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ORIGINAL ARTICLE

Biostratigraphic correlation of Santonian-Maastrichtian calcareous nanofossil biozones with planktonic foraminifera zonation, Interior Fars region of the Zagros, southwest Iran

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Abstract
Received data considered the stratigraphic distribution of nanofossils and compared with planktonic foraminifera in the Sepidan section. The Gurpi Formation is well exposed in the Sepidan section, Interior Fars, southwest Iran. It consists of 358 m of shale and argillaceous limestone with lime shale. Thirty-nine calcareous nannofossils species from 19 genera were identified in the Sepidan section. According to the distribution of calcareous nannofossil assemblages, the Upper Cretaceous succession was subdivided into 12 biostratigraphic zones, suggesting the late early Santonian to latest Maastrichtian age. Also, the examination of the studied samples resulted in the identification of 20 planktonic foraminifer taxa, assigned to seven genera. Based on the stratigraphic distribution of the planktonic foraminifera, nine foraminiferal biozones were determined. Foraminiferal investigations show that the age of the Gurpi Formation is assigned to the Santonian to late Maastrichtian. Both established nanofossil and planktonic foraminifera biozones were correlated.

Keywords Biostratigraphy · Calcareous nannofossils · Cretaceous · Planktonic foraminifera · Zagros · Zone

Introduction

The Zagros Basin is a section of the Alpine–Himalayan system formed along the Arabian–Eurasia collision (Berberian and King 1981). The Zagros Mountains consists of more than 10,000 m of Mesozoic–Cenozoic strata, composed of a folded rock succession, with northwest–southeast trend (Setudehnia 1978). So tectonically, this basin is part of a foreland basin, deposited dominantly with a thick sedimentary sequence of carbonate and clastic sediments, which was formed in the late Triassic. In fact, the mentioned sediments were deposited in a subsiding trough in the late Triassic. The Zagros folded belt is divided into four stratigraphic zones which are Lurestan, Khuzestan, Coastal and Interior Fars zones (James and Wynd 1965; Motiei 1995; Kamali et al. 2006). In coastal and interior Fars, the subsidence of the basin started at the Santonian which is synchronous with global sea level rise (James and Wynd 1965; Motiei 1994; Alavi 2004). The Gurpi Formation is one of the lithostratigraphic units of the upper Cretaceous deposits and is exposed throughout most of the Agreement Area. For the first time, James and Wynd (1965) studied the Gurpi Formation as pelagic facies of Zagros upper Cretaceous sequence which is composed of shale and limy shale. Generally, the lower lithologic contact of this rock unit is marked by an obvious disconformity (oxidized zone) with underlying formations (Ilam or Sarvak formations) and the upper lithostratigraphic limit is covered by Pabdeh Formation in the coastal and interior Fars regions. The Gurpi Formation laterally changes to shallow water carbonates of the Tarbur Formation in some parts of the interior Fars area (Afghah 2010). Most of the studies on the Gurpi Formation have predominantly focused on stratigraphy, microfauna and sedimentology in various stratigraphic sections of the Zagros (e.g., Ghasemi-Nejad et al. 2006; Darvishzadeh et al. 2007; Khosrowtehrani 2008; Hemmati-Nasab et al. 2008; Afghah and Ghiyasi 2013; Beiranvand and Ghasemi-Nejad 2013; Beiranvand et al. 2014; Darabi and Sadeghi 2017; Esmaeilbeig 2018). In recent years, the biozonation of Gurpi Formation was provided by the calcareous nannofossils

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(Hadavi et al. 2007; Senemari and Azizi 2012; Senemari and Sohrabi Molla Usefi 2012; Senemari 2017). But few studies deal with the correlation and comparison of calcareous nannofossil biozones and foraminiferal biozonation (e.g., Senemari et al. 2008). For biostratigraphic study of the Gurpi Formation (based on calcareous nannofossils and planktonic foraminiferal assemblage), the Sepidan section was investigated in interior Fars, SW of Iran. Vertical distribution of calcareous nannofossils and foraminifers supported different zones, ranging from Santonian to Maastrichtian for the Gurpi Formation. The main goal of the present study is investigation of calcareous nannofossils' biostratigraphic zonation and correlation with the foraminiferal assemblage in the Sepidan section.

Geological and geographical setting

The studied stratigraphic section is located in the Fars Province, about 108 km NW of Shiraz, which covers the area between longitudes 51° 50′–51° 55′ E and latitudes 30° 25′–30° 30′ N (Fig. 1). Based on Alavi (2004), the Sepidan stratigraphic section is located in the folded zone of the Zagros. The studied section represents an NW–SE trend similar to the Zagros trend. As mentioned before, the studied section is referred to as the interior Fars zone (James and Wynd 1965) (Fig. 2). Cretaceous through Oligo-Miocene sequences [Sarvak (Cenomanian), Gurpi (Santonian-Maastrichtian), Pabdeh (Paleocene–Oligocene) and Asmari (Oligo-Miocene)] are well exposed in the Sepidan section. The mentioned succession previously recorded in this area by Afghah and Fadaei (2015). Additionally, the Gurpi Formation consists of sequence shale, argillaceous limestone and limy shale, which overlies the Sarvak Formation (Cenomanian) disconformity and is disconformity covered by the shale of the Pabdeh Formation (Figs. 3, 4, 5).

Materials and methods

The lithostratigraphic characteristic was determined by detailed field work. 180 samples were collected from the Gurpi Formation and analyzed for fossiliferous assemblages. Samples of the calcareous nannofossils were processed following the smear slide technique of Bown and Young (1998). Calcareous nannofossils were studied using an Olympus BH2 under cross-polarizer and plain polarizer light (XPL and PPL) microscope at magnification of 1000×. The biostratigraphic zonation of the studied section was performed and compared with the global standard biostratigraphic zonation, such as Sissingh (1977) and Burnett (1998). The study of planktonic taxa was provided through thin sections. The thin sections were prepared from the collected samples. Identification and determination of Cretaceous planktonic foraminifera and biozones was based on the global standard biostratigraphic zonation of Caron (1985); Sliter (1989); Premoli Silva and Verga (2004), as well as regional zonation of Esfandyari Bayat and Rameh (2016). Finally, calcareous nannofossil zonation was compared with the results of planktonic foraminifer zonation.

Stratigraphy

The Gurpi Formation is encompassed between limestone of Sarvak formation as underlaying formation and shale of Pabdeh formation which covers the Gurpi Formation (Fig. 3). The Gurpi Formation of the Sepidan section consists of a sedimentary succession with a thickness of 358 m, which is composed of shale, argillaceous limestone and limy shale. Actually, in terms of lithology, it is divided into three distinct parts: the Santonian to early Campanian limy shale with iron nodules in the lower part (111 m thick), Campanian to early Maastrichtian argillaceous limestone interlayered with limy shale of the middle part (192 m thick), and late Maastrichtian shale interbedded with argillaceous limestone (55 m thick) in the upper part.

