Discussion on *Orbitoides concavatus* Rahaghi 1976, *Praeomphalocyclus concavatus* Meriç and Çoruh 1991, *Postomphalocyclus meriçi* İnan 1992 and *Pseudomphalocyclus blumenthali* Meriç 1980

Reza Azizi[1*]

1- M.Sc. in Paleontology and Stratigraphy, Department of Geology, Faculty of Science ,University of Isfahan, Isfahan, Iran.

* Corresponding Author: azizireza6716@yahoo.com

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Abstract

In the Upper Maastrichtian, orbitoidal benthic foraminifera are very abundant in carbonate sequence of the Tethys realm. The Tarbur Formation, in 5 Km southwest of Semirom with abundant orbitoidal benthic foraminifera to Late Maastrichtian age and 462 m thickness composed of carbonate and terrigenous rocks. In the present paper, author has reviewed new data related to species; *Orbitoides concavatus* Rahaghi 1976, *Praeomphalocyclus concavatus* Meriç and Çoruh 1991, *Postomphalocyclus meriçi* İnan 1992 and *Pseudomphalocyclus blumenthali* Meriç 1980. Among many known orbitoidal foraminifera, the Tarbur Formation yielded a new species, here in tentatively assigned to the genus *Praeomphalocyclus* Meriç and Çoruh. The species was first described and properly illustrated by Rahaghi, under the name of *Orbitoides concavatus* n. sp. Based on the morphometric data in this study and other studies in the Tethys area done by other researchers; both *Orbitoides concavatus* Rahaghi 1976 and *Praeomphalocyclus concavatus* Meriç and Çoruh 1991 are nomen nudum. Also *Postomphalocyclus meriçi* İnan 1992 is considered synonymous with *Pseudomphalocyclus blumenthali* Meriç 1980 in here. *Pseudomphalocyclus blumenthali* appears to be quite common in the Tarbur Formation has been reported by researchers in Turkey, Syria, Iraq, Iran, Saudi Arabia, Qatar, Oman, Yemen and Somalia. This species indicate shallow marine environments and may be restricted to the Late Maastrichtian.

Keywords: *Orbitoides*, *Postomphalocyclus*, *Praeomphalocyclus*, *Pseudomphalocyclus*, Late Maastrichtian, Iran.

1- Introduction

The type section of the Tarbur Formation was provided firstly by Farshadfar *et al*. (1960) and was selected as a type section by James and Wynd (1965). The Tarbur Formation is a predominantly carbonate lithostratigraphic unit that out crops in the Zagros basin, between the main Zagros reverse fault and the high Zagros and the east of Sabzpushan fault (Maghfouri-Moghadam *et al*., 2009). This formation mainly consists of carbonate and terrigenous rocks. The carbonate rocks mainly contain a rudist facies with abundant of orbitoidal benthic foraminifera such as *Lepidorbitoides*, *Orbitoides*, *Monolepidorbis*, *Sirtina*, *Siderolites*, *Pseudomphalocyclus* and *Omphalocyclus* (e.g. Amiri Bakhtiar, 2007; Azizi, 2012; Asgari Pirbaluti *et al*., 2013, Dehghani *et al*., 2013, Vaziri-Moghaddam *et al*., 2013; Afghah and Yaghmour, 2014; Abyat and Lari, 2015; Azizi *et al*., 2015; Payandeh *et al*., 2016; Schlagintweit *et al*., 2016).

2- Geographical Location of Studied section

The study area with geographical coordinates of N: 31° 22' 48" and E: 51° 32' 01" is located at about 5 km southwest of Semirom (Fig. 1). This formation consists of limestones, shales and sandstones with a total thickness of 462 m in the Semirom section and has a gradual and conformable contact with underlying red shale unit (S_2) while it is overlaid by the Kashkan Formation which is marked by an erosional surface (Azizi, 2012).

