New findings of *Loftusia* species (Foraminifera) based on morphometric analysis from the Tarbur Formation in Iran

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Abstract

One section of the Tarbur Formation (462 m thickness) located about 5 km southwest of Semirom was studied. It consists of carbonate and terrigenous rocks and contains abundant large benthic foraminifera assigned to the Late Maastrichtian. In the Upper Maastrichtian, *Loftusia* is very abundant in carbonate sequence of the Middle East Tethyan realm. *Loftusia* is an important genus for palaeontologists, stratigraphers, petroleum geologists and field geologists because it is a good palaeoenvironmental indicator and provides excellent resolution in age interpretations of sediments. Based on the morphometric data from thin sections, *Loftusia turcica* (A), *Loftusia ketini* (A), *Loftusia morgani, Loftusia kahtaensis, Loftusia baykali, Loftusia coxi, Loftusia minor* (A and B), *Loftusia harrisoni, Loftusia oktayi* and *Loftusia occidentalis* and from isolated specimens, *Loftusia turcica* (B), *Loftusia ketini* (B), *Loftusia morgani, Loftusia elongata* and *Loftusia persica* were recognized in the study area which can be confirmed Late Maastrichtian age for the Tarbur Formation in mentioned section. Among the mentioned species, *Loftusia turcica* (A and B), *Loftusia ketini* (A and B), *Loftusia oktayi, Loftusia kahtaensis* and *Loftusia occidentalis* are reported for the first time from Iran.

Keywords: Tarbur Formation; Semirom; *Loftusia*; Late Maastrichtian; Morphometric Analysis.

1- Introduction

During the Maastrichtian, thrust faulting along the main Zagros range (SW Iran) led to NE–SW oriented expansion of carbonate platform development with incorporated rudist formations (Motiei, 1993). This succession in the Zagros region was provided for the first time by Farshadfar *et al*. (1960) and selected as a type section by James and Wynd (1965) who proposed the name Tarbur Formation for these deposits.

The major lithology of the Tarbur Formation in the High Zagros and Interior Fars consists of rudist limestones, sometimes in alternation with marls and sometimes with shale and sandstones sequences. Towards Coastal Fars it grades into pelagic limestones, shales and marls of the Gurpi Formation. The thickness of this formation is high in the Interior Fars and decreases towards in the Coastal Fars (Amiri Bakhtiar, 2007).

The Tarbur Formation of the Zagros region (SW Iran) is mainly siliciclastic in composition, though it also incorporates some carbonate units including several rudist lithosomes (Khazaei *et al.*, 2010). This formation consists of limestones, shales and sandstones with a total thickness of 462 m in the Semirom area. The study area is located in the eastern part of Zagros Mountain, in the interior Fars of the High Zagros. These units generally show lateral changes in thickness, composition and facies. The limestones contain a rudist facies with

larger foraminifers such as *Loftusia*, *Lepidorbitoides*, *Orbitoides* and *Omphalocyclus* (Azizi *et al.*, 2015; Azizi *et al.*, 2016). The exact age of the Tarbur Formation is not well established (e. g. Amiri Bakhtiar, 2007; Azizi, 2012; Asgari Pirbaluti *et al.*, 2013).

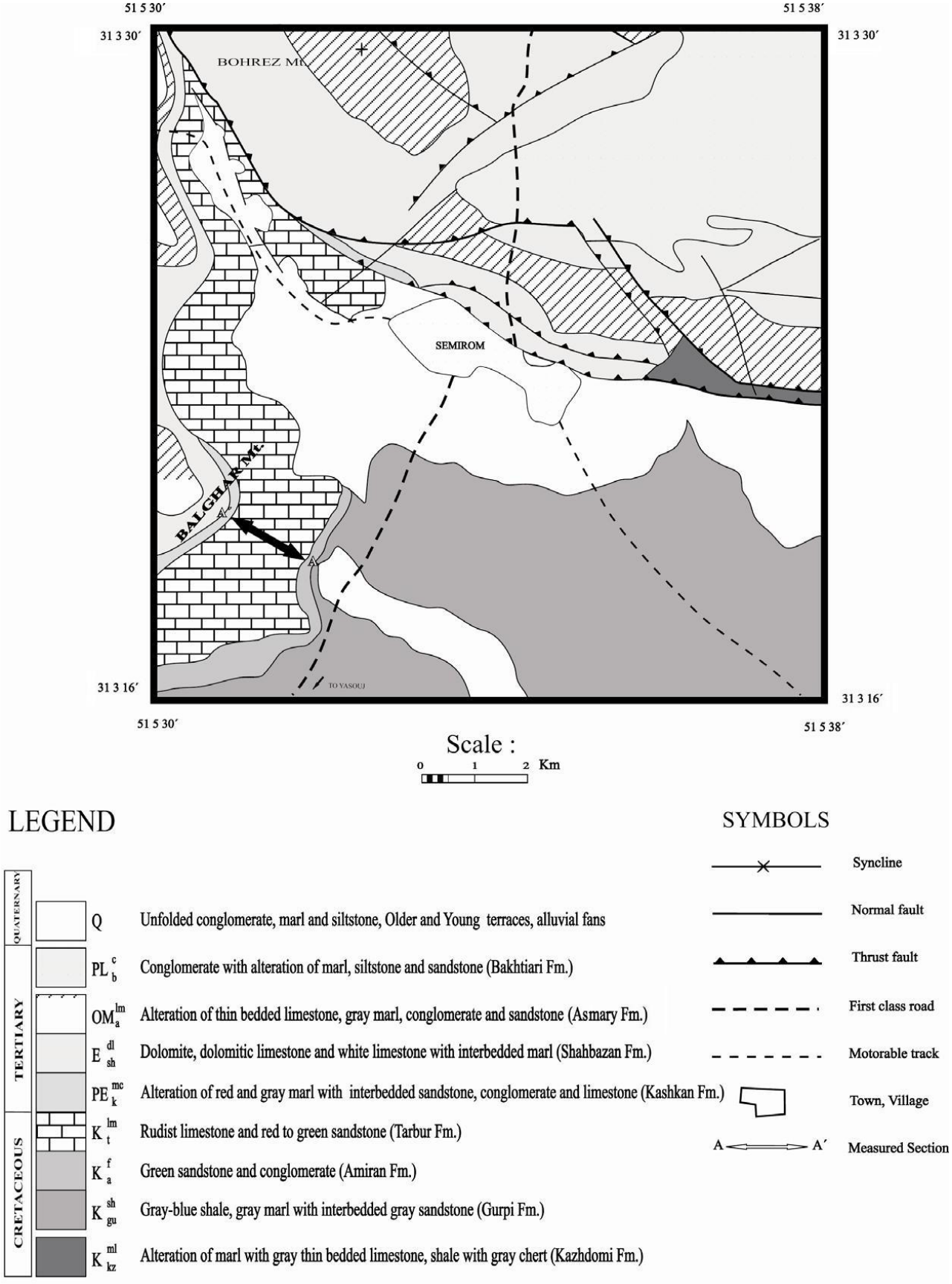


Figure 1) Geographical location map of the studied section, 5 km south west of Semirom, Iran (Alavi, 1996).

2- Geographical Location of Studied section

The study area with geographical coordinates of N: 31° 22' 48" and E: 51° 32' 01" is located about 5 km south west of Semirom (Fig. 1). The thickness of the Tarbur Formation in the studied section is 462 meters. According to the field observation, three litholigical units are recognized in the Tarbur Formation (Fig. 13). This formation mainly consists of carbonate and terrigenous rocks and has a gradual and conformable contact with underlying red shale unit (S_2: this lithostratigraphic unit has been separated of the Tarbur Formation, based on different in lithology, fossils content and sedimentary environment) (Azizi, 2012) while is overlaid by the Kashkan Formation which is marked by an erosional surface.

3- Materials and Methods

Systematic sampling was conducted and over 200 samples were collected from the selected section. Thin sections and isolated specimens were prepared and studied with morphometrical and statistical analysis on some fossil samples (*Loftusia*, *Omphalocyclus* and *Orbitoides*). The identification of larger benthic foraminifera (*Loftusia* in thin sections and isolated specimens) were performed according to Cox, 1937; Meriç *et al*., 2000; Meriç *et al*., 2001; Meriç and Görmüş, 2001; Meriç *et al*., 2004; Zambetakis–Lekkas and Kemeridou, 2004, 2006; and Al-Kubaysi, 2008.

Based on test dimensions, three groups of *Loftusia* species can be distinguished: small, medium and large sized. Test size measurements of small *Loftusia* species and their mean values are less than 7mm. Medium sized loftusiids are from 7mm to 40mm (Fig. 2). Some extreme values are given larger than 40mm. However, mean values between the indicated values and the individuals bigger than 40mm are rare in the *Loftusia* community (Meriç and Görmüş, 2001).

