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New Foraminifera and morphogroups from Sanganeh Formation in Takal Kuh section, western Kopeh Dagh basin

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Abstract
One stratigraphic section of the Sanganeh Formation (Lower Cretaceous), north-west of Kopeh Dagh, was measured and sampled. This formation consists of shale, calcareous shale and marls. The lower boundary with Sarcheshmeh Formation is conformable and upper boundary with Kalat Formation is unconformable. Biostratigraphic studies led to identification of 21 genera and 48 species of benthic foraminifera. Based on foraminifera fauna, a Late Aptian age is suggested for Sanganeh Formation at this locality. Using identified foraminifera, *Gavelinella flandrini* assemblage zone is proposed. This biozone coincides with global biozones. Palaeoecological studies led to recognition of three calcareous benthic and two agglutinated benthic morphogroups.

Keywords: Foraminifera, biostratigraphy, morphogroups, Sanganeh Formation, Kopeh Dagh.

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Introduction

The Kopeh Dagh sedimentary basin located in north-east Iran, southern Turkmenistan and Afghanistan and is composed of Mesozoic and Cenozoic sedimentary successions. The Iranian part of the Kopeh Dagh basin is geographically located between 35° 30' and 38° 15' N latitude and 54° 00' and 61° 13' E longitude. Fifteen formations have been introduced in Kopeh Dagh basin. The Cretaceous formations include Shurijeh, Zard, Tirgan, Sarcheshmeh, Sanganeh, Aitamir, Abderaz, Abtalkh, Nyzar and Kalat (Afshar-Harb 1994). In this paper, we introduce foraminifera contents from the Late Aptian interval of Sanganeh Formation in the western Kopeh Dagh basin. The foraminifera assemblages have been used for interpreting the biostratigraphic and palaeoecologic conditions. We believe these data can help in a better understanding of biostratigraphic position of the Sanganeh Formation in western Kopeh Dagh basin.

Stratigraphy

Sanganeh Formation

The name of Sanganeh Formation derives from the village of Sanganeh, 70 kilometers, north -east of Mashhad. The thickness of this formation at the type locality is about 740 meters (Afshar-Harb 1979) and is composed of dark grey to black weathered shale with greenish shale and a few thin siltstone beds. Based on foraminifera assemblages, the Sanganeh Formation is Albian in age (Kalantari 1969). However Immel et al. (1997) and Raisossadat (2002, 2004), based on ammonites, and Mahanipour (2010) and Raisossadat and Shokri (2011) based on nannofossils reported the early Aptian - early Albian age for this formation in the Kopeh Dagh basin.

Material and methods

In order to study foraminifera at Takal Kuh section, 50 samples have been collected. These samples were disaggregated using %5 hydrogen peroxide, washed through 60, 80 and 100 µm mesh sieves. After drying the residue, the samples were picked and studied under binocular microscope at a magnification of X40. The SEM has been used at Tehran University for better identification of assemblages. In order to morphogroups recognition, 166 specimens have been collected from forty nine samples (table 1).

Table 1. Counts of foraminifera in Takal Kuh section

Sample Number	Calcareous benthic foraminifera	Agglutinate benthic foraminifera	CM-1	CM-2	CM-3	AGM-1	AGM-2
Tk-1		2				2	
Tk-2	2	2		2			2
Tk-3	6	2	6				2
Tk-4		2					
Tk-5							
Tk-6							
Tk-7							
Tk-8	12	6		6	6	2	4
Tk-9							
Tk-10		2					2
Tk-11							
Tk-12		2					2
Tk-13	2				2		
Tk-14	4		4				
Tk-15	2			2			
Tk-16	4		2	2			
Tk-17							
Tk-18	8		4	4			
Tk-19							
Tk-20	4			4			
Tk-21							
Tk-22	2		2				
Tk-23							
Tk-24		2				2	
Tk-25	2	2	2			2	
Tk-26							
Tk-27	2	2		2		2	2
Tk-28	2	4	2			2	2
Tk-29		4					4
Tk-30	2	4	2			2	2
Tk-31		2					2
Tk-32	12			10	2		
Tk-33	10	2	2	4	4		2
Tk-34	2			2			
Tk-35	6			6			
Tk-36	2			2			
Tk-37	6			4	2		
Tk-38		2				2	
Tk-39							
Tk-40							
Tk-41							
Tk-42	6	2		4			2
Tk-43							
Tk-44	2				2		
Tk-45	6		2	4	2		
Tk-46	2			2			
Tk-47							
Tk-48	10		10				
Tk-49	4			4			

Takal Kuh section

The studied section of Sanganeh Formation is located about 90 kilometers north-west of Ashkhaneh along the road to Shahrabad. For access to the measured section, a track road passable by car is used for about 15 kilometres.

The exact location of the section is at 37°42' N latitude and 56°9' E longitude (Fig. 1). Sanganeh Formation, with 505 m thickness at this location, conformably overlies the Sarcheshmeh and unconformably underlies the Kalat Formations (Fig. 2).

