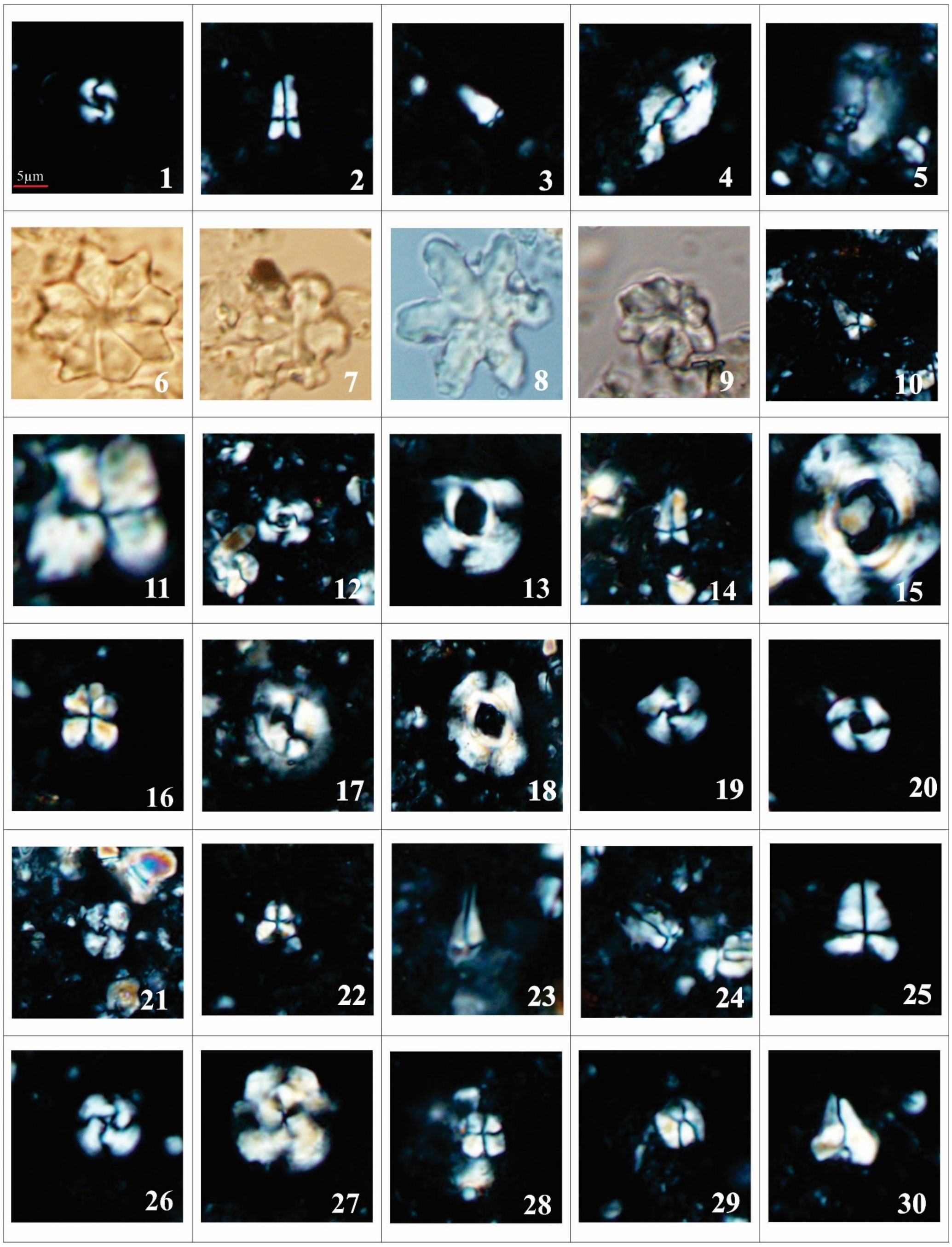

Figure 3. Identified calcareous nannofossils from the study section (Scale bar: 5μm)

radically with low percentages.

