Investigating the paleoecological characteristics of Abtalkh Formation at Bahadorkhan Section (Central Kopet-Dagh) based on planktonic and benthic foraminifera

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Abstract

Study of a late Late Santonian to Late Campanian hemipelagic succession from Abtalkh Formation at the Bahadorkhan section (Central Kopet-Dagh) enabled us to verify paleoecology changes based on planktonic and benthic foraminifera assemblage. Bahadorkhan section is consisted of calcareous shale, lime marl, marl, and a few dispersed chalky limestone beds. Upper and lower boundaries of Abtalkh Formation are conformable with Abderaz and Neyzar formations. Since foraminifera are proper tools for paleoecological investigations, we used them in three methods to analyze the changes of paleobathymetry: 1) Van der Zwaan's equations of determining depth and method (the ratio of planktonic foraminifera to benthic), 2) Leckie's morphotype model, and 3) investigating the changes of benthic foraminifera and the ratio of agglutinated benthic foraminifera to the utilized calcareous benthic foraminifera. Trox model (the ratio of epifaunal to infaunal (Ep/In)) was also used with the goal of identifying oxygen level and nutrients. According to the statistical counting, four stages of changes in depth and environmental conditions in this section with age range of late Late Santonian- Late Campanian were observed. According to the analysis, in the Early Campanian, P/B ratio and infaunal benthic are high which indicates the high level of water and eutrophic environment. In such an environment, nutrient and oxygen levels are respectively high and low. Then, at end of the Early Campanian and the beginning of Middle Campanian, water level decreases, and the environment moves toward oligotrophic conditions. During Middle Campanian and the early Late Campanian, water level increases again. Finally, during Late Campanian and along with the change of lithology to Neyzar Formation sandstones, we will witness the decrease of P/B ratio, water level drop, oxygen level increase, and nutrient decrease.

Keywords: *Abtalkh Formation, Kopet-Dagh Basin, Paleoecology, Planktonic and Benthic Foraminifera.*

Introduction

According to micropaleontological studies, Bahadorkhan section is categorized into 4 biozones including 1) *Globotruncanita elevate* partial range zone, 2) *Globotruncana ventricosa* interval zone, 3) *Radotruncana calcarata* total range zone, and 4) *Globotruncanella havanensis* partial range zone. This section was deposited at the end of late Late Santonian-Late Campanian (Honarmand *et al*., 2015). Abtalkh Formation is a major thick Late Cretaceous sedimentary unit in Kpoet-Dagh basin (Aghanabati, 2004).

A number of objective and inclusive biostratigraphic and paleoecological studies have been delivered over the past years, which all addressed different sections of this Formation across the Kopet-Dagh basin; for instance, Vahidinia (2007) reported age Early Campanian-Early Maastrichtian for type section, Ahmadi *et al*. (2013) reported age Late Santonian-Early Maastrichtian for Padeha section, Nyazi *et al*. (2013) confirmed a Campanian age at the Qareh-Sou section, Ghourchaei *et al*. (2014) reported ages Campanian, Early Campanian-Maastrichtian, and Early Maastrichtian, respectively, for Qareh-Sou, Itamir, and Nokhandan sections all based on the planktonic foraminiferal content. Hadavi and Notghi Moghaddam (2002), Hadavi and Khodadadi (2002), and, finally, Hadavi (2004) determined Early Campanian age based on the nannofossil biozonation of the Abtalkh Formation in the stratotypic area.

The late Santonian to late Campanian interval represents a period of major sea-level fluctuations in the Tethyan area (Lüning *et al*., 1998; Li *et al*., 2000). This study will focus on the various characteristics such as depth, oxygen, and nutrient level based on the statistical counting of planktonic and benthic foraminifera. Generally speaking, as depth increases, the frequency of planktonic foraminifera increases as well (Berger & Diester-Haass, 1988; Nigam & Henriques, 1992). This could be because of turmoil reduction which is due to the increase of distance from coastline. This increased distance raises primary production. As a matter of fact, with the increase of distance from coastline and reduction of nutrients arrived from lands, the number of planktonic foraminifera increase to a certain point.

Furthermore, pelagic ecosystem with all of its complicated food chains is only completed in depths that cover all of the photic area. The increase of depth leads to the arrival of semi-deep and deep planktonic foraminifera in the ecosystem. However, with respect to benthic foraminifera, the situation is a bit more complicated and less predictable. Sometimes, where it is not expected (such as basins without oxygen), their number increases (Van der Zwaan *et al*., 1990).

Evident characteristics of benthic foraminifera, including frequency and presence in different depths, makes them a proper basis for analyzing the paleoenvironmental changes like the change of sea level, oxygen level, and nutrient level (Van der Zwaan *et al*., 1999). However, benthic foraminifera are not very susceptible to environmental changes and factors such as temperature and salinity have no impact on their distribution (Diester-Haass, 1988; Van der Zwaan, 1990). In the past, bathymetry was more focused on the identification of species with similar depths, yet now, research is more oriented toward the ratio of planktonic to benthic foraminifera (Jorissen *et al*., 2007).

The objective of the present study is to focus on changes in paleobathymetry during deposition of Abtalkh Formation by three methods, including Van der Zwaan's equations of determining depth and method (the ratio of planktonic foraminifera to benthic), (Fig.4), Leckie's (1987) morphotype model (Fig.5), and investigating the changes of benthic foraminifera and the ratio of agglutinated benthic foraminifera to the utilized calcareous benthic foraminifera. 70 samples with the highest number of benthic foraminifera were chosen with the goal of considering the changes of oxygen and nutrients. Then, the ratio of planktonic and benthic foraminifera to ratio of epifaunal to infaunal (Ep/In) was estimated by Trox model (Fig.6).

Geographical Location of the Study Area

The understudy section is located on the main road from Ghoochan, 40 kilometers out of Dargarz. After travelling for three kilometers on a sidetrack, we arrive at the section site located in the northwestern mountains of Bahadorkhan village. The place is known as Hussein Kadkhoda. The Geographical coordinates of the understudy section were 58° 35′ 01 east latitude and 37° 41′ 25″ north latitude (Fig. 1).