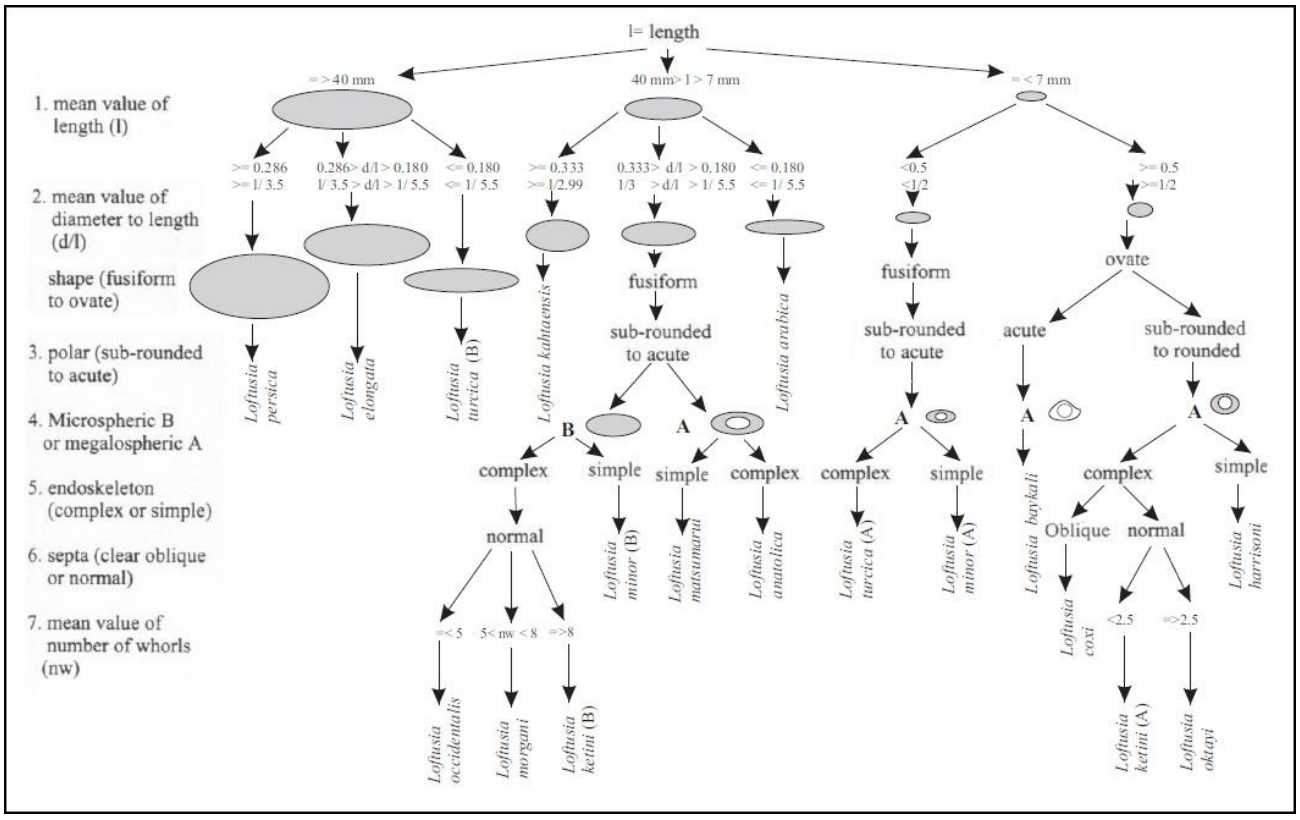


Figure 2) Key to species identification of Loftusia (Meriç and Görmüş, 2001).

The following is a summary of general morphological features of *Loftusia*, both external and internal (Fig. 2). External features are such as test shape, test size (1), test diameter (d), ratio of diameter to length (r), traces of septa and polar features. Internal features are such as the nucleoconch (nc), its size and shape, the number of whorls (nw), coiling parameter (cp) or growth rate (gr), the number of septa (ns) and number of chambers (nch) and test structure (Meriç and Görmüş, 2001). Occurrence of microspheric (B) or megalospheric (A) forms is also an important feature in distinguishing species. Some *Loftusia* species show very complex endoskeleton structure while others have simple walls (Fig. 2). The individuals having complex endoskeleton structure contain small extra clasts such as ophiolite particles, opaque pieces, quartz minerals and others. Septa are seen complex in this type of species (Meriç and Görmüş, 2001).

4- Microbiostratigraphy

The first named *Loftusia* species, *Loftusia persica* Brady is known from Iran (Brady, 1869). *Loftusia* Brady is benthic foraminifera of Maastrichtian age and is known from outer platform facies of the Tethys. The genus *Loftusia* is characterized by planispiral fusiform test which has non–laminar agglutinated with calcareous cement, calcitic wall structure. The shell has a labyrinthic wall with irregular septa and chamberlets (Fig. 3). It appears that the genus is abundant in Arabo–Iranian platforms and Turkey, rare in Croatia, Serbia, Greece and Italy, and totally absent in regions further to the west (Zambetakis–Lekkas and Kemeridou, 2006).

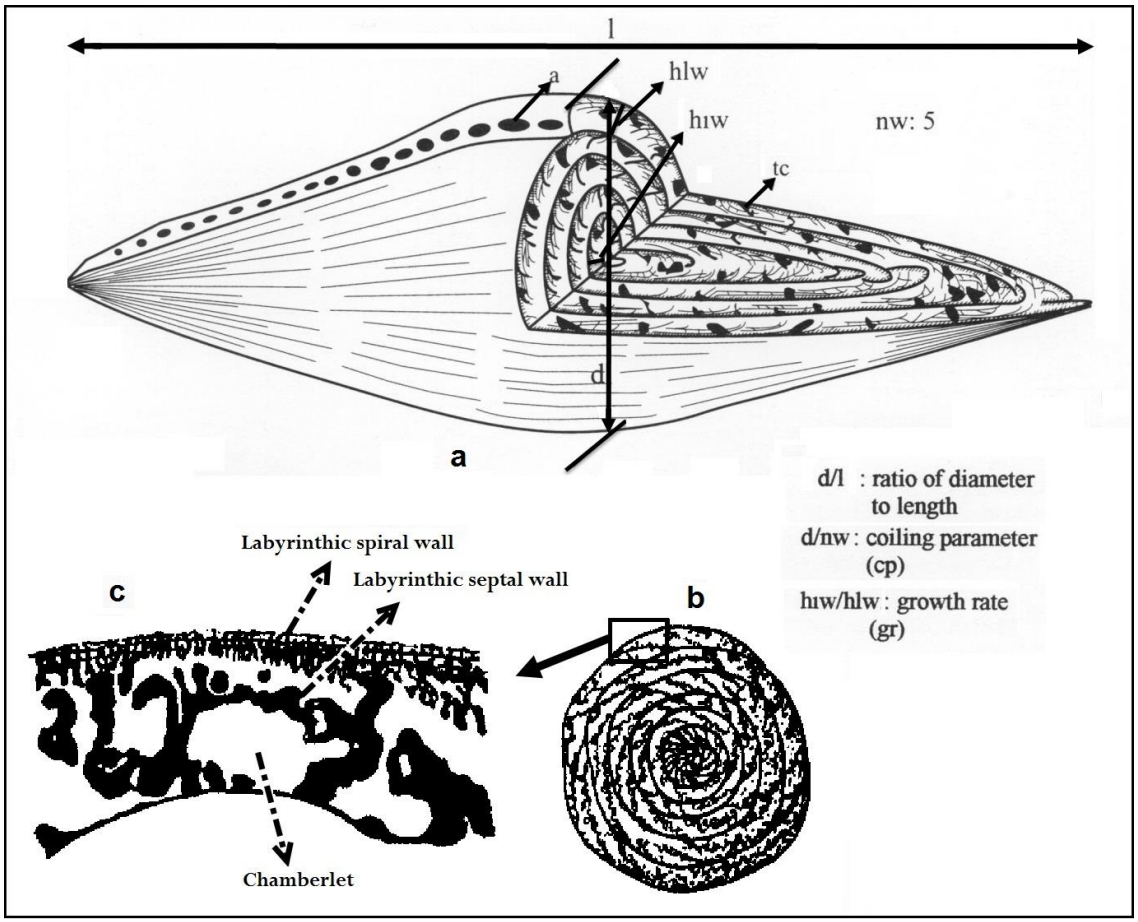


Figure 3) Schematic block diagram of Loftusia showing its principal external and internal structure (a) (l. test length, d. test diameter, hiw. height of first whorl, hlw. height of last whorl, tc. tiny clasts, a. apertures, nw. number of whorls), together equatorial section (b) and cross section of wall (c) (Bracier, 1980; Meriç and Görmüş, 2001).