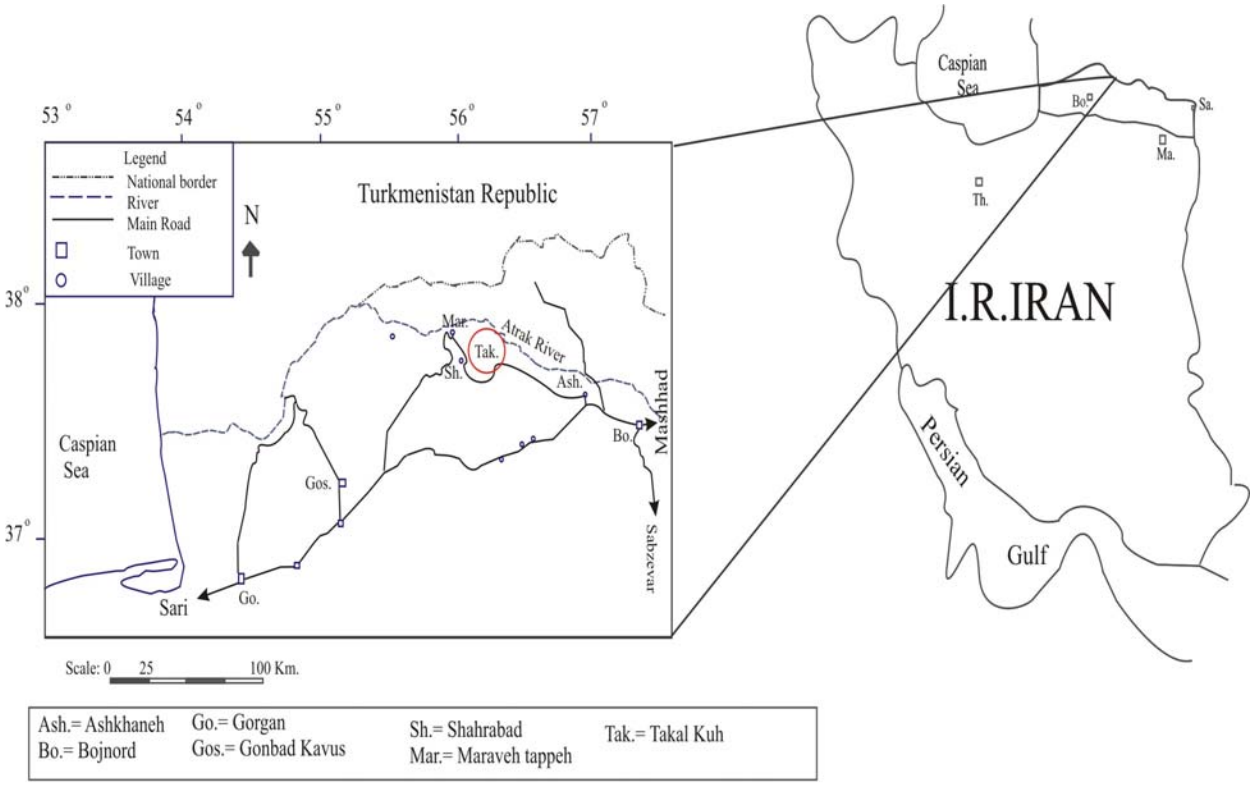

Figure 1. Geographical names and their positions, location of measured section is shown with circle.