Discussion

Paleoecology:

Paleobathymetry Using Planktonic and Benthic Foraminifera

Wright (1977) studied the contemporary seas and suggested Depth=e $^{(0.042\times\%P+3.48)}$ (e = 2.718281 …Neper Number) for paleobathymetry. In this equation, the percentage of planktonic foraminifera (%P) is derived according to %P = (P/P+B) × 100. As we know, the increase of depth raises the number of planktonic foraminifera. Berger and Diester-Haass (1988) used P/B ratio as a production indicator and showed that the importation of nutrients by primary producers has a fundamental role in this equation. Since the entrance of organic nutrients depends on depth, the increase of depth leads to the reduction of organic nutrients touching substratum. Therefore, nutrients affect the distribution of species according to depth and, due to the decrease of nutrients entered the environment, environment, P/B will increase with the increase of depth.

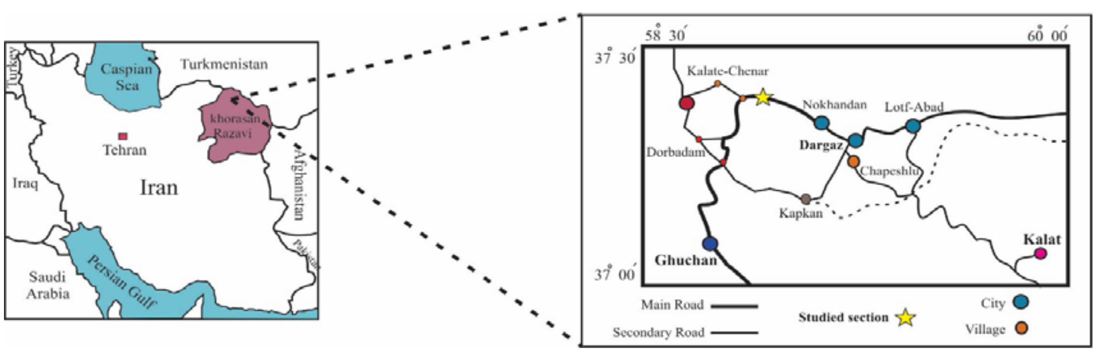

Figure 1. Geographical location map and road access to study area

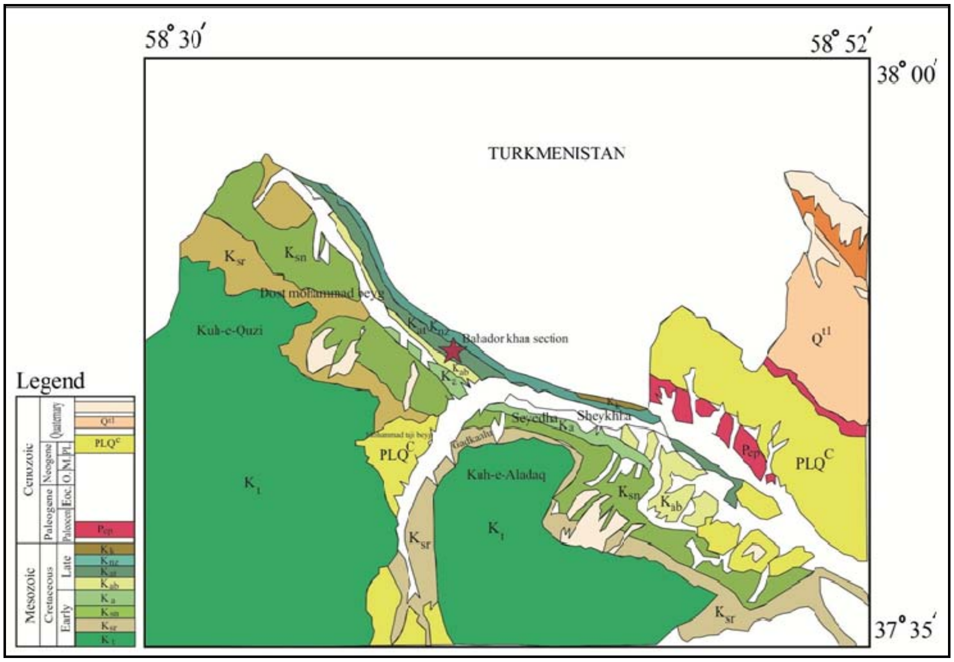

Figure 2. The partial of Nokhandan 1:100000 geological map (modified from Ghaemi, 2004)

Changes and distribution of benthic foraminifera in different depths depend on their life manners. Benthic foraminifera do not only live between water surface and sediments, yet in some cases, they could be even sought in 10 cm depth below water surface and sediments (Velic, 2007).

Depth Equations

Van der Zwaan *et al*. (1990) stated that the frequency pattern of benthic foraminifera in relation with depth shows the increase of benthic foraminifera between regions close to beach and those on the edge of continental shelf. This number decreases in deeper regions. This pattern is directly influenced by the carbon content that exists in deposits. The carbon content also affects inflaunal benthic foraminifera. Taking these factors into account, they suggested Depth= $e^{(3.58718+0.03534\times\%P)}$ (e=2.718281…Neper Number), where the number of planktonic foraminifera is counted according to %P*= (P/P+B-inf) ×100. In this study, to determine the paleodepth of Abtalkh Formation in the understudy region, the ratio of Planktonic to benthic foraminifera is determined randomly in each sample with 300 microfossils. It was estimated via using Van der Zwaan *et al.* (1990) method and Depth=$e^{(3.58718+0.03534\times\%p^*)}$ formula (Table 2).

The analyses showed that in *Globotruncanita elevate* zone at the late Late Santonian-Early Campanian, the proportion of planktonic foraminifera was high, which indicates the great depth of zone at that time (Fig. 4). Then, at the end of *Globotruncanita elevata* and in the beginning of *Globotruncana ventricosa* zone, planktonic foraminifera is reduced and benthic foraminifera has increased. This shows the decrease of depth at the late Early Campanian and the early Middle Campanian. Then, during Middle Campanian, the depth increases and the percentage of planktonic foraminifera rises. During Early Campanian and at the end of *Globotruncanita elevata* zone, benthic foraminifera frequency outnumber planktonic foraminifera, which itself reveals the decrease of depth at the same time. The results of these analyses show the change of depth from 457 m to 49 for this formation (Fig.4). Such a depth represents mesopelagic and epipelagic sea environment and paleodepth of upper bathyal and sublittoral zones (Fig. 3).