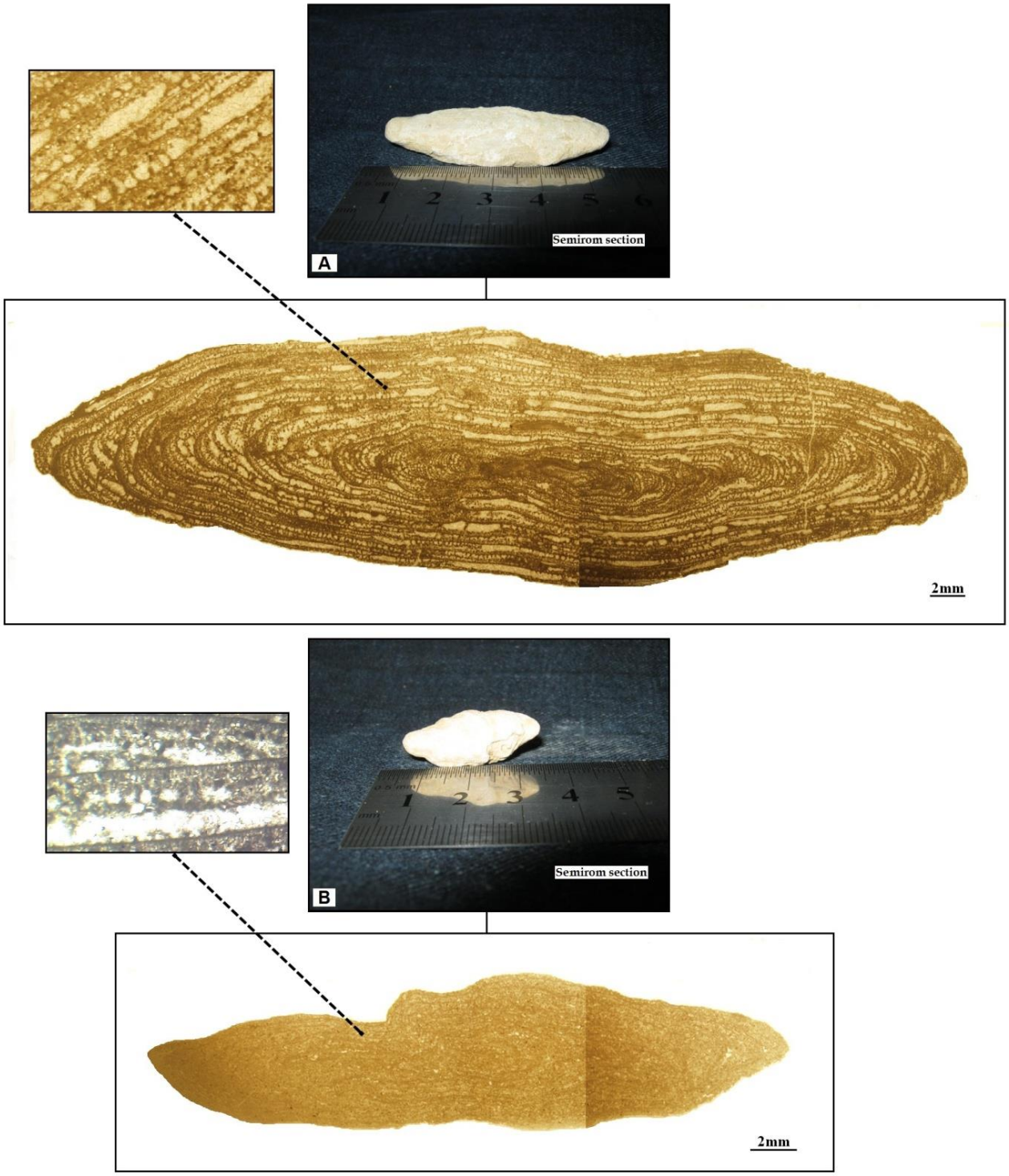


Figure 4) Loftusia species in isolated specimens; A: Loftusia elongata, B: Loftusia ketini (B) (See morphometric data there in Table 1).

4.1- *Loftusia* species in isolated specimens

Based on the morphometric data from isolated specimens, *Loftusia turcica* (B), *Loftusia ketini* (B), *Loftusia morgani*, *Loftusia elongata* and *Loftusia persica* are recognized at the study area (Table 1 and Figs. 4, 5, 6 and 12). Among the mentioned species, *Loftusia turcica* (B) and *Loftusia ketini* (B) species are systematically reported for the first time from Iran (see appendix: list of taxa mentioned in the text).

4.2- *Loftusia* species in thin sections

Based on the morphometric data from thin sections, *Loftusia turcica* (A), *Loftusia ketini* (A), *Loftusia morgani*, *Loftusia kahtaensis*, *Loftusia baykali*, *Loftusia coxi*, *Loftusia minor*

(A and B), *Loftusia harrisoni*, *Loftusia oktayi* and *Loftusia occidentalis* are recognized at the study area (Table 2 and Figs. 9, 10 and 13). Among the mentioned species, *Loftusia turcica* (A), *Loftusia ketini* (A), *Loftusia oktayi*, *Loftusia kahtaensis* and *Loftusia occidentalis* species are systematically reported for the first time from Iran (see appendix: list of taxa mentioned in the text).

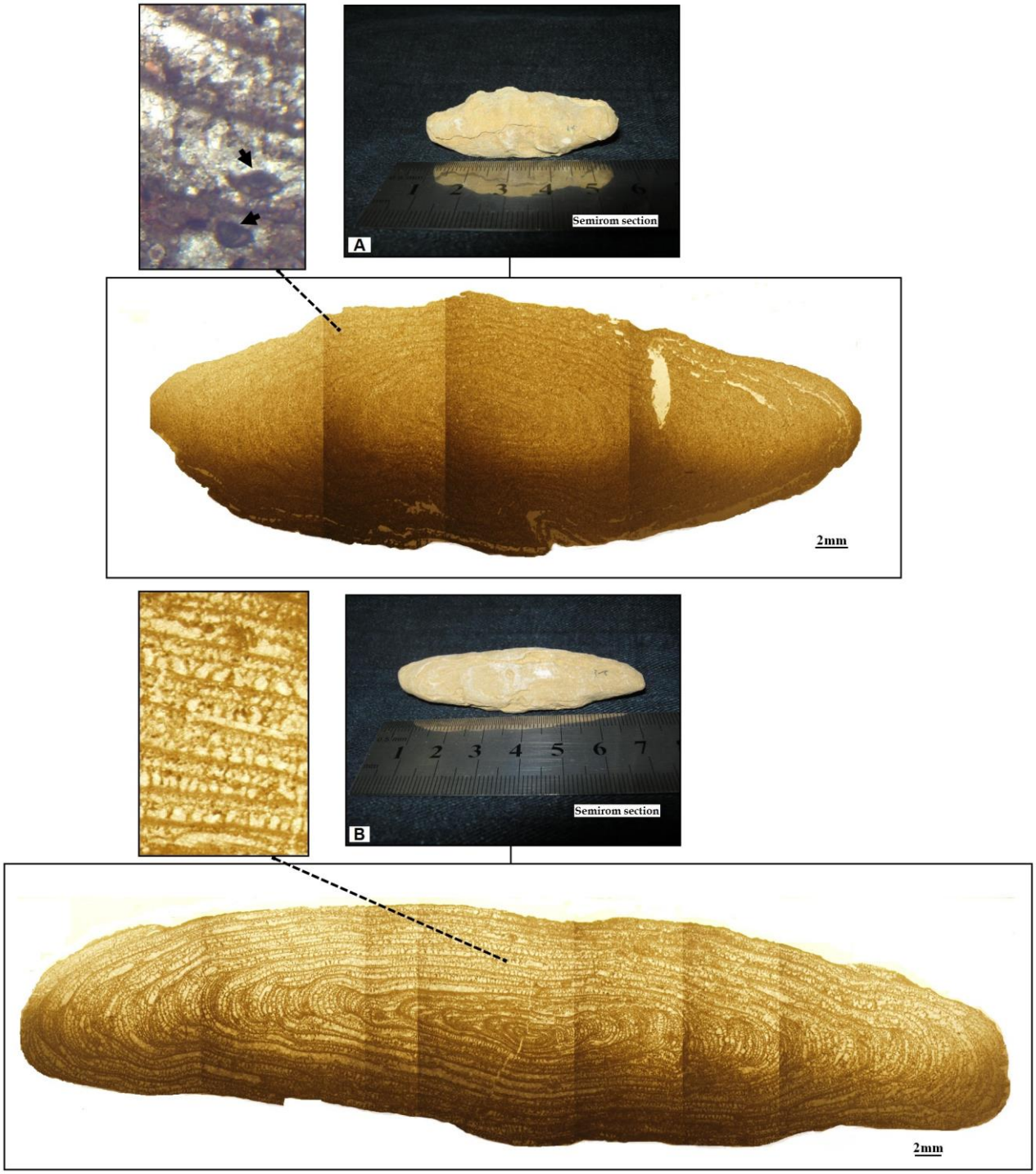


Figure 5) Loftusia species in isolated specimens; A: Loftusia persica, B: Loftusia elongate (See morphometric data there in Table 1).

