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Biostratigraphy of Foraminifera at The Upper Cretaceous and Lower Paleogene Strata in The Kuh-E Genu, Bandar Abbas City, Northwestern Persian Gulf, Southern Iran

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Abstract

The study area is located in Tang-e Bagh at Kuh-e Genu, approximately 69 km, northern Persian Gulf. The age relationships of Sarvak, Gurpi, and Pabdeh formations were unclear in the study area because of the low-resolution biostratigraphy. Therefore, 152 samples were collected. All samples contain well-preserved foraminifers that permit clarification of the age of these formations. Nine benthic species (5 genera) and sixty-eight planktonic foraminiferal species (29 genera) were identified that were arranged eleven biozones with high resolution of biostratigraphy. Biozone Ⅰ corresponds to the total range of Orbitolina qatarica in the Mauddud Member of Sarvak Formation, suggesting the Cenomanian (middle Cenomanian) age. The biozone Ⅱ is characterized by the total range of Dicarinella asymetrica in the basal part of Gurpi Formation, indicating the Santonian age. Therefore, there is a hiatus between the Sarvak and Gurpi formations that includes part of the Mauddud Member, the whole Ahmadi Member, and the Ilam Formation. This hiatus encompasses the late Cenomanian to Coniacian that is marked by a few meters of Fe-stained deposits in the Kuh-e Genu; the interval range zones Ⅲ to Ⅶ as well as Abathomphalus mayaroensis zone Ⅷ (TRZ) are present within the rest of Gurpi Formation and suggests the Campanian to Maastrichtian. The biozones IX-XI are present within the Pabdeh Formation that corresponds to a Not Zone and two interval range zones (P1b, P1c-P2), suggesting Danian. Based on microfacies, texture, and paleontological analysis, a deep-water environment suggests for Gurpi and Pabdeh formations and shallow marine conditions for Sarvak Formation.

Keywords: Biostratigraphy; Upper Cretaceous; Lower Paleogene; Kuh-e Genu; NW Persian Gulf.

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Introduction

The study was conducted in Tang-e Bagh (Tang-e means valley and Bagh means garden) at Kuh-e Genu, approximately 69 km northwestern Bandar Abbas city (northern Persian Gulf). A road from Bandar Abbas to the study area is the main link (25 km paved and 34 km unpaved). A thick Cretaceous and Paleogene succession is well exposed and developed in Tang-e Bagh with geographical coordination of 27°26'96" N and 56°12'22" (Fig. 1). The succession has been divided into Gadvan, Dariyan, Kazhdumi, Sarvak, Gurpi, Pabdeh, Asmari, and Mishan formations in ascending stratigraphic order with low biostratigraphic resolution [1-3]. In this study, the Sarvak, Gurpi, and Pabdeh formations were considered to identify their microfauna to verify the following goals: (1) refine the biostratigraphy of the Sarvak (106 m), Gurpi (74.2 m), and basal part of the Pabdeh formations (42.5 m); (2) establish local biozones for the identification of Upper Cretaceous and Lower Paleogene in the Zagros Mountains, southern Iran; (3) confirm continuity and discontinuity sedimentation from the Upper Cretaceous to Lower Paleogene during the time interval represented by investigated rock units; (4) Presence or absence of Ahmadi Member of Sarvak Formation; (5) Presence or absence of Ilam Formation; (6) Duration of the geological gap between Sarvak and Gurpi formations, and (7) Presence or absence of discontinuity between Gurpi and Pabdeh formations.

Stratigraphy and previous works

The measured and sampled stratigraphic section was chosen in Tang-e Bagh, where the Cretaceous and Paleogene strata have a thickness of more than 1184 m, and they are discussed in ascending stratigraphic order:

The Sarvak Formation was previously called mid-Cretaceous limestone, Rudist limestone, Hippuritic limestone, Lashtagan limestone, or Bangestan limestone [1]. This formation has a thickness of 821 m at its type locality (Tang-e Sarvak) in the central part of the southern flank of Kuh-e Bangestan, but in the study area, the thickness of this formation reduces to 106 m. The Sarvak Formation has been divided into Mauddud and Ahmadi Members. The Mauddud Member of the Sarvak Formation is equivalent to the Mauddud Formation of Kuwait [1]. This member is characterized by the presence of *Trocholina cf. lenticularis*, and *Orbitolina concava zone*. This member consists of thick-bedded, gray to brown Orbitolina limestone. This member extends throughout coastal Fars from 61 to 122 m in thickness and conformably lies on the Kazhdumi Formation. The Ahmadi Member was previously called *Exogyra* marls with thin-bedded limestone. The Ahmadi Member contains microfauna such as *Hemicyclammina sigali*, *Favusella washitensis*, which differs from the Mauddud Member of the Sarvak Formation. The Mauddud Member is disconformably overlaid with the Ilam Formation within the coastal Fars (Fig. 2). It should be mentioned that the Ahmadi Member and Ilam Formation are not present in Tang-e Bagh at Kuh-e Genu, northern Persian Gulf. Based on microfauna such as *Pithonella ovalis*, *Globigerina sp*., and *Hedbergella sp*., the Sarvak Formation is assigned to Albian-Turonian in Khuzestan, Fars, and Lurestan provinces

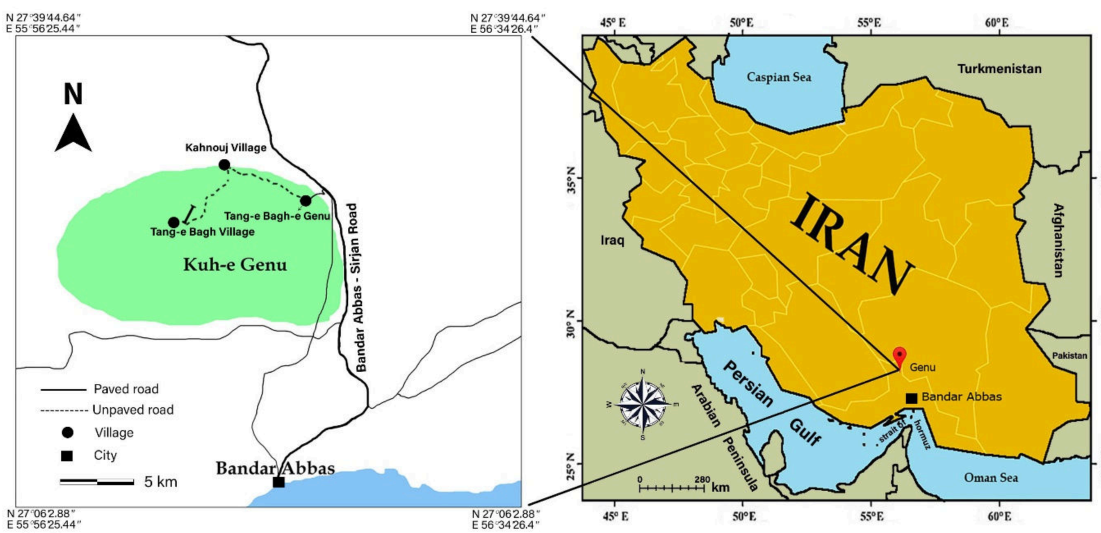

Figure 1. Location map of the study area and connection to an adjacent city.

