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Campanian-Maastrichtian benthic foraminifera in the North Africa and Southwest Asia, Southern Tethys

Abstract

This study used modern taxonomical consideration, describes and illustrates the two hundred and fifty Campanian-Maastrichtian small benthic foraminiferal species belonging to 79 genera of Suborders Textulariina, Miliolina, Lagenina and Rotaliina from six localities in the Southern Tethys: North Africa (Tunisia, Egypt) and Southwest Asia (Palestine, United Arab Emirates, Iraq, Iran). Thirty one species are treated here as new: *Trochammina naqabensis, Gaudryina iranensis, Dorothia aegyptica, Dorothia arabica, Dorothia palestinica, Marssonella iranica, Laevidentalina pamaensis, Pseudonodosaria saritae, Tollmannia palestinica, Lenticulina naqabensis, Lenticulina palestinica, Saracenaria naqabensis, Frondovaginulina aegyptica, Astacolus naqabensis, Hemirobulina naqabensis, Planularia naqabensis, Vaginulina naqabensis, Vaginulina sinaiensis, Globulina palestinica, Bolivinoides naqabensis, Luxostomum naqabensis, Praebulimina naqabensis, Pleurostomella naqabensis, Valvulineria palestinica, Cibicidoides iranica, Valvalabamina palestinica, Osangularia iranica, Osangularia palestinica, Gyroidinoides palestinica, Gyroidinoides naqabensis* and *Gavelinella tunisica.* The recorded foraminiferal assemblage occurs in open marine environments, from middle continental shelf to upper bathyal (50m-500m water depth).

Keywords: benthic foraminifera, campanian, maastrichtian, Africa, Tunisia, Egypt, Asia, Palestine, UAE, Iraq, Iran, Southern Tethys

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Introduction

Two hundred and fifty diagnostic Campanian-Maastrichtian small benthic foraminiferal species were described from six localities in the Southern Tethys: Tunisia, Egypt, Palestine, UAE, Iraq and Iran (Figure 1).

Figure 1 Location map of the study countries in North Africa (Tunisia, Egypt) and Southwest Asia (Palestine, UAE, Iraq, Iran).

Material of study

Two hundred and fifty well preserved of the Campanian-Maastrichtian benthic foraminiferal species are recorded and the new thirty one species of them are treated here as new based on modern taxonomical consideration, and illustrated from six localities in the North Africa and southwest Asia in the Southern Tethys. A comparative study by many authors of the Campanian-Maastrichtian planktic foraminiferal biozones from different countries: Northern Tethys: France,[1] and Southern Tethys: Tunisia, Libya, Egypt and Iraq,[2–6] are presented in Table 1.

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Table 1 Planktic foraminiferal biozones of the Late Campanian-Late Maastrichtian from different countries in the Northern Tethys (France) and Southern Tethys (Tunisia, Libya, Egypt and Iraq) (after Bejaoui et al.)[3]

	Late Campanian	Early Maastrichtian		Late Maastrichtian	
Barr (1970)	*Belemnitella mucronata*	*Belemnitella lanceolata*		*Belemnitella junior*	*Belemnitella cosimirovensis*
Tronchetti (2001)	*Bolivinoides decoratus*	*Bolivinoides miliaris*			
El-Nady (2006)	*Gansserina gansseri*			*Abathomphalus mayaroensis*	
Jaff et al. (2014)	*"lower" Gansserina gansseri*	*"upper" Gansserina gansseri*	*C. contusa*		
Saïdi and Zaghbib-Turki (2016)	*Bolivinoides decoratus*	*Bolivinoides miliaris*	*Bolivinoides draco*		
Bejaoui et al. 2019	*Rugoglobigerina rotundata*	*Rugoglobigerina scotti*	*P. acervulinoides*	*Abathomphalus mayaroensis*	
	Bolivinoides decoratus	*Bolivinoides miliaris*	*Bolivinoides draco*		

Systematic paleontology

The modern taxonomy of two hundred and fifty Campanian-Maastrichtian benthic foraminiferal species is followed the classification of Loeblich & Tappan,[7] which belonging to 79 genera: 14 agglutinated genera, 1 Miliolid genus, 25 Lagenid genera, and 34 of Rotaliid genera. Thirty-one species of the recorded species are treated here as new species, which illustrated in Plate 1 (Figure 1a & b).

Plate 1 (bar scale=100μm)