Results

Thirty-nine calcareous nannofossil species from 9 genera were identified in the Sepidan section. Based upon the vertical distribution of the identified nannofossils, biozonation was established. Additionally, 12 biozones are described. The received biostratigraphic data were compared with planktonic foraminiferal zonations of the Tethyan Santonian to Maastrichtian succession. The examination of the studied samples resulted in the identification of 20 planktonic foraminiferal species belonging to seven genera. Based on the stratigraphic distribution of the foraminifers, nine foraminiferal biozones (*Dicarinella asymetrica* Zone to *Abathomphalus mayaroensis* Zone) were determined. The results are consistent with the general trend of planktonic foraminifera and calcareous nannofossils in the Gurpi Formation.

Discussion

Biostratigraphy based on calcareous nannofossils

The identification of paleoenvironment is determined by biofacies (Al-Wosabi and Alaug 2012). Biozonation of the studied section is based on the stratigraphic distribution of calcareous nannofossils and planktonic foraminifera. The calcareous nannofossils were investigated as a useful

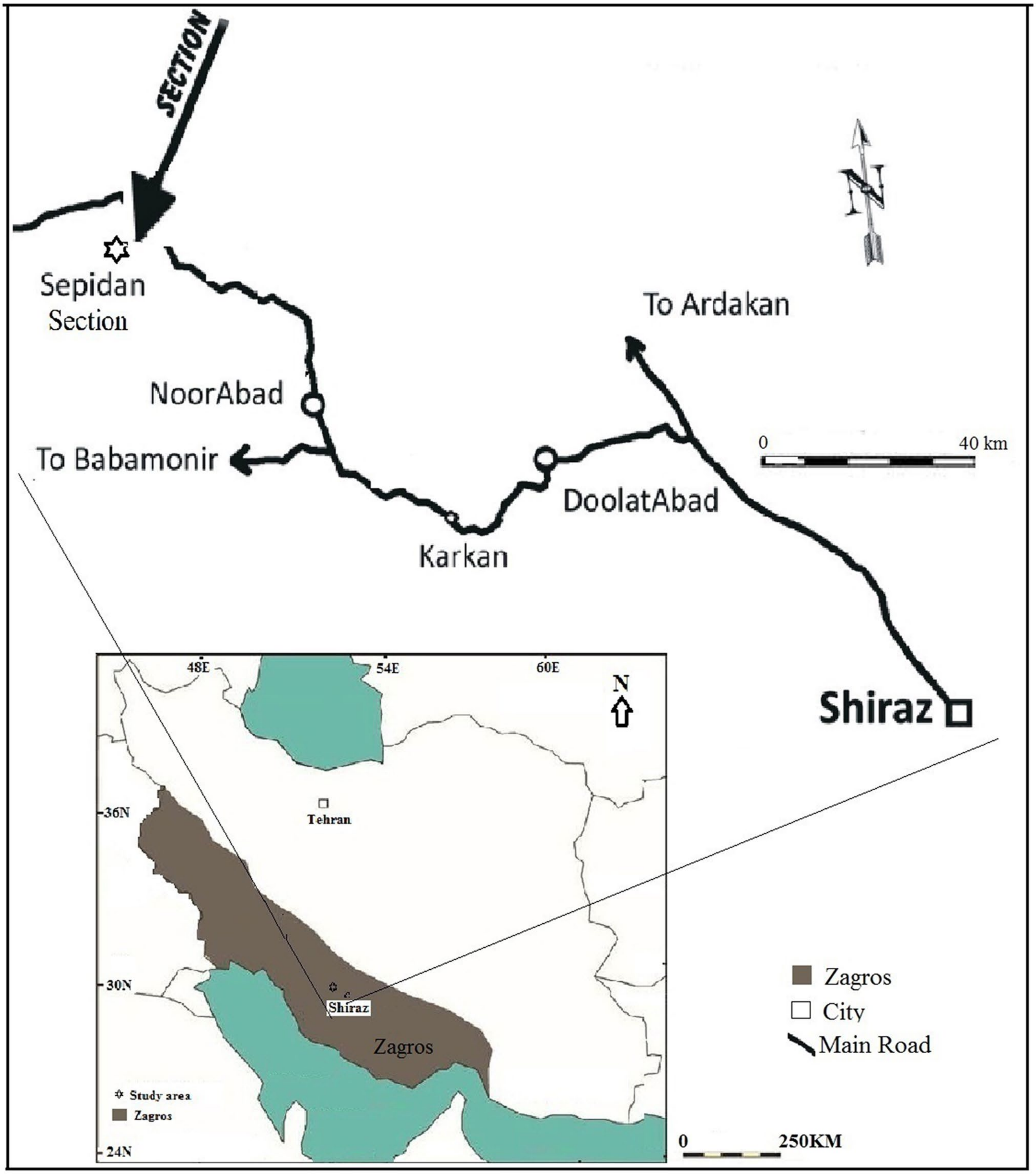

Fig. 1 Location of the studied section, northwest Shiraz (SW Iran)

tool for biostratigraphic zonation (Sissingh 1977; Perch-Nielsen 1985; Thierstein and Young 2004). The presence of calcareous nanofossils in collected samples confirms that the favorable environment is seawater. Therefore, calcareous nannofossils are valuable indicators, as their distribution is influenced by the seawater conditions in which they live (Eshet and Almogi-Labin 1996). The stratigraphic ranges of the taxa and biozones are shown in the distribution chart (Fig. 6). According to Cretaceous Coccoliths (CC) of Sissingh zonation (1977),