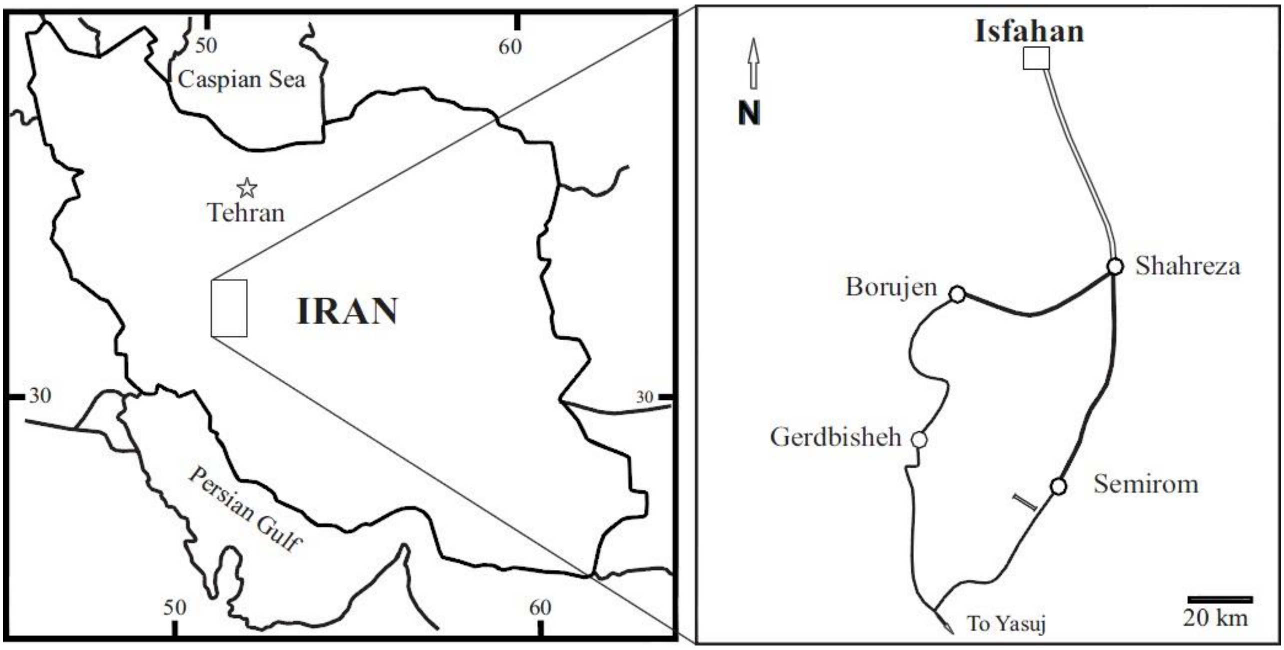


Figure 1) The location map of the studied section (double line symbols) near Semirom in the central part of the Zagros Mountains, SW Iran.

3- Materials and Methods

Larger benthic foraminifera develop complicated endoskeletons, which are reproduced precisely with each successive generation. These internal structures permit the taxa of such microfossils to be accurately identified, even when they are randomly thin-sectioned (Boudagher-Fadel, 2008). The thickness of the Tarbur Formation in the studied section is 462 meters and consists of three litholigical units. Systematic sampling was conducted and more than 110 samples were collected from the measured section. Thin sections were prepared and studied with morphometric analysis on orbitoidal benthic foraminifers. The identification of benthic foraminifera were performed according to Meriç and Çoruh 1991; İnan, 1992; Loeblich and Tappan, 1998; Özcan, 2007, Boudagher-Fadel, 2008; Meriç *et al.*, 2010; Zambetakis-Lekkas, 2010; Albrich *et al.*, 2014; and Görmüş, 2015.

4- Discussion

In the Late Cretaceous, new simple rotaliines evolved (to extraordinary power of God) into forms with complicated three-layered structures, the orbitoids. All orbitoids were derived from small benthic foraminifera with a simple, spiral chamber arrangement (Boudagher-Fadel, 2008). The first observed *Orbitoides concavatus* Rahaghi was in the Senonian deposits exposed near Kermanshah (Rahaghi, 1976). Meriç and Çoruh (1991) interpreted the specimens of *Orbitoides concavatus* Rahaghi from the Campanian of Iran (Rahaghi 1976; pl. 4, figs. 11-25) as a primitive type of *Omphalocyclus* and established the new genus *Praeomphalocyclus concavatus* (Rahaghi) for these specimens (Meriç and Çoruh 1991; pl. 1, figs. 1-16). Yet, adequately combining new observations on the present material with illustrations provided by Rahaghi and Meriç and Çoruh remains a difficult task (Fig. 2).