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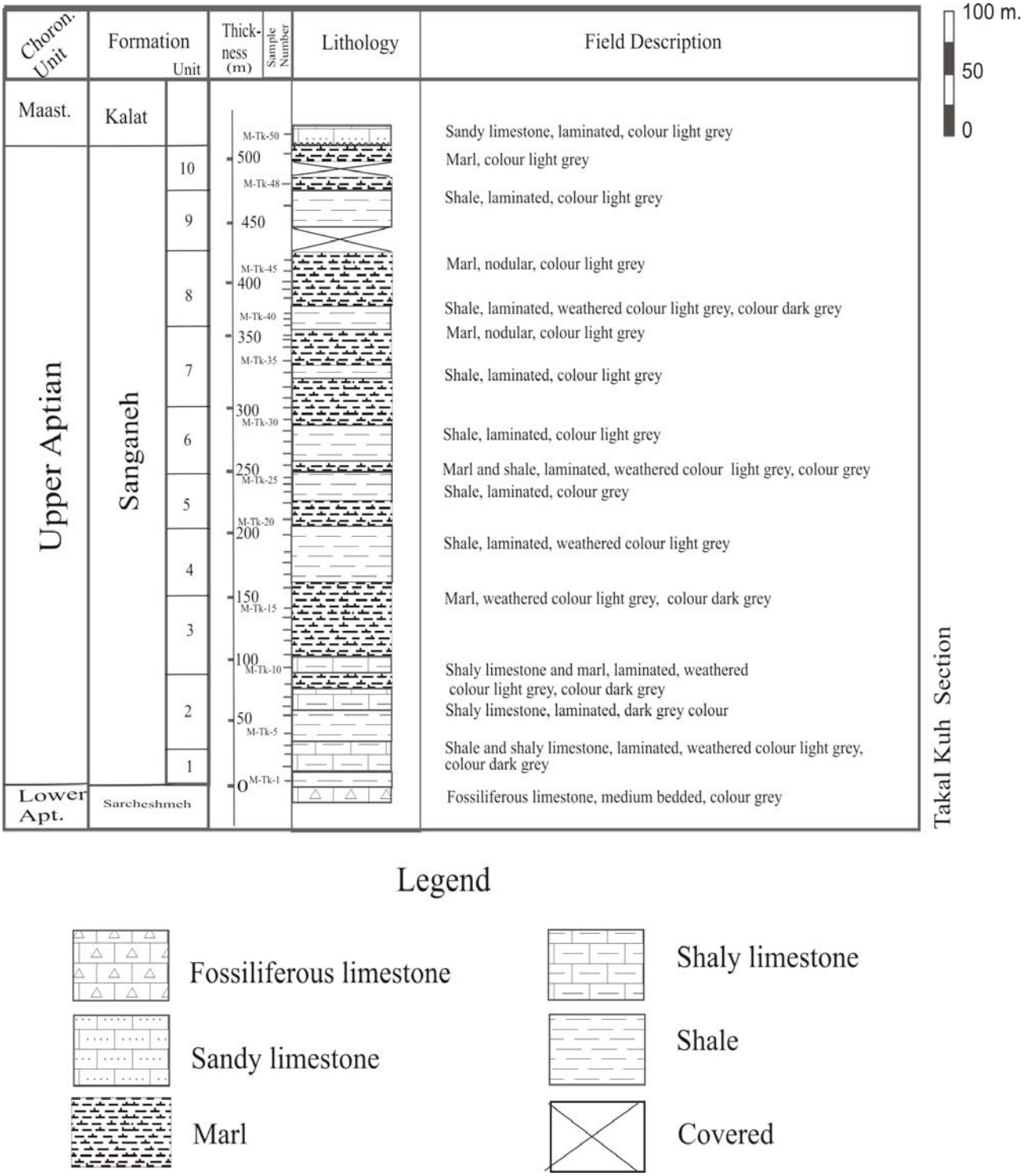

Figure 2. Stratigraphic column of Sanganeh Formation at Takal Kuh section

The succession of Sanganeh Formation from the base to the top is divided into 10 portions as follows:

1- The lower portion is about 22 m. of shale, with light grey color. This part is conformably overlain the grey color medium-bedded limestone of the Sarcheshmeh Formation.

2- This portion is about 67 m. thick and is composed of alternation of laminated and grey color shaly limestone and light grey marl. Foraminifera are mostly found in the marl portion

3- This portion is composed of 50 m. thin-bedded to laminated, dark grey color marl and light grey shale.

4- 50 m. dark grey shale is forming this portion of the succession.

5- This portion is about 50 m. thick and is composed of dark grey shale.

6- 50 m. alternation of thin bedded, dark grey marl, and light green shale form this portion of the succession.

7- It is composed of 65 m. laminated, grey to greenish grey shale.

8- 55 m. marl, thin-bedded to laminated, light grey formed this portion of the section.

9- 52 m. alternation of light grey shale, with a few thin-bedded to laminated, light grey marly beds forms this portion of the studied section.

10- Finally, the uppermost portion consists of 36 m. marl with occasional thin- bedded limestone.

The upper portion is underlies unconformably by the basal sandy limestone of the Kalat Formation (Maastrichtian age). The foraminifera assemblage fauna in the Sanganeh Formation (Fig. 3) suggest a Late Aptian age for this formation at this locality (for example, Loeblich and Tappan 1988; Moullade et al. 2008; Scheibnerova 1972; Weidich 1990).

The assemblage of foraminifera in Takal Kuh section

Bed-by-bed sampling at the Takal Kuh section for biostratigraphic studies provides a firm basis for a biozonation in the Late Aptian of the Kopeh Dagh basin. This study led to identification of 15 genera and 30 species of calcareous benthic foraminifera, and 6 genera and 18 species of arenaceous benthic foraminifera. Moreover, the faunas show very close affinities with those from Lower Cretaceous benthic foraminifera of the Indian Ocean (Holbourn and Kaminski 1997).

Thus, based on this study, one biozone can be introduced for Takal Kuh section as *Gavelinella flandrini assemblage* Zone.

This biozone have been previously introduced by Holbourn and Kaminski (1997).