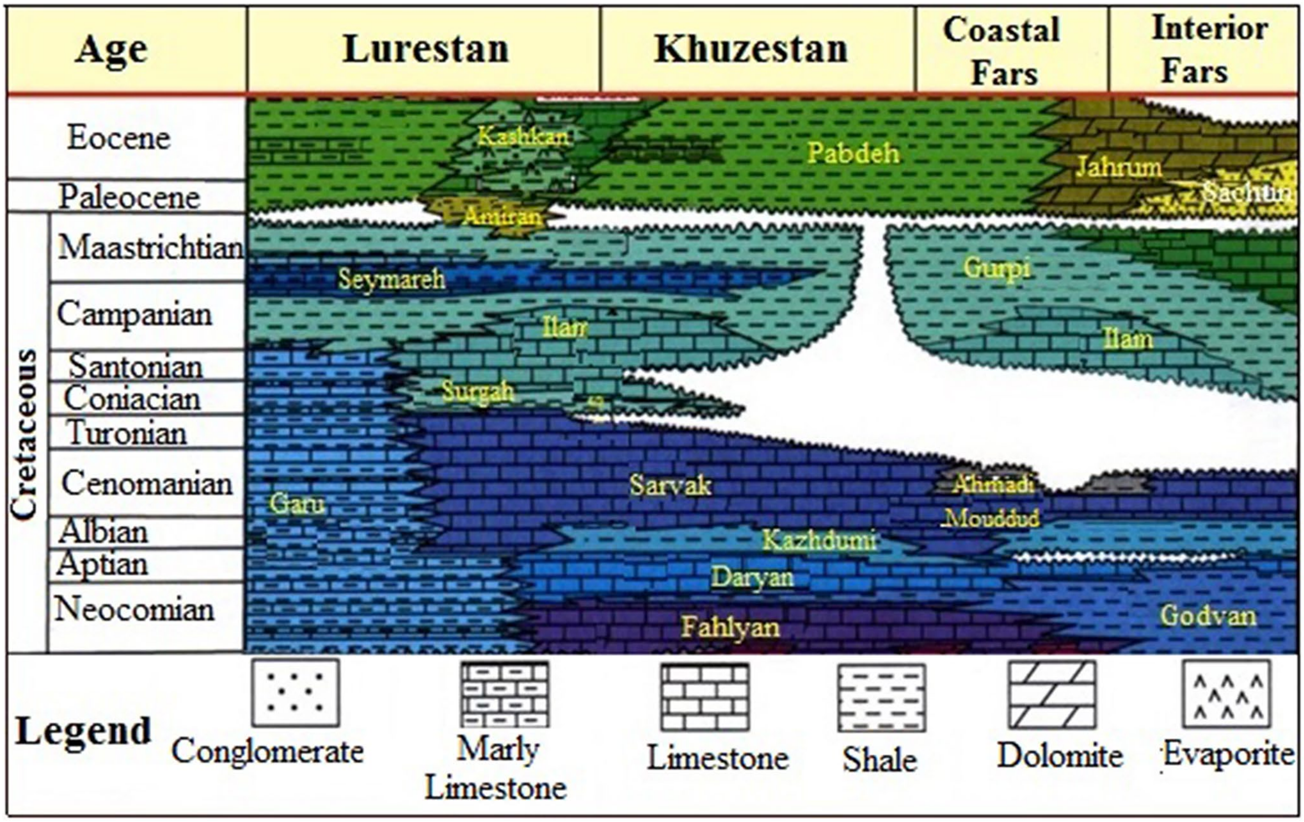

Fig. 2 Distribution of different formations in the Zagros Basin (James and Wynd 1965)

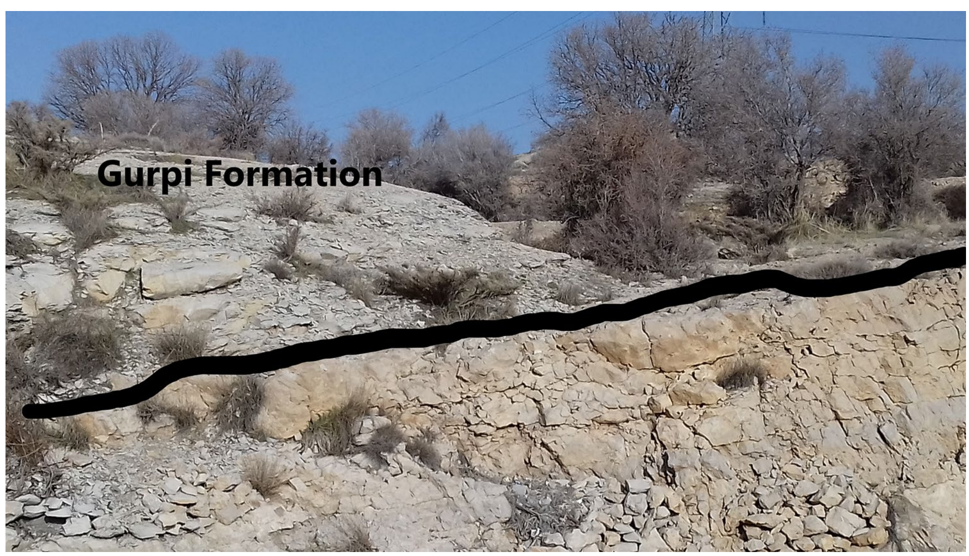

Fig. 3 The boundary between Sarvak, Gurpi and Pabdeh formations in the studied section

Upper Cretaceous (UC) of Burnett zonation (1998) and Nannofossils Cretaceous (NC) of Roth zonation (1978), the calcareous nannofossil zonation is provided in the present study. Based on our biostratigraphic data, the Sepidan section is assigned from the late early Santonian (*Reinhardtites anthophorus* nannofossil Zone/CC15) to the latest Maastrichtian (*Nephrolithus frequens* nannofossil Zone/CC26). The taxa in this study are illustrated in the plate (Fig. 7). The identified biozones are described from the base to top as follows:

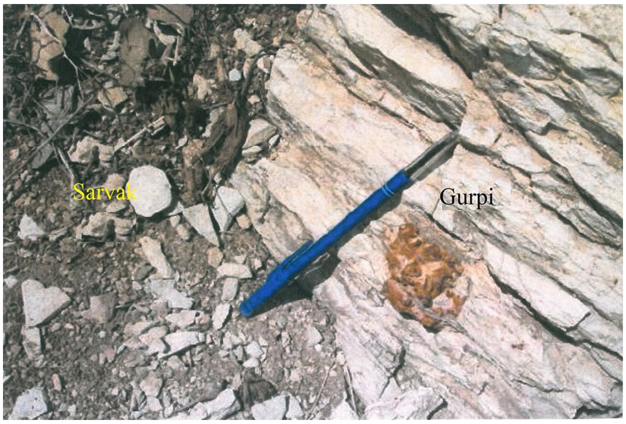

Fig. 4 The boundary between Sarvak and Gurpi formations in the studied section

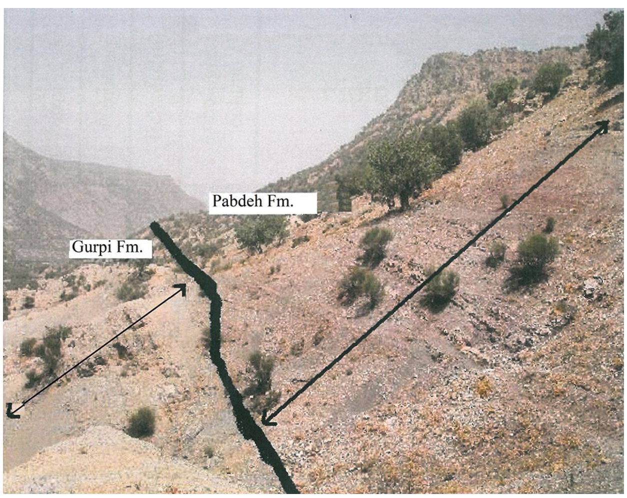

Fig. 5 The boundary between Gurpi and Pabdeh formations in the studied section

CC15 zone

The first biozone spans the interval from the FO of *Reinhardtites anthophorus* to the FO of *Lucianorhabdus cayeuxii*, equivalent to NC16 of Roth zonation (1978). The age of this zone is referred to as late early Santonian.

CC16 zone

The next biozone in the studied section spans the interval from the FO of *Lucianorhabdus cayeuxii* to the FO of *Calculites obscurus,* which is assigned to early late Santonian and equivalent to the upper part of zone NC16 of Roth zonation (1978). The first occurrence of *Lucianorhabdus cayeuxii* to the FO of *Calculites obscurus* defines the lower part of subzone UC11c of Burnett zonation (1998). So this zone is equivalent to the subzone UC11c of Burnett zonation (1998).

CC17 zone

This zone is marked by the first occurrence (FO) of *Calculites obscurus* to the FO of *Aspidolithus parcus parcus* (= *Broinsonia parca parca*), equivalent to zone NC17 of Roth zonation (1978), which is related to the late Santonian–early Campanian. The first occurrence of *Arkhangelskiella cymbiformis* to the FO of *Aspidolithus parcus parcus* coincides with UC13 of Burnett zonation (1998). Due to the presence of species *Arkhangelskiella cymbiformis*, this zone is also equivalent to UC13 of Burnett zonation (1998). The thickness of the zones CC15, CC16 and CC17 is 46 m.