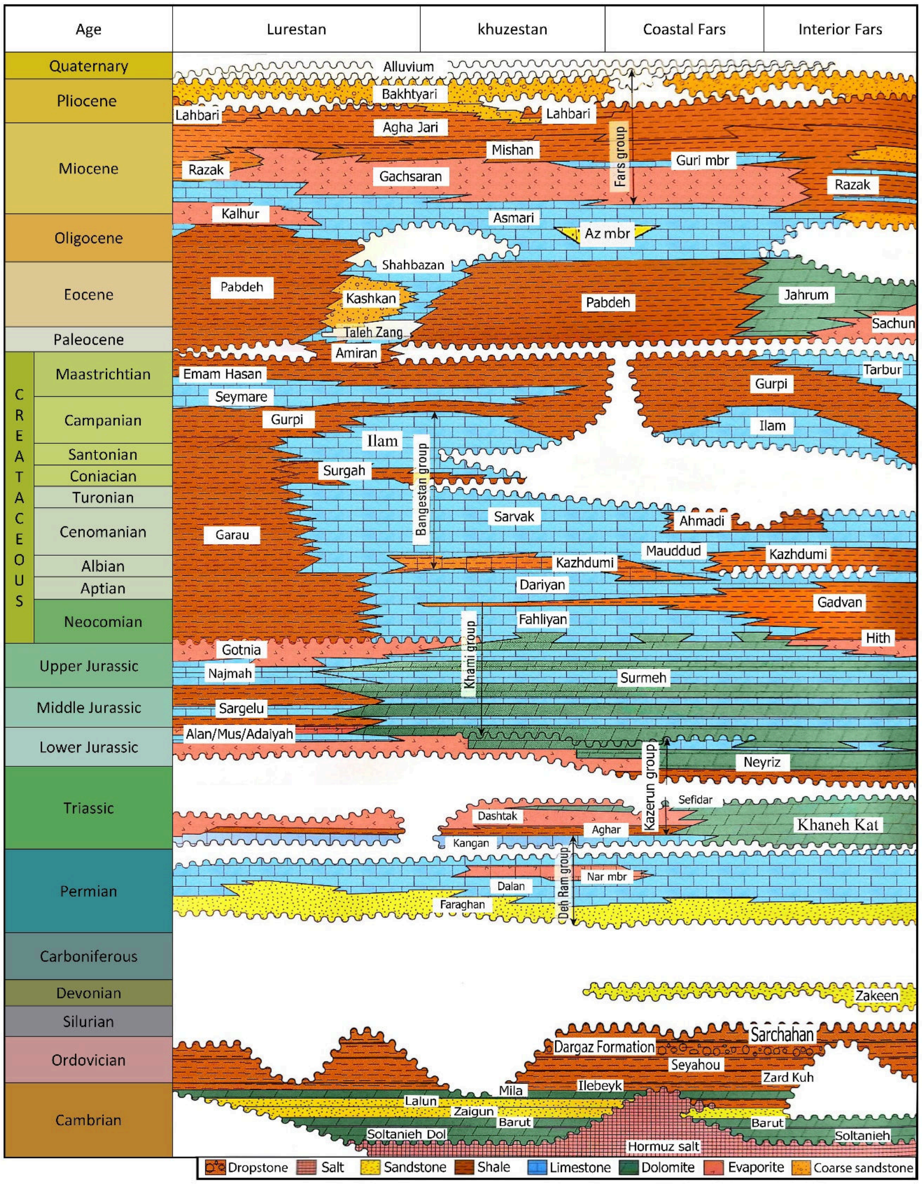

Figure 2. Composite stratigraphy column for the Zagros Basin, southern Iran [67-69].

[1]. The Gurpi Formation, previously called Globigerina Marl or Dezak Marl, and then was divided into the Gurpi and the Pabdeh formations [1]. This formation has a thickness of 320 m at its type locality in Tang-e Pabdeh, where locates north of the Lali oil field, but its thickness reduces from 320 m to 74.2 m in Kuh-e Genu. The Gurpi Formation consists of dark bluish-gray, marine marl, and shale with subordinate marly limestone. This formation lies on the Ilam Formation with minor disconformity in the Zagros Mountains. The Gurpi formation has been previously divided into the Emam Hasan and the Lopha limestone members and recently only Seymare member throughout the Zagros Basin (Fig. 2). The Emam Hasan limestone Member is named after Tang-e Emam Hasan on the southwestern flank of the anticline of the same name. These members are not presented in the study area. The upper contact of the Gurpi Formation is also disconformable in Fars and parts of Khuzestan, but it is conformable in the Lurestan province. This boundary is placed at the base of the

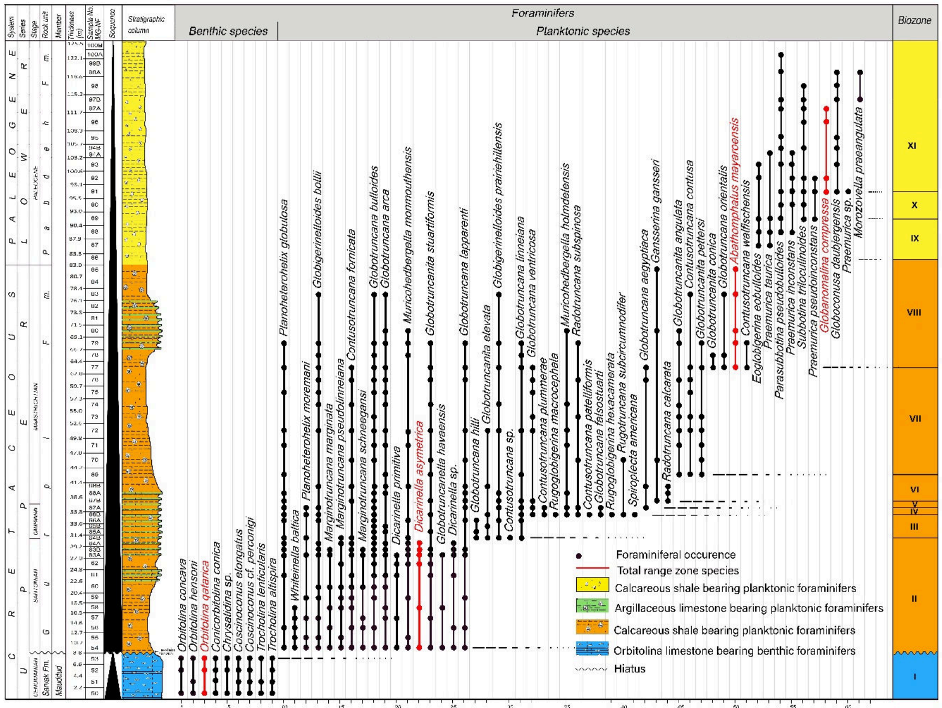

Fig. 3.

Figure 3. Stratigraphic distribution of selected foraminifers in the Sarvak, Gurpi, and Pabdeh formations at Kuh-e-Genu, northern Persian Gulf, Southern Iran.

purple shale member of the Pabdeh Formation in the southern part of the Zagros Basin. Based on diagnostic foraminifers such as *Gansserina gansseri*, *Globotruncanita stuarti*, *Racemiguembelina fructicosa*, and *Abathomphalus mayaroensis*, the Santonian to Maastrichtian is assigned to the Gurpi Formation in the Khuzestan and Fars provinces and Campanian to Paleocene in the Lurestan province [1]. The Pabdeh Formation was previously called the Globigerina Marl or Dezak Marl [1]. This formation has a thickness of 799 m at Tang-e Pabdeh (type section) on the southeastern end of Kuh-e Pabdeh. It consists of gray shale and thin argillaceous limestone. The Pabdeh Formation is divided into the purple shale member at the base of the Pabdeh Formation and the Taleh Zang Member (Fig. 2). The purple shale member consists of silty to sandy purple-red gray shale and argillaceous limestone containing fish scales, but the Taleh Zang Member is comprised of clean limestone, which is restricted to the Lurestan province. Based on diagnostic microfauna such as *Morozovella velascoensis* and *Globanomalina pseudomenardii*, the Late Paleocene to Oligocene in the Khuzestan and Fars provinces and the Late Paleocene to Miocene in the Lurestan province are suggestive of the Pabdeh Formation [1].

Materials and Methods

In this study, 152 surface samples were collected from an outcrop succession (Sarvak, Gurpi, and Pabdeh formations) in Kuh-e Genu. Sixty-one out of 152 samples were used for this paper. While the succession has a thickness of 231.5 m, only 125.5 m out of this thickness is used for this article, and the remaining 106 meters contain extremely abundant Orbitolina which will be presented in another paper. The collected samples are designated herein by numbers (50-100B) are preceded by prefixes referring to the collectors (MG, Mohammad Ghavidel Syooki; NF, Nadia Farsi) (Fig. 3). The samples were treated in the paleontology lab of Payam-e Noor University. All samples were proven to have planktonic and benthic foraminifers along with green algae, radiolaria, echinoid, gastropod, and bivalve components. Ninety thin sections were prepared and used for identification of different species and supplying microscopic photos by light microscope. All hand specimen samples and microscopic slides relating to this study are housed in the paleontological collections of the Payam-e noor university under-sample numbers MG-NF 50-100B.