1. *Reticulofenestra minuta* (Roth, 1970); 2. *Sphenolithus ciperoensis* (Bramlette & Wilcoxon, 1967) Howe (2021); 3. *Sphenolithus predistensis* Bramlette & Wilcoxon, 1967; 4. *Helicosphaera euphratis* Haq, 1966; 5. *Helicosphaera ethologa* Bown, 2005; 6. *Discoaster barbadiensis* Tan Sin Hok, 1927; 7. *Discoaster deflandrei* Bramlette & Riedel; 8. *Discoaster nodifer* (Bramlette & Riedel, 1954) Bukry, 1973; 9. *Discoaster* sp.; 10. *Sphenolithus radians* Deflandre *in* Grassé, 1952; 11. *Sphenolithus moriformis* (Brönnimann & Stradner, 1960) Bramlette & Wilcoxon, 1967; 12. *Reticulofenestra* sp.; 13. *Reticulofenestra* sp.; 14. *Sphenolithus radians* Deflandre *in* Grassé, 1952; 15. *Reticulofenestra umbilicus* (Levin, 1965) Martini & Ritzkowski, 1968; 16. *Sphenolithus moriformis* (Brönnimann & Stradner, 1960) Bramlette & Wilcoxon, 1967; 17. *Coccolithus pelagicus* (Wallich 1877) Schiller, 1930; 18. *Reticulofenestra dictyoda* (Deflandre *in* Deflandre & Fert, 1954); 19. *Cyclicargolithus floridanus* (Roth & Hay, *in* Hay *et al.*, 1967) Bukry, 1971; 20. *Reticulofenestra minuta* (Roth, 1970); 21. Cyclicargolithus floridanus (Roth & Hay, in Hay *et al.*, 1967) Bukry, 1971; 22. Sphenolithus apoxis (Bergen & de Kaenel, in Bergen et al. 2017); 23. *Sphenolithus celsus* (Haq, 1971), Howe (2021); 24. *Sphenolithus predistentus* Bramlette & Wilcoxon, 1967; 25. *Sphenolithus radians* Deflandre *in* Grassé, 1952; 26. *Reticulofenestra reticulate* (Gartner & Smith, 1967) Roth & Thierstein, 1972; 27. *Reticulofenestra stavensis* (Levin, 1965) Varol, 1989; 28. *Sphenolithus coni-*