CC18 zone

The next biozone is defined as the interval from the FO of *Aspidolithus parcus* to the last occurrences (LO) of *Marthasterites furcatus* and corresponds to the early Campanian. This zone is equivalent to the lower part of NC18 of Roth zonation (1978) and UC14 (UC14a^{TP}, UC14b^{TP}, UC14c^{TP} and lower part of UC14d^{TP}) of Burnett zonation (1998). Burnett´ zoning markers including: *Aspidolithus parcus parcus* (*Broinsonia parca parca*), *A. parcus constrictus* (= *Broinsonia parca constricta*), and *C. verbeekii* are observed in this zone. The thickness of this zone is 30 m.

CC19 zone

The next zone is distinguished as the interval from the LO of *Marthasterites furcatus* to the FO of *Ceratolithoides aculeus* which corresponds to the late early Campanian. This zone is due to the first occurrence of *Ceratolithoides aculeus* equivalent to the upper part of the zone of NC18 of Roth zonation (1978) and the lower part of the zone UC15 (UC15a^{TP}) of Burnett zonation (1998). Also, the first appearance of *Misceomarginatus pleniporus* at the beginning of zone UC15 was not recorded. The thickness of this zone is measured to be approximately 35 m.

CC20 zone

The *Ceratolithoides aculeus* Zone is distributed from the interval from the FO of *Ceratolithoides aculeus* to the FO of *Quadrum sissinghii* (= *Uniplanarius sissinghii*). This zone is equivalent to the lower part of NC19 of zonation of Roth (1978) and UC15b^{TP} subzone of Burnett zonation (1998). The age determination of this zone confirms late early Campanian and this zone extended about 45 m.

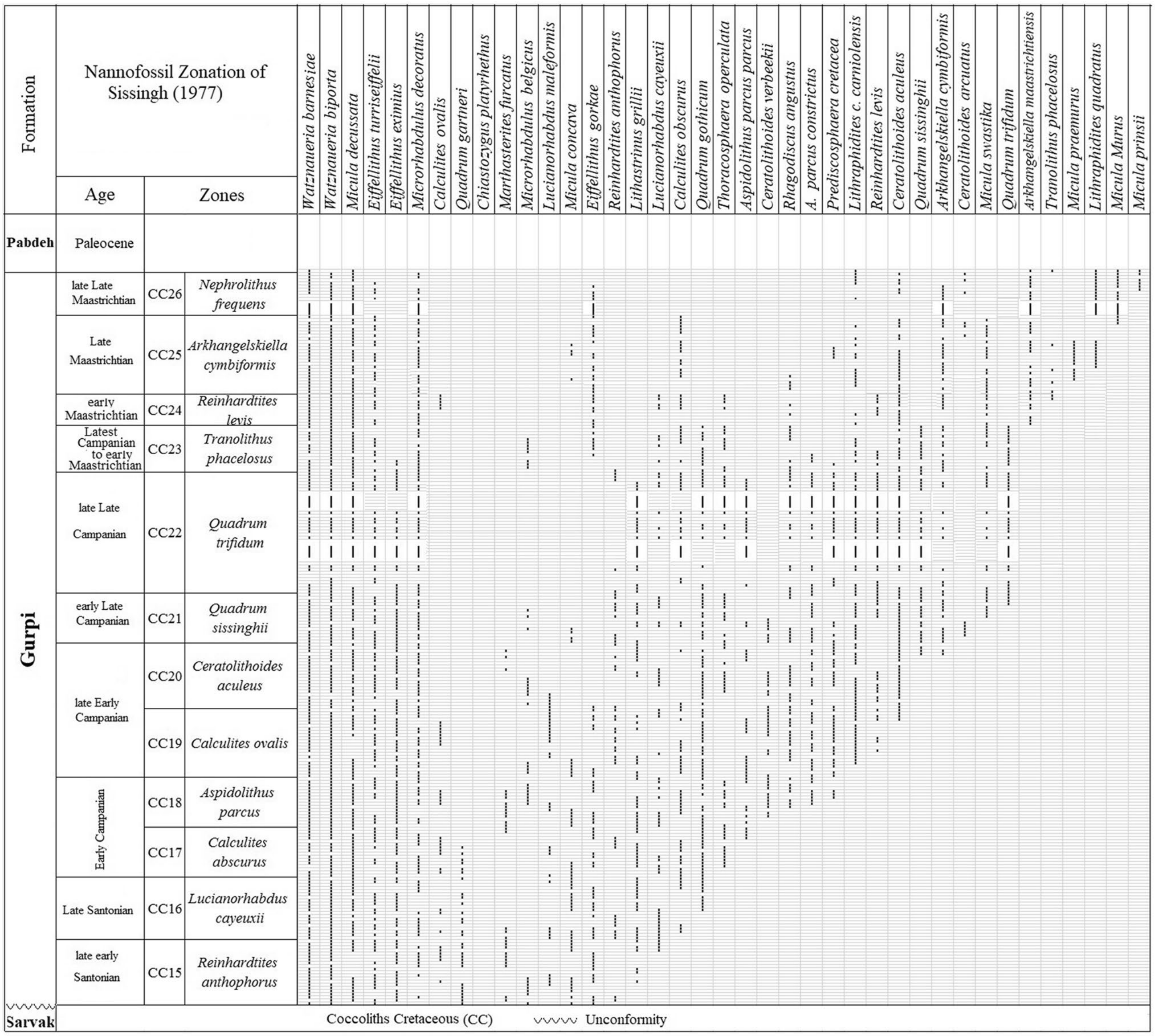

Fig. 6 Biostratigraphy based on calcareous nannofossils of Gurpi Formation, Sepidan section

CC21 zone

This zone is described by the FO of *Quadrum sissinghii* to the FO of *Quadrum trifidum* (= *Uniplanarius trifidus*) that referred to the early late Campanian. The *Uniplanarius sissinghii* Zone is equivalent to the upper part of NC19 of Roth zonation (1978) and UC15c^{TP} subzone of Burnett zonation (1998). The thickness of this zone is 22 m.

CC22 zone

The next zone in the argillaceous limestone of the Gurpi Formation is from the first occurrence (FO) of *Quadrum trifidum* to the last occurrences of *Reinhardtites anthophorus*, which refers to the latest Campanian and equivalent to the lower part of zone NC20 of Roth zonation (1978). Also, this zone is equivalent to the upper part of UC15 zone (UC15d^{TP} and UC15e^{TP}) of Burnett zonation (1998). In this zone, the first occurrence (FO) of *Reinhardtites levis* was recorded. The thickness of this zone is measured to be about 95 m.