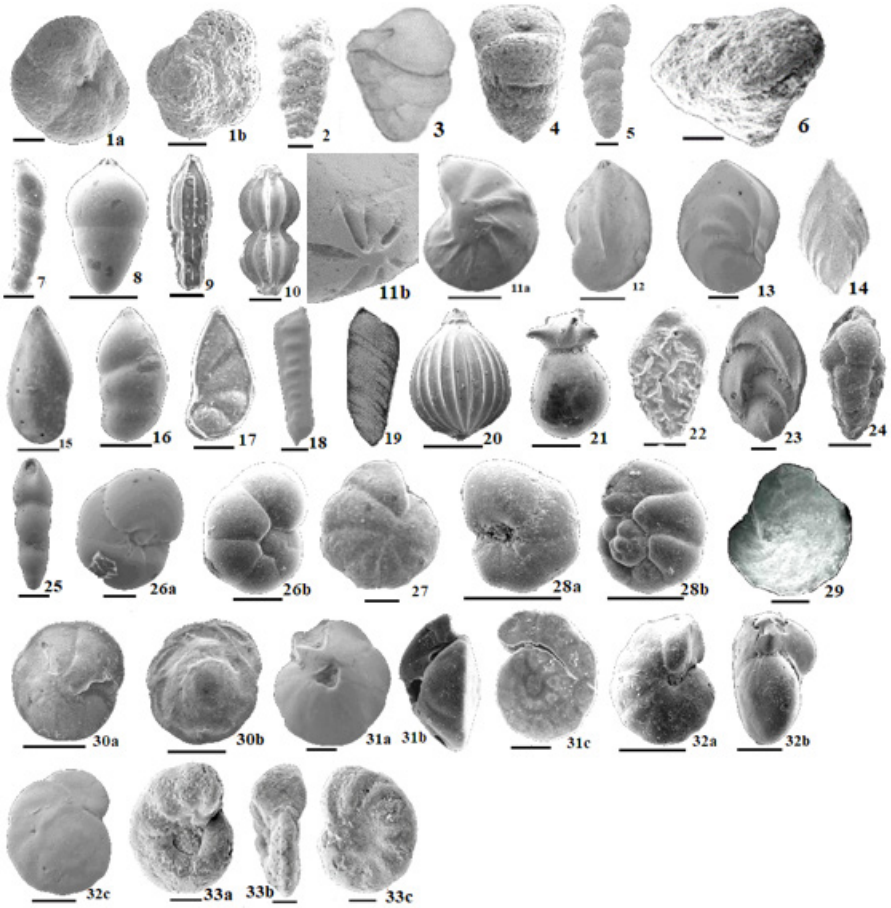

Figure 1a, b *Trochammina naqabensis*, **2.** *Gaudryina iranensis*, **3.** *Dorothia aegyptica*, **4.** *Dorothia arabica*, **5.** *Dorothia palestinica*, **6.** *Marssonella iranica*, **7.** *Laevidentalina pamaensis*, **8.** *Pseudonodosaria saritae*, **9.** *Tollmannia palestinica*, **10.** *Pyramidulina raphanistriformis* (Gümbel[14]), **11a, b.** *Lenticulina naqabensis*, **12.** *Lenticulina palestinica*, **13.** *Saracenaria naqabensis*, **14.** *Frondovaginulina aegyptica*, **15.** *Astacolus naqabensis* **16.** *Hemirobulina naqabensis*, **17.** *Planularia naqabensis*, **18.** *Vaginulina naqabensis*, **19.** *Vaginulina sinaiensis*, **20.** *Lagena sulcata* Walker & Jacob,[17] **21.** *Globulina palestinica*, **22.** *Bolivinoides naqabensis*, **23.** *Luxostomum naqabensis*, **24.** *Praebulimina naqabensis*, **25.** *Pleurostomella naqabensis*,**26a, b.** *Valvulineria palestinica*, **27.** *Cibicidoides iranica*, **28.** *Valvalabamina palestinica*, **29.** *Osangularia iranica*, **30a, b.** *Osangularia palestinica*, **31a, b.** *Gyroidinoides palestinica*, **32a-c.** *Gyroidinoides naqabensis*, **33a-c.** *Gavelinella tunisica.*

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Order Foraminiferida Eichwald, 18308

Suborder textulariina Delage & Hérouard, 1896[9]

1. ***Trochammina naqabensis*** **Anan, n. sp.** (=*Trochammina*? sp.1-Ashckenazi-Polivoda,[10] p. 91, pl.1, Figures 16-18).

Etymology: after Naqab Desert, south Palestine (Figure 1).

Stratigraphic level: Campanian-Maastrichtian of Pama Quarry, Naqab (Figure 2).

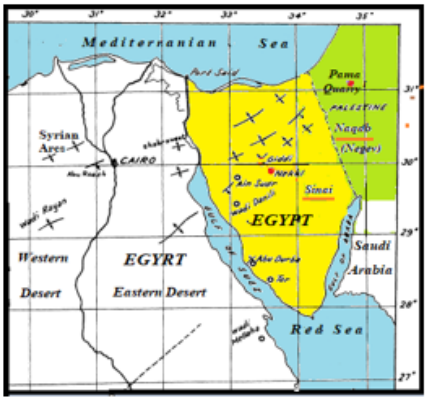

Figure 2 Location map of the studied sections: Pama Quarry in Naqab Desert (southwest Palestine), and Nekhl section in Sinai Desert (northeast Egypt) (after Said & Kenawy,[11] with some modification).

Diagnosis: Concave-convex trochospiral coarsely agglutinated test, 5 inflated chambers in the last whorl increasing gradually, sutures depressed, subangular lobulate periphery, high curved interiomarginal arch aperture.

Remarks: This species differs from the Campanian Mexican *Trochammina sliteri* Anan[11] by lesser number of chambers (5 than 7), lobulate periphery without keel (than keeled periphery), and high curved interiomarginal arch aperture (than low curved slit interiomarginal arch aperture).

2.***Gaudryina iranensis*** **Anan, n. sp.** (=*Gaudryina laevigata* - Ghoorchaei et al.,[12] p. 42, pl. 2, Figure 3).
Etymology: after NE Iran.

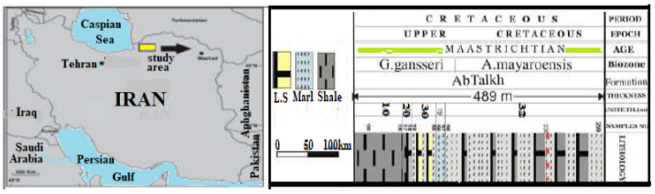

Figure 3 Location and stratigraphic log of AbTalkh Formation at Aitamir section, west of the Kopeh-Dagh basin, Northeast Iran (after Ghoorchaei et al.[10])

Stratigraphic level: Maastrichtian of AbTalkh Formation of Aitamir section, west of Kopeh-Dagh basin, n. Iran (Figure 3).

Diagnosis: Elongate agglutinated test, tiny triserial stage, 6-7 biserial gradually added, discoidal inflated chambers, periphery rounded, depressed sutures.

Remarks: The species differs from the Caribbean form by longer test, and more additional biserial stage.

3. ***Dorothia aegyptica*** **Anan, n. sp.** (=*Dorothia* cf. *conulus* – Said & Kenawy,[13] p. 128, pl. 1, Figure 54).Etymology: after the Arab Republic of Egypt (Figure 1).

Stratigraphic level: Maastrichtian, Nekhl section, Sinai, Egypt (Figure 4).