Biostratigraphy

In this study, seventy-seven species were identified and permitted to establish eleven foraminiferal biozones in Tang-e Bagh, Kuh-e Genu. The encountered biozones are either Total Range Zone (TRZ) or Interval Range Zone (IRZ). These are discussed in ascending stratigraphic order as follows:

Zone Ⅰ. Orbitolina qatarica Zone (TRZ)

This zone, marked by the presence of the total range

Plate I

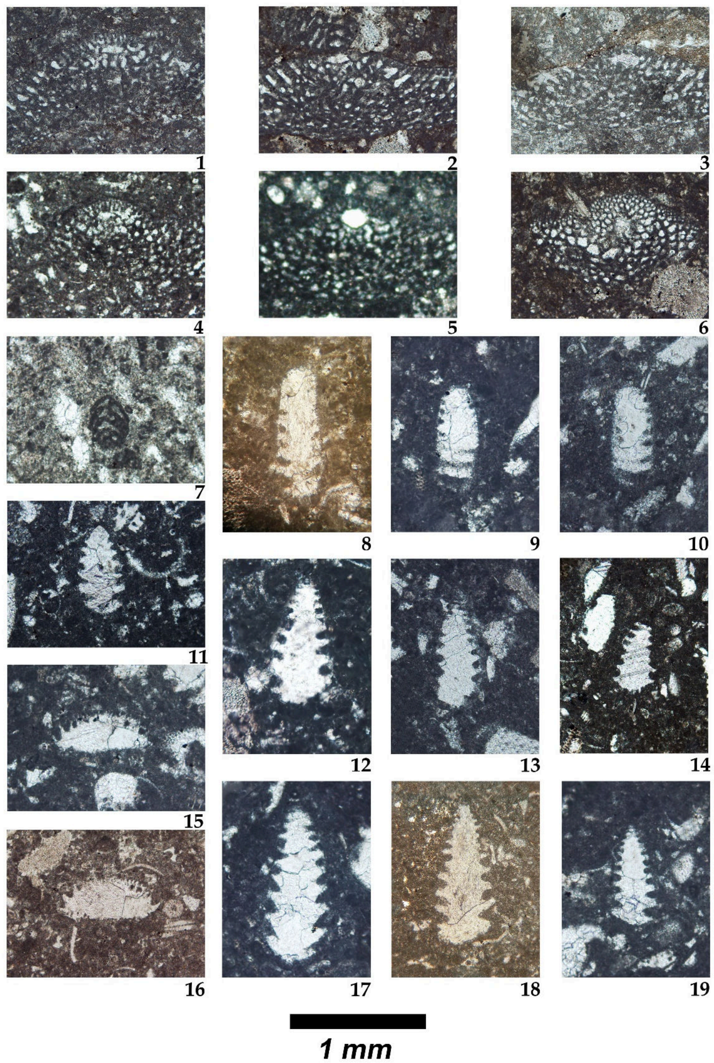

Plate I

Fig. 1. *Orbitolina concava* [5] (sample MG-NF 50-53) (axial section with visible proloculus).
Figs. 2,3. *Orbitolina hensoni* [6] (sample MG-NF 50-53) (axial section with visible proloculus).
Fig. 4. *Orbitolina qatarica* [4] emend. [6] (sample MG-NF 50-53) (axial section with visible proloculus).
Figs. 5,6. *Conicorbitolina conica* [7] (sample MG-NF 50-53) (axial section with visible proloculus).
Fig. 7. *Chrysalidina gradata* [44] (sample MG-NF 50-53) (axial section).
Figs. 8-10. *Coscinoconus elongatus* [8] (sample MG-NF 50-53) (axial section).
Figs. 11-14. *Coscinoconus* cf. *perconigi* [9] (sample MG-NF 50-53) (axial section).
Figs. 15,16. *Trocholina lenticularis* [4] (sample MG-NF 50-53) (axial section).
Figs. 17-19. *Trocholina altispira* [4] (sample MG-NF 50-53) (axial section).

Figure 4. Illustration of the Fe-stained horizon between the Sarvak (uppermost) and the Gurpi (lowermost) formations in Tang-e Bagh, Kuh-e-Genu, northwest of Bandar Abbas city, Southern Iran.

zone of *Orbitolina qatarica* [4] (Plate I, Fig. 1) that extends through a thickness of 8.8 m (MG-NF 50 to MG-NF 53) in the Mauddud Member of the Sarvak Formation (Fig. 3). The associated microfaunas are *Orbitolina concava* [5], *Orbitolina hensoni* [6], *Conicorbitolina conica* [7], *Chrysalidina sp*., *Coscinoconus elongatus* [8], *Coscinoconus cf. perconigi* [9], *Trocholina lenticularis* [10], and *Trocholina altispira* [4] (Fig. 3). Among these microfaunas, *Coscinoconus elongatus* [8] ranges from Late Jurassic to early Late Cretaceous, but the remainders are confined to Albian-Cenomanian. *Orbitolina qatarica* [4] was originally reported from the middle Cenomanian strata of Qatar (Dukhan-1 Well), whereas [6] suggested early to middle Cenomanian for this species. In this study, Orbitolina qatarica [4] is recorded from the Zagros Basin of Iran for the first time. Based on the stratigraphic potential of this species, the Mauddud Member of the Sarvak Formation is assigned to the middle Cenomanian. Therefore, a major erosional event (hiatus) is present between the Sarvak and the Gurpi formations in Kuh-e-Genu that encompasses part of the Mauddud Member, the whole Ahmadi Member, and the Ilam Formation. This erosional surface is signified by a few meters of Fe-stained sediments at the lowermost part of the Gurpi Formation (Fig. 4).

Zone Ⅱ. Dicarinella asymetrica Zone (TRZ)

This zone is marked by the presence of *Dicarinella asymetrica* [11] (Plate II, Fig. 14) with rare frequencies and includes a thickness of 21.5 m (MG-NF 54 to MG-NF 64B). In the lowermost part of the Gurpi Formation, Dicarinella asymetrica has a total range of latest Coniacian to Santonian age [12] (Fig. 3), which is correlatable to equal time in other parts of the world [13-20]. The associated planktonic foraminifers of this biozone are *Dicarinella primitiva* [21], *Muricohedbergella monmouthensis* [22], *Globotruncanita stuartiformis* [21], *Globotruncanella havanensis* [23], *Globotruncana lapparenti* [24] (Plate III, Fig. 1), *Dicarinella sp*., *Dicarinella cf. asymetrica* [11], *Planoheterohelix globulosa* [25], *Whiteinella baltica* [26], *Planoheterohelix moremani* [27], *Globigerinelloides bollii* [28], *Marginotruncana marginata* [29], *Marginotruncana cf. marginata* [29], *Marginotruncana pseudolinneiana* [28], *Contusotruncana fornicata* [30], *Contusotruncana cf. fornicata* [30], *Marginotruncana schneegansi* [11], *Globotruncana bulloides* [31], *Globotruncana arca* [32], and *Globotruncana cf. arca* [32]. Herein, it should be mentioned that the stratigraphic range of Globotruncanella havanensis was previously confined to early Campanian to late Maastrichtian, whereas, in this study, its stratigraphic range is begun from Santonian age rather than Campanian because of its association with other foraminifers of the Santonian age. These associated species range within the Late Cretaceous (Cenomanian to Maastrichtian) and continue into the succeeding biozones. Furthermore, many planktonic foraminifers, including *Hedbergella cf. infracretacea* [33], *Favusella washitensis* [34], *Dicarinella algeriana* [35], *Helvetoglobotruncana*