Leckie's (1987) Morphotype Model

An important method for the analysis of vertical movement of the sedimentary basin floor is the reconstruction of changes of paleodepth according to the geometrical shape of the Planktonic foraminifera. In 1987, Leckie categorized planktonic foraminifera into three groups according to their depth and geometrical shape:

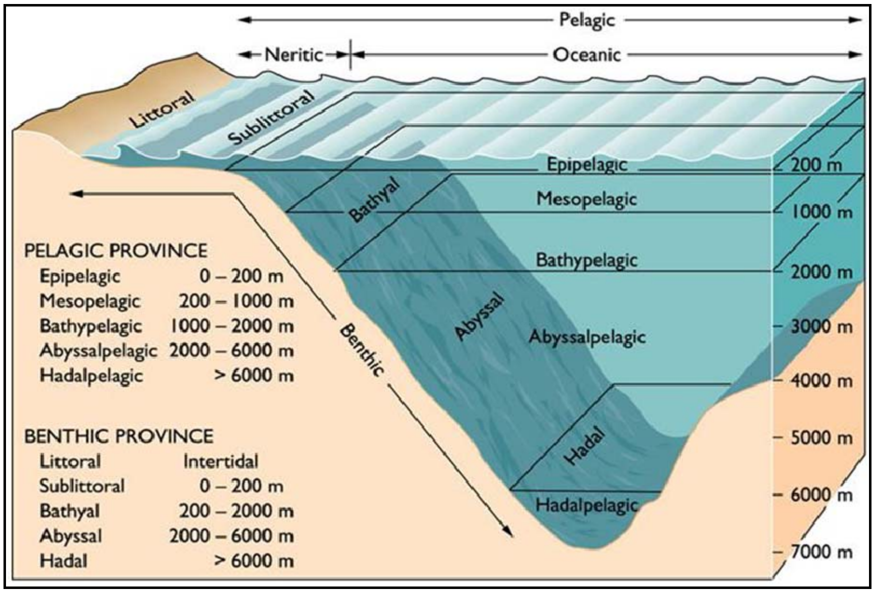

Figure 3. The main subdivisions of the marine environment (Adapted from, Van Morkhoven et al., 1986) Depositional depth of Abtalkh Formation

1) Epicontinental sea fauna (ESF); 2) Shallow water fauna (SWF); and 3) Deep water fauna (DWF). As a result, forms that could be put into each group are:

1. ESF: Samples of this depth include straight shells (biserial and there serial) such as: Heterohelix and Guembelitria (Leckie, 1987; Premoli-Silva and Sliter, 1999) (Table 1).

2. SWF: Samples related to this depth involve trochospiral shells with spherical chambers with no kill. They are light and have little ornament such as *Muricohedbergella delrioensis*. A great part of the small planispiral samples such as Globigerinelloides genus are related to relatively shallow ESF or marginal sea fauna (Eicher, 1969; Sliter, 1972) (Table 1).

3. DWF: Samples of these depths have trochospiral shells with compact chambers and primary kill such as Praeglobotruncana. Some samples have trochospiral shells with compact chambers and kill, such as Marginotruncanids and Globotruncana (Caron & Homewood, 1983; Leckie, 1987, 1989; Premoli-Silva & Sliter, 1999) (Table 1).

According to the above-mentioned points, 300 planktonic foraminifera were counted in 70 samples and the percentage of the morphotypes in each sample was estimated. The analyses showed that during the end of Late Santonian-beginning of Early Campanian and Middle Campanian, the frequency of DWF foraminifera, which are the fauna of deep water *Globotruncana arca*, *Globotruncanita elevate*, have been high. During the late Early Campanian and Late Campanian, with the decrease in the sea level, the percentage of ESF and SWF including *Heterohelix globlosa*, *Archeoglobigerina cretacea*, *Macroglobigerine-lloides prairohelensis*, which are the fauna of shallow water, increases (Fig. 5).

Table 1. Different kinds of morphotype group of planktonic foraminifera (Leckie, 1987)

ESF%	SWF%	DWF%
Heterohelix	*Hedbergella*	*Marginotruncana*
Laeviheterohelix	*Whiteinella*	*Dicarinella*
Psudotextularia	*Globigerinelloides*	*Globotruncana*
Guembelitria	*Archeoglobigerina*	*Globotruncanita*

Analysis of the Change of Sea Level According to the Variation in the Composition of Calcareous to Agglutinated Shells of Benthic Foraminifera

Benthic foraminifera are generally used to infer palaeodepths and consequently to infer relative sea-level changes (Sliter & Bakre, 1972; Auber and Brggren, 1976; Keller, 1988, 1992). One major factor that shows the relative change of sea level is the change of materials in a benthic foraminifera wall. On the other hand, Late Santonian-Late Campanian is one of the most important and varying times in the late Cretaceous relative sea levels on a global scale (Luning *et al*., 1998; Li *et al*., 2000). This is identified via the change of frequency and variety of benthic foraminifera.

Besides using the above-mentioned methods to analyze the changes of sea level during deposition of Abtalkh Formation, changes of benthic foraminifera shell were also studied. Generally speaking, the decrease of depth leads to the frequency of benthic foraminifera. The increase of depth results in the increase of the ratio of foraminifera with agglutinated shell to foraminifera with calcareous shell. Species with non-calcareous agglutinated shell show more depth than species with calcareous agglutinated shell (Holbourn *et al*., 2001, Nagy *et al*., 2001). Therefore, in the understudy section, the ratio of agglutinated benthic foraminifera to calcareous benthic foraminifera changes through four stages.