Gavelinella flandrini Assemblage Zone*:*

This biozone is an assemblage zone. This zone is identified by presence of calcareous and arenaceous benthic foraminifera such as *Gavelinella flandrini*, *Lingulogavelinella* sp., *Gaudryina praedividens*, and *Gyroidinoides infracretacea*. This biozone is suggested for the Late Aptian age (Holbourn and Kaminski 1997), which could be attributed from 10 to 490 m of Sanganeh Formation in the studied section (Fig. 3).

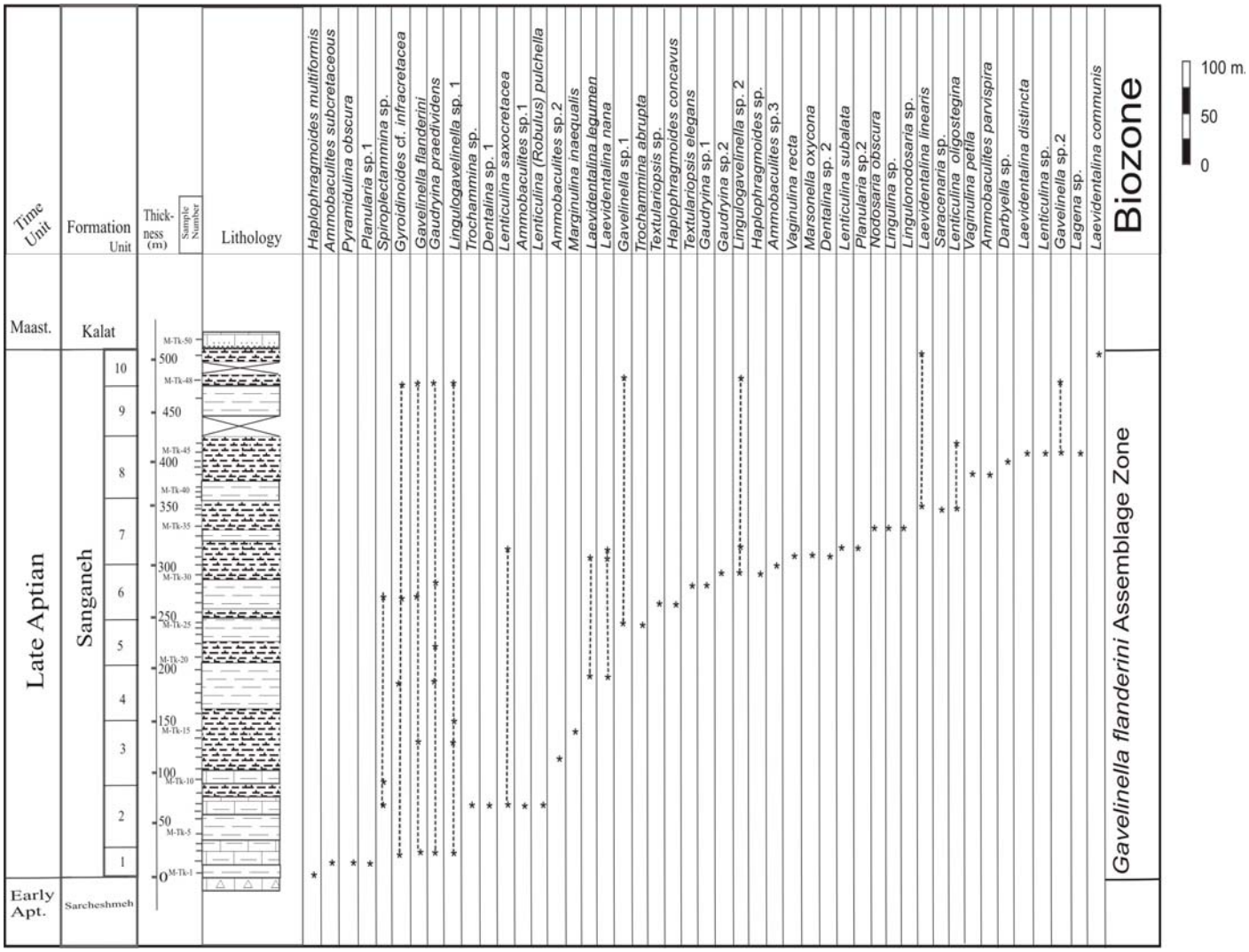

Figure 3. Foraminifera range chart of Sanganeh Formation at Takal Kuh section

Foraminifera morphogroups

Previous studies of benthic morphological groups by Koutsoukos and Hart 1990), Nagy (1992) and Tyzka (1994) show a strong relationship between environmental conditions and morphotypes. According to Corliss and Chen (1988), Koutsoukos and Hart (1990) and Coccioni and Galeotti (1993), there are an acceptable relationship between test morphology and inferred habitat of foraminifera fauna. Friedrich et al. (2003) believed that the benthic foraminiferal assemblages as well as stable isotope data can be used to interpret the oxygen content of bottom waters, organic matter flux to the sea floor, and sea-level changes during the Late Aptian time.