Plate II

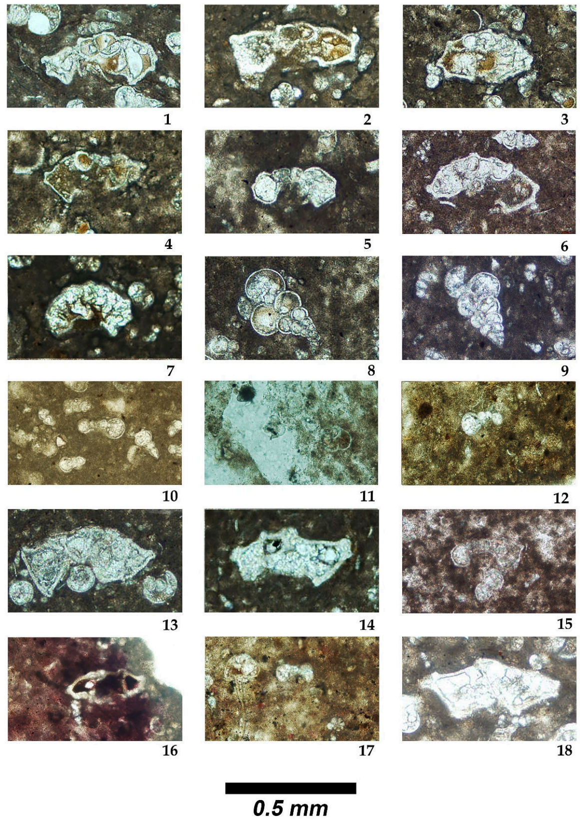

Plate II

Fig. 1. *Marginotruncana marginata* [29] (sample MG-NF 54-63A).
Fig. 2. *Marginotruncana pseudolinneiana* [28] (sample MG-NF 54-64B).
Fig. 3. *Contusotruncana fornicata* [30] (sample MG-NF 54-77).
Fig. 4. *Marginotruncana schneegansi* [11] (sample MG-NF 54-63A).
Fig. 5. *Globotruncana bulloides* [31] (sample MG-NF 54-83).
Fig. 6. *Globotruncana arca* [32] [30] (sample MG-NF 54-83).
Fig. 7. *Dicarinella imbricata* [37] (sample MG-NF 54-60).
Fig. 8. *Planoheterohelix globulosa* [25] (sample MG-NF 54-79).
Fig. 9. *Planoheterohelix moremani* [27] (sample MG-NF 54-67A).
Fig. 10. *Globigerinelloides bollii* [28] (sample MG-NF 54-83).
Fig. 11. *Favusella washitensis* [34] (sample MG-NF 54-57).
Fig. 12. *Whiteinella baltica* [26] (sample MG-NF 54-58).
Fig. 13. *Globotruncanita stuartiformis* [21] (sample MG-NF 54-79).
Fig. 14. *Dicarinella asymetrica* [11] (sample MG-NF 54-64B).
Fig. 15. *Globotruncana hilli* [28] (sample MG-NF 64B-66A).
Fig. 16. *Dicarinella algeriana* [35] (sample MG-NF 54-57).
Fig. 17. *Helvetoglobotruncana praehelvetica* [36] (sample MG-NF 54-59).
Fig. 18. *Dicarinella primitiva* [21] (sample MG-NF 54-63A).

praehelvetica [36], and *Dicarinella imbricata* [37], are present which have been recycled from the Ahmadi Member of the Sarvak Formation and the whole Ilam Formation into the basal part of Gurpi Formation. Therefore, there is a hiatus between the Mauddud Member of Sarvak Formation and Gurpi Formation, encompassing late Cenomanian to the end of Coniacian. This statement corresponds to the absence of the

Plate III

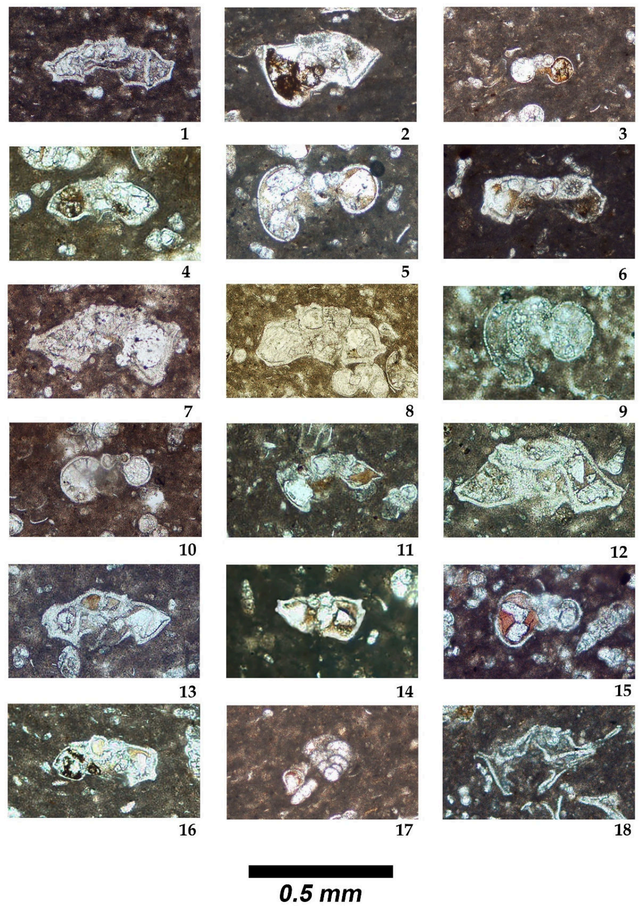

Plate III

Fig. 1. *Globotruncana lapparenti* [24] (sample MG-NF 54-79).
Fig. 2. *Globotruncanita elevata* [40] (sample MG-NF 64B-72).
Fig. 3. *Muricohedbergella monmouthensis* [22] (sample MG-NF 54-80).
Fig. 4. *Globotruncanella havanensis* [23] (sample MG-NF 54-63A).
Fig. 5. *Globigerinelloides prairiehillensis* [28] (sample MG-NF 64B-83).
Fig. 6. *Globotruncana linneiana* [44] (sample MG-NF 64B-79).
Fig. 7. *Globotruncana ventricosa* [41] (sample MG-NF 66B-77).
Fig. 8. *Contusotruncana plummerae* [46] [70] (sample MG-NF 66B-67A).
Fig. 9. *Rugoglobigerina macrocephala* [47] (sample MG-NF 66B).
Fig. 10. *Muricohedbergella holmdelensis* [48] (sample MG-NF 66B-80).
Fig. 11. *Radotruncana subspinosa* [49] (sample MG-NF 66B-79).
Fig. 12. *Contusotruncana patelliformis* [46] [70] (sample MG-NF 66B).
Fig. 13. *Globotruncana falsostuarti* [11] (sample MG-NF 66B-67A).
Fig. 14. *Globotruncana aegyptiaca* [45] (sample MG-NF 67A-77).
Fig. 15. *Rugoglobigerina hexacamerata* [47] (sample MG-NF 66B).
Fig. 16. *Rugotruncana subcircumnodifer* [46] (sample MG-NF 66B-70).
Fig. 17. *Spiroplecta americana* [50] (sample MG-NF 66B).
Fig. 18. *Radotruncana calcarata* [54] (sample MG-NF 67B-68B).

Ahmadi shale Member of the Sarvak Formation and the whole thickness of the Ilam Formation. Based on palaeontological, sedimentological, and mineralogical components, four microfacies (MF-1 to MF-2) were recognized in the basal part of the Gurpi Formation, thereby indicating a deep-water environment (Table 1). It should be mentioned that this biozone has been recorded from the Kopeh-Dagh region, NE Iran [38]

Table 1. Microfacies of the studied samples of the Sarvak, Gurpi, and Pabdeh formations, in Tang-e Bagh, Kuh-e Genu, Southern Iran.