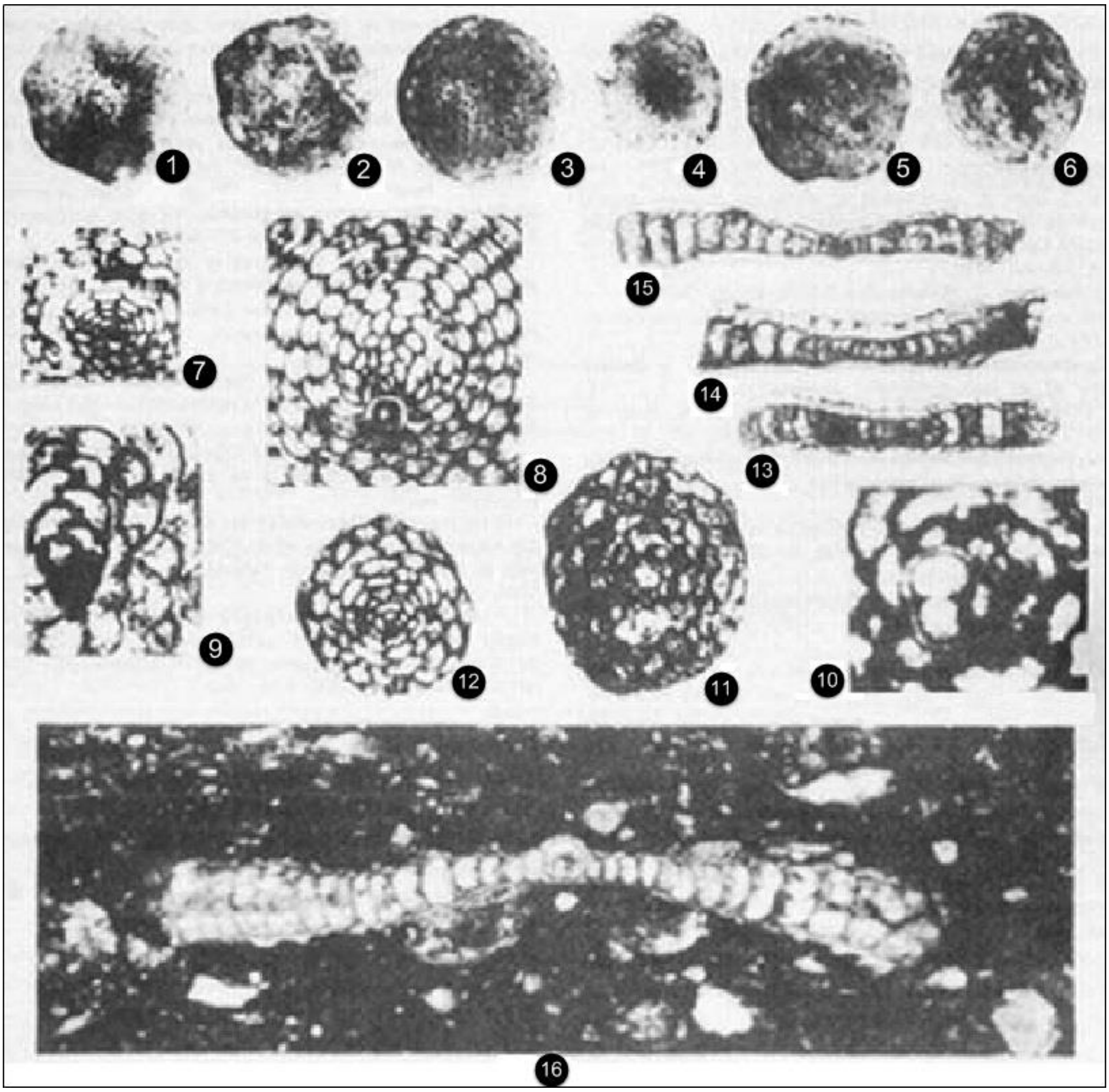


Figure 2) Different views of Praeomphalocyclus concavatus (Rahaghi); 1-15: Orbitoides concavatus Rahaghi, all specimens are from West Iran, 1-6: External views, x 20, 7-9: Portions of equatorial section showing initial biserial chambers, 7: x 60, 8: x 56, 9: x 160, 10: Portion of equatorial section showing bilocular embryonic apparatus, x 144, 11-12: Equatorial section of megalospheric form, x 40, 13-15: Axial sections, 13-14: x 56, 15: x 36, 16: Axial section of the passage between Praeomphalocyclus and Omphalocyclus, x 47, from South-East Turkey (modified after Rahaghi 1976; Meriç and Çoruh 1991).

For several reasons, *Orbitoides concavatus* Rahaghi does not belong to the genus *Orbitoides* (Meric and Çoruh, 1991): 1) The description of the macrospheric embryo of *Orbitoides concavatus* Rahaghi, the protoconch is not completely surrounded by the deuteroconch (Fig. 2, No. 10). This indicates that this organism is more similar to the genus *Omphalocyclus* which has a macrospheric embryo where the deuteroconch does not surround the protoconch completely.

2) Rahaghi mentions that the width of the equatorial chambers increases gradually from the center to the periphery of the test (Fig. 2, No. 11-12). This feature is a clear indication of an Omphalocyclinae rather than an Orbitoidinae origin, because in Omphalocyclinae, the increase of width/height ratio of equatorial

chambers in equatorial sections is a determinative character.

