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Alien Benthic Foraminifers from Turkish Strait System

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Abstract

The Sea of Marmara is under the influence of the Black Sea and the Mediterranean. The salinity difference between these two seas causes the formation of two-layer stratification in the Sea of Marmara, an upper layer formed by the fresh waters of the Black Sea and a denser layer formed below 25 m of depth, by the more saline waters of the Mediterranean. The salinity difference, together with the seasonally changing meteorological events are the major factors which shape the main current system. The Mediterranean waters enter the Dardanelles cross the Sea of Marmara and flows into the Black Sea via İstanbul Strait, which enables the dispersion of the alien foraminifer species already established on the Aegean coasts into the Sea of Marmara. Besides, the Sea of Marmara includes important harbors, suggesting that there is an extensive pressure of alien species introduced by ballast waters. In this study, 322 sediment samples, obtained from different localities in Dardanelles, İstanbul Strait and Sea of Marmara, were investigated for the alien foraminifer species. The results are combined with the previous records in the literature for creating an alien foraminifer checklist for the Sea of Marmara. 10 alien foraminifer species belonging to 9 genera were found in Dardanelles, 32 alien species from 28 genera in the Sea of Marmara, and only 2 alien species from 2 genera were found in İstanbul Strait. Majority of these alien species have Indo-Pacific or Atlantic origin, suggesting that shipping may be the most possible mode of introduction. But it is also observed that some of the Indo-Pacific originated species which were introduced Suez Canal and formed established populations along the Turkish coastline are also found in Dardanelles, indicating that major currents systems are also playing a role in the dispersion patterns of the alien foraminifers in the Sea of Marmara. Another important factor may be the thermal submarine springs found on the bottom of the Sea of Marmara, which may create suitable environmental conditions and enhance the establishment of thermophilic alien species.

Keywords: Foraminifers, Alien, Turkish Strait System, İstanbul Strait, Dardanelles

Introduction

Sea of Marmara is an inner sea which covers an area of 11,200 km² and is connected to Black Sea via İstanbul Strait, to Aegean Sea via Dardanelles. It is divided into two regions; the Northern Shelf starts from Gallipoli and extends towards Gulf of İzmit, whereas Southern Shelf lays between Karabiga and Gulf of Gemlik. Four pits with approximately 1200 m depth are located between the two shelves (Figure 1).

Salinity difference between the Black Sea and the Mediterranean results in the stratification of the water column in the straits (İstanbul and Dardanelles) and also in the Sea of Marmara. This stratification plays the major role in shaping the current system. In İstanbul Strait, fresh waters of Black Sea (salinity ‰16-18) flow towards the Sea of Marmara and then to the Aegean Sea via Dardanelles on the surface. However, more saline and dense waters of the Mediterranean (salinity ‰38-39) flows towards the Black Sea at the bottom (Figures 2 and 3).

Due to the diffusion between layers, the salinities of the surface and bottom layers reaches to %22-24 and %36, respectively. The halocline layer between these two layers are formed around 25 m depth (Eryılmaz et al., 2000; Eryılmaz and Yücesoy Eryılmaz, 2003). The upper layer circulation in the Sea of Marmara is anti-cyclonic and caused by the water level difference between the Black Sea and the Aegean Sea (Ünlüata et al, 1990; Beşiktepe et al, 1994, 2000; Erdik and Beji, 2018). On the other hand, changes in the meteorological parameters, amount of rain, speed and direction of the winds can also affect the currents and may

result in the formation of local deviations in the main current systems.

Benthic foraminifer assemblages in the Sea of Marmara have been studied by many researchers and a rich foraminifer fauna, including considerable amounts of alien genera and species have been reported. In the framework of the present study, 322 sediment samples from northern and southern coasts of the Sea of Marmara (Figure 4) investigated for alien foraminifer species and previous records in the literature are reviewed for constructing an alien foraminifer checklist for the Sea of Marmara.