Sample No. (MG-NF)	Facies Name	Planktonic Frequency	Components
100	Planktonic foraminiferal wackestone (MF2)	Very rare	Planktonic foraminifera such as *Parasubbotina pseudobulloides*; Benthic foraminifera such as *Rotalia*, *Nodosaria* and *Lenticulina*; Iron oxide
99	Planktonic foraminiferal wackestone (MF2)	Rare	Planktonic foraminifera such as *Morozovella praeangulata*; Benthic foraminifera such as *Rotalia*, *Nodosaria* and *Lenticulina*; Echinoid spine
98	Planktonic foraminiferal wackestone (MF2)	Very rare	Planktonic foraminifera such as *Globoconusa daubjergensis*; Benthic foraminifera such as *Rotalia*; Serpulids; Echinoid spine
97	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Morozovella praeangulata*; Iron oxide; Echinoid spine
96	Planktonic foraminiferal wackestone (MF2)	Rare	Planktonic foraminifera such as *Globanomalina compressa*; Benthic foraminifera such as *Nodosaria*
95	Planktonic foraminiferal wackestone (MF2)	Rare	Planktonic foraminifera such as *Eoglobigerina eobulloides*; Benthic foraminifera such as *Nodosaria*; Serpulids
94	Planktonic foraminiferal wackestone (MF2)	Very rare	Planktonic foraminifera such as *Parasubbotina pseudobulloides*; Iron oxide
93	Planktonic foraminiferal wackestone (MF2)	Rare	Planktonic foraminifera such as *Praemurica inconstans* and *Acarinina* sp.
92	Planktonic foraminiferal wackestone (MF2)	Rare	Planktonic foraminifera such as *Globanomalina compressa*
91	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Praemurica pseudoinconstans*; Benthic foraminifera such as *Lenticulina* and *Nodosaria*; Iron oxide
90	Planktonic foraminiferal wackestone (MF2)	Rare	Planktonic foraminifera such as *Praemurica inconstans*; Iron oxide
89	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Eoglobigerina eobulloides*; Benthic foraminifera such as *Textularia* and *Lenticulina*; Iron oxide
88	Planktonic foraminiferal wackestone (MF2)	Rare	Planktonic foraminifera such as *Praemurica taurica*; Benthic foraminifera such as *Textularia*; Intraclasts
87	Planktonic foraminiferal wackestone (MF2)	Rare	Planktonic foraminifera such as *Eoglobigerina eobulloides*; Benthic foraminifera such as Elphidium sp.; Worm
86	Planktonic foraminiferal wackestone (MF2)	Very rare	Planktonic foraminiferal remains; *Radiolaria* such as *Nassellaria*
85	Planktonic foraminiferal wackestone (MF2)	Very rare	Planktonic foraminifera such as *Gansserina gansseri*; Benthic foraminifera such as *Rotalia*; *Radiolaria*
84	Planktonic foraminiferal wackestone (MF2)	Very rare	Planktonic foraminiferal remains; Iron oxide
83	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Globotruncana orientalis*; Clay; Iron Oxide
82	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminiferal remains
81	Planktonic foraminiferal wackestone (MF2)	Rare	Planktonic foraminiferal remains; Benthic foraminifera such as *Rotalia*
80	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Abathomphalus mayaroensis*; Iron oxide
79	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Contusotruncana walfischensis*; Benthic foraminifera such as *Textularia*; Iron oxide
78	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Globotruncana orientalis*; Iron oxide
77	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Globotruncanita conica*; Benthic foraminifera such as *Textularia*; Iron oxide
76	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Globotruncana aegyptiaca* and *Contusotruncana contusa*; Iron oxide
75	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Contusotruncana contusa* and *Globotruncana arca*; *Radiolaria*
74	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Globotruncanita stuartiformis*; *Radiolaria;* Iron oxide; Intraclasts
73	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Globotruncanita pettersi* and *Globotruncanita angulata*; *Radiolaria*
72	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Contusotruncana contusa* and *Globotruncana ventricosa*; *Radiolaria;* Iron oxide; Intraclasts
71	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Globotruncanita angulata* and *Muricohedbergella holmdelensis*; *Radiolaria*
70	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Globotruncanita pettersi*
69	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Globotruncana linneiana* ; Benthic foraminifera such as *Lenticulina;* Iron oxide
68	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Globotruncana arca*
67	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Globotruncana aegyptiaca* and *Globotruncanita stuarti*; *Radiolaria*

and Interior Fars region of the Zagros, SW Iran [39].

Zone Ⅲ. Globotruncanita elevata Zone (IRZ)

This zone is characterized by the first appearance of

Table 1. Ctd

Sample No. (MG-NF)	Facies Name	Planktonic Frequency	Components
66	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Contusotruncana plummerae* and *Globotruncana ventricosa*; *Radiolaria*
65	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Globotruncana hilli* and *Globotruncana bulloides*
64	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Globotruncanita elevata* and *Globigerinelloides prairiehillensis*
63	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Dicarinella asymetrica* and *Globotruncanella havanensis*
62	Planktonic foraminiferal wackestone (MF2)	Moderate	Planktonic foraminifera such as *Dicarinella primitiva* and *Globotruncanita stuartiformis*
61	Radiolaria - planktonic foraminifera wackestone (MF1)	Frequent	Planktonic foraminifera such as *Planoheterohelix globulosa*; *Radiolaria*
60	Planktonic foraminiferal wackestone (MF2)	Frequent	Planktonic foraminifera such as *Contusotruncana fornicata*; Benthic foraminifera such as Lenticulina; sparitic calcite
59	Radiolaria - planktonic foraminifera wackestone (MF1)	Frequent	Planktonic foraminifera such as *Globotruncana bulloides*; *Radiolaria*
58	Radiolaria - planktonic foraminifera wackestone (MF1)	Moderate	Planktonic foraminifera such as *Marginotruncana marginata*; *Radiolaria*
57	Radiolaria - planktonic foraminifera wackestone (MF1)	Frequent	Planktonic foraminifera such as *Globigerinelloides bollii* and *Globotruncana arca*; *Radiolaria*
56	Radiolaria - planktonic foraminifera wackestone (MF1)	Frequent	Planktonic foraminifera such as *Whiteinella baltica* and *Globotruncana lapparenti*; *Radiolaria*
55	Radiolaria - planktonic foraminifera wackestone (MF1)	Frequent	Planktonic foraminifera such as *Muricohedbergella monmouthensis* and *Marginotruncana pseudolinneiana*; *Radiolaria*
54	Radiolaria - planktonic foraminifera wackestone (MF1)	Frequent	Planktonic foraminifera such as *Planoheterohelix moremani*; Benthic foraminifera such as *Lenticulina*; *Radiolaria*; Iron oxide; Intraclasts
53	Bioclastic - Trocholina wackestone	Non	Benthic foraminifera such as *Trocholina lenticularis* and *Trocholina altispira*; Bivalves; Gastropods; Green algae; Echinoid spine; Miliolids
52	Bioclastic - Coscinoconus wackestone	Non	Benthic foraminifera such as *Coscinoconus elongatus* and *Coscinoconus cf. perconigi*; Bivalves; Green algae; Miliolids
51	Bioclastic - Orbitolina wackestone	Non	Benthic foraminifera such as *Orbitolina hensoni* and *Conicorbitolina conica;* Bivalves; Green algae; Miliolids
50	Bioclastic - Orbitolina wackestone	Non	Benthic foraminifera such as *Orbitolina concava* and *Orbitolina qatarica*; Bivalves; Gastropods; Green algae

datum (FAD) of *Globotruncanita elevata* [40] to the first appearance of datum of *Globotruncana ventricosa* [41] that includes a thickness of 4.4 m (MG-NF 64B to MG-NF 66B). This interval range zone corresponds to those of G. elevata zones of [14, 18-20, 42, 43], indicating early Campanian age (Table 2). As it has been shown in Fig. 3, the associated planktonic fauna are *Planoheterohelix globulosa* [25], *Planoheterohelix moremani* [27], *Globigerinelloides bollii* [28], *Marginotruncana pseudolinneiana* [28], *Contusotruncana fornicata* [30], *Contusotruncana cf. fornicata* [30], *Globotruncana arca* [32], *Globotruncana bulloides* [31], *Muricohedbergella monmouthensis* [22], Globotruncanita stuartiformis [21], *Globotruncana lapparenti* [24], *Globotruncana cf. lapparenti* [24], *Globigerinelloides prairiehillensis* [28], *Globotruncana hilli* [28], *Contusotruncana sp*., and *Globotruncana linneiana* [44]. Among the above-mentioned foraminifers, only Planoheterohelix moremani [27], is a long-ranging species in the Cretaceous (Albian to Maastrichtian) and the remainders are confined to the Late Cretaceous (Turonian to Maastrichtian). From the sedimentological and paleontological point of view, this biozone corresponds to MF-2 (Table 1).