Asgari Pirbaluti *et al.* (2013) is distinguished of *Loftusia baykali-Loftusia oktayi* zone and *Loftusia baykali* interval subzone from Late Maastrichtian in Iran and Al-Kubaysi (2008) *Loftusia morgani* range zone from Late Maastrichtian in Iraq. 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 studied section. Considering the morphometric measurement and identification of index species of *Loftusia* in thin sections and isolated specimens (*Loftusia morgani, Loftusia persica*, *Loftusia kahtaensis, Loftusia baykali* and *Loftusia oktayi*) and other larger benthic foraminifera such as *Omphalocyclus* (*Omphalocyclus macroporus*), *Lepidorbitoides* (*Lepidorbitoides socialis*) and *Orbitoides* (*Orbitoides apiculata*) (Azizi *et al.*, 2015; Azizi *et al.*, 2016), the age of Tarbur Formation can precisely be considered as Late Maastrichtian at the studied section (Table 3 and Fig. 11).

Table 1) Morphometric data of Loftusia species in isolated specimens from Semirom section.

sample	l mm	d mm	d/l	nw	species
T_6	57	14.6	0.25	13	*L. elongata*
T_8	43.4	14	0.32	18	*L. persica*
T_{12}	46.2	16.1	0.34	16	*L. persica*
T_{14}	28	5.6	0.20	9	*L. ketini* (B)
T_{18}	72	16.4	0.22	14	*L. elongata*
T_{21}	59	8.2	0.13	6	*L. turcica* (B)
T_{23}	21.9	5.2	0.23	8	*L. ketini* (B)
T_{31}	69.2	11.1	0.16	9	*L. turcica* (B)
T_{32}	20.2	5.2	0.25	6	*L. morgani*
T_{33}	53	14.2	0.26	16	*L. elongata*
T_{34}	19	4.8	0.25	6	*L. morgani*

Table 2) Morphometric data of Loftusia species in thin sections from Semirom section.

sample	l mm	d mm	d/l	nw	species
T_{17}	5.4	3.8	0.70	3	*L. coxi*
T_{17}	6.2	1.5	0.24	2.5	*L. turcica* (A)
T_{23}	5.2	3	0.57	2	*L. baykali*
T_{24}	11	6.1	0.55	2	*L. harrisoni*
T_{52}	18	7.5	0.41	6	*L. kahtaensis*
T_{53}	14.7	4.4	0.29	4	*L. minor* (B)
T_{56}	11.6	7.6	0.65	5	*L. kahtaensis*
T_{67}	5.5	4.3	0.78	2.5	*L. ketini* (A)
T_{67}	7.4	3.6	0.48	2	*L. minor* (A)
T_{70}	5.3	1.6	0.3	2	*L. turcica* (A)
T_{75}	5.8	3.7	0.63	2.5	*L. oktayi*
T_{75}	19	4.8	0.25	6	*L. morgani*
T_{76}	5.3	4	0.75	2.5	*L. ketini* (A)
T_{78}	9.3	4.2	0.45	3	*L. occidentalis*
T_{82}	4.1	2.3	0.56	3	*L. baykali*

5- Palaeoecology and Palaeobiogeography

The genus *Loftusia* is abundant in Arabo–Iranian platforms and rare in eastern Mediterranean and totally absent in western Mediterranean (Fleury *et al.*, 1990; Goldbeck 2007). This genus of larger benthonic foraminifera with complex internal structure is represented by several species confining mostly to the Maastrichtian. It is reported from the Middle East, Eastern Turkey, Iran, Iraq, Qatar and Oman (Meriç and Mojab, 1977; Fig. 8). Based on the new palaeobiogeography data of *Loftusia* genus (Meriç and Görmüş, 2001; Zambetakis–Lekkas and Kemeridou, 2006; Goldbeck, 2007), it was found in Italy, Croatia, Yugoslavia, Greece, Macedonia, Turkey, Syria, Iraq, Iran, Saudi Arabia, Qatar, Oman, Yemen and Somalia (Fig. 7). The restricted distribution of this Late Cretaceous taxon is suggesting small dispersal potential possibly due to ecological constraints (Govindan, 2008).

The litholigical occurrences of *Loftusia* genus vary between limestone, sandy limestone and sandstone. Both, lithology and faunal association, indicate a shallow–water environment from low to higher energetic setting (Goldbeck, 2007). Meriç and Görmüş (2001) have argued for coastal and fore–reef environments, while Inan (1996) has interpreted a back reef environment. These differences are based on observations from different species, but the morphology of *Loftusia* indicates that this genus is able to withstand high-energetic environmental conditions (Goldbeck, 2007). The *Loftusia* genus may have favored well mostly oligotrophic conditions in reefal settings down to a depth of 30 meters (Goldbeck, 2007).

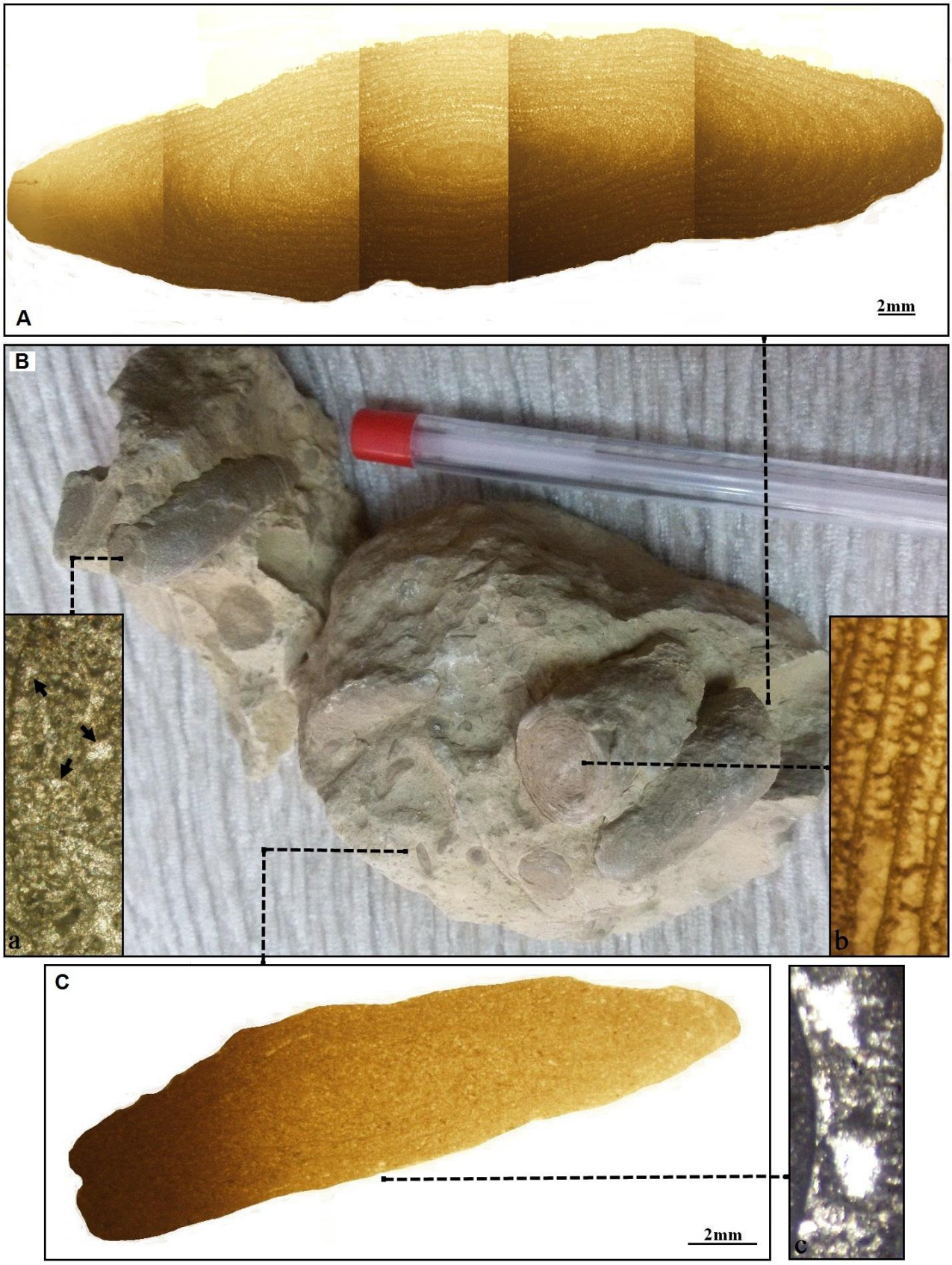


Figure 6) Loftusia species in isolated specimens; A: Loftusia elongata, B: Current accumulated shells of Loftusia in rock, showing growth rings (a): Loftusia turcica (B) and (b): Loftusia elongata, C: Loftusia morgani (See morphometric data there in Table 1).