CC23 zone

The mentioned zone is extended toward the top of the Gurpi Formation. It is described by LO of *Reinhardtites anthophorus* to the LO of *Tranolithus phacelosus* (= *Tranolithus orionatus*) and is assigned to the latest Campanian to early Maastrichtian. This zone is equivalent to the upper part of NC20

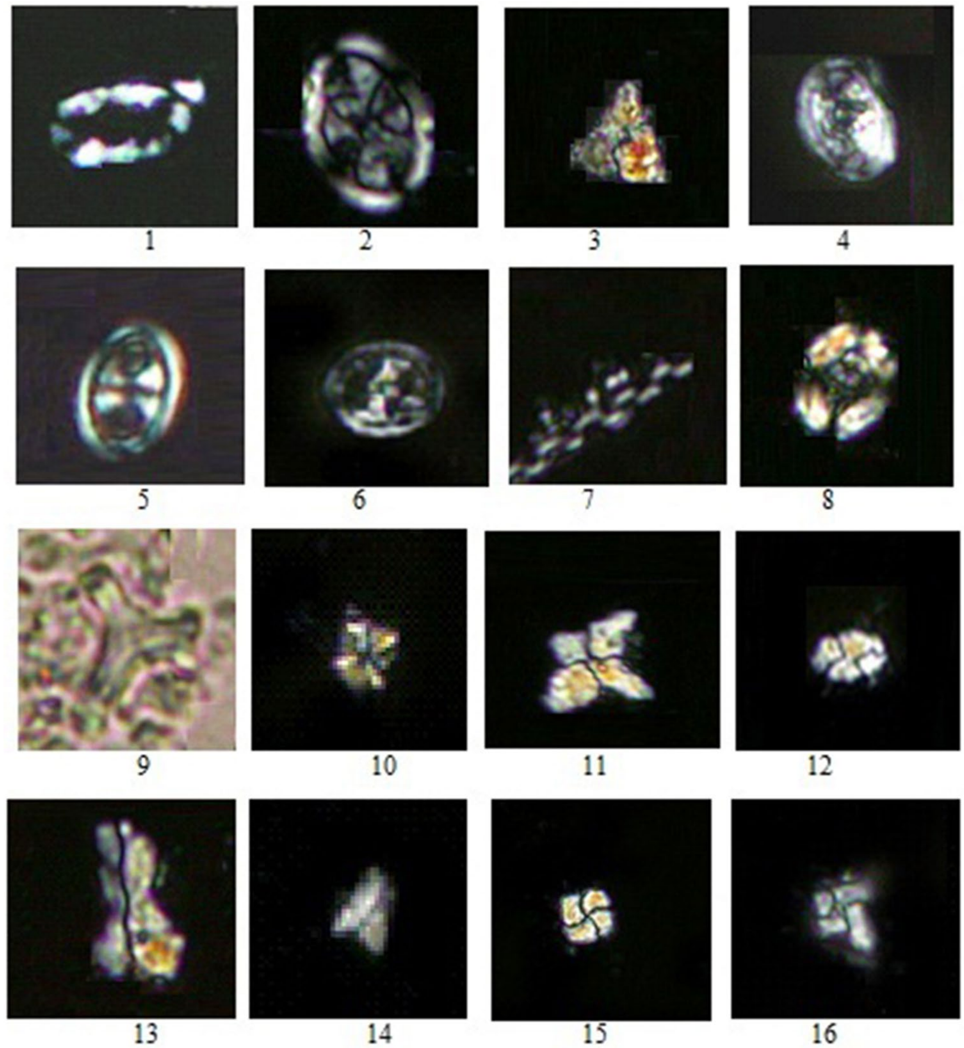

Fig. 7 Plate: All figures in light microghraphs × 1000; the taxa considered in the present figure are referenced in Perch-Nielsen (1985); ***1***, *Rhagodiscus angustus* (Stradner, 1963) Reinhardt (1971) (XPL); ***2***, *Arkhangelskiella cymbiformis* Vekshina (1959); ***3***, *Quadrum trifidum* (Stradner) Prins & Perch-Nielsen 1977, (XPL); ***4***, *Reinhardtites levis* Prins & Sissingh in Sissingh (1977); ***5***, *Tranolithus orionatus* (Reinhardt. 1966a) Reinhardt. 1966b. (XPL); ***6***, *Reinhardtites anthophorus* (Deflandre, 1959) Perch-Nielsen (1968), (XPL); ***7***, *Microrhabdulus decoratus* Deflandre (1959); ***8***, *Aspidolithus parcus parcus* (Stradner, 1963) Noel (1969); ***9***, *Marthasterites furcatus* (Deflandre in Deflandre & Fert, 1954) Deflandre, 1959 (PPL); ***10***, *Micula decussata* Vekshina (1959); ***11***, *Quadrum sissinghii* Perch-Nielsen (1984b), (XPL); ***12***, *Calculites obscurus* (Deflandre, 1959) Prins and Sissingh in Sissingh (1977); ***13***, *Lucianorhabdus cayeuxii* Deflandre, 1959, (XPL); ***14***, *Ceratolithoides aculeus* (Stradner, 1961) Prins & Sissingh in Sissingh (1977); ***15***, *Micula praemurus* (Bukry, 1973) Stradner & Steinmetz (1984); ***16***, *Micula prinsii* Perch-Nielsen, 1979

of the Roth zonation (1978) and UC16^{TP}–UC17^{TP} zones of Burnett zonation (1998). The last occurrence of *Aspidolithus parcus constrictus* (UC16^{TP} and UC17^{TP} zones boundary) and *Quadrum trifidum* (upper part of UC17^{TP} zone) was recorded. This zone is approximately extended by 30 m.

CC24 zone

The *Reinhardtites levis* Zone is determined from the interval of the LO of *Tranolithus orionatus* to the last occurrence of *Reinhardtites levis*. The age of the zone is early Maastrichtian. This zone is equivalent to the lower part of NC21 of Roth zonation (1978) and UC18^{TP} of Burnett zonation (1998). The thickness of this zone is 9 m.

CC25 zone

The next recorded unit of Sepidan is described as CC25 zone. The *Arkhangelskiella cymbiformis* Zone appears from the interval of the LO of *Reinhardtites levis* to the first occurrence of *Nephrolithus frequens*. In the present study, *Nephrolithus frequens* is not recognizable. Therefore, the upper boundary of this zone is determined by the first occurrences of *Micula murus.* Some of the species in this zone are *Lithraphidites quadratus*, *Micula murus* and *Micula praemurus.* This zone is equivalent to the upper part of NC21 and NC22 of Roth zonation (1978) and UC19^{TP}, UC20a^{TP} of Burnett zonation (1998). The age of zone is late Maastrichtian. The thickness of this zone is 28 m.

CC26 zone

The last bioevents recorded from gray shale of upper Cretaceous/latest Maastrichtian is the zone CC26, defined as the interval from the first occurrences to last occurrences of *Nephrolithus frequens.* However, in low latitudes (including Iran), *Nephrolithus frequens* is not recognizable but here the FO of *Micula murus* and then *Micula prinsii* can be used to determine the approximate boundary of the CC25–CC26 biozones of the late Maastrichtian–latest Maastrichtian. Some of the species in this zone are *Micula murus, Micula prinsii,* and *Thoracosphaera operculata.* This zone is equivalent to zone NC23 of Roth zonation (1978) and UC20b^{TP} and UC20d^{TP} of Burnett zonation (1998). The first appearance of *Ceratolithoides kamptneri* at the beginning of subzone UC20c^{TP} was not recorded. Therefore, in the present study UC20c^{TP} is not recognizable. The age of the zone is latest Maastrichtian. The thickness of this zone is 18 m.