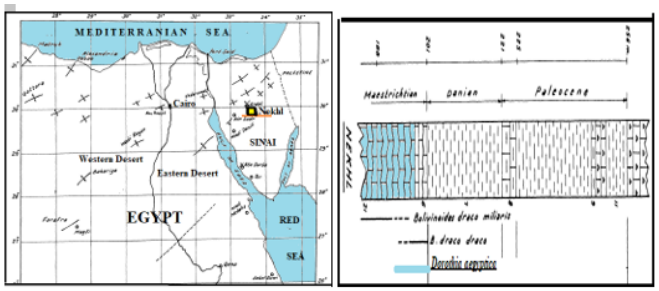

Figure 4 Location and stratigraphic log of Nekhl section, north Sinai, Egypt (after Said & Kenawy[11]).

Diagnosis: Short finely agglutinated test, tiny rounded trochospiral enrolled early stage, followed by few added biserial end stage, depressed sutures, basal interiomarginal slit aperture.

Remarks: The Egyptian species differs from *Dorothia arabica* Anan, n. sp. by shorter test, rounded trochospiral early stage than tapering shape, semi-circular than elongated slit aperture.

4. ***Dorothia arabica*** **Anan, n. sp.** (=*Dorothia* cf. *oxycona* – Abdelghani,[14] p. 398, Figure 7.3).

Etymology: after the United Arab Emirates (UAE).

Stratigraphic level: Maastrichtian, Qarn El Barr section, north UAE (Figure 5).

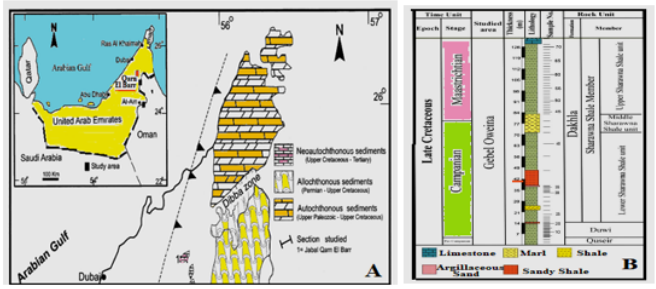

Figure 5 Location and stratigraphic log of Qarn El Barr section, north UAE (after Abdelghani[12]).

Diagnosis: Short cylindrical finely agglutinated test, tiny trochospiral enrolled early stage, followed by few added biserial end stage, circular periphery in cross section, depressed sutures, basal interiomarginal slit aperture.

Remarks: This species differs from *Dorothia oxycona* Carsey by shorter test, few biserial stage, and slit basal aperture.

5. ***Dorothia palestinica*** **Anan, n. sp.** (=*Dorothia* sp. 1 - Ashckenazi-Polivoda,[10] p. 93, pl. 1, Figure 9).

Etymology: after the State of Palestine (Figure 1).

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, south Palestine (Figure 6).

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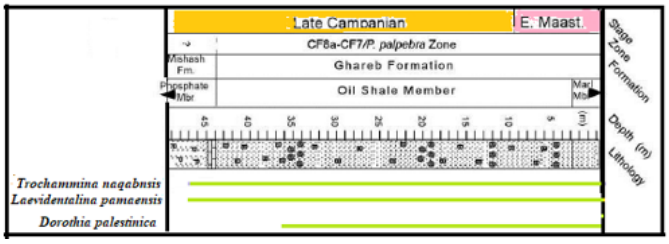

Figure 6 Stratigraphic rages of the three new species: *Trochammina naqabensis, Laevidentalina pamaensis* and *Dorothia palestinica.*

Diagnosis: Nearly inclined elongate moderately agglutinated test, early stage trochospirally enrolled, followed by biserial arrangement with four-five chambers per whorl increasing gradually as added, circular periphery in cross section, depressed sutures, basal interiomarginal slit aperture.

Remarks: This species differs from the type species *Dorothia* (Carsey) by coarser agglutinated wall, inclines elongated test (than nearly parallel sides), more added biserial chambers stage, and more depressed sutures.

6. ***Marssonella iranica* Anan, n. sp.** (=*Marssonella* sp. - Ghoorchaei et al.,[12] p. 42, pl. 2, Figure 4).

Etymology: after the Islamic Republic of Iran.

Stratigraphic level: Maastrichtian *Gansserina gansseri* - *Abathamphalus mayaroensis* Planktic Foraminiferal Zone, AbTalkh Formation at Aitamir section, west of the Kopeh-Dagh basin (Figure 3).

Diagnosis: Conical with coarse grained agglutinated shorted length test, circular in section, tiny four-five chambers per whorl of early trochospiral stage, followed by rapidly increasing diameter biserial stage, slightly depressed sutures, low basal arch aperture.

Remarks: This Iranian species differs from the type species by shorter length test.

Suborder Lagenina Delage & Hérouard, 1896[15]

7.*Laevidentalina pamaensis* Anan, n. sp. (=*Laevidentalina* sp. 1 - Ashckenazi-Polivoda,[10] p. 95, pl. 2, Figure 4).

Etymology: after Pama quarry, Naqab Desert, south Palestine (Figure 2).

Stratigraphic level: Campanian-Maastrichtian of Pama quarry (Figure 6).

Diagnosis: Elongate arcuate smooth test, large rounded proloculus, followed by four inflated uniserial chambers, oblique sutures, terminal aperture.

Remarks: This species differs from the type species *Laevidentalina aphelis* Loeblich & Tappan by larger proloculus, fewer number of uniserial chambers, and oblique sutures.

8. ***Pseudonodosaria saritae* Anan, n. sp.** (=*Pseudonodosaria* sp. 1 - Ashckenazi-Polivoda,[10] p. 96, pl. 2, Figure 5).

Etymology: after Sarit Ashckenazi-Polivoda, research student of Ben-Gurion University of the Negev, Israel.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry.

Diagnosis: Smooth conical test, discoidal in cross section, 4-5 uniserial chambers rapidly increased as added, rounded periphery, slightly depressed sutures, terminal radiate aperture with numerous radiating slits.