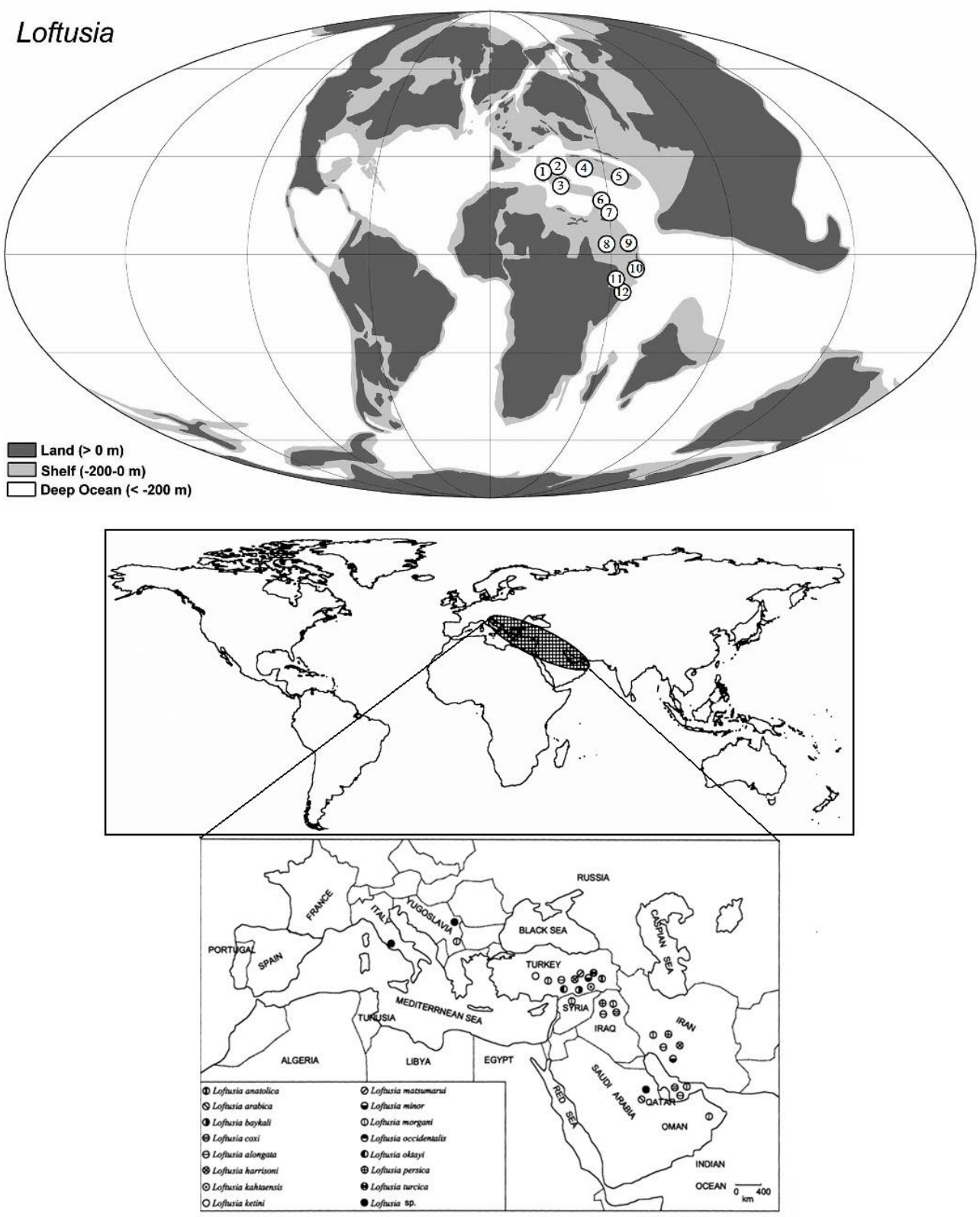


Figure 7) Global geographical distributions of Loftusia species. 1: Italy; 2: Yugoslavia and Croatia; 3: Greece and Macedonia; 4: Turkey; 5: Iran; 6: Syria; 7: Iraq; 8: Saudi Arabia; 9: Qatar; 10: Oman; 11: Yemen and 12: Somalia (Meriç and Görmüş, 2001; Goldbeck, 2007).

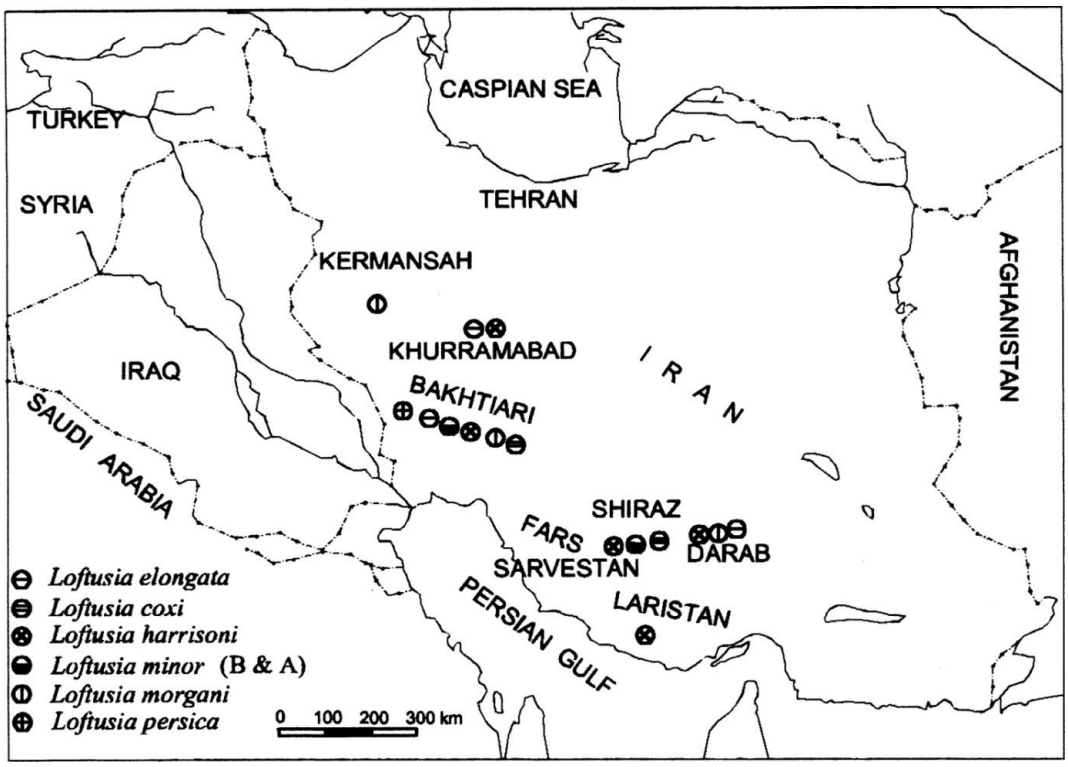


Figure 8) Geographical distribution map of Loftusia species in Iran (Meriç and Mojab, 1977).