Biostratigraphy based on planktonic foraminifera and correlation with calcareous nannofossils

There is no correlative data of interior Fars upper Cretaceous pelagic foraminifera and calcareous nannofossil region. Actually, biostratigraphic study of the Sepidan section is the first data which deals with stratigraphic distribution of the upper Cretaceous foraminifera and calcareous nannofossils in this area. The correlation between foraminifera and nannofossils in the Gurpi Formation in Sepidan is an applicable proof for other biocorrelations in different parts of the Zagros Basin. Planktonic foraminifera are diverse in samples of the Gurpi Formation at the studied section (Fig. 8). As previously mentioned, these zonal schemes are compared with the Tethyan nannofossil standard zonation (e.g., Sissingh 1977) and other biozonation (Figs. 9, 10). The presented zonal scheme consists of the global and regional standard zonation (Premoli Silva and Verga 2004; Esfandyari Bayat and Rameh 2016) (Fig. 10). The taxa in this study are illustrated in the plate (Fig. 8). According to biostratigraphic data, the determined biozones are described as follows.

Dicarinella asymetrica Zone

The *Dicarinella asymetrica* Taxon Range Zone (TRZ) is distinguished by the total range of *Dicarinella asymetrica.* So, the lower boundary is indicated with the FO of *Dicarinella asymetrica* and the upper boundary of this zone is marked by the LO of *Dicarinella asymetrica*. In fact, the upper boundary of this zone coincides with the extinction of dicarinellids. The age of this zone is referred to as early Santonian to earliest Campanian (Caron 1985;

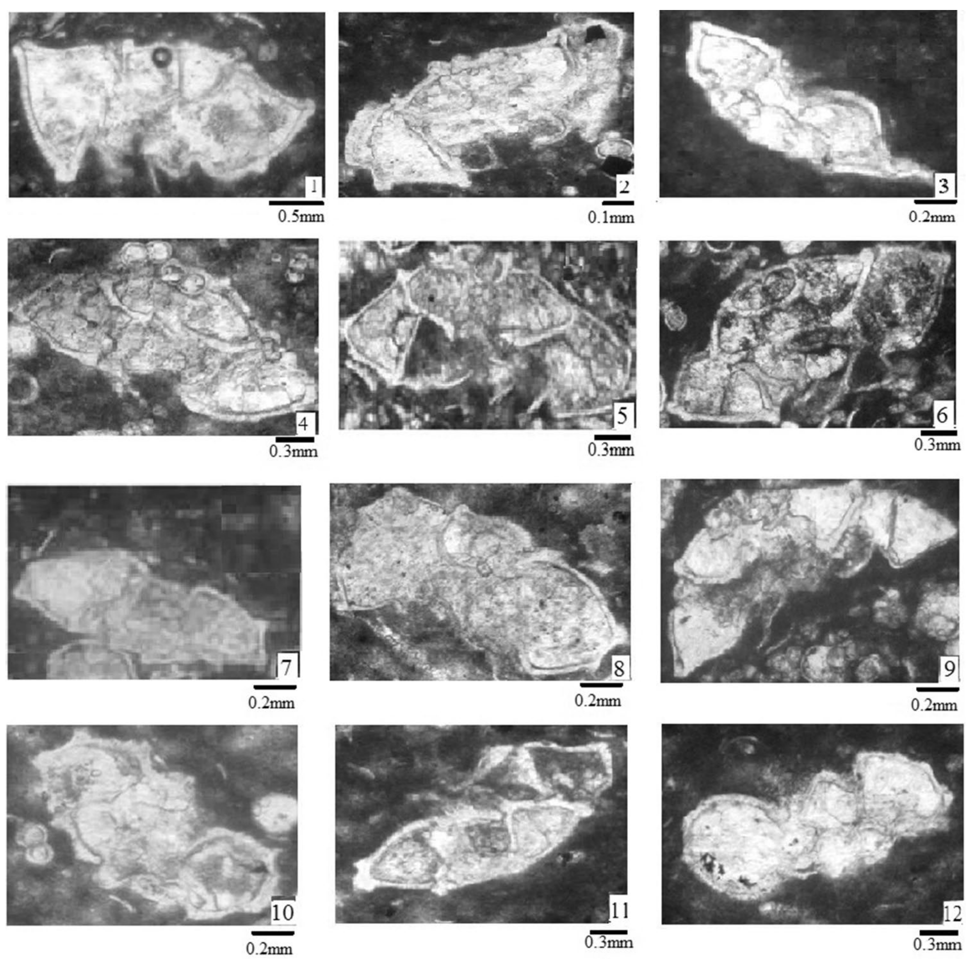

Fig. 8 Plate: the taxa considered in the present figure are referenced in Loeblich and Tappan (1989); ***1***, *Globotruncanita elevata* (Brotzen, 1934); ***2***, *Globotruncana ventricosa* (White, 1928); ***3***, *Globotruncanella havanensis* (Voorwijk, 1937); ***4***, *Globotruncana falsostuarti* (Gandolfi, 1955); ***5***, *Globotruncanita arca* (Cushman, 1926); ***6***, *Globotruncanita stuarti* (de Lapparent, 1918); ***7***, *Abathomphalus mayaroensis* (Bolli, 1951); ***8***, *Globotruncana aegyptiaca* (Nakkady, 1950); ***9***, *Globotruncana lapparenti* (Carsey, 1926); ***10***, *Globotruncana bulloides* (Vogler, 1941); ***11***, *Globotruncana lapparenti* (Carsey, 1926); ***12***, *Globotruncana hilli* (Banner & Blow, 1960)

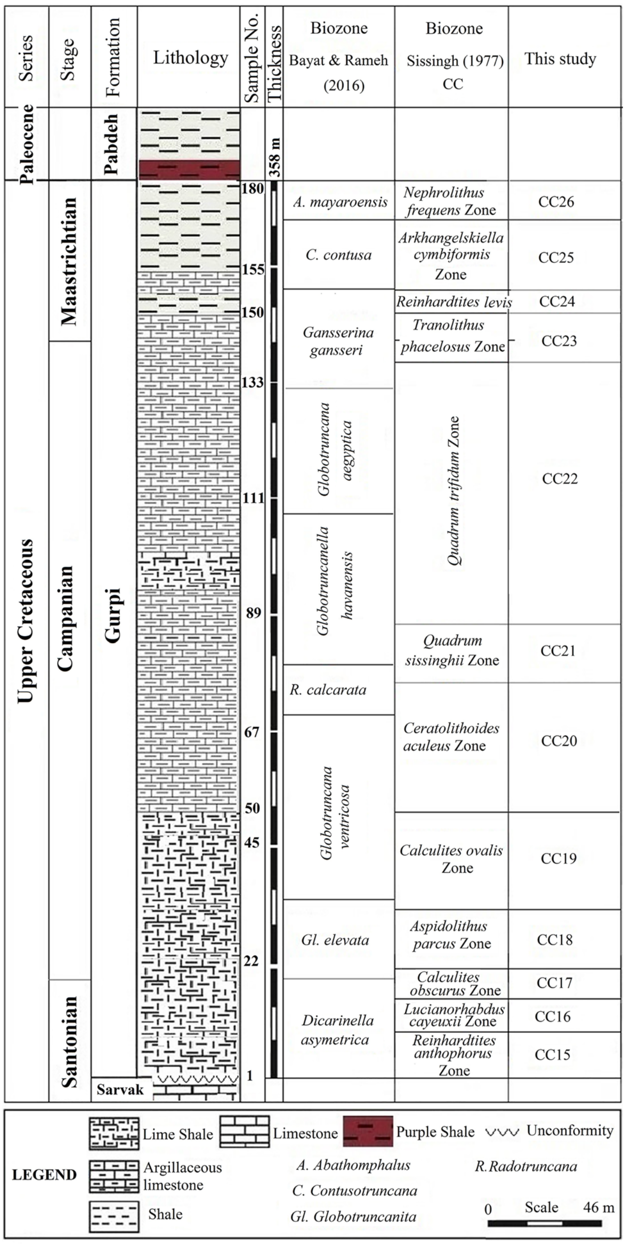

Fig. 9 Biostratigraphy of Gurpi Formation and comparison with global standard zonation and regional zonation