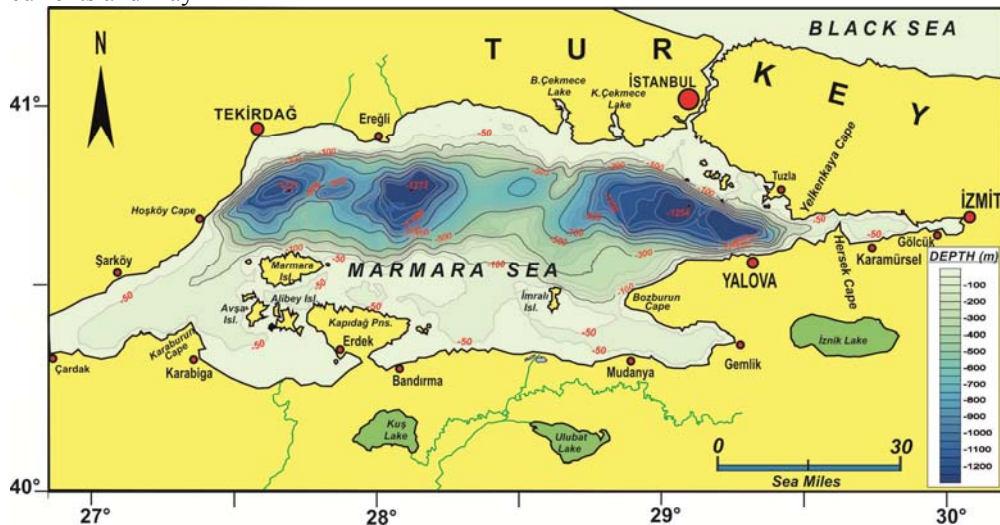


Fig 1. Bathymetric map of Sea of Marmara (Eryılmaz, 1995b; Eryılmaz and Kırca, 1998).



Figure 2. Bottom currents in Sea of Marmara (Eryılmaz, 1999).