Zone IV. Globotruncana ventricosa (IRZ)

This zone, defined by the FAD of *Globotruncana ventricosa* [41] to the FAD of Globotruncana aegyptiaca [45], and extends within a thickness of 1.1 m (MG-NF 66B to MG-NF 67A). This biozone corresponds to the *G. ventricosa* zone of [14, 18, 42, 43], indicating Campanian age (see Table 2). As it has been shown in Fig. 3, the associated planktonic foraminifers of this biozone are *Planoheterohelix globulosa* [25], *Planoheterohelix moremani* [27], *Globigerinelloides bollii* [28], *Globotruncana bulloides* [31], *Globotruncanita stuartiformis* [21], *Globotruncana lapparenti* [24], *Globigerinelloides prairiehillensis* [28], *Globotruncanita elevata* [40], *Globotruncana linneiana* [44], *Contusotruncana plummerae* [46], *Rugoglobigerina macrocephala* [47],

Table 2. Correlation of encountered biozones of the Gurpi Formation in Tang-e Bagh, Kuh-e Genu, Southern Iran with other parts of the world (compiling after [12, 14, 18, 42, 43, 52, 53]).

Age (Myr)	Period	Epoch	Stage	This study	Coccioni and Premoli Silva, 2015	Premoli Silva and Verga, 2004	Robaszynski et al., 2000	Caron, 1985	Wonders, 1980	Sigal, 1977	Bolli, 1966
66.0	Cretaceous	Late	Maastrichtian	*A. mayaroensis* TRZ *C. contusa* IRZ *G. gansseri* IRZ *G. aegyptiaca* IRZ	*P. hantkeninoides* *P. elegans* *P. hariaensis* *A. mayaroensis* *C. contusa* *G. gansseri*	*A. mayaroensis* *C. contusa* + *R. fructicosa* *G. gansseri* *G. aegyptiaca*	*A. mayaroensis* *G. gansseri*	*mayaroensis* *gansseri* *aegyptiaca* *havanensis*	*mayaroensis* *contusa* *gansseri* *ricarinata*	*mayaroensis* *gansseri* *stuarti* + *falsostuarti*	*mayaroensis* *gansseri* *lapparenti.tricarinata*
72.1±0.2			Campanian	*G. ventricosa* IRZ *G. elevata* IRZ	*G. aegyptiaca* *G. havanensis* *R. calcarata* *C. plummerae* *G. elevata*	*G. havanensis* *R. calcarata* *G. ventricosa* *G. elevata*	*G. falsostuarti* *G. calcarata* *G. ventricosa* *G. arca* *S. rugocostata* *G. elevata*	*calcarata* *ventricosa* *elevata*	*calcarata* *ventricosa* *elevata*	*calcarata* *elevata* + *stuartiformis*	*calcarata* *stuarti*
83.6±0.2			Santonian	*D. asymetrica* TRZ	*D. asymetrica*	*D. asymetrica*		*asymetrica*	*carinata* *concavata*	*concavata* + *carinata*	*fornicata* *concavata*
86.3±0.5			Coniacian	(hatched)	*D. concavata*	*D. concavata*		*concavata* *primitiva*	*primitiva*	*concavata*	*schneegansi*
89.8±0.3			Turonian	(hatched)		*M. sigali* + *D. primitiva* *H. helvetica* *W. archaeocretacea*		*M. sigali* *helvetica* *archaeocretacea*	*sigali* *helvetica* *archaeocretacea*	*sigali* + *schneegansi* *helvetica*	*helvetica* *gigantea*
93.9			U / M / L Cenomanian	*O. qatarica* TRZ		*R. cushmani* *R. reicheli* *R. globotruncanoides*		*cushmani* *reicheli* *brotzeni*	*cushmani* *globotruncanoides* *appenninica*	*cushmani* *globotruncanoides* + *brotzeni*	*cushmani* *reicheli* *brotzeni*
100.5		Early	Albian			*R. appenninica* *R. ticinensis* *B. breggiensis* *T. primula* *M. planispira*		*appenninica* *ticinensis* *subticinensis* *breggiensis* *primula*	*appenninica* + *buxtorfi* *ticinensis* + *buxtorfi* *praebuxtorfi* *ticinensis* *subticinensis*	*appenninica* + *buxtorfi* *breggiensis* *reicheli* + *primula* *planispira*	*appenninica* *ticinensis* *roberti*
~113.0			Aptian			*P. bejaouaensis* *H. trocoidea* *G. algerianus* *G. ferreolensis* *L. cabri* *G. blowi*		*bejaouensis* *gorbachikae* *algeriana* *cabri* *blowi*		*bejaouensis* *trochoidea* *algeriana* *ferreolensis* *cabri* *blowi* / *maridalensis* *gottisi* / *duboisi* *similis*	
~125.0			Barremian			*H. similis* + *H. mitra*		*sigali*		*sigali*	
~129.4			Hauterivian			*H. sigali* + *H. infracretacea*		*hoterivica* minute planktic foraminifera		*gr. hauterivica*	
~132.9											

Muricohedbergella holmdelensis [48], *Radotruncana subspinosa* [49], *Contusotruncana patelliformis* [46], *Globotruncana falsostuarti* [11], *Rugoglobigerina hexacamerata* [47], *Rugotruncana subcircumnodifer*

[46], *Spiroplecta americana* [50], and *Kuglerina cf. rotundata* [47], suggesting Turonian to Maastrichtian. From the sedimentological and paleontological point of view, this biozone corresponds to MF-2 (Table 1).

Zone V. Globotruncana aegyptiaca Zone (IRZ)

This zone is marked by the FAD of Globotruncana aegyptiaca [45] to the FAD of Gansserina gansseri [51] and extends through a thickness of 1.4 m (Fig. 3; MG-NF 67A to MG-NF 67B). Based on the stratigraphic potential of the Globotruncana aegyptiaca and comparison with those of [14, 19, 20], the latest Campanian to early Maastrichtian age is suggested for this biozone of the Gurpi Formation (Table 2). As it has been shown in Fig. 3, the associated planktonic foraminifers of zone V consist of *Planoheterohelix globulosa* [25], *Planoheterohelix moremani* [27], *Globigerinelloides bollii* [28], *Contusotruncana fornicata* [30], *Contusotruncana cf. fornicata* [30], *Globotruncana bulloides* [31], *Globotruncanita stuartiformis* [21], *Globotruncana lapparenti* [24], *Globigerinelloides prairiehillensis* [28], *Globotruncana linneiana* [44], *Globotruncana ventricosa* [41], *Contusotruncana plummerae* [46], *Muricohedbergella holmdelensis* [48], *Radotruncana subspinosa* [49], *Globotruncana falsostuarti* [11], and *Kuglerina cf. rotundata* [47], suggesting Turonian to Maastrichtian. From the sedimentological and paleontological point of view, this biozone corresponds to MF-2 (Table 1).

Zone VI. Gansserina gansseri Zone (IRZ)

This zone is characterized by the FAD of *Gansserina gansseri* [51] to the FAD of *Contusotruncana contusa* [32] and extends through a thickness of 4.2 m (MG-NF 67B to MG-NF 69). Based on the stratigraphic potential of the *Gansserina gansseri biozone* and its comparison to those of [14, 18, 42, 43, 52, 53], this part of the Gurpi Formation is assigned to early-middle Maastrichtian (Table 2). As it has been shown in Fig. 3, this zone also contains *Planoheterohelix globulosa* [25], *Globigerinelloides bollii* [28], *Contusotruncana fornicata* [30], *Contusotruncana cf. fornicata* [30], *Globotruncana bulloides* [31], *Muricohedbergella monmouthensis* [22], *Globotruncana arca* [32], *Globotruncana cf. arca* [32], *Globotruncanita stuartiformis* [21], *Globotruncana lapparenti* [24], *Globotruncanita elevata* [40], *Globigerinelloides prairiehillensis* [28], *Globotruncana linneiana* [44], *Globotruncana ventricosa* [41], *Muricohedbergella holmdelensis* [48], *Globotruncana aegyptiaca* [45], and *Radotruncana calcarata* [54], extending from Turonian to Maastrichtian. From the sedimentological and paleontological point of view, this biozone corresponds to MF-2 (Table 1).