Remarks: This species resembles *Pseudonodosaria obesa* (Loeblich & Tappan), but differs by elongated conical test (than fusiform conical test), and last chambers consist about one-third the length of test ⅓ (than one-half ½ size).

9. ***Tollmannia palestinica* Anan, n. sp.** *(= Pyramidulina* sp. 1 - Ashckenazi-Polivoda,[10] p. 97, pl. 2, Figure 8).

Etymology: after the State of Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry (Figure 7).

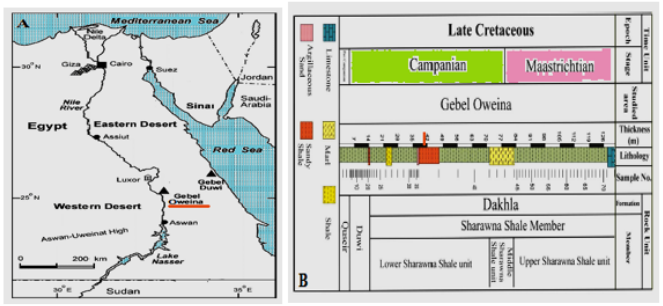

Figure 7 Stratigraphic ranges of the new species *Tollmannia palestinica* and *Saracenaria naqabensis*.

Diagnosis: Test has elongated three chambers increase rapidly in breadth as added without apiculate base, final chamber comprising half the length of the test, sutures depressed, surface ornamented with longitudinal ribs, aperture terminal on an elevated neck.

Remarks: It differs from *T. omari* Anan[16] by its thinner width elongate test, three chambers than two, without apical apiculate base.

10. ***Pyramidulina raphanistriformis* (Gümbel**[17]**)** (=*Pyramidulina* sp. 2 - Ashckenazi-Polivoda,[10] p. 98, pl. 2, Figure 9).

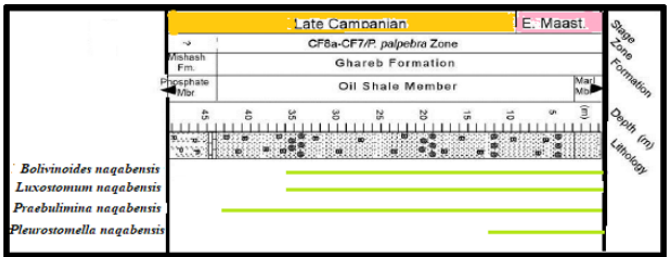

Figure 8 Location and stratigraphic log of Dakhla Shale of Gabal Oweina section, south Egypt (after Orabi et al[15]).

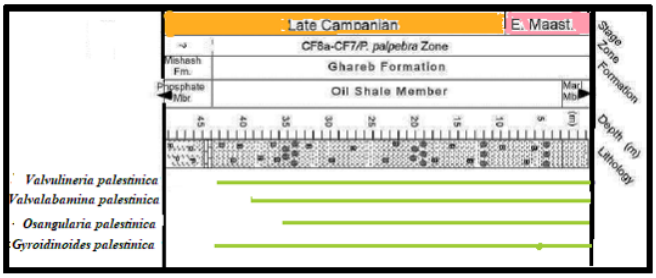

Figure 9 Stratigraphic ranges of the new species: *Bolivinoides naqabensis, Luxostomum naqabensis, Praebulimina naqabensis* and *Pleurostomella naqabensis.*

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Remarks: This Palestinian species has closely resembled with *Pyramidulina raphanistriformis* (Gümbel).

11. **a, b. *Lenticulina naqabensis* Anan, n. sp.** (=*Lenticulina* spp. - Ashckenazi-Polivoda,[10] p. 98, pl. 2, Figures 13, 14).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine.

Diagnosis: Enrolled lenticular planispiral smooth involute test, 10 chambers in the last whorl increase slowly in size as added, biumbonate with an elevated arms over the chambers extends from umbilical boss to near periphery, sutures radial depressed, faint peripheral keel, radiate slit-like aperture at the peripheral angle and slightly produced.

Remarks: This species differs from the other species by elevated arms extends from umbilical boss to near periphery, and diagnostic shape of the radiate slit-like aperture.

12. ***Lenticulina palestinica* Anan, n. sp.** (=*Lenticulina* spp. - Ashckenazi-Polivoda,[10] p. 98, pl. 2, Figure 16).

Etymology: after the State of Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine.

Diagnosis: Enrolled elongated planispiral smooth involute test, the last chamber elongated and consist about ⅔ size of the test, flush sutures, mature peripheral keel, radiate slit-like aperture at the peripheral angle and slightly produced.

Remarks: This species differs from *Lenticulina naqabensis* Anan by elongated test (than lenticular), more elongated last chamber in the last whorl, lack of biumbonate boss, flush sutures (than depressed), mature peripheral keel.

13. ***Saracenaria naqabensis* Anan, n. sp.** (=*Saracenaria* sp. 1 - Ashckenazi-Polivoda,[10] p. 99, pl. 2, Figure 17).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 7).

Diagnosis: Planispirally smooth test enrolled in the early stage, later four flaring rectilinear uniserial stage and triangular in section, apertural face broad and flat with acute margins, raised curved limbate sutures, aperture radiate at the dorsal angle, and produced on a short neck.

Remarks: This species differs from the type species *Saracenaria italica* Defrance by larger planispiral early stage, lesser numbers regular width uniserial later stage as added, and raised limbate sutures.

14. ***Frondovaginulina aegyptica* Anan, n. sp.** (*Frondicularia* sp. – Orabi et al.,[18] p. 406, Figure 4G).

Etymology: after the Arab Republic of Egypt.

Stratigraphic level: Campanian, Dakhla Formation, Gabal Oweina, Egypt (Figure 8).

Diagnosis: According to Loeblich & Tappan,[7] the genus *Frondicularia* Defrance was treated as a junior synonym of the genus *Frondovaginulina* Schubert. The *F. aegyptica* has palmate flattened smooth fusiform test, large fusiform proloculus, followed by four astacoline chambers, arched raised sutures, terminal aperture produced on a neck.