3) The biserial heterohelicid stage is more pronounced in the embryo of Omphalocyclinae than Orbitoidinae. Thus, it may also indicate an Omphalocyclinae origin.

4) Although Rahaghi mentioned that there are no pillars and lateral chambers in the axial sections and the heights of the chambers increase towards the periphery of the test. These properties strongly indicate an Omphalocyclinae origin rather than the Orbitoidinae. Besides, if there are no pillars present in tests, the vermiform ornaments seen on the surface could not be the traces of the pillars as argued by Rahaghi. These ornaments must be the traces of the equatorial chamber walls as seen on the tests surfaces of the Omphalocyclinae (Meric and Çoruh, 1991).

In this study, the known species *Orbitoides concavatus* can be reviewed significantly as in many previous reports from Iran, improperly were reported in axial and vertical sections (e.g. Khosrow Tehrani and Afghah 2004, pl. 1, Fig. 1; Vahidinia *et al.* 2007, pl. 2, Fig. 5; Afghah 2009, pl. 2, Fig. 4; Afghah 2010, p. 70, Fig. 5-3-19, p. 71, Fig. 5-3-20; Abyat *et al.* 2014, pl. 3, Fig. 1; Afghah 2016, p. 176, Fig. 4a; Schlagintweit *et al.* 2016, Fig. 8K). Therefore, it could be concluded that the species described by Rahaghi (*Orbitoides concavatus*) could not be included in *Orbitoides*. Also based on the recent study (Özcan, 2007), the specimen of *Praeomphalocyclus concavatus* Meriç and Çoruh is a nomen nudum, because it is more or less similar to the *Pseudomphalocyclus* (Fig. 2, No. 16) (Azizi *et al.*, 2016) and absent morphometric data there in Meriç and Çoruh (1991).

In addition to Rahaghi (1976) reports *Neumannites granulata* n. sp. and *Iranites ornatus* n. sp. from the Late Cretaceous (Campanian-Maastrichtian) of Iran and Libya. Both species show distinct features of *Sirtina* and was reported to form *Sirtina (Iranites) ornatus* (Rahaghi) (indicating the Middle-Late Maastrichtian) and *Sirtina (Neumannites) granulata* (Rahaghi) (indicating the Campanian period) by Meriç and Çoruh (1991). Also Loeblich and Tappan (1988) included these species in the genus *Sirtina*. *Iranites ornatus* is now considered to be a *Sirtina orbitoidiformis* (Fig. 5f, Goldbeck, 2007). However reported by some researchers previous in error at different names from Iran (e.g. Jalili *et al.* 2014, pl. 2, fig. 4; Schlagintweit *et al.* 2016, fig. 8I).

Some specimens have been vaguely described as having the lateral chamberlets developed just only at one side of the equatorial layer in supposedly Late Maastrichtian beds were attributed to *Postomphalocyclus* (İnan, 1992, Fig. 4C and Fig. 5E). Internal morphologic features and exact stratigraphic position of this taxon, described from several badly preserved specimens in thin sections, are not known. Moreover, İnan's evolutionary model from *Omphalocyclus* via *Postomphalocyclus* to *Pseudomphalocyclus* is highly conceptual and is not based on documented data (Özcan, 2007, Fig. 3). It is very probable that these specimens might have lost some of the already weakly developed lateral chamberlets following the post mortal transportation. Also some specimens in the material studied of Özcan (2007), although sporadic, that are essentially similar to *Omphalocyclus* but with several layers of lateral chamberlets (Özcan, 1993, Fig. 4j). Meriç (1980) erected the genus *Pseudomphalocyclus* for these specimens, assigning them a Late Maastrichtian age. This is considered to be a valid taxon representing a side line of *Omphalocyclus*, starting almost from the phylogenetic level of *Omphalocyclus cideensis* Özcan 2007. However, these lateral chamberlets are very irregular and mostly indistinctly developed at both sides of the test (Özcan, 2007). Since the development of lateral chamberlets in *Pseudomphalocyclus* is occasionally very poor and shows considerable variation in different specimens, *Postomphalocyclus* is considered synonymous with *Pseudomphalocyclus* in here (Özcan, 2007). Also morphometric data these that given by İnan (1992), are more or less similar (Table 2) and improperly were reported (Özcan, 2007; Azizi *et al.*, 2016).