Zone VII. Contusotruncana contusa Zone (IRZ)

This zone is characterized by the FAD of *Contusotruncana contusa* [32] to the FAD of Abathomphalus mayaroensis [51] and includes a thickness of 20.6 m (MG-NF 69 to MG-NF 77). Based on the stratigraphic potential of the Contusotruncana contusa and its comparison with those of [18, 19, 43], this part of the Gurpi Formation is assigned to middle Maastrichtian (Table 2). Likewise, this zone also contains *Planoheterohelix globulosa* [25], *Globigerinelloides bollii* [28], *Contusotruncana fornicata* [30], *Contusotruncana cf. fornicata* [30], *Globotruncana bulloides* [31], *Globotruncana arca* [32], *Globotruncana cf. arca* [32], *Muricohedbergella monmouthensis* [22], *Globotruncanita stuartiformis* [21], *Globotruncana lapparenti* [24], *Globotruncanita elevata* [40], *Globigerinelloides prairiehillensis* [28], *Globotruncana linneiana* [44], *Globotruncana ventricosa* [41], *Muricohedbergella holmdelensis* [48], *Radotruncana subspinosa* [49], *Rugotruncana subcircumnodifer* [46], *Globotruncana aegyptiaca* [45], *Gansserina cf. gansseri* [51], *Globotruncanita angulata* [55], *Contusotruncana cf. contusa* [32], and *Globotruncanita pettersi* [46], extending throughout Upper Cretaceous (Cenomanian to Maastrichtian). From the sedimentological and paleontological point of view, this biozone corresponds to MF-2 (Table 1).

Zone VIII. Abathomphalus mayaroensis Zone (TRZ)

This zone is characterized by the total range of *Abathomphalus mayaroensis* [51] (Plate IV, Fig. 7) and includes a thickness of 21 m (MG-NF 77 to MG-NF 85). Based on the stratigraphic potential of the A. mayaroensis and its comparison with those of [14, 18, 42, 43, 52, 53], a Late Maastrichtian is suggested for the upper part of the Gurpi Formation in the study area (Table 2). The associated planktonic foraminifers of this biozone are Planoheterohelix globulosa [25], *Globigerinelloides bollii* [28], *Contusotruncana fornicata* [30], *Contusotruncana cf. fornicata* [30], *Globotruncana bulloides* [31], *Globotruncana arca* [32], *Globotruncana cf. arca* [32], *Muricohedbergella monmouthensis* [22], *Globotruncanita stuartiformis* [21], *Globotruncana lapparenti* [24], *Globigerinelloides prairiehillensis* [28], *Globotruncana linneiana* [44], *Globotruncana ventricosa* [41], *Muricohedbergella holmdelensis* [48], *Radotruncana subspinosa* [49], *Globotruncana aegyptiaca* [45], *Gansserina gansseri* [51], *Globotruncanita angulata* [55], *Contusotruncana*

Plate IV

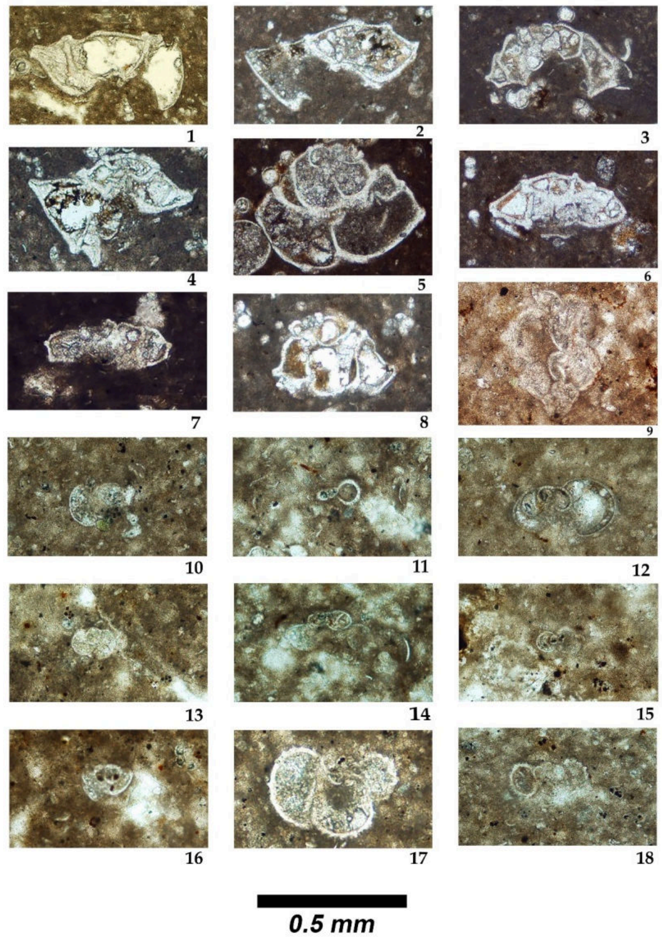

Plate IV

Fig. 1. *Gansserina gansseri* [51] (sample MG-NF 67B-85).
Fig. 2. *Globotruncanita angulata* [55] (sample MG-NF 69-80).
Fig. 3. *Contusotruncana contusa* [32] (sample MG-NF 69-83).
Fig. 4. *Globotruncanita pettersi* [46] (sample MG-NF 69-79).
Fig. 5. *Globotruncanita conica* [41] (sample MG-NF 77).
Fig. 6. *Globotruncana orientalis* [56] (sample MG-NF 77-83).
Fig. 7. *Abathomphalus mayaroensis* [51] (sample MG-NF 77-85).
Fig. 8. *Contusotruncana walfischensis* [57] (sample MG-NF 77-79).
Fig. 9. *Planoglobulina carseyae* [30] [70] (sample MG-NF 86).
Fig. 10. *Praemurica inconstans* [61] (sample MG-NF 88-94A).
Fig. 11. *Parasubbotina pseudobulloides* [60] (sample MG-NF 88-100A).
Fig. 12. *Subbotina triloculinoides* [60] (sample MG-NF 89-98).
Fig. 13. *Eoglobigerina eobulloides* [58] (sample MG-NF 87-93).
Fig. 14. *Globanomalina compressa* [60] (sample MG-NF 91-97B).
Fig. 15. *Praemurica pseudoinconstans* [65] (sample MG-NF 89-92).
Fig. 16. *Morozovella praeangulata* [65] (sample MG-NF 97B-99A).
Fig. 17. *Globoconusa daubjergensis* [66] (sample MG-NF 91-99A).
Fig. 18. *Praemurica taurica* [59] (sample MG-NF 87-94A).

contusa [32], *Globotruncanita pettersi* [46], *Globotruncanita conica* [41], *Globotruncanita cf. conica* [41], *Globotruncana orientalis* [56], *Contusotruncana walfischensis* [57], ranging in the Upper Cretaceous (Late Cenomanian to Late Maastrichtian). From the sedimentological and paleontological point of view, this biozone corresponds to MF-2 (Table 1).

Zone IX. (Not Zone)

This zone is present at the basal part of the Pabdeh Formation which is characterized by the presence of reworked species (e.g., *Planoglobulina carseyae* [30]; *Pseudoguembelina costulata*? [27]) and the appearance of species such as *Eoglobigerina eobulloides* [58], *Praemurica taurica* [59], *Parasubbotina pseudobulloides* [60], and *Praemurica inconstans* [61]. This zone includes a thickness of 7.4 m (MG-NF 86 to MG-NF 89). This part of the Pabdeh Formation can be assigned to the lowermost Paleogene age based on stratigraphic position, but one cannot assign its foraminiferal association to a well-known biozone that has been proposed for the lower Paleocene [62-64]. Hence, this part of the Pabdeh Formation is introduced as a Not Zone. From the sedimentological and paleontological point of view, this biozone corresponds to MF-2 (Table 1).