Remarks: This species differs from the type species *F. inversa* Reuss by fusiform test and proloculus, raised sutures.

15. ***Astacolus naqabensis* Anan, n. sp.** (=*Astacolus* sp. 1 - Ashckenazi-Polivoda,[10] p. 99, pl. 2, Figure 20).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 7).

Diagnosis: Flattened smooth test elongate in outline, enrolled early stage but later uncoiling uniserial, elongated broad and low chambers added on a slightly curved axis, flush curved sutures, acute periphery, radiate terminal aperture at the dorsal angle.

Remarks: This species is distinguished by flush sutures.

16. ***Hemirobulina naqabensis* Anan, n. sp.** (=*Hemirobulina* sp. 1 - Ashckenazi-Polivoda,[10] p. 100, pl. 2, Figure 22).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 7).

Diagnosis: Elongate smooth test, circular in section, few chambers added in a slight curve at the base but later becoming uniserial rectilinear, sutures oblique depressed, terminal aperture at the dorsal angle and produced on a neck.

Remarks: This species is characterized by few uniserial rectilinear chambers.

17. ***Planularia naqabensis* Anan, n. sp.** (=*Hemirobulina* sp. 1 - Ashckenazi-Polivoda,[10] p. 100, pl. 2, Figure 23).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 7).

Diagnosis: Large flattened broadly ovate smooth test, enrolled early stage similar to *Astacolus*, followed by three later uncoiling uniserial elongated broad low chambers added on a slightly curved axis, sutures curved limbate depressed, periphery carinate, radiate aperture at the dorsal angle.

Remarks: This species differs from other species by fewer three uniserial chambers, and limbate depressed sutures.

18. ***Vaginulina naqabensis* Anan, n. sp.** (=*Vaginulina* sp. 1 - Ashckenazi-Polivoda,[10] p. 100, pl. 3, Figure 1).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine.

Diagnosis: Elongate uniserial rectilinear smooth test and laterally compressed, apiculate early stage of the test, dorsal and ventral margins straight nearly parallel, 8-10 uniserial chambers, septa slightly oblique thickened and elevated, acute periphery, radiate aperture at dorsal angle and slightly produced.

Remarks: This species is characterized by straight dorsal and ventral margins nearly parallel.

19. ***Vaginulina sinaiensis* Anan, n. sp.** (=*Vaginulina* sp. 1 – Said & Kenawy,[13] p. 135, pl. 3, Figure 5).

Etymology: after Sinai, north Egypt.

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Stratigraphic level: Maastrichtian of the Nekhl section, north Sinai, Egypt (Figure 2).

Diagnosis: Elongate uniserial rectilinear smooth test and laterally compressed, dorsal and ventral margins straight but not parallel, 6-7 uniserial chambers, septa slightly oblique thickened limbate and raised, acute periphery, radiate aperture at dorsal angle and slightly produced.

Remarks: This species differs from *V. naqabensis* Anan[19] by fewer number of chambers (7 than 10), divergent sides (than parallel sides).

20. ***Lagena sulcata*** **Walker & Jacob**[20] (=*Lagena* sp. 1 - Ashckenazi-Polivoda,[10] p. 101, pl. 3, Figure 3).

Remarks: This Palestinian species has closely resembled with *Lagena sulcata* Walker & Jacob[9].

21. ***Globulina palestinica*** **Anan, n. sp.** (=*Lagena* sp. 1 - Ashckenazi-Polivoda,[10] p. 101, pl. 3, Figure 2).

Etymology: after the State of Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 9).

Diagnosis: Ovate smooth involute test, circular in section, flush sutures, obscured aperture by fistulose growth with radiating tubular projections that end in small rounded openings.

Remarks: This species is characterized by involute ovate smooth test, and fistulose growth that obscured terminal aperture with radiating tubular projections that end in small rounded openings.

Suborder Rotaliina Delage & Hérouard, 1896[21]

22. ***Bolivinoides naqabensis*** **Anan, n. sp.** (=*Bolivinoides* cf. *velascoensis* - Ashckenazi-Polivoda,[10] p. 103, pl. 3, Figure 9).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 9).

Diagnosis: Moderately elongated biserial test, 4-5 pairs chambers increasing gradually as added, depressed sutures, ornamented surface by raised irregular rows of discontinuous ribs, some of them parallel to the sutures or crossed it, basal aperture at the base of the final chamber.

Remarks: This species differs from other members of the genus Bolivinoides by its discontinuously irregular rows of raised ribs, parallel to the sutures or crossed it.

23. ***Luxostomum naqabensis*** **Anan, n. sp.** (=*Loxostomum* sp. 1 - Ashckenazi-Polivoda,[10] p. 104, pl. 3, Figure 11).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 9).

Diagnosis: Fusiform smooth test, few biserial pairs chambers ended by uniserial chamber, truncated periphery, deeply curved depressed sutures, terminal aperture.

Remarks: It differs from the type species by fusiform test (than elongate), fewer biserial chambers, deeper sutures.

24. ***Praebulimina naqabensis*** **Anan, n. sp.** (=*Praebulimina* sp. 1 - Ashckenazi-Polivoda,[10] p. 108, pl. 4, Figure 3).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 9).

Diagnosis: Elongate triserial test, inflated chambers gradually added, depressed sutures, surface covered with numerous minute rounded knobs, loop aperture at the base of the final chamber.

Remarks: It is characterized by gradual added triserial chambers, and ornamented by numerous minute rounded knobs.

25. ***Pleurostomella naqabensis*** **Anan, n. sp.** (=*Pleurostomella* sp. 1 - Ashckenazi-Polivoda,[10] p. 112, pl. 4, Figure 13).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 9).

Diagnosis: Elongate smooth rounded earlier test, followed by nearly lenticular 6 alternating inflated chambers, depressed sutures, highly arched apertural face vertical with a sharply-pointed thick tooth extending inward.