Sliter 1989; Premoli Silva and Verga 2004). The lithological aspect of this biozone is composed of calcareous shale which is extended approximately 38 m. This biozone was recorded from Zagros previously (James and Wynd 1965; Vaziri Moghaddam 2002; Rahimi et al. 2015; Solgi et al. 2015; Esfandyari Bayat and Rameh 2016). According to calcareous nannofossils, this zone lies in the CC15, CC16 and CC17 zones.

Globotruncanita elevata Partial Range Zone

The *Globotruncanita elevata* Partial Range Zone (PRZ) determines the stratigraphic interval with *Globotruncanita elevata,* from the LO of *Dicarinella asymetrica* which is coeval with the FO of *Globotruncana ventricosa* and corresponds to the early Campanian age. The diagnosed planktonic foraminifers of this biozone are composed of *Globotruncanita elevata, Globotruncana arca, Globotruncana lapparenti, Globotruncana bulloides, Globotruncana linneiana,* and *Globotruncanita stuartiformis.* The thickness of the biozone is measured to be about 33 m. Similar to *Dicarinella asymetrica* Zone, this zone was previously recorded from Zagros (James and Wynd 1965; Vaziri Moghaddam 2002; Rahimi et al. 2015; Solgi et al. 2015; Esfandyari Bayat and Rameh 2016) and Tethyan realms (Caron 1985). According to calcareous nannofossils, this zone lies in the CC18 zone.

Globotruncana ventricosa Interval Range Zone

This zone is marked by the interval from the FO of *Globotruncana ventricosa* to the FO of *Radotruncana calcarata* and corresponds to the late early Campanian to early late Campaninan. Premoli Silva and Verga (2004) have confirmed *Globotruncana falsostuarti* as an associated taxon in the *Globotruncana ventricosa* Zone which represents mid-Campanian. The thickness of the biozone is measured to be approximately 71 m. The planktonic foraminiferal taxa which are associated with this zone include *Globotruncana lapparenti, Globotruncana arca, Globotruncana linneiana, Globotruncanita elevata*, *Globotruncana ventricosa, Globotruncanita stuarti, Globotruncanita stuartiformis, Globotruncana bulloides,* and *Globotruncana hilli.* This zone was recorded from the Zagros Basin (James and Wynd 1965; Vaziri Moghaddam 2002; Rahimi et al. 2015; Solgi et al. 2015; Esfandyari Bayat and Rameh 2016). According to biozonation of calcareous nannofossils, this zone is referred to in the CC19 and lower part of CC20.

Radotruncana calcarata Total Range Zone

This zone is identified by the TRZ of *Radotruncana calcarata.* The lower boundary is indicated with the FO of *Radotruncana calcarata* and the upper boundary with the last occurrence of the *Radotruncana calcarata* species. The age of this zone is indicated as the mid-Campanian in this section. The thickness of the biozone is 20 m. This zone is characterized by the most important species: *Globotruncana lapparenti, Globotruncanita stuarti, Globotruncana arca, Globotruncana linneiana, Globotruncana bulloides, Globotruncanita stuartiformis,*

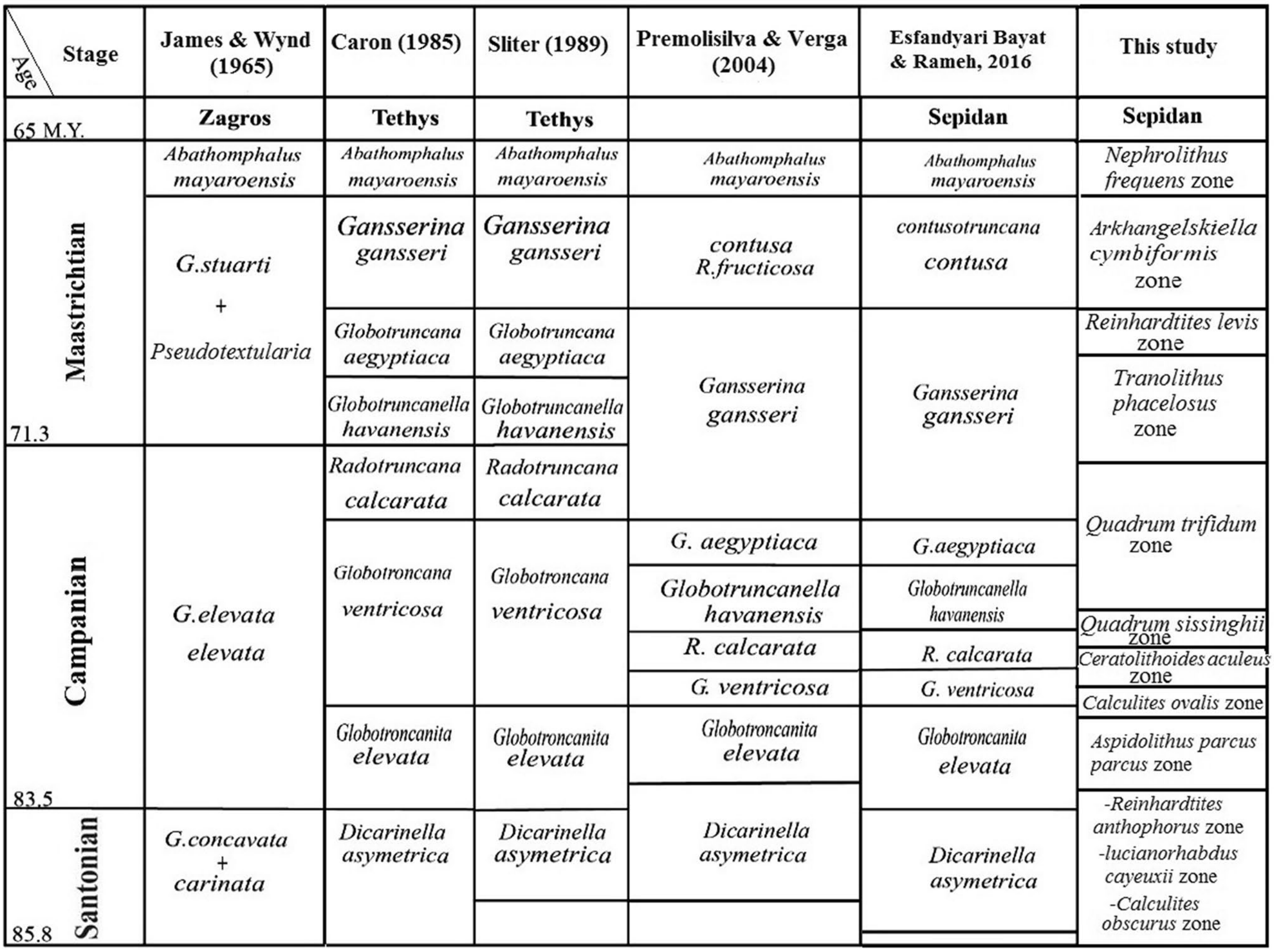

Fig. 10 Correlation of some of the worldwide standard biozonation based on planktonic foraminifera with the studied section based on calcareous nannofossils