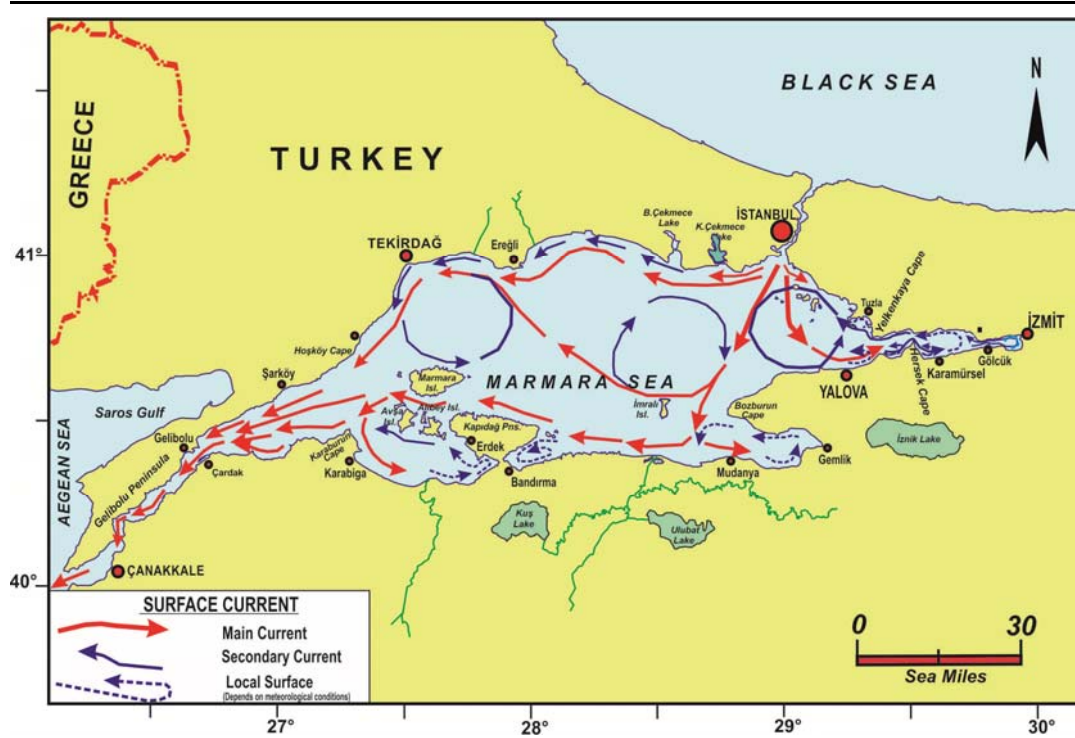


Figure 3. Surface currents in Sea of Marmara (Eryılmaz, 1999).

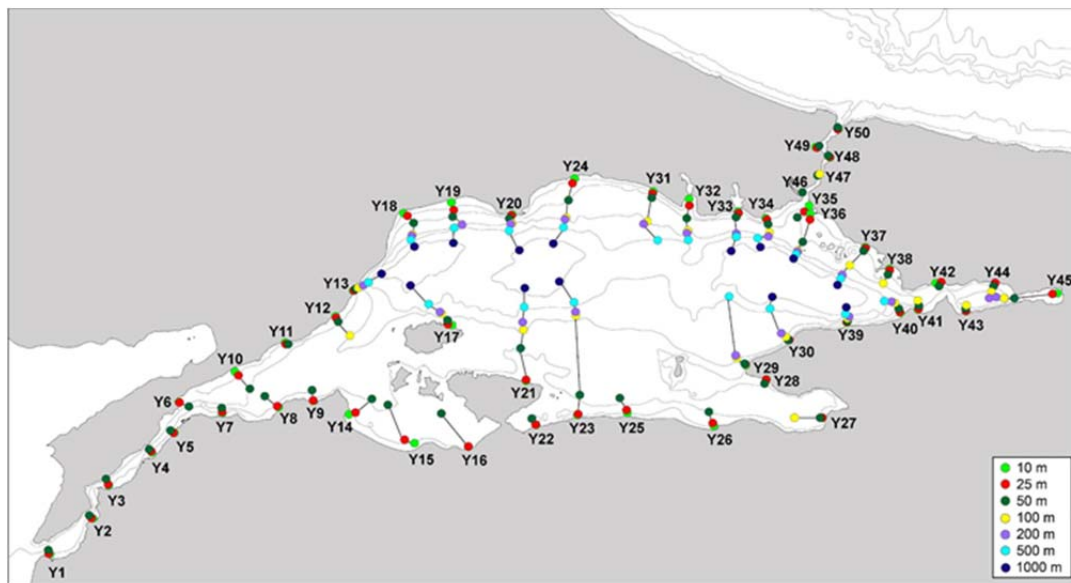


Figure 4. Locations and depths of the stations investigated in the scope of TÜBİTAK Project no: 111Y268.

Results

The distribution patterns of the alien foraminifers have been found as follows: *Adercotryma glomeratum* (Brady) (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016)

deep basin, *Textularia cushmani* Said (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Southern Shelf, *Cornuspiroides striolata* (Brady) (Sakınç, 2008, pl. 2, fig. 10; Fig. 5, Y9; Kırcı-Elmas, 2013, Kırcı-Elmas and Meriç, 2016) Southern Shelf, *Adelosina longirostra*