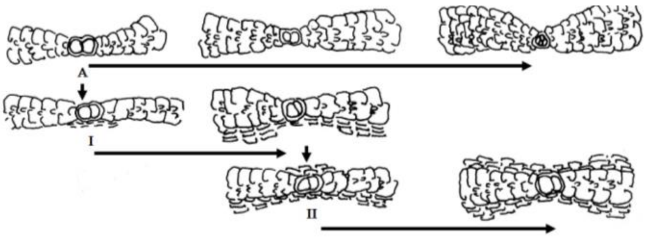


Figure 3) The interpretation of development stages in Omphalocyclus (Lamarck), A: Ontogenetic growth period in Omphalocyclus (Lamarck), I: First step of evolution; Postomphalocyclus (İnan), II: Second step of evolution; Pseudomphalocyclus Meriç (modified after İnan, 1992).

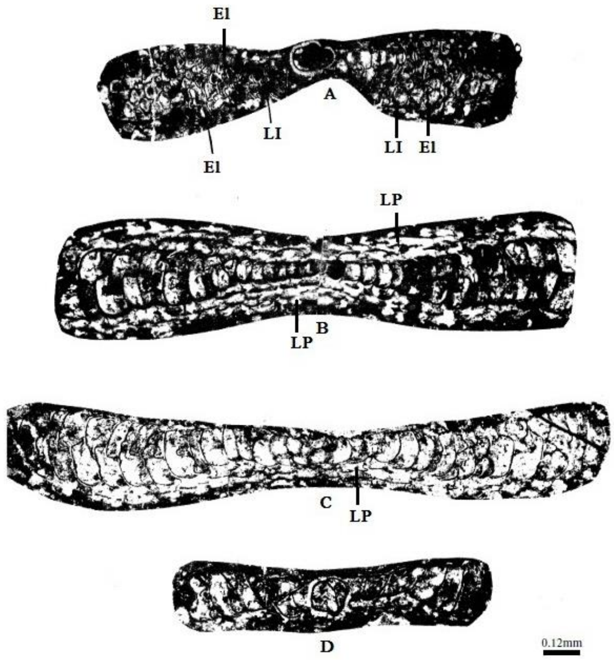


Figure 4) A: Omphalocyclus macroporus (Lamarck), Axial section, B: Pseudomphalocyclus blumenthali Meriç, Axial section, C: Postomphalocyclus meriçi (İnan), Holotype, Axial section, D: Postomphalocyclus meriçi (İnan), Paratype, Axial section. (El: Equatorial orbitoidal little chambers, LI: Lateral orbitoidal little chambers, LP: Lateral chambers and pillars) (modified after İnan, 1992).

Therefore, based on the this study, five species of orbitoidal benthic foraminifers such as *Orbitoides concavatus* Rahaghi 1976, *Neumannites granulata* Rahaghi 1976, *Iranites ornatus* Rahaghi 1976, *Praeomphalocyclus concavatus* Meriç and Çoruh 1991 and *Postomphalocyclus meriçi* İnan 1992 are nomen nudum and referable to the known genera *Sirtina* Bronnimann and Wirz 1962, *Omphalocyclus* Bronn 1853 and *Pseudomphalocyclus* Meriç 1980 (Fig. 5). Based on fossil content, the *Omphalocyclus*–*Loftusia*–*Siderolites calcitrapoides* Assemblage Zone is recognized in the Tarbur Formation. This assemblage zone is equivalent to Biozone 37 of Wynd (1965) and confirms the Maastrichtian age for the study section. Considering the morphometric measurement and identification of index species such as *Omphalocyclus macroporus*, *Lepidorbitoides socialis*, *Orbitoides apiculata* and *Pseudomphalocyclus blumenthali* (Fig. 6 and Table 1), the age of Tarbur Formation can precisely be considered as Late Maastrichtian at the study area.

5- Systematic Palaeontology, Palaeoecology and Palaeobiogeography

Family: Orbitoididae Schwager 1876

Subfamily: Orbitoidinae Schwager 1876

Genus: *Pseudomphalocyclus* Meriç 1980

Pseudomphalocyclus blumenthali Meriç 1980

Pseudomphalocyclus blumenthali n. sp. Meriç 1980, p. 85; Loeblich and Tappan 1998, pl. 731, figs. 8-11; Meriç, Görmüş, Luger, İnan and Çoruh 2010, p. 123.

Test large, up to 4.9 mm in diameter, discoidal to slightly biconcave, periphery rounded, the bilocular and trilocular or quadrilocular megalospheric embryo is followed by a single row of arcuate equatorial chambers. The alternating zones of rapidly widening equatorial chambers caused growing to two layers of chambers and finally three layers near the periphery. Three to four layers or lateral chamberlets are present at the centre of the test, decreasing to one or two layers near the periphery, with numerous thin short pillars between the lateral chamberlets (Loeblich and Tappan, 1998; Boudagher-Fadel, 2008). The Iranian specimens reported from *Pseudomphalocyclus blumenthali* in this paper to lateral chamberlets (LP) are mostly distinctly developed at both sides of the test and to size of test variation between 2.8 to 4.2 mm. *Pseudomphalocyclus blumenthali* appears to be quite common in the Tarbur Formation (Fig. 5) that was reported as a Acme Zone from Semirom section to Late Maastrichtian age (Azizi, 2012).