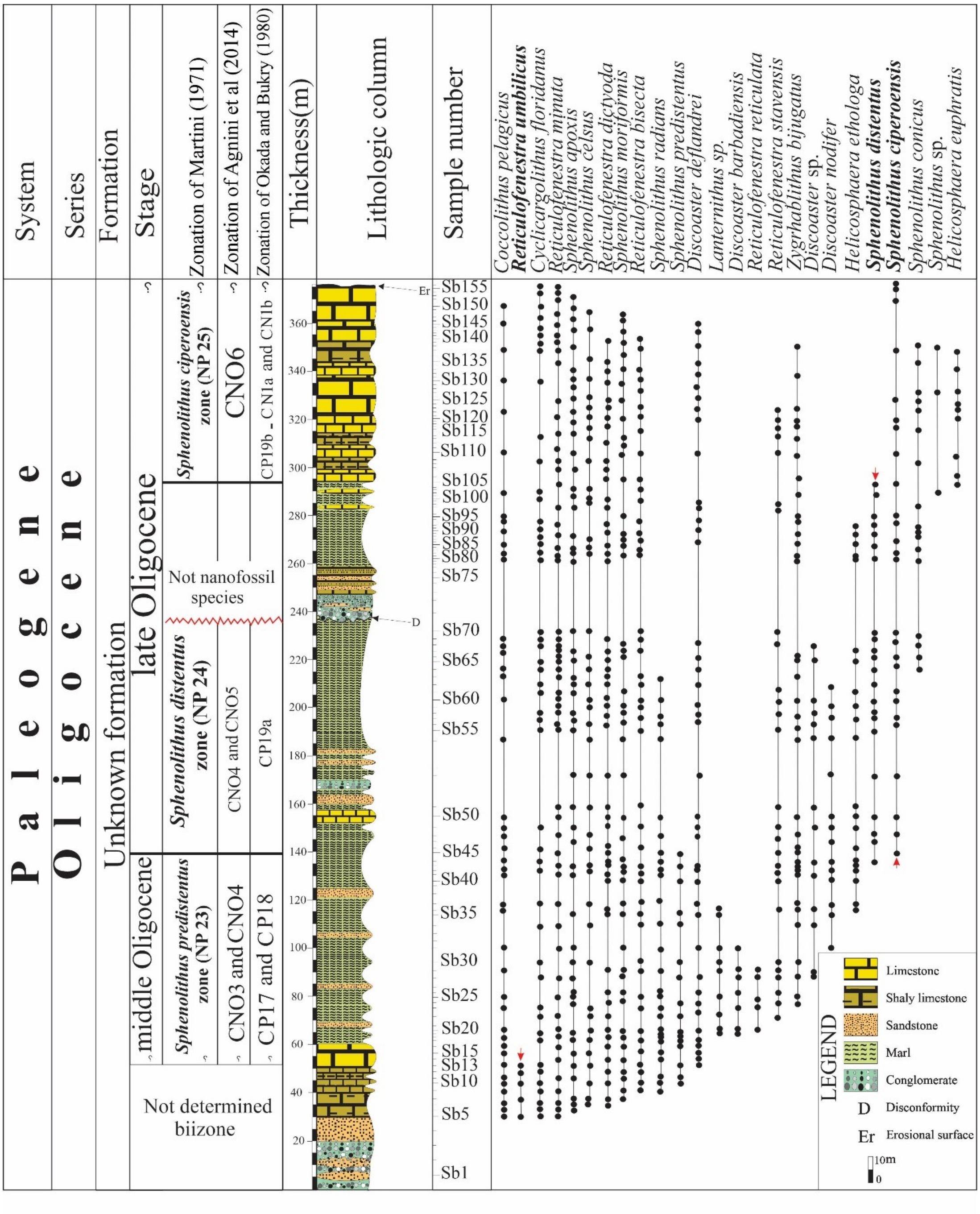

Figure 4. Identified nannofossils species and nanno-biozones in the Sabzevaran section.

cus Bukry, 1971; 29. *Lanternithus* sp.; 30. *Zygrhablithus bijugatus* (Deflandre *in* Deflandre & Fert, 1954) Deflandre, 1959.

4.2 Biostratigraphy and nannofossil event

LO and FO of nannofossil taxa, across the studied stratigraphic interval help us to determined biozones in the Sabzevaran section. The events have been recorded in this section are: LO *Reticulofenestra umbilica*, FO *Sphenolithus ciperoensis*, LO *Sphenolithus distentus*. All biozone boundaries of marker species are illustrated in the Figure. 3. According to the marker species, three nanno-biozones were determined that are: *Sphenolithus predistentus*, *Sphenolithus distentus* Zone and *Sphenolithus ciperoensis* zones (Fig. 4). The three identified biozones comprise the CP (Coccolith Paleogene) biozones of Okada and Bukry (1980) zonation and the CNO (Calcareous Nannofossils Oligocene) biozones of Agnini et al. (2014) zonation.

These biozones are as follow:

***Sphenolithus predistentus* Zone (NP23 zone):**

This zone was proposed by Bramlette and Wilcoxon (1967) then Martini (1970). It ranges from the last occurrences of *Reticulofenestra umbilica* to the first occurrences of *Sphenolithus ciperoensis*. Its age is referred to middle Oligocene.

Remarks: In the low latitudes, *Sphenolithus* and *Discoaster* are the best markers for the definition of the biozones.

In the studied section, the lower boundary of the zone NP23 is determined with the LO of *Reticulofenestra umbilica* which occurs 50 meters from the base of the section (sample No. 13) whereas the upper boundary of this zone is determined by the FO of *Sphenolithus ciperoensis* in which occurs 140 meters from the base of the section (sample No. 45). The mentioned zone is the oldest identified zone from the studied sections attaining about 90 meters in thickness. The NP23 zone is equivalent to CP17 and CP18 zones of the Okada and Bukry (1980) and the CNO3-CNO4 zones of Agnini et al. (2014).

Due to the lithological aspect of the lower boundary of the section (samples No.1 to No.13, 50 m-thick) and because the absence of index nannofossil species, it was not possible to determine the age of the lower boundary of the section.

***Sphenolithus distentus* Zone (NP24 zone):**

Its age is assigned to late Oligocene. This zone ranges from the FO of *Sphenolithus ciperoensis* to the LO of *Sphenolithus distentus* (Bramlette and Wilcoxon, 1967).

Remarks: The NP24 zone has been determined on the base of bio-events referring to the presence of *Sphenolithus ciperoensis* and *Sphenolithus distentus*.

In this section, by the FO of *Sphenolithus ciperoensis* at 140 meters from the base of the section (sample No. 45), base of the NP24 is determined; but the upper boundary of this zone is marked by the LO of *Sphenolithus distentus* at 294 meters from the base of the section (sample No. 105). Its thickness is about 154 meters. The NP24 zone is equivalent to the CP19a zone of Okada and Bukry (1980) and the upper part of CNO4 – lower part of CNO5 zones of Agnini et al. (2014).