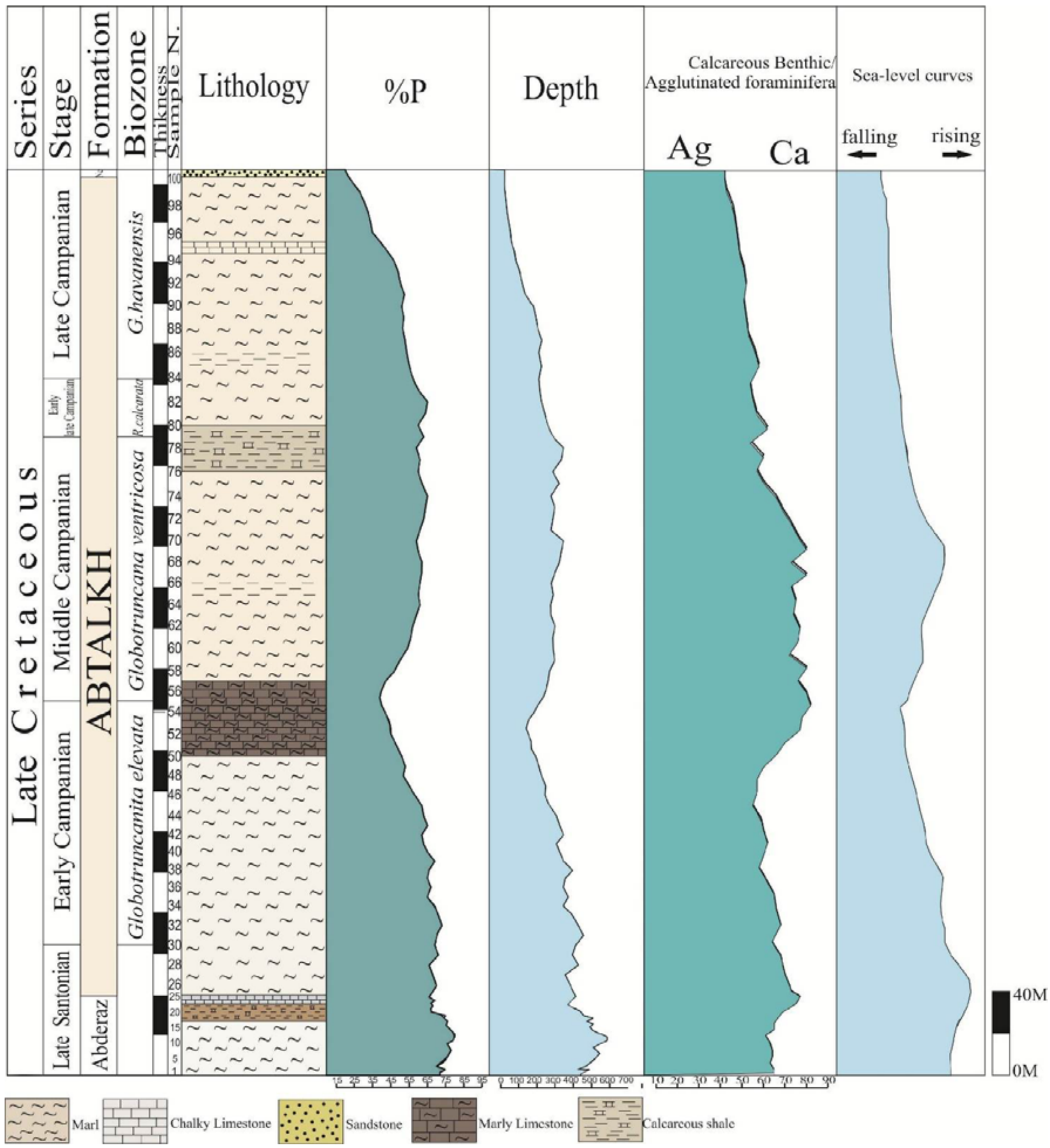

Figure 4. Curve sea level changes based on equations of depth determination and composition changes of benthic foraminifera shell

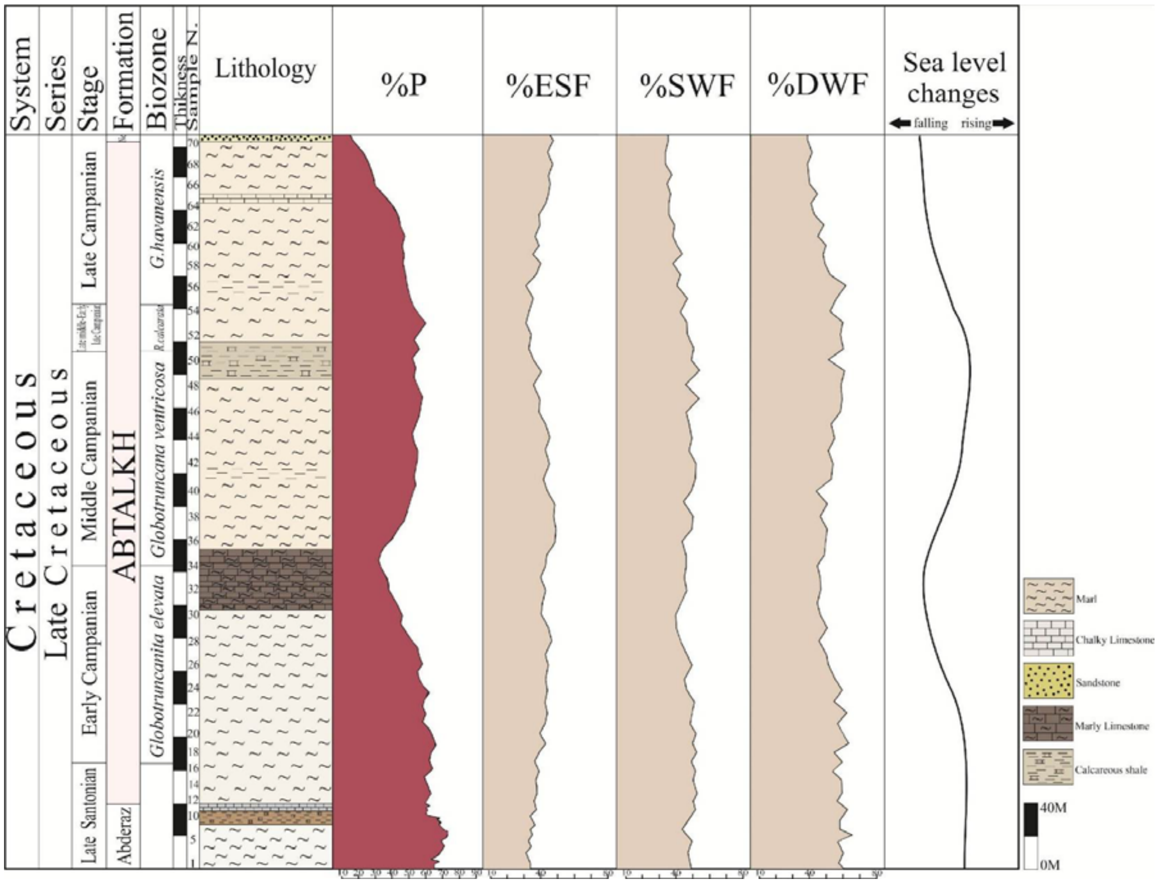

Figure 5. Different morphotypes curve related to sea level changes of Abtalkh Formation at Bahadorkhan section