Globotruncanita elevata, and *Globotruncana hilli.* According to calcareous nannofossils, this zone is equal to the upper part of the CC20 zone and the lower part of CC21.

Globotruncanella havanensis Partial Range Zone

The mentioned zone is established by the interval from the last occurrence of *Radotruncana calcarata* to the first occurrence of *Globotruncana aegyptica,* which corresponds to the late Campaninan. The thickness of the biozone is measured to be approximately 56 m. Bilotte et al. (2001) have recorded *Globotruncanella havanensis* from the upper Campanian sequence of Tercis Les Basin of France. Established biozones of calcareous nannofossils confirm that this zone corresponds with the upper part of the CC21 zone and lower part of CC22.

Globotruncana aegyptica Interval Range Zone

The *Globotruncana aegyptica* Zone is recognized in argillaceous limestone. The lower biostratigraphic limit of this biozone is distinguished by the first occurrence of *Globotruncana aegyptica* and the upper biostratigraphic limit is marked by the first occurrence of *Gansserina gansseri* which refers to the late Campaninan. The thickness of the biozone is 50 m. This zone was described from Tethys (Caron 1985; Sliter 1989) and is characterized by planktonic foraminiferal taxa: *Globotruncana falsostuarti, Globotruncanita stuarti, Globotruncanella havanensis, Globotruncana bulloides, Globotruncanita stuartiformis, Globotruncana orientalis, Globotruncana rosetta, Globotruncana ventricosa, Globotruncana arca,* and *Globotruncana lapparenti.* Based on the received biostratigraphic data of calcareous nannofossils, this zone is comparable with the CC22 zone.

Gansserina gansseri Interval Range Zone

This zone is defined by the first occurrence of *Gansserina gansseri* to the first occurrence of *Contusotruncana Contusa* which is assigned to the latest Campanian to early Maastrichtian. The thickness of the biozone is measured to be about 46 m. The *Gansserina gansseri* Interval Range Zone was previously described from Tethys (Caron 1985; Sliter 1989), which was described as *Gansserina gansseri* Zone by the mentioned studies, and the age of upper Campanian to lower Maastrichtian was confirmed. Therefore, the latest Campanian to early Maastrichtian age is acceptable for this biozone. The common foraminiferal assemblage of this biozone consists of *Globotruncanita stuarti, Globotruncanita angulata, Globotruncana insignis, Globotruncana bulloides, Globotruncana falsostuarti, Globotruncana arca, Globotruncana aegyptica, Globotruncana orientalis, Globotruncanita stuartiformis,* and *Globotruncana lapparanti.* The determined biozones of calcareous nannofossils in this section support that this zone lies in the upper part of CC22, CC23 and CC24.

Contusotruncana contusa Total Range Zone

This zone is distinguished by the TRZ of *Contusotruncana contusa* which refers to the late early Maastrichtian to early late Maastrichtian. This zone is extended approximately 28 m. The common foraminifers of this biozone are composed of: *Globotruncanita stuartiformis, Globotruncana lapparanti, Globotruncana arca, Globotruncana bulloides, Globotruncanita angulata, Globotruncana falsostuarti, Globotruncanita stuarti,* and *Globotruncana insignis.* This zone is synchronous with CC25 zone of the identified calcareous nannofossils.

Abathomphalus mayaroensis Interval Range Zone

This biozone is described in the Sepidan section for the first time. This zone is defined by the first occurrence of *Abathomphalus mayaroensis* to the disappearance of all genera of Globotruncanidae and corresponds to the late Maastrichtian. The thickness of the biozone is 18 m. The upper biostratigraphic limit of the Gurpi Formation in the Sepidan section is distinguished by the last occurrence of *Abathomphalus mayaroensis*, which has been recorded in the Lurestan area by Wynd previously (1965). The CC26 zone of calcareous nannofossils is coeval with the mentioned zone.

Conclusions

Received biostratigraphic data remarkably indicate paleogeographic implication. Actually, the investigated taxa of both nannofossils and planktic foraminifers reflect faunal provincialism characteristic in the studied area. However, the established biozones confirm the paleobiogeographic distribution of both taxa of nannofossils and planktic foraminifers. It is necessary to note that the reconstruction of paleogeographic distribution of both Upper Cretaceous calcareous nannofossils and planktons needs more biostratigraphic data of other stratigraphic sections along both coastal and interior Fars regions. The investigated nannofossils such as *Micula murus*, *Micula prinsii*, and *Thoracosphaera operculata* are coeval with *Abathomphalus mayaroensis* which indicate the late Maastrichtian age. Calcareous nannofossils and planktonic foraminifera are useful in determining the relative age of the Cretaceous strata. By evaluation of the calcareous nannofossils and planktic foraminifera in the Sepidan stratigraphic section and investigation of biozones, it is possible to examine the Gurpi Formation deposits. Based on the stratigraphic distribution of late Cretaceous planktons, the Gurpi Formation includes nine biozones with the age of Santonian to Maastrichtian. The interpretation of calcareous nannofossil biostratigraphic data enables the subdivision of the studied succession into 12 biozones at the more accurate age of late early Santonian to latest Maastrichtian. Therefore, the biostratigraphy of the Gurpi Formation in the Sepidan section reflects that the lower biostratigraphic limit of the Gurpi Formation is related to the late early Santonian (*Reinhardtites anthophorus* Zone), equivalent to *Dicarinella asymetrica* Zone which is an index taxon of the Santonian. The upper biostratigraphic limit of the Gurpi Formation is marked by the last occurrence of *Abathomphalus mayaroensis* (*Abathomphalus mayaroensis* Interval Range Zone/late Maastrichtian), equivalent with *Nephrolithus frequens* Zone (CC26), which is synchronous with the latest Maastrichtian in the Sepidan section. As can be seen, the results are consistent with the general trend of planktonic foraminifera and calcareous nannofossils of the Gurpi Formation. Therefore, biostratigraphic investigations of the Gurpi Formation indicate that the established calcareous nannofossil biozones are comparable to planktonic foraminiferal biozones. The paleogeographic distribution of planktic foraminifers supports discrepancy of provincialism data in the Zagros area because of the presence of *Abathomphalus mayaroensis*. As mentioned before, this taxon has not been recorded from Fars area. Therefore, it is required to study other exposures of the Gurpi Formation along the interior Fars region.

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