(d'Orbigny) (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Northern and Southern Shelves, Istanbul Strait, *A. milletti* Wiesner (Phipps et al., 2010) Northern Shelf, *Spiroloculina angulata* Cushman (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Southern Shelf, *S. antillarum* d'Orbigny (Meriç et al., 2009; Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Dardanelles, *Quinqueloculina parvula* Schlumberger (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Northern and Southern Shelves, deep basin and Istanbul Strait, *Biloculinella cylindrica* Todd (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) deep basin, *Ishamella apertura* Buzas and Severin (Sakınç, 2008, pl. 9, figs. 1, 2) Northern Shelf, *Peneroplis pertusus* (Forskal) (Meriç et al., 2009, table 2b; Gürseler et al., 2014; Gülen et al., 2017; Yümün, 2017, pl. 1, figs. 13, 14) Southern Shelf coast of Bandırma, Gulf of Erdek and Gulf of Gemlik, *P. planatus* (Fichtel and Moll) (Gürseler et al., 2014) Gulf of Erdek, northeast of Kapıdağ Peninsula Southern Shelf, *Coscinospira hemprichii* Ehrenberg (Gürseler et al., 2014) Gulf of Erdek Southern Shelf, *Dentalina albatrossi* (Cushman) (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016; Fig. 5, Y1, Y9, Y14, Y19, Y24, Y33) Dardanelles, Northern and Southern Shelves, *Dentalina vertebralis* (Batsch) (Sakınç, 2008; Fig. 5, Y1, Y14, Y17) Dardanelles and Southern Shelf, *Astacolus crepidulus* (Fichtel and Moll) (Sakınç, 2008, table 10, figs.5, 6; Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Dardanelles, Northern and Southern Shelves, *Marginulina gummi* Saidova (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Dardanelles and Southern Shelf, *Polymorphina fistulosa* (Cushman) (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016; Yümün, 2017, pl. 2, figs. 18, 19) Dardanelles, north of Kapıdağ Peninsula, Southern Shelf, *Cushmanina striatopunctata* (Parker and Jones) (Sakınç, 2008, pl. 11, fig. 1; Kırcı-Elmas, 2013; Meriç et al., 2014, pl. 48, fig. 7; Kırcı-Elmas and Meriç, 2016) Dardanelles, Northern and Southern Shelves, *Fissurina faba* (Balkwill and Millett) (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Southern Shelf, *Stainforthia concava* (Hoeglund) (Sakınç, 2008, pl. 13, figs. 3, 4; Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Northern and Southern Shelves, *Bulimina denudata* Cushman and Parker (Kırcı-

Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Southern Shelf, *Bolivina striatula* (Cushman) (Avşar, 2010) Northern Shelf, *Siphonina tubulosa* Cushman (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) deep basin, *Cibicidoides pachyderma* (Rzehak) (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Dardanelles and Southern Shelf, *Amphistegina lessonii* d'Orbigny (Gürseler et al., 2014) northeast and southwest of Kapıdağ Peninsula, Southern Shelf, *A. lobifera* Larsen (Meriç et al., 2005, table 2; Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016; Yümün, 2017, pl.2, fig. 1) coasts of Tekirdağ Northern Shelf and few specimens in 3 samples from west and northwest of Armutlu Peninsula on the Southern Shelf, *Haynesina paucilocula* (Cushman) (Kırcı-Elmas, 2013) Dardanelles, Northern and Southern Shelves, deep basin and Gulf of İzmit, *Nonion subturgidum* (Cushman) (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Southern Shelf, *Melonis barleeanus* (Williamson) Dardanelles, Northern and Southern Shelves, deep basin (Avşar, 2010; Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016), *Buccella granulata* (di Napoli Aliata) (Kırcı-Elmas, 2013; Kırcı-Elmas and Meriç, 2016) Northern and Southern Shelves, *Faujasina carinata* Bermudez (Sakınç, 2008, pl. 20, figs. 11, 12) Northern Shelf, *Porosonion granosum* (d'Orbigny) (Sakınç, 2008, pl. 19, figs. 9, 10) Southern Shelf (Meriç et al., 1995 and 2005; Sakınç, 2008; Meriç et al., 2009; Phipps et al., 2010; Avşar, 2010; Kırcı-Elmas, 2013; Meriç et al., 2014; Kırcı-Elmas and Meriç, 2016; Yümün, 2017).