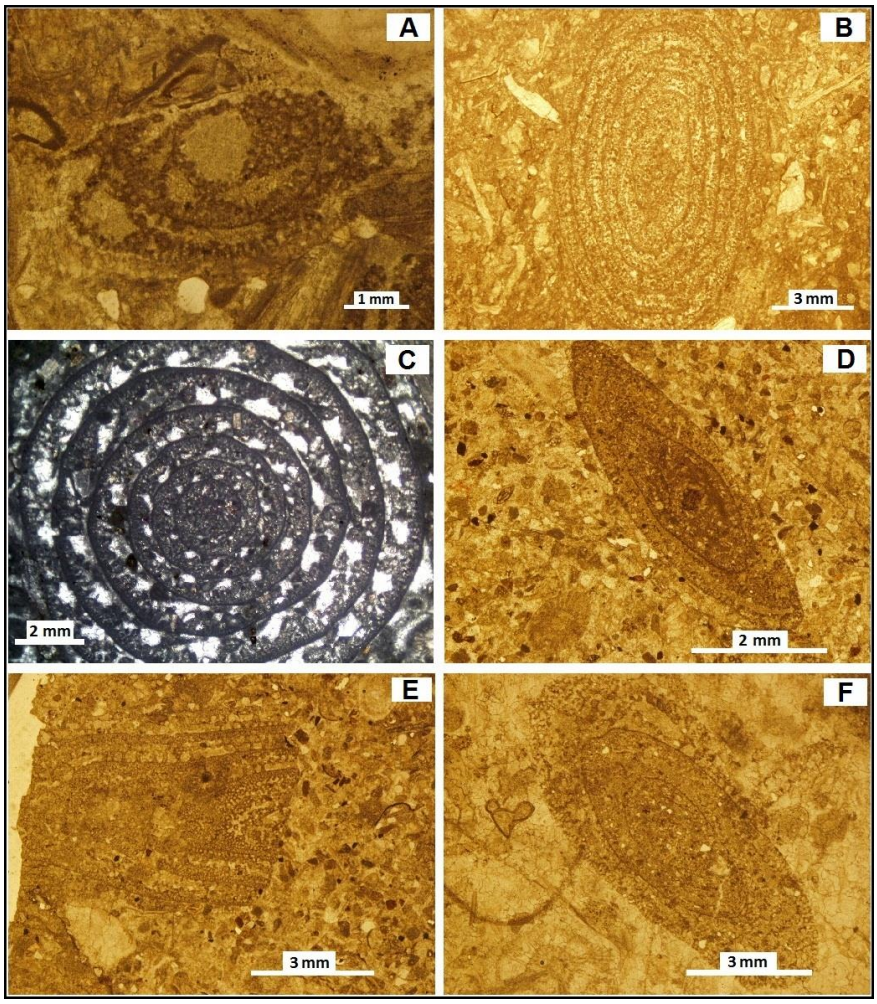


Figure 9) Loftusia species in thin sections; A: Loftusia baykali, B: Loftusia kahtaensis, C: Loftusia morgani, D: Loftusia turcica (A), E: Loftusia minor (B), F: Loftusia occidentalis (See morphometric data there in Table 2).

Table 3) The age comparison of index species of Loftusia in different regions of the Middle East with particular emphasis on Iran, Iraq and Turkey (Meriç and Görmüş, 2001).

		IRAN (Cox, 1937)	IRAQ (Al-Omari and Sadek, 1976)	TURKEY (Meriç et al. 2001)	MIDDLE EAST
MAASTRICHTIAN	LATE	*Loftusia morgani* *Loftusia persica-* *Loftusia elongata*	*Loftusia persica- Loftusia elongata*	*Loftusia morgani* *Loftusia anatolica* *Loftusia oktayi* *Loftusia baykali* *Loftusia kahtaensis*	*Loftusia morgani* *Loftusia anatolica* *Loftusia oktayi* *Loftusia baykali* *Loftusia kahtaensis*
	MIDDLE	*Loftusia elongata* *Loftusia minor*	*Loftusia elongata* *Loftusia coxi* and *Loftusia* spp.	*Loftusia elongata* *Loftusia harrisoni* *Loftusia minor* B and A	*Loftusia elongata* *Loftusia harrisoni* *Loftusia minor* B and A *Loftusia matsumarui*
	EARLY	*Loftusia harrisoni*			*Loftusia arabica*

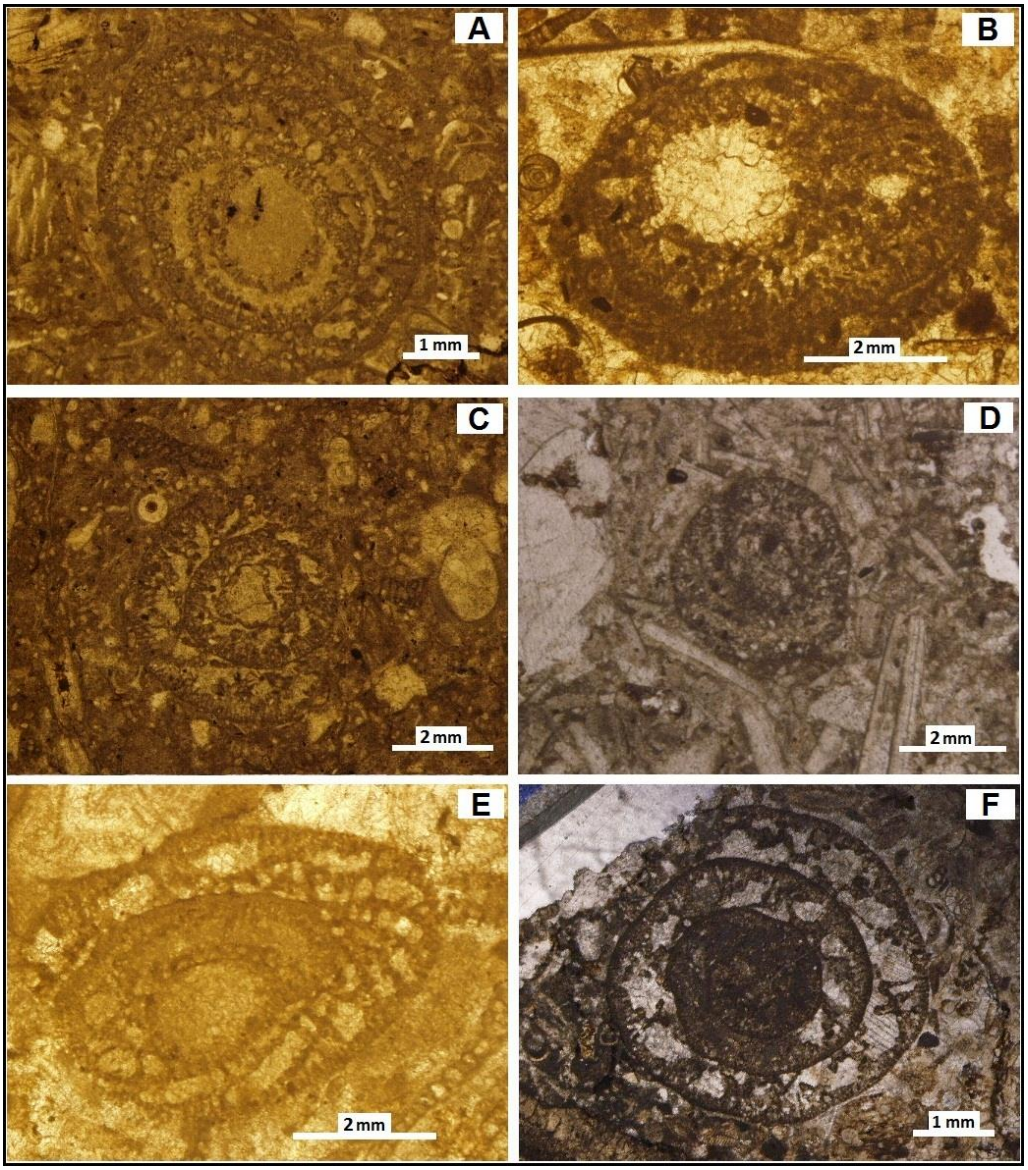


Figure 10) Loftusia species in thin sections; A: Loftusia harrisoni, B: Loftusia ketini (A), C: Loftusia oktayi, D: Loftusia ketini (A), E: Loftusia minor (A), F: Loftusia coxi (See morphometric data there in Table 2).