Remarks: This species resembles *Pleurostomella alternans* Schwager, but differs in the character of its aperture by vertical with sharply-pointed thick tooth, instead of simple tooth extending inward from each side in apertural face.

26. **a, b.** ***Valvulineria palestinica*** **Anan, n. sp.** (=*Valvulineria* sp.1 - Ashckenazi-Polivoda,[10] p. 113, pl. 4, Figures 17 &18).

Etymology: after the State of Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 10).

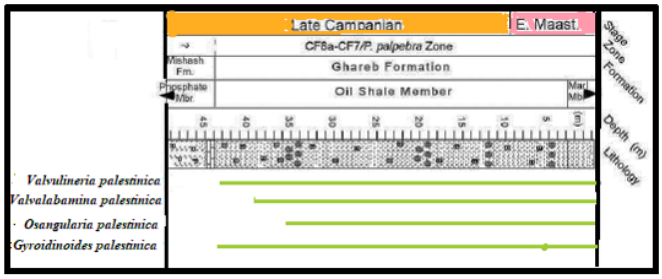

Figure 10 Stratigraphic ranges of the new species: *Valvulineria palestinica, Valvalabamina palestinica, Osangularia palestinica* and *Gyroidinoides palestinica.*

Diagnosis: Equally involute biconvex low trochospiral test, rounded periphery, 6 inflated chambers in last whorl, depressed sutures, low arched elliptical aperture, which covered by a thin membrane-like plate, and not-completely fills umbilical area below the lunate umbilicus.

Remarks: This species nearly resembles Late Campanian *Valvulineria iraqensis* Anan,[19] but differs in less numbers of chambers in the last whorl, smaller final chamber, and less closed umbilical area by thinner membrane-like plate.

27. ***Cibicidoides iranica*** **Anan, n. sp.** (=*Cibicidoides* sp. *coonensis* - Ghoorchaei et al.,[12] p. 42, pl. 3, Figure 15).

Etymology: after Iran.

Stratigraphic level: Maastrichtian of AbTalkh Formation of Aitamir section, west of Kopeh-Dagh basin, N. Iran (Figure 3).

Diagnosis: Low trochospiral perforated test, nearly triangular last involute chambers, convex umbilical side, curved depressed sutures, angular periphery, interiomarginal equatorial arch aperture.

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Remarks: It is distinguished by convex umbilical side, nearly triangular last formed chambers, acute periphery, and depressed curved sutures.

28. **a, b. *Valvalabamina palestinica* Anan, n. sp.** (=*Valvalabamina* sp.1 - Ashckenazi-Polivoda,[10] p. 117, pl. 5, Figures 15, 16).

Etymology: after the State of Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine (Figure 10).

Diagnosis: Trochospiral biconvex smooth test, nine-twelve chambers in the final whorl, 7-8 chambers in the final whorl increasing gradually as added, radial depressed sutures, large open umbilicus, high arched umbilical-extraumbilical aperture in a depressed apertural area.

Remarks: This species differs from the type species *Valvalabamina lenticula* (Reuss[22]) by more inflated biconvex test and chambers, less numbers of chambers in the last whorl, and larger and open umbilical area.

29. ***Osangularia iranica* Anan, n. sp.** (=*Osangularia* sp. - Ghoorchaei et al[12], p. 42, pl. 4, Figure 10).

Etymology: after Iran.

Stratigraphic level: Maastrichtian of AbTalkh Formation of Aitamir section, west of Kopeh-Dagh basin, n. Iran (Figure 3).

Diagnosis: High trochospiral lenticular biumbonate finely perforated test, limbate curved raised sutures, carinate periphery with faint keel, areal interiomarginal aperture at the base of the chamber face.

Remarks: It is distinguished by carinate test, faint peripheral keel, and raised limbate sutures.

30. **a, b. *Osangularia palestinica* Anan, n. sp.** (=*Osangularia* sp.1 - Ashckenazi-Polivoda,[10] p. 118, pl. 6, Figures 1, 2).

Etymology: after the State of Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry (Figure 10).

Diagnosis: Highly trochospiral biumbonate lenticular smooth test, 8 chambers in the last whole gradually as added, radial slightly depressed sutures in ventral side but raised in dorsal side, acute periphery with mature keel, acute angle deep interiomarginal aperture at the base of the last chamber face.

Remarks: This species differs from the type species Osangularia lens Brotzen by lesser numbers of chambers, larger elongate last chamber, and wider extended of the aperture.

31. **a-c. *Gyroidinoides naqabensis* Anan, n. sp.** (=*Gyroidinoides* sp.1-Ashckenazi-Polivoda,[10] p.122, pl. 7, Figures 4–6).

Etymology: after the Naqab Desert, south Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry, Naqab Desert, south Palestine.

Diagnosis: Lenticular smooth biconvex trochospiral test, faintly convex spiral side, but d highly convex umbilical side, radial slightly curved sutures in the ventral side but faintly raised in the dorsal side, acute periphery with faint keel, open umbilicus, low interiomarginal slit aperture from umbilicus to periphery, and extending to the dorsal side.

Remarks: This species resembles *Gyroidinoides zelandia* (Finlay), but differs by more rounded lenticular test, wider open umbilicus, tighter slit aperture, and faintly keel.

32. **a, b. *Gyroidinoides palestinica* Anan, n. sp.** (=*Gyroidinoides* sp.2 - Ashckenazi-Polivoda,[10] p. 122, pl. 7, Figures 7-9).

Etymology: after the State of Palestine.

Stratigraphic level: Campanian-Maastrichtian of Pama quarry (Figure 10).

Diagnosis: Lenticular smooth biconvex trochospiral test, faintly convex spiral side, but d highly convex umbilical side, radial depressed sutures, small deep umbilicus, rounded periphery, low interiomarginal slit aperture from the umbilicus to the periphery, and extending in the dorsal side, with lip.

Remarks: This species differs from Gyroidinoides naqabensis by more numbers of chambers, more inflated last chamber, smaller umbilicus, and rounded periphery (than acute with keel).