In this study, the identification of benthic foraminifera was conducted based on Cushman (1946), Bolli and Beckmann (1994), Algret and Thomas (2001), Algret and Molina (2003) and Ghoorchaei *et al*. (2012). The study of Abtalkh Formation benthic foraminifera in Bahadokhan section led to the identification of a number of agglutinated forms including *Bulimina reussi*, *Clavulinoides asper*, *Dorothia bulletta*, *Gaudryina carinata, Gaudryina pyramidata*, *Marssonella oxycona*, *Rhizammina* sp., and also several foraminifera with calcareous shell such as *Laevidentalina haeggi, Nodosaria limbata*, *Gyroidinoides nuttida*, *Planularia complanata, Laevidentalina legume*, and *Lenticulina convergenus*.

During the late Late Santonian to Early Campanian, the ratio of non-calcareous agglutinated foraminifera in *Globotruncanita elevate* biozone was 77%-65% which is more than calcareous foraminifera (Table 3). The decrease of depth in the beginning of Middle Campanian led to a 45% decrease of the same ratio. During Middle Campanian and the beginning of Late Campanian, the increase of depth again led to the rise of agglutinated benthic foraminifera to 80% in *Globotruncana ventricosa* and *Radotruncana calcarata* zone. During Late Campanian and in *Globotruncanella havanensis* zone, calcareous benthic foraminifera decreased as the depth reduced by 42%-43% (Fig. 4), (Table 3).

Determining the Changes of Oxygen and Nurtients

Different studies have shown that factors such as changes in oxygen and nutrients affect the distribution of benthic foraminifera (Berger and Haass, 1988; Van der Zwaan *et al*., 1990; Jorissen *et al*., 2007). epifaunal benthic foraminifera is directly dependent on nutrients imported from water surface, thus it has a quite clear relationship with depth. However, benthic species more often use organic content of sediments. Therefore, change of epifaunal to infaunal foraminifer is a valid basis for the evaluation of nutrients in an environment.