***Sphenolithus ciperoensis* Zone (NP25 zone):**

This zone was determined by Martini (1967) and Bramlette and Wilcoxon (1967) and is attributed to late the Oligocene. It is explained from the LO of *Sphenolithus distentus* to the LO of *Helicosphaera recta* and/or Sphenolithus ciperoensis.

Remarks: Previously, although the disappearance of the *Helicosphaera recta* and the *Sphenolithus ciperoens* which was expressed as a synchronous event, but some new carried out researches (Agnini et al., 2014) shows that the extinction of these two species is not a synchronous event.

In the investigated deposits, the lower boundary of NP25 is determined with the absent of *Sphenolithus distentus* (sample No. 105).

Although the last occurrences of *Helicosphaera recta* or that of *Sphenolithus ciperoensis* should be referred to the upper boundary of the *Sphenolithus ciperoensis* zone, these events were not observed in the study section.

According to the index nannofossil species, the last 81 meters of the section studied certainly belong to the NP25 zone. This zone is equivalent to the CP19b, CN1a and CN1b zones of Okada and Bukry (1980) and the largest parts of CNO5 and CNO6 zones of Agnini et al. (2014). The stratigraphic distribution of the identified calcareous nannofossils (NP23-NP25), allows assigning the upper part of the section to the middle - late Oligocene (Rupelian-Chattian) interval.

4.3 Paleoecology

Distribution and index species of nannofossil taxa are used for paleoecological studies and conditions. In this research the important taxa for paleoecological investigations are: *Coccolithus*, *Sphenolithus*, *Reticulofenestra*, *Discoaster* and

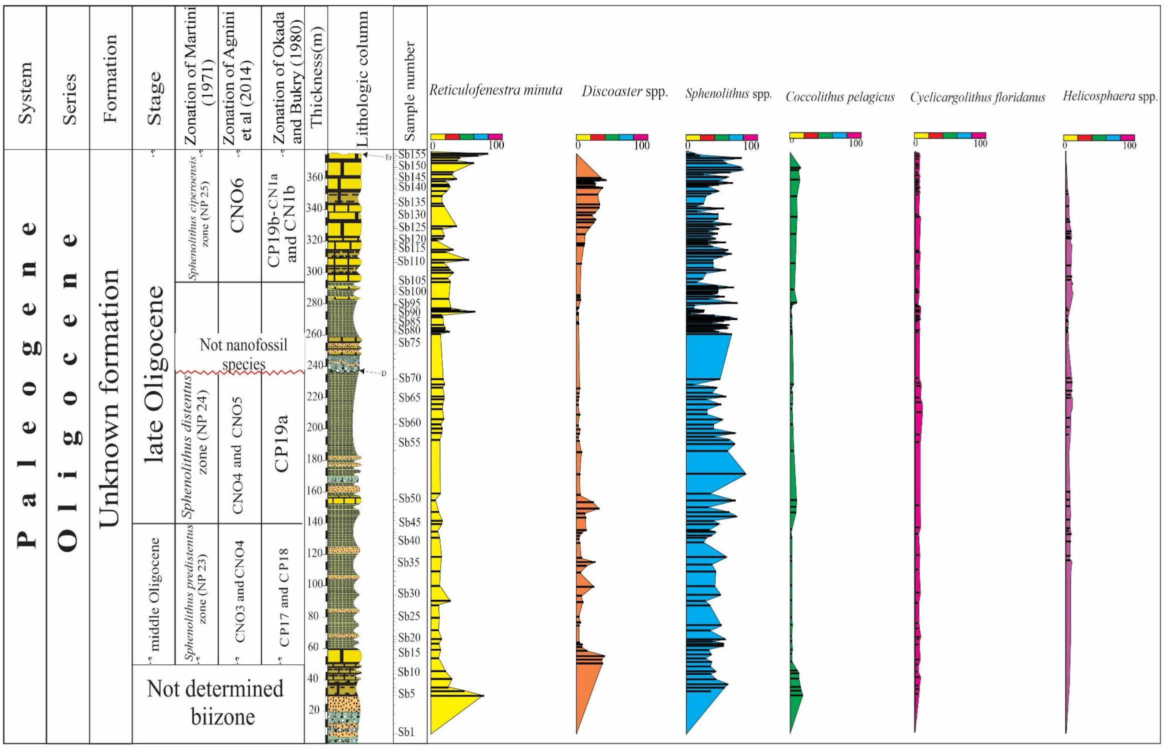

Figure 5. Vertical changes in the relative abundance of the calcareous nanofossil index species for paleotemperature, paleonutrient and paleodepth in the study area.