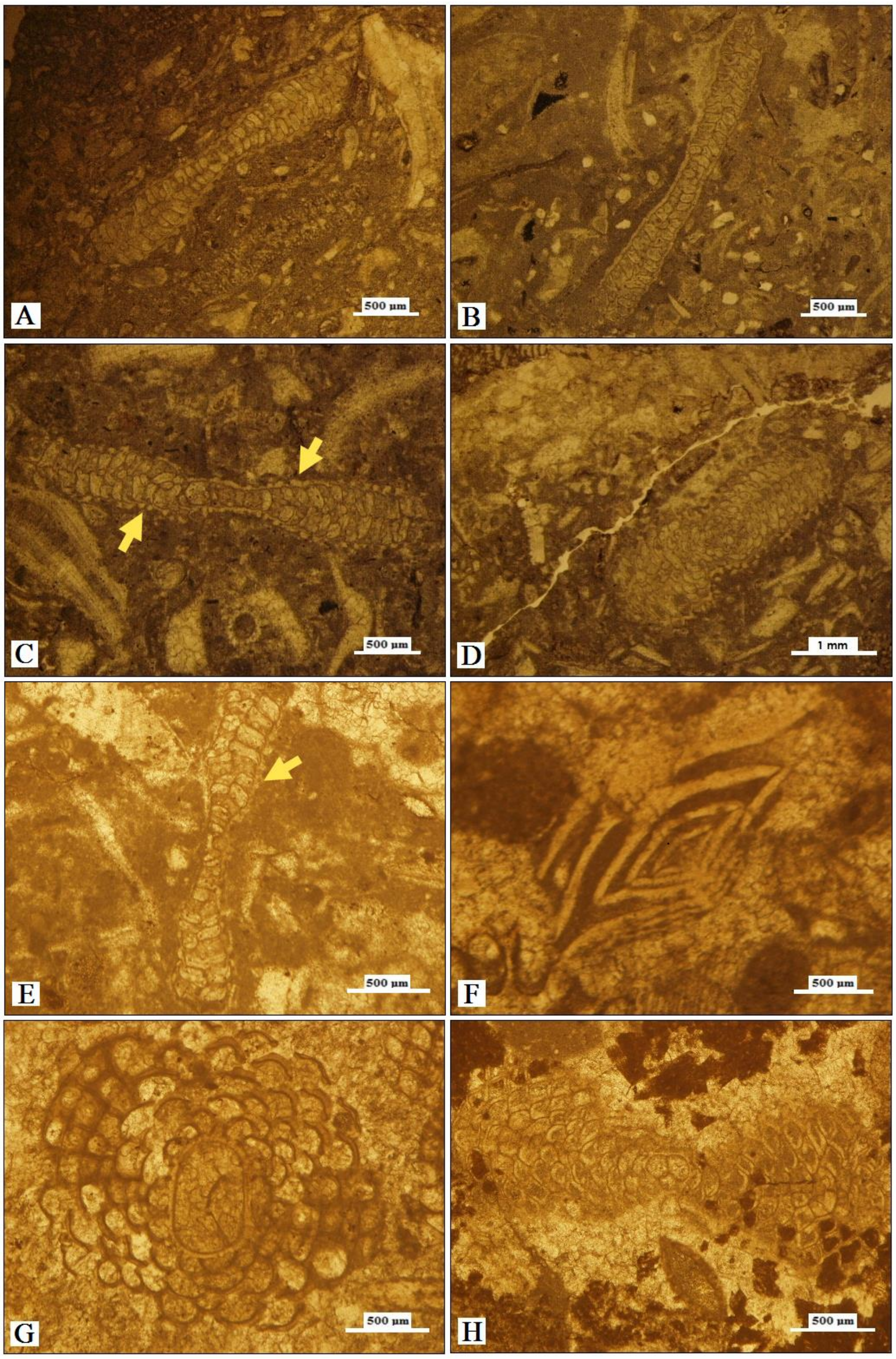


Figure 5) A-C: Pseudomphalocyclus blumenthali, pay attention to lateral chamberlets (LP) in the genus Pseudomphalocyclus are mostly distinctly developed at both sides of the test (double symbols), D-E: Pseudomphalocyclus blumenthali (Postomphalocyclus meriçi), lateral chamberlets (LP) are distinctly developed in a side of the test (symbol), F: Sirtina orbitoidiformis, G: Omphalocyclus macroporus, H: Omphalocyclus sp.