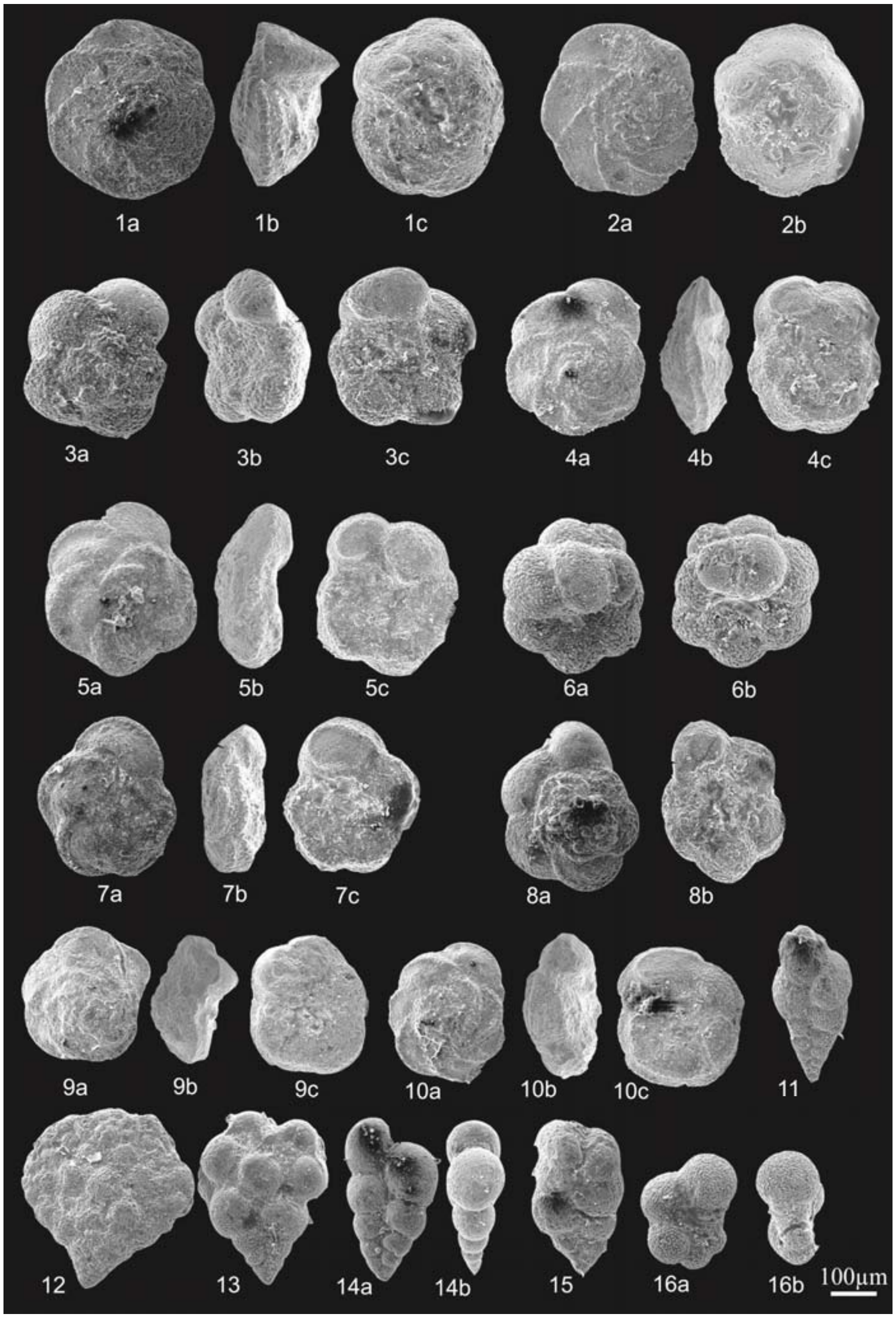

Plate 1. 1.*Globotruncanita stuartiformis* (Dalbiez, 1955); sample no.70; Globotruncanita elevata Zone. AFUM52. 2. *Globotruncanita stuarti* (Lapparent, 1918); sample no.93; Globotruncana havanensis Zone. AFUM69. 3. *Globotruncanella havanensis* (Voorwijk, 1937); sample no.84; AFUM55. 4. *Globotruncana mariei* (Banner & Blow, 1960); sample no.52; Globotruncanita elevata Zone. AFUM70. 5. *Marginotruncana coronata* (Bolli, 1945); sample no.24; Globotruncanita elevata Zone. AFUM71. 6. *Macroglobigerinelloides multispinus* (Lalicker, 1984); sample no.96; Globotruncana havanensis Zone. AFUM72. 7. *Marginotruncana marginata* (Reuss, 1845); sample no.25; Globotruncanita elevata Zone. AFUM73. 8. *Globotruncana rugosa* (Marie, 1941); sample no.79; Radotruncana calcarata Zone. AFUM74. 9. *Contusotruncana pataliformis* (Gandolfi, 1955); sample no.89; Globotruncana havanensis Zone. AFUM75. 10. *Globotruncana bulloides* (Vogler, 1941); sample no.74; Globotruncana ventricosa Zone. AFUM76. 11. *Heterohelix labellosa* (Nederbragt, 1990); sample no.98; Globotruncana havanensis Zone. AFUM77. 12-13. *Ventrilabrella austiniana* (Cushman, 1938); sample no.49; Globotruncanita elevata Zone. AFUM78. 14. *Heterohelix carinata* (Cushman, 1938); sample no.61; Globotruncana ventricosa Zone. AFUM79. 15. *Heterohelix papula* (Belford, 1960); sample no.26; Globotruncanita elevata Zone. AFUM80. 16. *Muricohedbergella holmdelensis* (Olsson, 1964); sample no.86; Globotruncana havanensis Zone. AFUM81.