Erbacher et al. (1998) stated that benthic foraminifera can serve as a sensitive tool to provide a better understanding of the conditions at the sea floor during the Aptian time.

The benthic foraminifera assemblage of the Sanganeh Formation at Takal Kuh section allowed to distinguish three calcareous (CM1-CM3) and two agglutinated morphogroups (AGM1-AGM2) (Figs. 4 and 5).

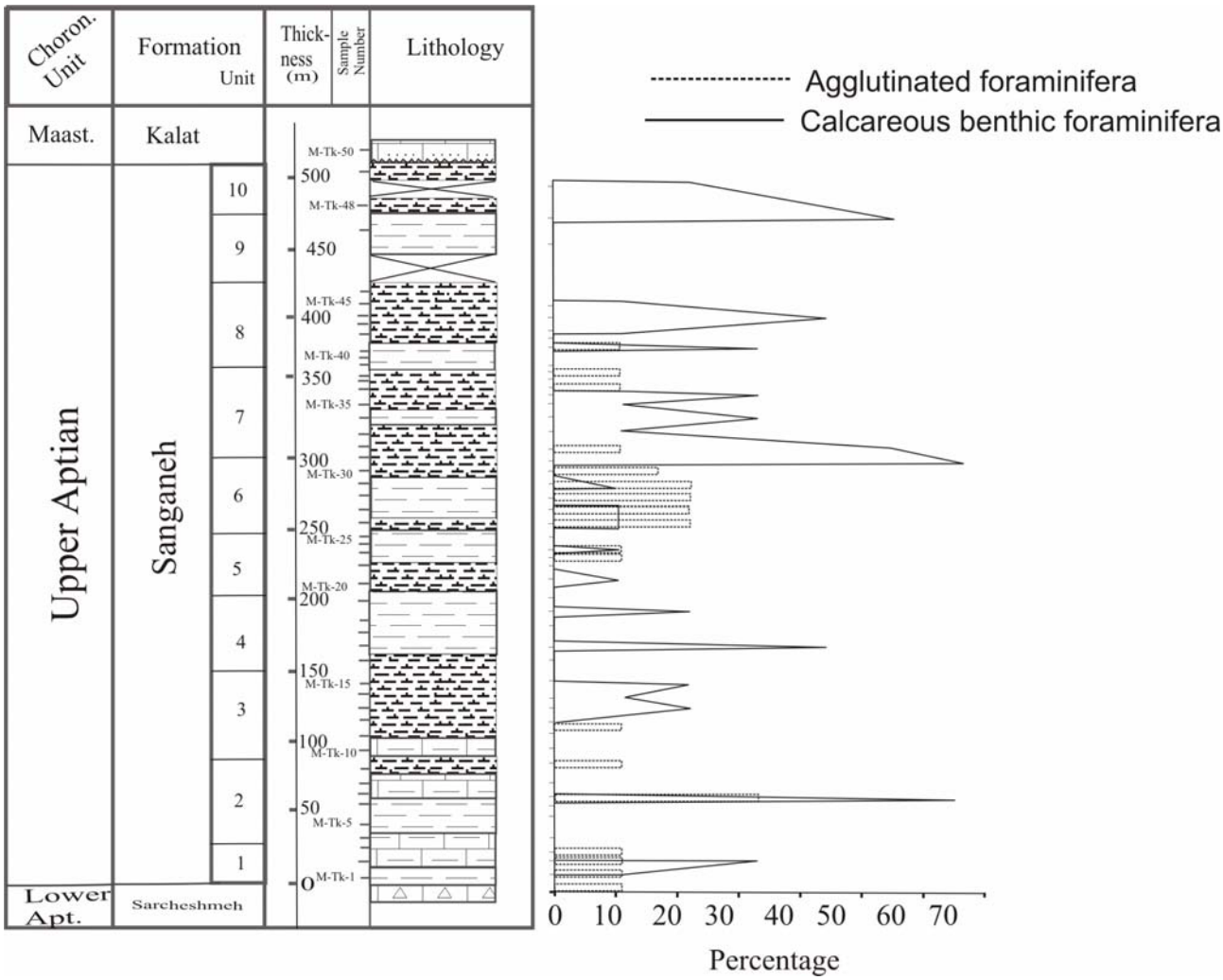

Figure 4. Abundance of agglutinated and calcareous benthic foraminifera in Takal Kuh section