Table 2. Morphometric data of three species Omphalocyclus macroporus (Lamarck), Postomphalocyclus meriçi İnan and Pseudomphalocyclus blumenthali Meriç that given by İnan, 1992.

Species	**Axial diameter (mm)**	**Thickness (mm)**
Omphalocyclus macroporus	1.2-4	0.2-0.6
Postomphalocyclus meriçi	1.25-4	0.25-0.6
Pseudomphalocyclus blumenthali	1.4-2.8	0.22-0.7

The genus *Pseudomphalocyclus* is abundant in Arabian platforms, between Turkey and Somalia. Based on the new data on the palaeobiogeography of *Pseudomphalocyclus blumenthali* species (Meriç *et al.*, 2010), it was found in Turkey, northeast Syria, northern Iraq, Iran, Saudi Arabia, Qatar, Oman, Yemen and Somalia (Fig. 7), have similar features in the views of lithologies and faunal associations. This species indicate shallow water palaeoenvironment and may be restricted to the Late Maastrichtian (Meriç *et al.*, 2010).

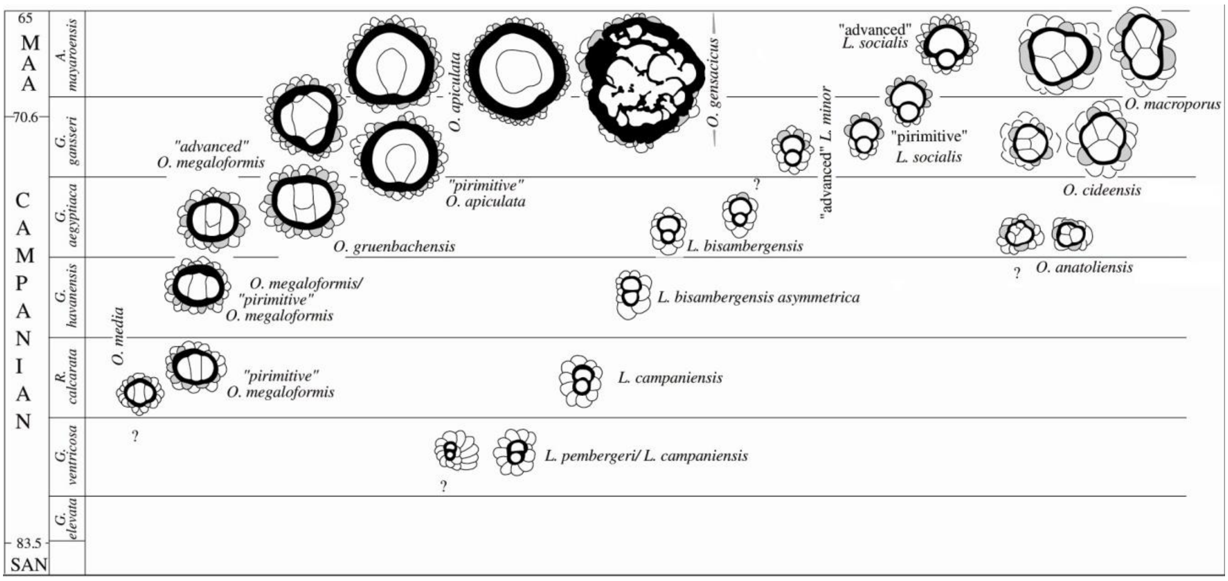
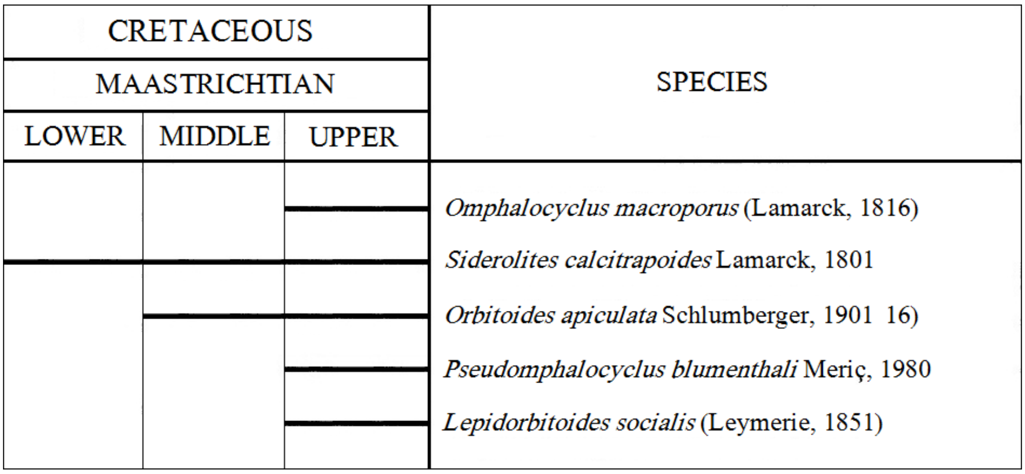