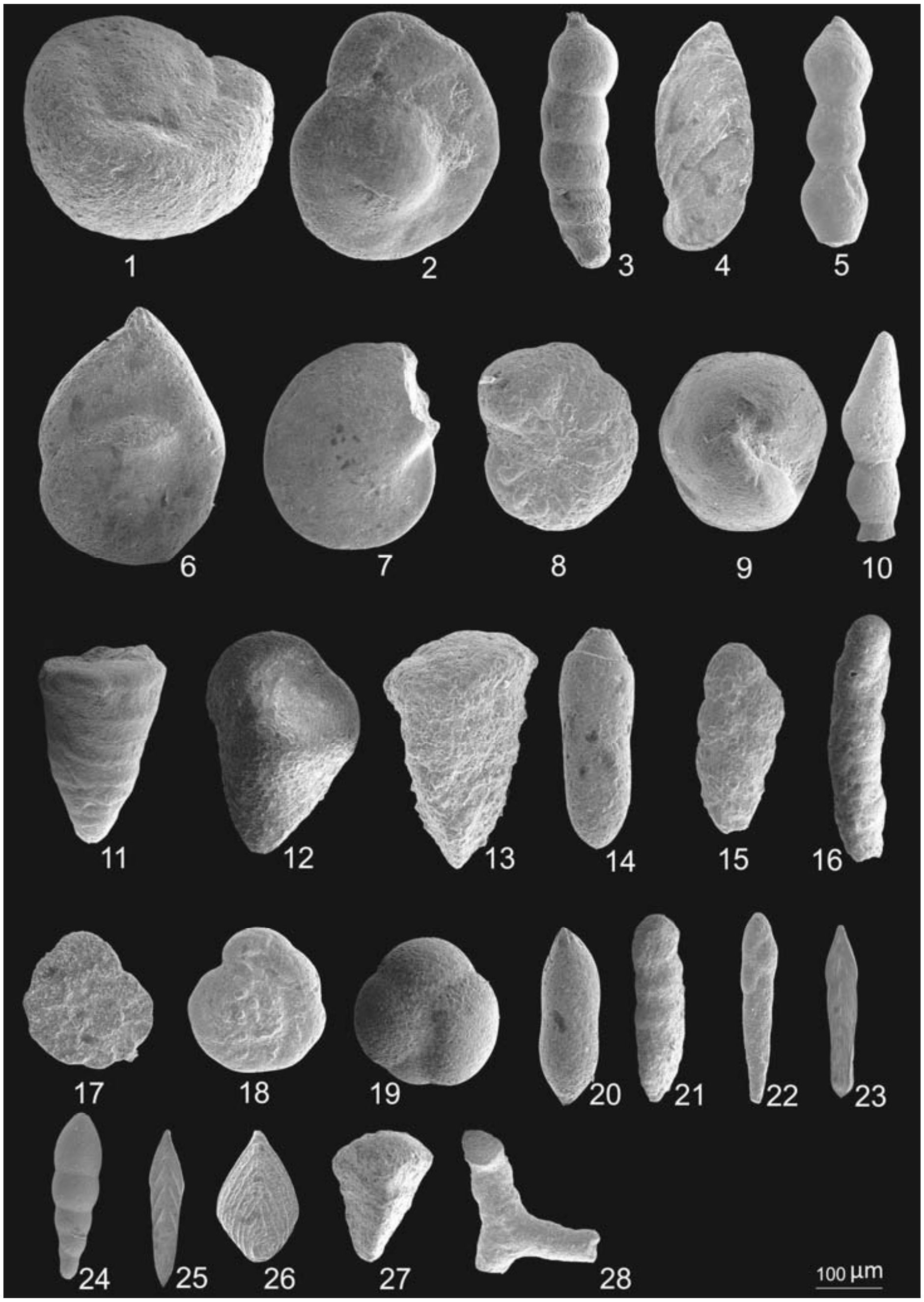

Plate 2. 1.*Gyroidinoides nuttida* (Reuss); sample no.7.AFUM1; 2. *Alabamina creta* (Finlay,1940); sample no.14.AFUM2; 3. *Laevidentalina haeggi* (Brotzen); sample no.35.AFUM3; 4. *Planularia complanata* (Reuss); sample no.4.AFUM4; 5. *Dentalina catenula* (Reuss); sample no.57.AFUM5; 6. *Lenticulina convergenus* (Reuss); sample no.66.AFUM6; 7. *Lenticulina* sp., sample no.17.AFUM7; 8. *Anomalina rubiginosa* (Cushman); sample no.19.AFUM8; 9. *Globorotalites micheliniana* (D'Orbigny); sample no.54.AFUM9; 10. *Dentalina reflexa* (Reuss); sample no.12.AFUM10; 11. *Marssonella axycona* (Reuss); sample no.27.AFUM11; 12. *Marssonella* sp.(Morrow); sample no.59.AFUM12; 13. *Gaudryina carinata* (Franke,Izlaz); sample no.29.AFUM13; 14. *Dentalina megalopolitan* (Cushman); sample no.39.AFUM14; 15. *Dorothia bulletta* (Plummer); sample no.21.AFUM15; 16. *Pseudoclavulina arenuta*; sample no.67.AFUM16; 17. *Stensioeina excolata* (Reuss); sample no.62.AFUM17; 18. *Brotzenella* sp. (Marie); sample no.22.AFUM18; 19. *Quadrimorphina allomorphinoides* (Reuss); sample no.46.AFUM19; 20. *Nodosaria* cf *limbata* (D'Orbigny); sample no52.AFUM20; 21. *Clavulinoides* cf *asper* (Cushman); sample no;24.AFUM21; 22. *Loxostomum subrostratum* (Ehrenberg); sample no.30.AFUM22; 23. Frondicularia striatula (Reuss); sample no.69.AFUM23; 24. *Pseudonodosaria mutabilis* (Lamark); sample no.37.AFUM24; 25. *Frondicularia arkadelphiana* (Cushman); sample no.42.AFUM25; 26**.** *Neoflabelina reticulate* (Reuss); sample no.5.AFUM26; 27. Gaudryina pyramidata (Cushman); sample no.25.AFUM27; 28. *Rhizammina* sp. (Grzybowski);s ample no.58.AFUM28;

Table 2. The percent of planktonic and benthic foraminifera

Sample.N	%P	Depth	Sample.N	%P	Depth	Sample.N	%P	Depth
1	72	441.25	35	65	345.25	69	62	289.59
2	75	490.24	36	67	370.11	70	60	279.70
3	70	411.21	37	65	345.25	71	61	299.84
4	73	457.32	38	66	357.47	72	59	321.74
5	75	490.24	39	69	397.16	73	61	333.13
6	76	508.09	40	65	345.25	74	63	345.25
7	77	526.06	41	63	321.74	75	64	279.70
8	78	544.67	42	62	309.83	76	65	289.59
9	77	526.06	43	65	345.25	77	62	299.84
10	76	508.09	44	63	321.74	78	60	279.70
11	78	544.67	45	62	309.83	79	61	321.74
12	80	584.47	46	58	269.87	80	59	289.59
13	80	584.47	47	55	242.90	81	63	333.13
14	78	544.67	48	52	245.82	82	60	345.25
15	76	508.09	49	53	226.59	83	64	289.59
16	75	490.24	50	51	211.16	84	65	260.65
17	76	508.09	52	49	196.78	85	60	242.90
18	74	473.49	52	45	171.06	86	57	226.59
19	75	508.09	53	45	171.06	87	55	218.63
20	73	457.32	54	42	153.97	88	53	211,16
21	72	441.25	55	40	143.48	89	52	226.56
22	70	411.21	56	42	153.97	90	51	211.16
23	67	370.11	57	42	183.56	91	53	226.56
24	67	370.11	58	47	203.94	92	51	203.94
25	68	383.59	59	54	234.60	93	49	196.78
26	70	411.21	60	50	251.75	94	47	183.56
27	68	383.59	61	57	260.65	95	39	138.58
28	66	357.47	62	59	279.70	96	35	120.47
29	71	426.18	63	61	299.84	97	35	108.43
30	69	397.16	64	60	289.59	98	32	94.17
31	70	411.21	65	60	289.59	99	30	84.76
32	73	457.32	66	61	299.84	100	28	49.09
33	71	426.18	67	60	279.70			
34	69	397.16	68	60	279.70			

Table 3. The percent of agglutinated & calcareous benthic foraminifera

Sample.N	%Ag	%Ca	%Ep	%In	Sample.N	%Ag	%Ca	%Ep	%In
1	35	65	28	72	36	22	78	55	45
2	37	63	28	72	37	28	72	47	53
3	35	65	30	70	38	23	77	48	52
4	36	64	28	72	39	22	78	44	56
5	38	62	29	71	40	26	74	45	55
6	39	61	32	68	41	27	73	40	60
7	35	65	30	70	42	20	80	38	62
8	35	65	30	70	43	16	84	32	68
9	33	67	26	74	44	20	80	30	70
10	30	70	31	69	45	27	73	33	67
11	24	76	28	72	46	30	70	29	71
12	27	73	29	71	47	33	67	30	70
13	29	71	28	72	48	41	59	26	74
14	30	70	32	68	49	40	60	20	80
15	31	69	35	65	50	43	57	28	72
16	32	68	34	66	51	38	62	30	70
17	35	65	33	67	52	42	58	34	66
18	34	66	37	63	53	44	56	31	69
19	32	68	36	64	54	46	54	34	66
20	33	67	40	60	55	43	57	38	62
21	35	65	46	54	56	43	57	50	50
22	37	63	46	54	57	46	54	54	46
23	41	59	50	50	58	47	53	60	40
24	40	60	52	48	59	48	52	64	36
25	38	62	51	49	60	50	50	56	44
26	41	59	56	44	61	49	51	48	52
27	43	57	54	46	62	48	52	52	48
28	42	58	59	41	63	50	50	52	48
29	42	58	61	39	64	51	49	47	53
30	38	62	63	37	65	52	48	52	48
31	32	68	60	40	66	53	47	58	42
32	22	78	62	38	67	53	47	40	60
33	21	79	59	41	68	54	46	37	63
34	19	81	60	40	69	57	43	39	61
35	22	78	55	45	70	58	42	33	67