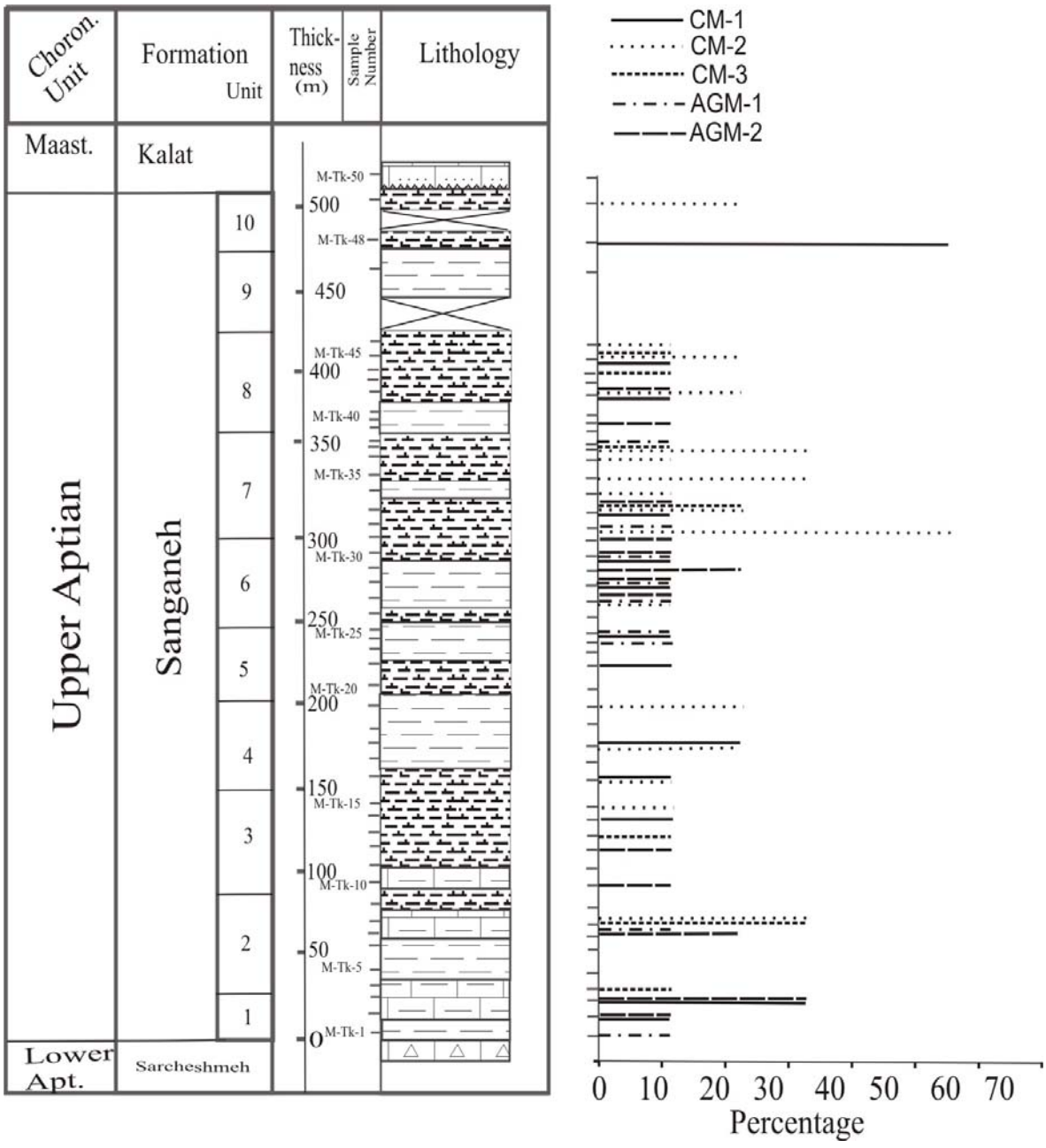

Figure 5. Benthic foraminifera morphogroups in Takal Kuh section

This classification is based on morphology, life position, feeding habitat and environment of benthic foraminifera.

Calcareous morphogroup1 (CM1)

This morphogroup consists of taxa with planispiral to trochospiral test shape which is typical for aerobic and eutrophic to mesotrophic environments. Most of these taxa are epifaunal forms, active deposit feeders and have been identified in the middle-outer shelf to upper slope deposits (Coccioni and Galeotti 1993). *Gavelinella* and *Gyroidinoides* are the common examples of this group (Pl. 1, M).

Calcareous morphogroup2 (CM2)

Test shape is elongated and flattened to straight periphery. Life position is shallow to deep infaunal, deposit feeder, neritic to upper bathyal, aerobic to dysaerobic, mesotrophic to eutrophic environment conditions (Ruckheim et al. 2006). The most taxa belong to this group are *Dentalina, Lagena, Lingulina, Nodosaria, Planularia*, *Laevidentalina* and *Marginulina* (Pl. 1, F, H, I, K, L).

This morphogroup seems to be indicative of well oxygenated and seems to have preferred meso-eutrophic living conditions.

Calcareous morphogroup3 (CM3)

The foraminifera fauna dominated by taxa such as *Lenticulina* and *Darbyella* (Pl. 1, B-D, N-P) could have the following specific characteristics: biconvex test shape, active deposit feeders, eutrophic to mesotrophic conditions as is the case for epifaunal to deep infaunal assemblages. They can be found in a wide range of environment from sublithoral to upper bathyal, aerobic to dysaerobic conditions (Ruckheim et al. 2006).