Figure 6) Schematic stratigraphic relationship between Omphalocyclus and Late Cretaceous orbitoidiform genera Orbitoides and Lepidorbitoides in Turkey, and the correlation of their species with the planktonic foraminiferal zones (Özcan, 2007).

Table 1) Range chart of selected associated orbitoidal larger benthic foraminifers of the Tarbur Formation from Semirom section (Özcan, 2007; Meriç et al., 2010; Görmüş, 2015).



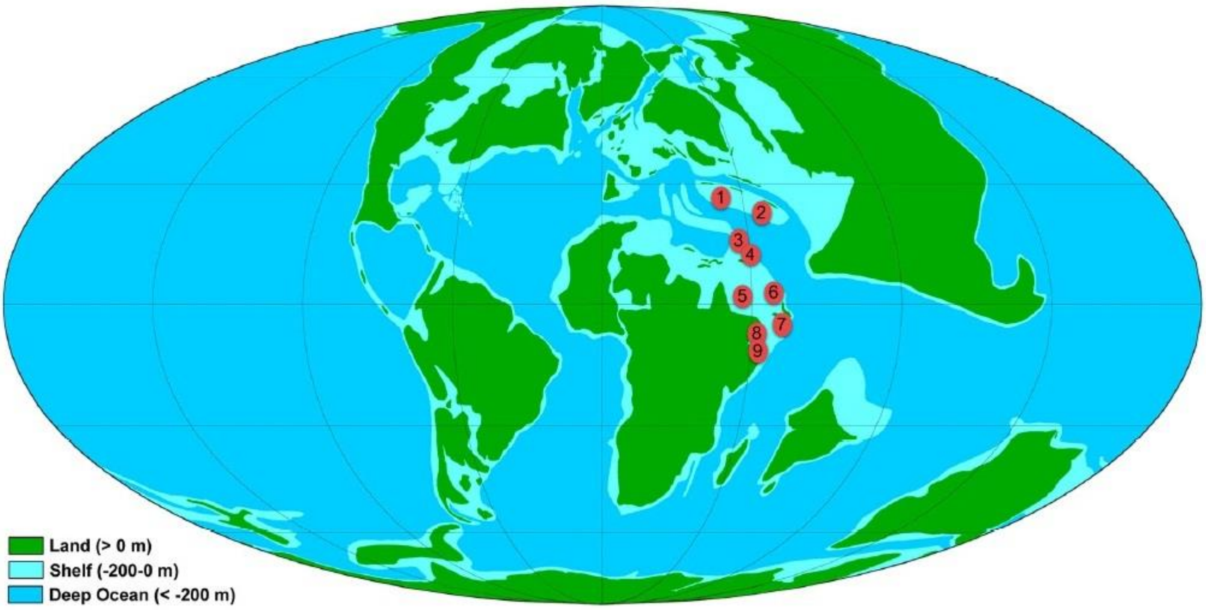


Figure 7) Palaeogeographic situation in the Maastrichtian (modified after Goldbeck, 2007) and global geographical distribution of the Pseudomphalocyclus blumenthali species (Meriç et al., 2010). 1: Turkey; 2: Iran; 3: Syria; 4: Iraq; 5: Saudi Arabia; 6: Qatar; 7: Oman; 8: Yemen and 9: Somalia.

5- Conclusions

In this study, species such as *Orbitoides concavatus* Rahaghi, *Praeomphalocyclus concavatus* Meriç and Çoruh, *Postomphalocyclus meriçi* İnan and *Pseudomphalocyclus blumenthali* Meriç have been reviewed. Both *Orbitoides concavatus* Rahaghi and *Praeomphalocyclus* Meriç and Çoruh are nomen nudum. Also *Postomphalocyclus meriçi* İnan is synonymous with *Pseudomphalocyclus blumenthali* Meriç. In addition to the known species *Pseudomphalocyclus blumenthali* Meriç that was reported with errors in different names, it has been reviewed systematically and scientifically in this study. This species appears to be quite common in the Tarbur Formation and indicates shallow marine environments to Late Maastrichtian age.

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