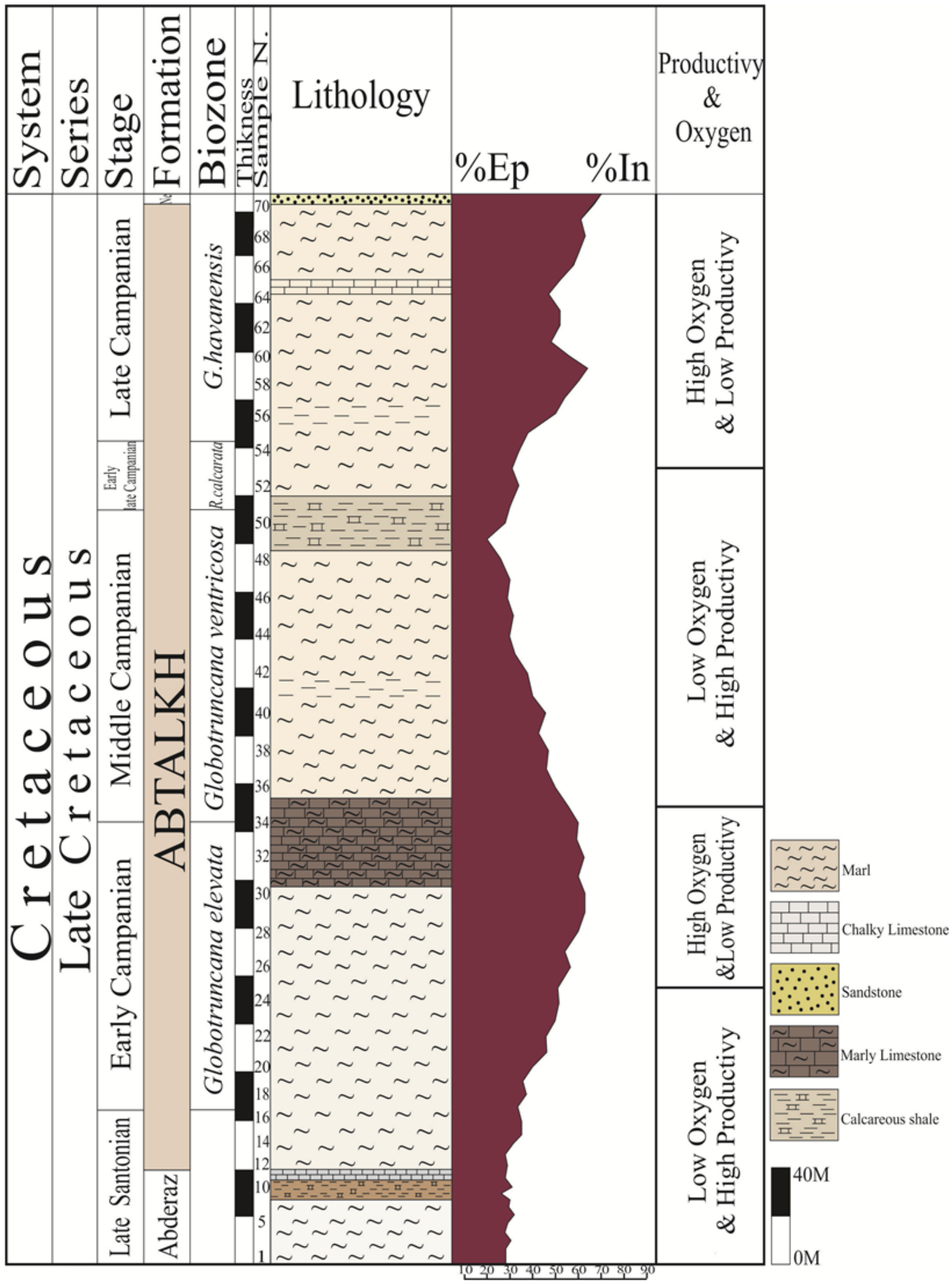

Figure 6. Stratigraphic column, the ratio of epifaunal to infaunal benthic foraminifera changes and oxygen and nutrient changes

Infaunal species show the amount of nutrients stored in sediments (Berger and Diester Haass, 1988). The Ep/In ratio was used to determine the amount of oxygen and nutrients. The increase of the ratio of planktonic foraminifera to benthic foraminifera could be observed more often in turbulent, shallow water and oligotrophic conditions. This showed the high level of oxygen and low quantity of the nutrients.

However, with increase of the infaunal species, the condition became more eutrophic and the depth also increased in the beginning and middle of section during the late Late Santonian-Early and Middle Campanian. This showed the decrease of oxygen and increase of nutrients during this time. Given the increase of this ratio and the high frequency of benthic foraminifera at the end of Early Campanian-Early Middle Campanian and the end of Late Campanian, environmental conditions moved toward oligotrophic and high oxygen level (Fig.6).

Conclusion

The analysis of paleoecological characteristics showed that during Abtalkh Formation deposition, sea level had four fluctuations. As it was observed, during the end of Late Santonian-Early Campanian and in *Globotruncanita elevata* biozone, the depth increased, and as a result, the ratio of planktonic to benthic foraminifera was high. Then, with the emergence of the late Early Campanian and the beginning of Middle Campanian in *Globotruncana ventricosa* biozone, the depth decreased, which is demonstrated by the increase of benthic foraminifera compared to planktonic fauna. During Middle Campanian-Late Campanian in *Radotruncana calcarata* biozone, the depth increased again. At the end of Late Campanian and in *Globotruncanella havanensis* zone, the sea level decreased as it reached Neyzar Formation sandstones.

The study of the ratio of epifaunal to infaunal benthic foraminifera in the 70 samples showed that the increase of the depth decreased this ratio. This showed a eutrophic environment and increase of the oxygen level. When the depth was decreased, the same ratio increased, and at the same time the environment moved toward oligotrophic conditions. The oxygen level was low and the nutrient level was high. Finally, the analyses showed changes of depth from 457 m to 49 m for Abtalkh Formation. Such a depth represents mesopelagic and epipelagic sea environment and paleodepth of upper bathyal and sublittoral zones. Four stages of the changes were observed in the depth and environmental conditions.

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