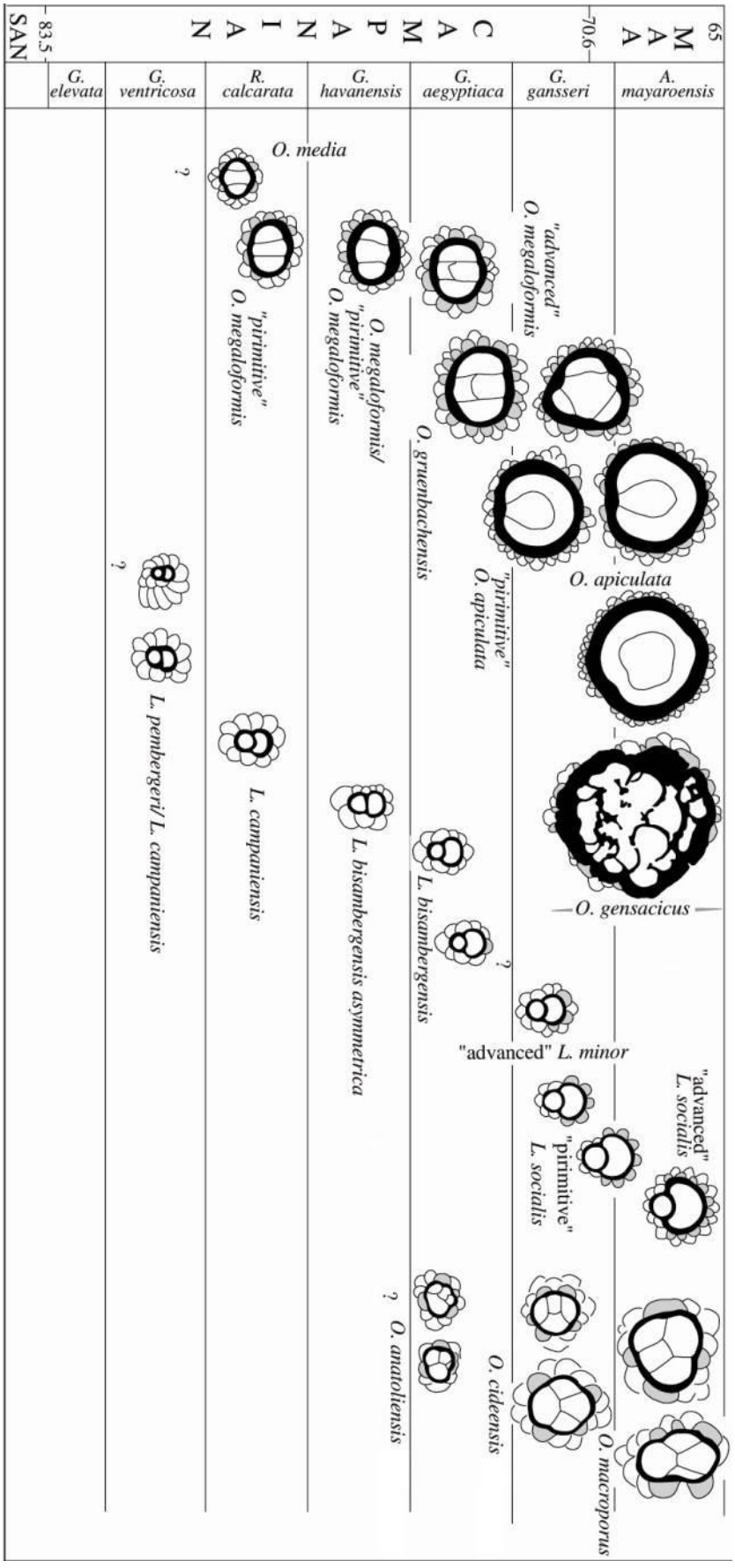
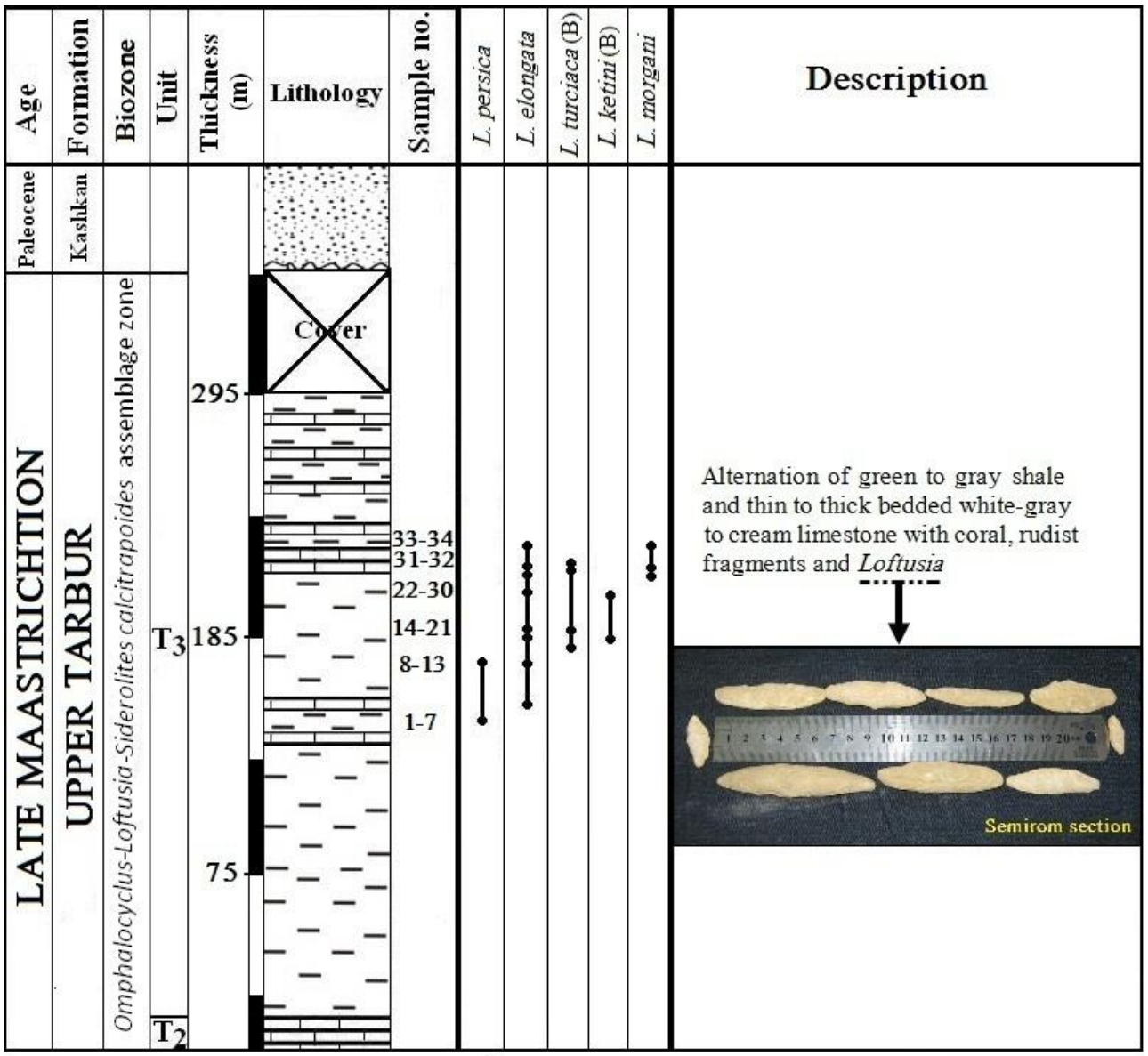


Figure 11) Schematic stratigraphic relationship between Omphalocyclus and late Cretaceous orbitoidiform genera Orbitoides and Lepidorbitoides in Turkey, and the correlation of their species with the planktonic foraminiferal zones (Özcan, 2007).