Conclusions

Alien foraminifer genera and species were abundantly observed in different locations in Dardanelles and Sea of Marmara. Until now, together with the results of the present study, 28 genera and 33 species have been found in the Turkish Straits System (Table 1). 10 alien species have been found in Dardanelles, whereas, only two alien species observed in İstanbul Strait, suggesting that some of the aliens which have been established in the Aegean Sea expanded their range of distributions, introduced via Dardanelles and dispersed in the Sea of Marmara by the currents (Figure 2 and 3). The distribution patterns of

some of the alien foraminifers around the harbors, such as Tekirdağ, Bandırma and Gemlik, also suggests that some of the alien species should have been introduced to the Sea of Marmara by ballast waters, near to these harbors and dispersed to by the currents. The presence of hot water springs in the Sea of Marmara may create favorable environmental conditions for the Indo-Pacific originated aliens, which may enhance the dispersion of these thermophilic species (Figure 5).

Alien foraminifer species were observed either on the northern shelf, or on the southern shelf, or on both. Only few species were found on the deep basin. The İstanbul Strait is pretty much influenced by the Black Sea and the fresh water creates an unfavorable environment for the alien foraminifer species. To date, only *Sorites orbiculus* Ehrenberg has been recorded in the Black Sea, which has a very limited distribution between the exit of İstanbul Strait and Şile (Meriç et al., 2010).

The alien foraminifer species recorded in the Turkish Straits System included 28 genera and 33 species. Sakıncı (2008) has mentioned that *Cornuspiroides striolata* (Brady) has been found in Gulf of Piran (Adriatic Sea), citing Cimerman and Langer (1991). However, the photograph given by Cimerman and Langer (1991) was showing a broken test fragment (Pl. 15, fig. 8), which is absolutely not representing the genus and the species. Besides, Sakıncı (2008) has noted that *Ishamella apertura* Buzas and Severin, *Cushmanina striatopunctata* (Parker and Jones), *Stainforthia concava* (Hoeglund) and *Faujasina carinata* d'Orbigny have not been recorded elsewhere in the Mediterranean, but has not made any comment

on the possibility of their alien origin. The species given as *Dentalina* sp.1 by Sakıncı (2008) which has been found on the southern shelf is actually *Dentalina vertebralis* (Batsch) observed on the Australian coasts (Yasinski and Jones, 1995). Although Kırıcı-Elmas (2013) has given most of the alien species and Yümün (2017) has recorded *Polymorphina fistulosa* (Cushman), *Peneroplis pertusus* (Forskal) and *Amphistegina lobifera* Larsen on the western coasts of Sea of Marmara, none of the authors has discussed their origin.

The amount of alien foraminifer genera and species recorded in the Sea of Marmara is considerable. Numerous hot and cold-water submarine springs are known to exist on the bottom of the Sea of Marmara (Figure 5). Besides the surface and bottom currents, these water exits are suggested to enhance the distribution and also the establishment of the thermophilic alien species. Future studies around these springs, as well as on the southern shelf, which is influenced by the currents from Dardanelles, will probably reveal more alien records.

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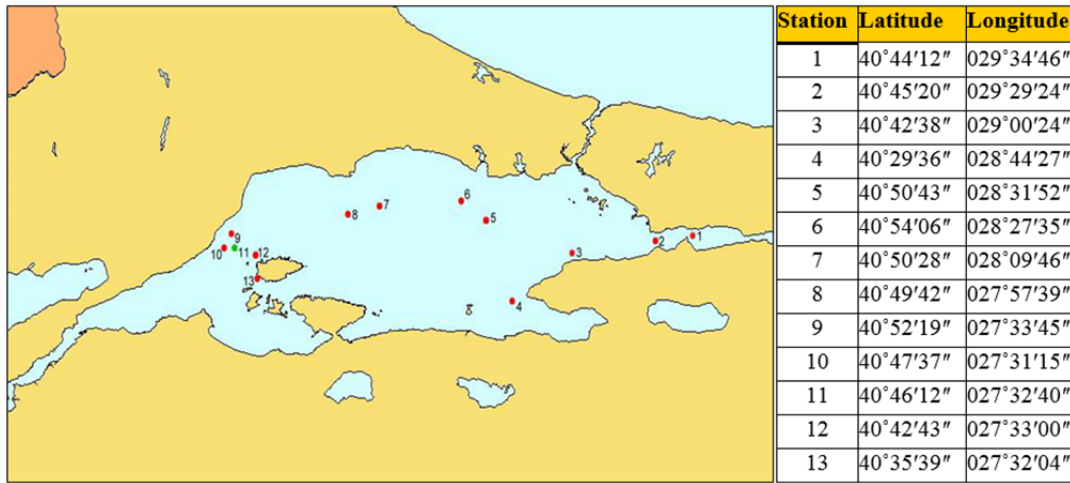