33. **a-c. *Gavelinella tunisica* Anan, n. sp.** (=*Gavelinella* cf. *ammonoides* - Bejaoui et al.,[3] p. 524, Figure 12.3).

Etymology: after Tunisia.

Stratigraphic level: Campanian-Maastrichtian (C-M) of Kalâat Senan section, north-western Tunisia (Figure 11).

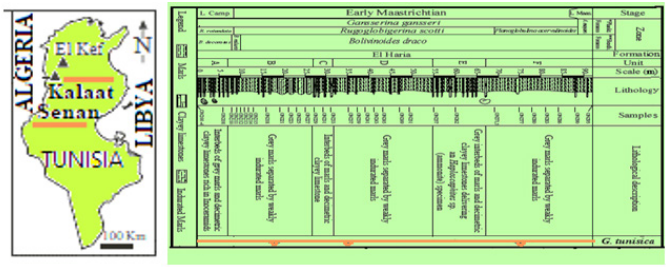

Figure 11 Location and stratigraphic log of Kalâat Senan section, north-western Tunisia (after Bejaoui et al[3]).

Diagnosis: Flattened perforated low trochospiral test, 12-14 crescentic chambers, depressed ventral and dorsal sides, rounded periphery, depressed sutures, low interiomarginal slit aperture extending near the periphery around the chamber margin with a narrow lip.

Remarks: This species differs from the other species by depressed ventral and dorsal sides, depressed sutures and low interiomarginal slit aperture, than closed umbilicus by small umbilical boss, raised sutures, and high arched aperture.

Paleogeography

Some authors, i.e.: Abdelghany,[14] Ashckenazi-Polivoda,[10] Bejaoui et al.,[3] Ghoorchaei et al.,[12] Jaff & Lawa,[23] Anan,[24–32] Orabi et al.,[18] noted that the Upper Cretaceous Tethys extended from Atlantic Ocean to Indo-Pacific Ocean via the Mediterranean Sea (Figure 12).

Figure 12 Paleogeographic map of Maastrichtian showing locations of some countries in the Tethys, i.e., Tunisia, Egypt, UAE, Iraq and Iran.

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The geographic distribution of the recorded Campanian-Maastrichtian benthic foraminiferal assemblage from six localities in the Southern Tethys (Tunisia, Egypt, UAE, Iraq, Iran) are presents in (Table 2).

An additional remark of the paleogeographic distribution of the recorded species can be presented:

i. Sixty-two agglutinated species (~24.8), 1 porcelaneous species, 61 Lagenid species (~24.4), 126 Rotaliid species (~50.4) are totally record from the study area.

ii. Seventy-three species from Tunisia (~29.2), 94 from Egypt (~37.6), 87 from Palestine (~34.8), 17 from UAE (~06.8), 34 from Iraq (~13.6), and 60 from Iran (~24.0).

iii. Forty-five of the recorded species (~18) were erected by the present author.

iv. Thirty-one of the recorded and illustrated species (~12.4) are treated here as new species.

v. One new species is illustrated from Tunisia (*Gavelinella tunisica*), 1 new species from UAE (*Dorothia arabica*), 3 new species from Egypt (*Dorothia aegyptica Frondovaginulina aegyptica* and *Vaginulina sinaiensis*), 4 new species from Iran (*Gaudryina iranensis, Marssonella iranica, Cibicidoides iranica* and *Osangularia iranica),* and 22 new species from Palestine (*Trochammina naqabensis, Dorothia palestinica, Laevidentalina pamaensis, Pseudonodosaria saritae, Tollmannia palestinica, Pyramidulina raphanistriformis, Lenticulina naqabensis, Lenticulina palestinica, Saracenaria naqabensis, Astacolus naqabensis, Hemirobulina naqabensis, Vaginulina naqabensis, Globulina palestinica, Planularia naqabensis, Bolivinoides naqabensis, Loxostomum naqabensis, Praebulimina naqabensis, Pleurostomella naqabensis, Valvulineria palestinica, Gyroidinoides naqabensis* and *Gyroidinoides palestinica*),

vi. Fourteen species (~05.6) are recorded of the genus *Cibicidoides*, 14 of *Bolivinoides,* 13 of *Anomalinoides*, 12 of *Gyroidinoides,* 10 of *Gaudryina*, 9 of *Spiroplectinella,* 8 of *Pseudoclavulina,* 7 of *Neoflabellina,* 6 of *Dorothia, Ramulina* and *Gavelinella,* 5 of *Laevidentalina, Pyramidulina, Lenticulina* and *Osangularia,* 4 of *Verneuilina, Marginulina Orthokaresteina* and *Pullenia,* 3 species of *Ammobaculites, Marssonella* and of *Stensioina.*

vii. The other species are recorded from one or two localities.

viii. Two species is recorded in all the six study species *Dorothia bulletta* and *Marssonella oxycona* (Reuss).

ix. Eleven recorded species (~04.4) are distribution in 4 localities: *Spiroplectinella laevis, Gaudryina pyramidata, Dorothia bulletta*, *Marssonella oxycona, Neoflabellina rugosa, Lagena sulcata, Sitella carseyi, Cibicidoides abudurbensis, Gyroidinoides girardanus, Gyroidinoides globosus* and *Gyroidinoides nitidus.*

x. Thirteen species (~12.0) are recorded in 3 localities: *Spiroplectinella knebeli, Clavulinoides asper, Clavulinoides trilatera, Pseudoclavulina farafraensis, Neoflabellina jarvisi, Ramulina plummerae, Pygmaeoseistron hispidum, Coryphostoma incrassata, Sitella cushmani, Cibicidoides beaumontianus, Osangularia cordieriana, Gyroidinoides girardanus* and *Angulogavalinella avnimelechi.*

xi. Thirty-four species (~13.6) are recorded in 2 localities: *Spiroplectinella dentata, Gaudryina austinana, Gaudryina rugosa, Verneuilina aegyptiaca, Arenobulimina gutta, Heterostomella foveolata, Pseudoclavulina amorpha, Pseudoclavulina clavata, Laevidentalina gracelis, Lenticulina rotulata, Neoflabellina rugosa, Guttulina tringonula, Ramulina ismaili, Ramulina pseudoaculeata, Bolivinoides dorreeni, Elhasaella alanwoodi, Eouvigerina subsculptura, Praebulimina carseyae, Praebulimina reussi, Sitella cushmani, Coryphostoma incrassata, Orthokaresteina parva, Stilostomella midwayensis, Cibicidoides alleni, Cibicidoides pseudoacutus, Pullenia coryelli, Nuttallides truempyi, Osangularia velascoensis, Anomalinoides sinaensis, Gyroidinoides globosus, Stensioina becariformis, Stensioeina pommerana, Gavelinella acuta* and *Angulogavelinella gracelis.*

xii. The other species are recorded only in one locality.