Subzone X (P1b). Subbotina triloculinoides Zone (IRZ)

This zone is characterized by the FAD of *Subbotina triloculinoides* [60] to the FAD of Globanomalina

Plate V

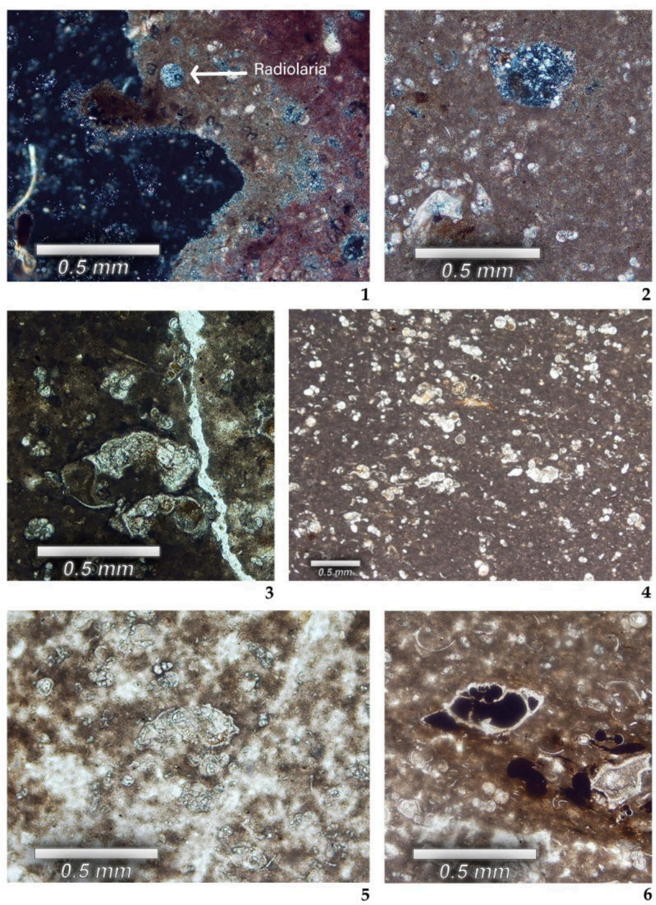

Plate V
Figs. 1,2. MF1: Radiolaria - planktonic foraminifera wackestone (samples MG-NF54-59,61).
Figs. 3-6. MF2: Planktonic foraminiferal wackestone (samples MG-NF60, 62-100).

compressa [60] and extends through a thickness of 5.1 m (MG-NF 89 to MG-NF 91). Based on the stratigraphic potential of the Subbotina triloculinoides and its comparison with those of other parts of the world [62-64], an Early Paleocene age (P1b) suggests for this thickness of the Pabdeh Formation in Kuh-e Genu (Table 3). The associated planktonic foraminifers of this biozone are *Eoglobigerina eobulloides* [58], *Praemurica taurica* [59], *Parasubbotina pseudobulloides* [60], *Praemurica inconstans* [61], and *Praemurica pseudoinconstans* [65], which extend through Danian (P0) to Thanetian (P4). From the sedimentological and paleontological point of view, this biozone corresponds to MF-2 (Table 1; Plate V, Figs. 3-6).

Subzone XI (P1c-P2). Globanomalina compressa (IRZ)

This interval zone is marked by the presence of *Globanomalina compressa* [60] and extends through a thickness of 30 m (MG-NF 91 to MG-NF 100B). Based on the stratigraphic potential of the Globanomalina compressa and its comparison with those of other parts of the world [62-64], an Early Paleocene age (P1c-P2) suggests this thickness of the Pabdeh Formation in the study area (Table 3). The associated planktonic foraminifers of this biozone are *Eoglobigerina eobulloides* [58], *Praemurica taurica* [59], *Parasubbotina pseudobulloides* [60], *Praemurica inconstans* [61], *Subbotina triloculinoides* [60], *Praemurica pseudoinconstans* [65], *Globoconusa daubjergensis* [66], *Praemurica sp., and Morozovella praeangulata* [65], which extend through Danian (P0) to Thanetian (P4). From the sedimentological and paleontological point of view, this biozone corresponds to MF-2 (Table 1).

Results and Discussion

A total of 152 surface samples were collected from the Sarvak (uppermost part), Gurpi, and Pabdeh formations in the Tang-e Bagh at the Kuh-e Genu, northern Persian Gulf. The samples were treated in the laboratories of Payame Noor and Tehran universities and resulted in the recognition of well-known benthonic and planktonic species, which clarify the age relationships of the studied rock units. A total of 80

Table 3. Correlation of encountered biozones of the Pabdeh Formation in Tang-e Bagh, Kuh-e Genu, Southern Iran with other parts of the world (compiling after [62-64]).

Period	Epoch	Stage	Zone		This study (Kuh-e Genu)	Wade et al., 2011	Berggren and Pearson, 2005	Olsson et al., 1999
Paleogene	Eocene	Ypresian	Zone E1					
Paleogene	Late Paleocene	Thanetian	Zone P5			*M. velascoensis*	*M. velascoensis*	←LA: M. velascoensis
Paleogene	Late Paleocene	Thanetian	Zone P4	c		*A. soldadoensis/G. pseudomenardii*	*A. soldadoensis/G. pseudomenardii*	←LA: G. Pseudomenardii
Paleogene	Late Paleocene	Thanetian	Zone P4	b		*A. subsphaerica*	*A. subsphaerica*	←FO: A. soldadoensis
Paleogene	Late Paleocene	Selandian	Zone P4	a		*G. pseudomenardii/P. variospira*	*G. pseudomenardii - P. variospira*	←LA: A. subsphaerica
Paleogene	Late Paleocene	Selandian	Zone P3	b		*I. albeari*	*I. albeari*	←FO: G. Pseudomenardii
Paleogene	Late Paleocene	Selandian	Zone P3	a		*I. pusilla*	*I. pusilla*	←FO: I. albeari
Paleogene	Early Paleocene	Danian	Zone P2		*G. compressa* IRZ	*P. uncinata*	*P. uncinata*	←FO: M. angulata
Paleogene	Early Paleocene	Danian	Zone P1	c	*G. compressa* IRZ	*G. compressa*	*G. compressa - P.inconstans*	←FO: P. uncinata
Paleogene	Early Paleocene	Danian	Zone P1	b	*S. triloculinoides* IRZ	*S. triloculinoides*	*S. triloculinoides*	←FO: G. compressa
Paleogene	Early Paleocene	Danian	Zone P1	a	Not Zone	*P. pseudobulloides*	*P. pseudobulloides*	←FO: P. triloculinoides
Paleogene	Early Paleocene	Danian	Zone Pα		Not Zone	*P. eugubina*	*P. eugubina*	←LA: P. eugubina
Paleogene	Early Paleocene	Danian	Zone P0		Not Zone	*G. cretacea*	*G. cretacea*	←FO: P. eugubina
Cretaceous	Late	Maastrichtian						←LA: most Late Cretaceous Taxa

foraminifer species were identified, including 9 benthic species (5 genera) and 68 planktonic species (29 genera). The encountered foraminifer species allow establishing 11 foraminifer biozones. Biozone I is marked by the presence of *Orbitolina qatarica* [4] at the upper part of the Mauddud Member of the Sarvak Formation, which corresponds to the total range of this species, indicating early Late Cretaceous (Cenomanian). It should be mentioned that the *Orbitolina qatarica* [4] is recorded for the first time from the Zagros Basin of Iran. Biozones Ⅱ to Ⅷ are present throughout the Gurpi Formation, suggesting Late Cretaceous (Santonian to late Maastrichtian). Therefore, a hiatus exists between the Sarvak and the Gurpi formations, spanning late Cenomanian to the end of Coniacian. This hiatus corresponds to the absence of the Ahmadi Member of the Sarvak Formation and the whole Ilam Formation that is marked by a few meters of Fe-stained sediments between the Sarvak Formation and the Gurpi Formation. Biozones IX to XI are present within the Pabdeh Formation and suggest Early Paleocene; therefore, the sedimentary deposition has been continued from Late Cretaceous to Early Paleocene (Danian) age. On the other hand, the presence of purple shale member of the Pabdeh Formation in the Lurestan and Khuzestan provinces and its absence in the Kuh-e Genu confirms the continuity of deposition from the Gurpi Formation up to the end of the Early Paleocene.

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