As stated above, two agglutinated morphogroups of benthic foraminifera were identified as follows:

Agglutinated morphogroup 1 (AGM1)

This morphogroup includes the forms with rounded planispiral test shape. Koutsoukos and Hart (1990) suggested that aerobic, mesotrophic to eutrophic environments are characteristic by a dominance of arenaceous shallow infaunal specimens which are active deposit feeders. These fauna can live in inner shelf to upper bathyal environment. *Haplophragmoides* and *Recurvoides* are typical genera in this morphogroup (Pl. 1, E).

Agglutinated morphogroup 2 (AGM2)

This morphogroup includes the elongate or sub cylindrical test shape which is indicative of the following characteristic of environmental conditions. All of these taxa are potentially shallow to deep infaunal, active deposit feeder and mesotrophic to eutrophic conditions, which are present in a wide range of marine environments from inner shelf to upper bathyal (Ruckheim et al. 2006).

These fauna appears to have been typical for moderately low levels of oxygen. *Ammobaculites*, *Textulariopsis*, *Marsonella* and *Gaudryina* could be classified in this morphogroup (Pl. 1, A, G, J).

Diversity and specific distribution of benthic assemblage foraminifera is mainly influenced by oceanic circulation patterns, oxygenation and nutrient availability, surface fertility, changes in depth of the CCD, and variations within the seawater chemistry such as PH (Van der Zwaan et al. 1999). According to Sen Gupta and Machain-Castillo (1993), temperature and salinity factors were relatively minor during the Late Aptian. The preservation of benthic foraminifera in Takal Kuh section varies from good to poor through out the studied interval. 15 calcareous and 6 arenaceous genera were identified. *Laevidentalina, Lenticulina, Gavelinella* and *Lingulogavelinella* are the most common calcareous benthics foraminifera. The arenaceous assemblage is dominated by *Ammobaculites* and *Gaudryina.*

In the lower part of the studied section (samples 1-16, Fig. 4), the abundance of calcareous benthic foraminifera varies from 11 to 66% and the agglutinated benthic

foraminifera varies from 11 to 33% percent respectively. The most abundance of calcareous and agglutinated benthic foraminifera can be seen in sample number 8 that can be related to unsuitable conditions, such as dysaerobic bottom-water or eutrophic environments. Samples 4-7 are barren and no agglutinated foraminifera have been found in samples 13-16. Based on low diversity and low abundance of ammonites and calcareous nannoplanktons, it is suggested that the lowermost shale portion was deposited under OAE (Oxygen Anoxic Event) (Raisossadat, 2002, Mahanipour, 2010).

The middle part of Sanganeh Formation (samples 16-32) is characterized by a distinctive increase in abundance of calcareous foraminifera (66%) in sample 32 and the maximum abundance of agglutinated foraminifera reach to 22% in samples 27 and 30. No agglutinated foraminifera have been found in samples 16-23 (Fig. 5). In the upper part of studied section (samples 33-49), the amount of calcareous foraminifera changes from 11 to 55% and the amount of agglutinated foraminifera is variable from 0 to 11%. There are two picks of benthic calcareous foraminifera in samples 33 and 48. Samples 38-41 do not contain any benthic calcareous foraminifera and samples 34-37, 43-49 lack of agglutinated foraminifera respectively. The most abundant calcareous morphogroups in Sanganeh Formation is morphogroup 2.

According to Gooday (1993) and Bernhard and Sen Gupta (1999), the oxygenation of the bottom water, both aerobic and dysaerobic types, shows fluctuation in the oxygen conditions so, may be best described as suboxic within the Late Aptian. The composition of benthic foraminifera assemblage in Takal Kuh section indicates aerobic, sometimes dysaerobic bottom-water conditions for the Late Aptian time.

There is also a fairly relationship between lithologhy and distribution of foraminifera morphogroups in most parts of the section. It seems the agglutinated foraminifera are more abundant in shales and shaly limestones while the calcareous foraminifera are abundant in marls and marly limestones. Kuhnt and Kaminski (1987) believed that the agglutinated foraminifera can use fine grain sedimentary particles for construction of their tests; therefore they can be found in shale. Calcareous foraminifera are also abundant in marls and marly limestones because the sedimentary environment is relatively good for the formation of carbonate. Therefore, it should be noted that from 21 identified genera, 15 are calcareous and can show a relatively suitable environment for carbonate production. In the middle and upper parts of the section, morphogroups are more diverse and it could be suggested a better environmental conditions in comparison with the lower part of the section. The presence of benthic foraminifera through out the section could suggest that oxygen level in the water was enough in some parts of the section to allow these organisms to live.

Conclusion

1- The Sanganeh Formation has a thickness of about 505 m at the studied section and consists of shale, marly shale, calcareous shale and marls. It is conformably overlain the Sarcheshmeh and unconformably underlies the Kalat Formations.