Helicosphaera (Fig. 5). These assemblages show, for the Central Iran basin, temperature, depth and nutrient indices relative to the Rupelian and Chattian interval time.

4.3.1 Temperature and latitude

Calcareous nannofossils are sensitive to changes temperature. Note that species belonging to the genera *Helicosphaera*, *Discoaster*, *Sphenolithus* and *Coccolithus pelagicus* are relative to warm waters in low latitude (Bralower, 2002); (Arney and Wise, 2016); (Holcova, 2005); (Bartol, 2009); (Ozdinova, 2013); (Albasrawi, 2016); (Albasrawi, 2016). Among nannofossil species, *Reticulofenestra minutia* was observed with high abundance in warm surface water at low-latitude than cold surface water at high-latitude (Wade and Bown, 2006).
Presence of *Reticulofenestra minutia*, *Discoaster defladrei*, *Discoaster barbadiensis*, *Discoaster nodifer*, *Helicosphaera euphratis*, *Sphenolithus distentus*, *Sphenolithus ciperoensis*, *Sphenolithus predistentus* indicate that the studied sediments were deposited in low-latitude with warm surface water (Fig. 5).

4.3.2 Nutrient

Abundance of calcareous nannoplankton species are relative to nutrient concentration (Bown et al., 2004); (Wade and Bown, 2006); (Blaj et al., 2009). So, the abundance and nannofossil assemblages determine the trophic regime of surface water (Herrle et al., 2003); (Erba, 2006). The taxa *Discoaster* and *Sphenolithus* are as K-selected genus and show oligotrophic conditions (Bralower, 2002); (Debert et al., 2012). Among nannofossil species, *coccolithus pelagicus*, *Cyclicargolithus floridanus* and *Helicosphaera carteri* are as R-selected species and indicate eutrophic and upwelling conditions (Perch-Nielsen, 1985); (Villa et al., 2008); (Bartol, 2009); (Shcherbinina, 2010); (Albasrawi, 2016).
In sabzevaran section, based on the presence of index species that explained above such as *Discoaster* and *Sphenolithus* and the not present or the low abundance of high productivity species (*Helicosphaera carteri*, *coccolithus pelagicus* and *Cyclicargolithus floridanus*) (Fig. 5), low surface water productivity conditions for the studied sequence was suggested.

4.3.3 Paleodepth

During the middle to late Oligocene, nannofossil was sensitive to changes in basin depth. Marker species in Sabzevaran section allow reconstruction of paleodepth. This study demonstrates that in the boundary between marl and limestone and sandstone and conglomerate layers nannofossil species decreased in the water depth during the Rupelian-Chattian.
In this regard, the occurrence of *Reticulofenestra umbilicus*, *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Discoaster deflandrei*, *Helicosphaera euphratis*, *Helicosphaera ethologa*, *Reticulofenestra minuta*, *Sphenolithus moriformis*, *Sphenolithus praedistentus*, and *Zygrhablithus bijugatus* are common in some slides. *Discoaster barbadiensis* and *Reticulofenestra stavensis* are represented by a few numbers of specimens (Fig. 5). Most of the species listed above reflect open marine to shelf conditions (Perch-Nielsen, 1985); (Bohaty and Zachos, 2003); (Thierstein and Young, 2004); (Jones et al., 2008); (Agnini et al., 2014) for the studied section.

5. Conclusion

Result of this study showed the NP23- NP25 nannofossil biozones of Martini (1971) equivalent to CP17-CN1b zones of Okada and Bukry (1980) and the CNO3-largest part of CNO6 of Agnini et al. (2014) encompassing the middle to late Oligocene (Rupelian-Chattian) interval time.
The nannofossil specimens of the studied section are moderately to well in preservation. Quantitative studies of warm water species and cold-water species and the variation in the abundance of index species point to low productivity for the Central Iran basin and suggest that the sediments belonging to the Sabzevaran section related to in low to medium latitudes with warm water and in a shallow sedimentary basin.

Authors Contributions
All authors have contributed equally in preparing the paper.

Availability of Data and Materials
Data is available on request from the authors. The data supporting this study's findings are available from the corresponding author, upon reasonable request.

Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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