Figure 5. Locations and the coordinates of submarine springs (●) and mud exits (●) observed in the Sea of Marmara.

Table 1. Checklist of alien Benthic foraminifers from Turkish Strait System. Dar (Dardanelles), SM (Sea of Marmara), İst (İstanbul Strait), A (Atlantic Ocean), P (Pacific Ocean), I (Indian Ocean), IP (Indo-Pacific), C (circumglobal), SC (Suez Canal), Sh (ship), Re (Range expansion from Aegean or Levantine coastlines).

Species	Dar	SM	İst	Global distribution	Probable vector
<i>Adercotryma glomeratum</i> (Brady),		+		A, P	Sh
<i>Textularia cushmani</i> Said,		+		I	Sh
<i>Cornuspiroides striolata</i> (Brady)		+		A, P	Sh
<i>Adelosina longirostra</i> (d'Orbigny)		+	+	A, P	Sh
<i>Adelosina milletti</i> Wiesner		+		P	SC+(Sh/Re)
<i>Spiroloculina angulata</i> Cushman		+		P	SC+(Sh/Re)
<i>Spiroloculina antillarum</i> d'Orbigny	+			A, P	(Sh/SC)+Re
<i>Quinqueloculina parvula</i> Schlumberger		+	+	A	Sh
<i>Biloculinella cylindrica</i> Todd		+		A	Sh
<i>Ishamella apertura</i> Buzas and Severin		+		A	Sh
<i>Peneroplis pertusus</i> (Forskal)		+		A, P	SC+Re
<i>Peneroplis planatus</i> (Fichtel and Moll)		+		IP	SC+Re
<i>Coscinospira hemprichii</i> Ehrenberg		+		IP	SC+Re
<i>Dentalina albatrossi</i> (Cushman)	+	+		A, P	Sh+Re
<i>Dentalina vertebralis</i> (Batsch)	+	+		P	Sh
<i>Astacolus crepidulus</i> (Fichtel and Moll)	+	+		A, P	Sh
<i>Marginulina gummi</i> Saidova	+	+		Endemic to New Zealand	Sh
<i>Polymorphina fistulosa</i> (Cushman)	+	+		IP	Sh+Re
<i>Cushmanina striatopunctata</i> (Parker and Jones)	+	+		A, P	Sh
<i>Fissurina faba</i> (Balkwill and Millet)		+		A	Sh
<i>Stainforthia concava</i> (Hoeglund)		+		A, P	Sh
<i>Bulimina denudata</i> Cushman and Parker		+		P	Sh
<i>Bolivina striatula</i> (Cushman)		+		C	Sh?

<i>Siphonina tubulosa</i> Cushman		+		C	Sh
<i>Cibicidoides pachyderma</i> (Rzehak)	+	+		A, P	Sh
<i>Amphistegina lessonii</i> d'Orbigny		+		C	(SC/Sh)+Re
<i>Amphistegina lobifera</i> Larsen		+		A, I	SC+Re
<i>Haynesina paucilocula</i> (Cushman)	+	+		A	Sh
<i>Nonion subturgidum</i> (Cushman)		+		IP	Sh
<i>Melonis barleeanus</i> (Williamson)	+	+		A	Sh
<i>Buccella granulata</i> (di Napoli Aliata)		+		A	Sh
<i>Faujasina carinata</i> Bermudez		+		A	Sh
<i>Porosonion granosum</i> (d'Orbigny)		+		A, P	Sh

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