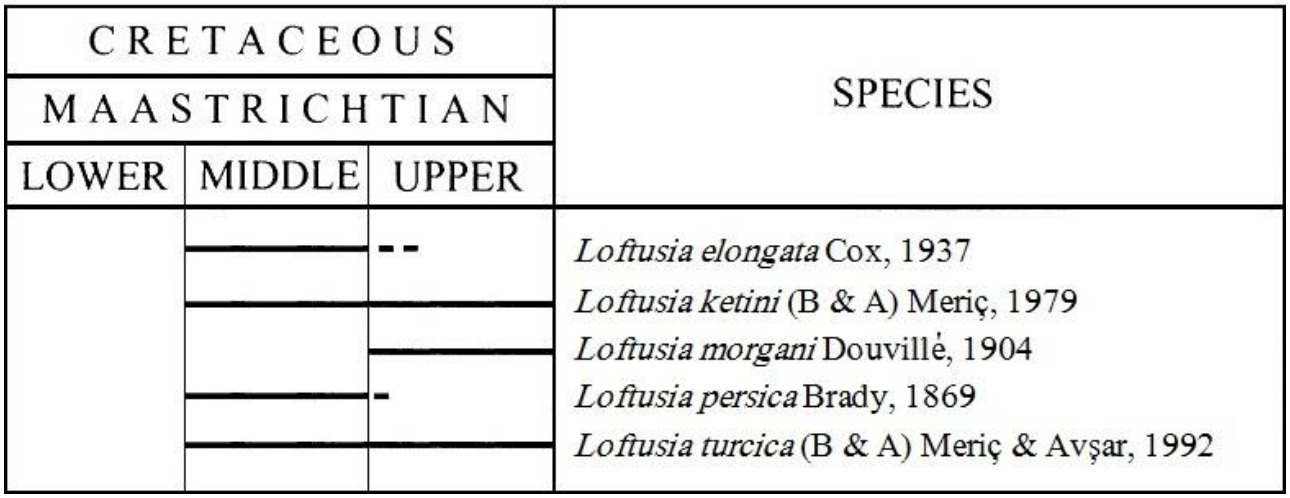
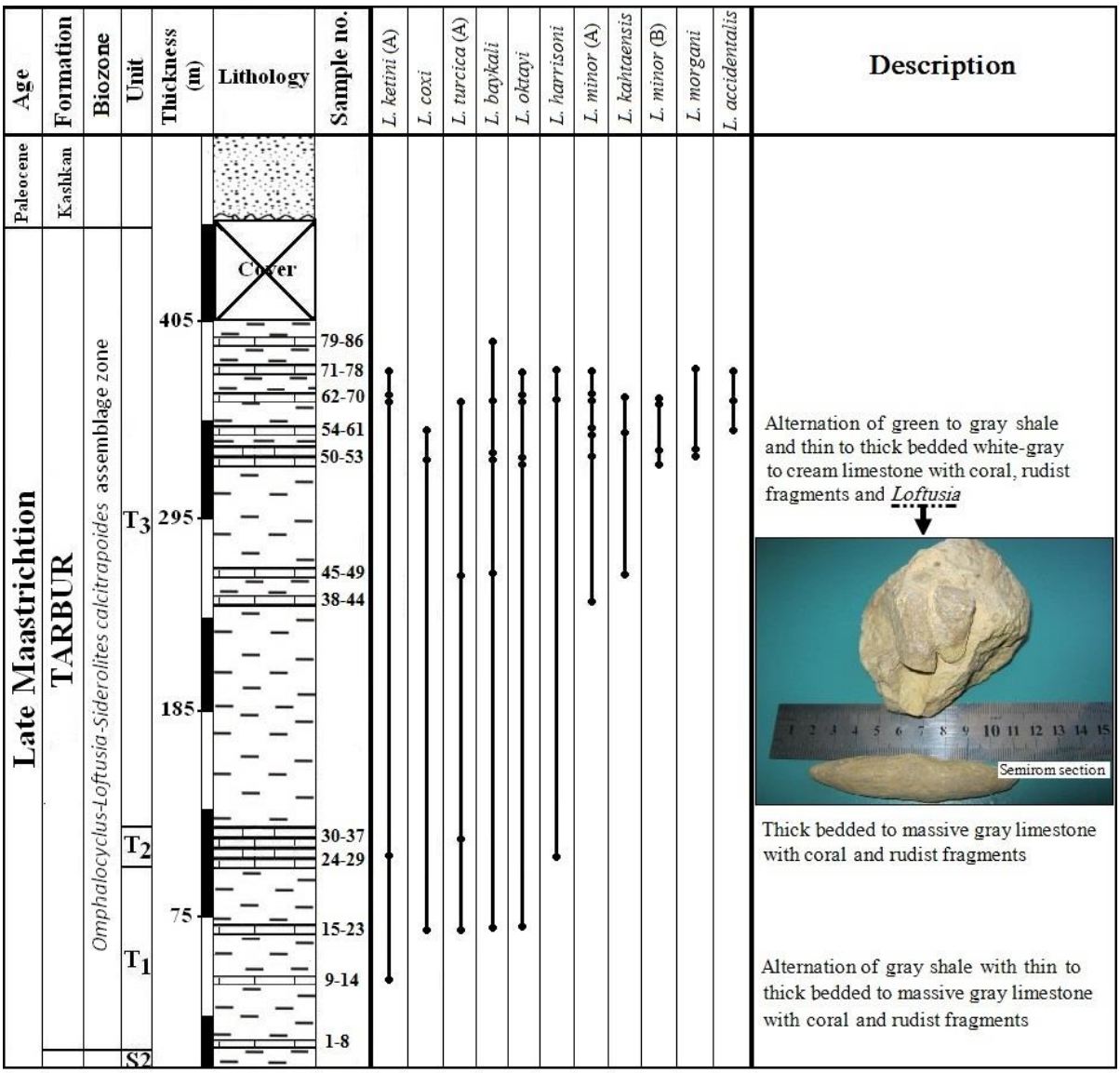


Figure 12) Biostratigraphic and Lithostratigraphic column together Range chart of Loftusia species in isolated specimens of the Tarbur Formation from the Semirom section.



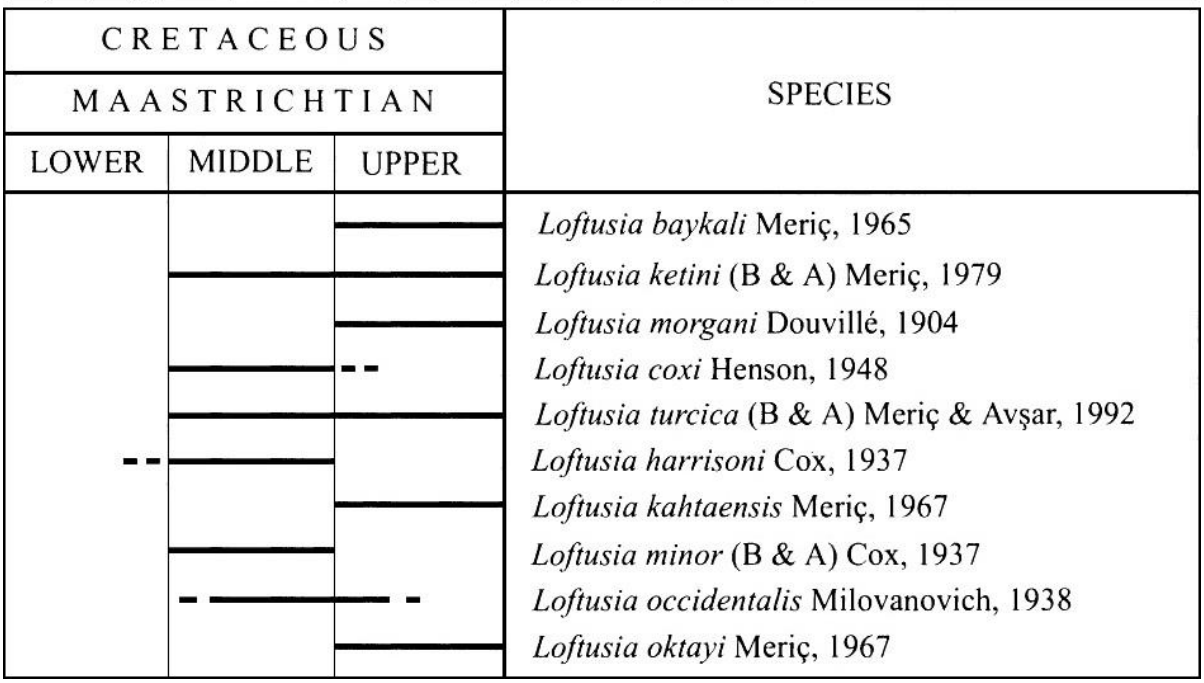


Figure 13) Biostratigraphic and Lithostratigraphic column together Range chart of Loftusia species in thin sections of the Tarbur Formation from the Semirom section (the correlation of their species with taxa mentioned in Table 3 and Figs. 11 and 12).

6- Conclusions

In this study, based on the morphometric data of *Loftusia* species of the Tarbur Formation from Semirom section, *Loftusia turcica* (A and B), *Loftusia ketini* (A and B), *Loftusia oktayi*, *Loftusia kahtaensis* and *Loftusia occidentalis* species are systematically reported for the first time from Iran (see appendix above) which can be confirmed the Late Maastrichtian age for the Tarbur Formation in the mentioned section.

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Appendix: List of taxa mentioned in the text

Loftusia occidentalis Milovanovich 1938

Loftusia occidentalis n. sp. Milovanovich 1938, p. 126-129, pl. 3, fig. 1; pl. 4, figs. 1-3. – MERIÇ and GÖRMÜS 2001, pl. 13, figs. 1-4.

Loftusia ketini (A) Meriç 1979

Loftusia ketini n. sp. MERIÇ 1979, p. 511-512, pl. 2, figs. 1-7. – MERIÇ and GÖRMÜS 2001, pl. 9, figs. 4-7.

Loftusia turcica (A) Meriç and Avsar 1992

Loftusia turcica n. sp. MERIÇ and AVSAR 1992, p. 303-304, pl. 2, figs. 5-10. – MERIÇ and GÖRMÜS 2001, pl. 15, figs. 7-9.

Loftusia oktayi Meriç 1967

Loftusia oktayi n. sp. MERIÇ 1967, p. 27-28, pl. 5, figs. 3-6. – AVSAR 1991, p. 144, pl. 2, figs. 1-6. – GÖRMÜS, MERIÇ and AVSAR 1995, p. 69, pl. 1, figs. 9-11. – MERIÇ and GÖRMÜS 2001, pl. 13, figs. 5-8.

Loftusia kahtaensis Meriç 1967

Loftusia kahtaensis n. sp. MERIÇ 1967, p. 28, pl. 5, figs. 7-10. – AVSAR 1991, p. 145, pl. 2, figs. 9-10. – MERIÇ and GÖRMÜS 2001, pl. 8, figs. 1-4.

Loftusia ketini (B) Meriç 1979

Loftusia ketini n. sp. MERIÇ 1979, p. 511-512, pl. 1, figs. 1-5. – MERIÇ and GÖRMÜS 2001, pl. 8, figs. 5-9; pl. 9, figs. 1-3.

Loftusia turcica (B) Meriç and Avsar 1992

Loftusia turcica n. sp. MERIÇ and Avsar 1992, p. 303-304, pl. 1, figs. 1-6; pl. 2, figs. 1-4. – MERIÇ and GÖRMÜS 2001, pl. 15, figs. 1-6.