Paleoenvirionment

According to available literatures, the data in (Table 1**)** are indicated that the recorded foraminiferal assemblage in the six studied localities in North Africa and Southwest Asia occurs in open marine environments, from continental marginal to abyssal (Figure 13). Some remarks can also be added:

i. Only four species (~0.02) are recorded from west Tethys in Trinidad in one hand, and east Tethys in N. Africa and SE Asia, in the other hand: *Clavulinoides aspera* Cushman, *Gaudryina laevigata* Franke, *Clavulinoides trilatera* Cushman, and *Heterostomella foveolata* (Marsson), which indicates limited connections between two localities.

ii. 167 species (~66.8) are recorded in far west North Africa (Tunisia and Egypt), but 200 species (~80.0) from SW Asia (Palestine, UAE, Iraq and Iran).

iii. The Sinai and Naqab basins (Figure 14) have richer faunal benthic foraminiferal assemblage in the study area: 173/250 species (~69.2), followed by Iraq and Iran basins: 96/250 (~38.4), 73/250 species from Tunisia (~29.2), and the lowest assemblage from UAE: 19/250 (~07.6). These percentages may due to the different environmental parameters between these basins, or not sufficient available literatures in that time.

iv. The Cretaceous Period was a time of major tectonic activity, and the Neo-Tethys evolved into a global EW-oriented seaway, and the South and North Atlantic basins opened, and this tectonic activity was affected on the distribution and foraminiferal biofacies of the study area (Figure 15).

v. Most paleoenvironmental depths of common benthic foraminiferal species according to many different authors (Berggren & Aubert, Ernst et al., Morsi et al., Anan [26,29–31,33–36]) are shown in Table 3.

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Table 3 Ppaleoenvironmental depths of some common benthic foraminiferal species that recorded in the study area, which indicated that the most recorded species favor the middle and outer neritic zone (50m-200m water depth) than the upper bathyal environment (200m-500m water depth).

Most common benthic foraminiferal species	Bathymetric range			
	neritic			upper bathyal
	inner	middle	outer	
Orthokarstenia spp.				
Lenticulina spp.				
Praebulimina spp.				
Bolivinoides spp.				
Bolivina spp.				
Nodosaria spp.				
Cibicidoides spp.				
Anomalinoides praeacutus				
Gyroidinoides spp.				
Gyroidinoides subangulata				
Osngularia spp.				
Cibicidoides alleni				
Gaudryina spp.				
Spiroplectinella spp.				
Anomalinoides affinis				
Neoflabellina spp.				
Lagena spp.				
Tritaxia midwayensis				
Pullenia cretacea				
Gyroidinoides globosus				
	50 m	100 m	200m	500m

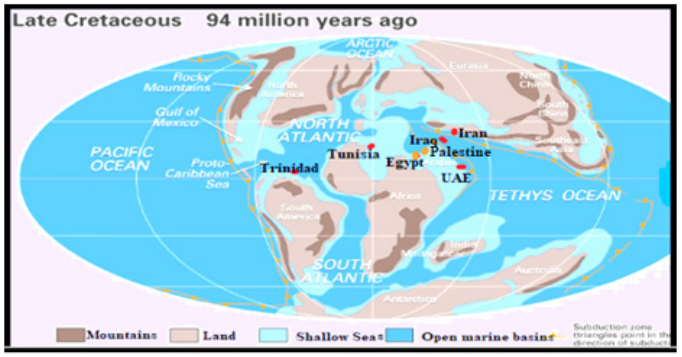

Figure 13 Paleogeographic map of the possible locations of the six countries in the east Tethys (North Africa and Southwest Asia) and west Tethys in Caribbean Sea (Trinidad) in the Late cretaceous time.

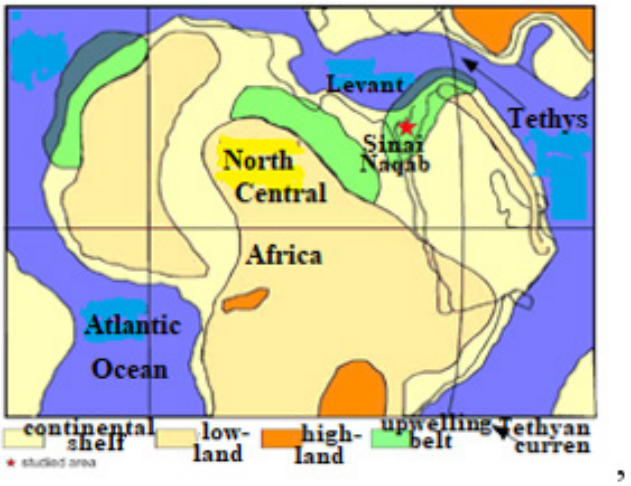

Figure 14 Campanian-Maastrichtian paleogeographic map of the Levant basin (after Ashckenazi-Polivoda[8]).

Figure 15 Paleogeography of the Neo-Tethys Ocean during the Maastrichtian showing the flow direction of the Tethyan Circumglobal Current (TCC) from east to west.

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None.

Conflicts of interest

The author declares that there are no conflicts of interest.

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