2- The biostratigraphic studies led to identification of 21 genera and 48 species of benthonic foraminifera. Based on foraminifera assemblage, one biozones is suggested as follows: *Gavelinella flandrini* Assemblage zone. This biozone coincides with global biozones. Based on foraminifera fauna the

Late Aptian age is suggested for the Sanganeh Formation at this locality.

3- The palaeoecologic studies led to identification of three calcareous benthic morphogroups and two arenaceous benthic morphogroups.

There are three picks of benthic calcareous foraminifera on the graph in sample numbers 8, 32 and 48. The composition of benthic foraminifera assemblage indicates aerobic to dysaerobic bottom-water conditions.

4- According to identified morphogroups in Sanganeh Formation, during the Late Aptian time, sedimentation in the Kopeh Dagh basin has taken place in the shallow to fairly deep water.

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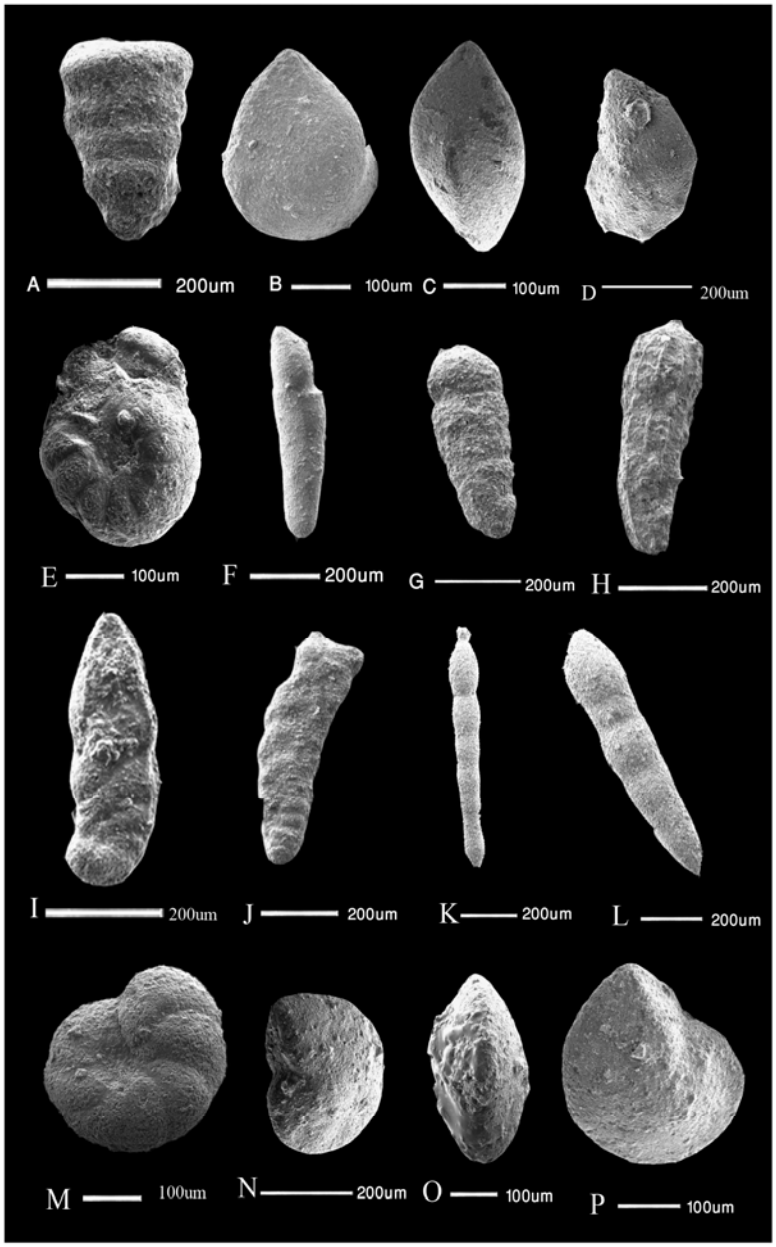
Plate 1



A- *Marsonella oxycona*, sample no. Tk-37-2; B, C- *Lenticulina subalata*, sample no. Tk-33-2; D- *Lenticulina (L.) saxocretacea*, sample no. Tk-8-4; E- *Haplophragmoides concavus*, sample no. Tk-27; F-*Laevidentalina nana*, sample no. Tk-33-4 ser1.; G-*Ammobaculites parvispira*, sample no. Tk-43-1; H- *Nodosaria obscura*, sample no. Tk-35; I- *Marginulina inaequalis*, sample no. Tk-15-4; J- *Gaudryina praedividens*, sample no Tk-29; K- *Laevidentalina linearis*, sample no. Tk-49-1; L-*Laevidentalina communis*, sample no. Tk- 49-3; M- *Gavelinella falndirini*, sample no. 14-1; N-P- *Darbyella* sp., sample no. Tk- 44-2.