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SHORT COMMUNICATION

Did *Spiroloculina antillarum, Articulina carinata, Coscinospira hemphrichii, Peneroplis pertusus, P. planatus, Sorites orbiculus, Astacolus insolithus, Siphonina tubulosa, Amphistegina lessonii* and *A. lobifera* reach the Mediterranean via the Suez Canal?

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Abstract

Many of the Indo-Pacific originated marine alien species are accepted to be introduced to the Eastern Mediterranean from Red Sea after the opening of Suez Canal and then dispersed towards the Western Mediterranean, as well as the Aegean Sea. However, alien foraminifer species, such as *Spiroloculina antillarum, Coscinospira hemprichii, Peneroplis pertusus, P. planatus, Sorites orbiculus, Astacolus insolithus, Siphonina tubulosa, Amphistegina lessonii* and *A. lobifera* have been found in the sediments from southeastern Turkey, which dated much before the Suez Canal. In Akkuyu (Mersin) *Amphistegina lobifera* were found to be abundant in sediment samples and the OSL (thermolunisence) method surprisingly revealed ages, 227.3±17.8 (Middle Pleistocene), 87.7±9.6 (Late Pleistocene) and 6.0±0.6 (Holocene) thousand years before present. This finding suggests that some alien foraminifers might have entered the Eastern Mediterranean, not from Suez Canal, but through the Red Sea-Gulf of Aqaba-Dead Sea Fault line and Arabian Gulf-Mesopotamia Basin.

As a result, the historical pathways, other than Suez Canal should be taken into consideration when defining the mode of introduction for Indo-Pacific originated alien species found in the Mediterranean.

Keywords: Foraminifers, Alien, Suez Canal, Mediterranean

Introduction

The alien benthic foraminifer species, *Spiroloculina antillarum, Coscinospira hemprichii, Peneroplis pertusus, P. planatus, Sorites orbiculus, Astacolus insolithus, Siphonina tubulosa, Amphistegina lessonii, A. lobifera* are accepted to be introduced to the Eastern Mediterranean via Suez Canal. However, recent findings show that they are also abundant in Middle Pleistocene, Late Pleistocene and Holocene sediments along the Turkish coastline. A connection between Red Sea and Eastern Mediterranean through Gulf of Aqaba-Dead Sea fault line, or through Arabian Gulf - Mesopotamia Basin, which is suggested to occured during Miocene might have been responsible for the introduction of these species (Popov etal., 2004; 2006; Okuş et al., 2004-2006) (Figure 1).

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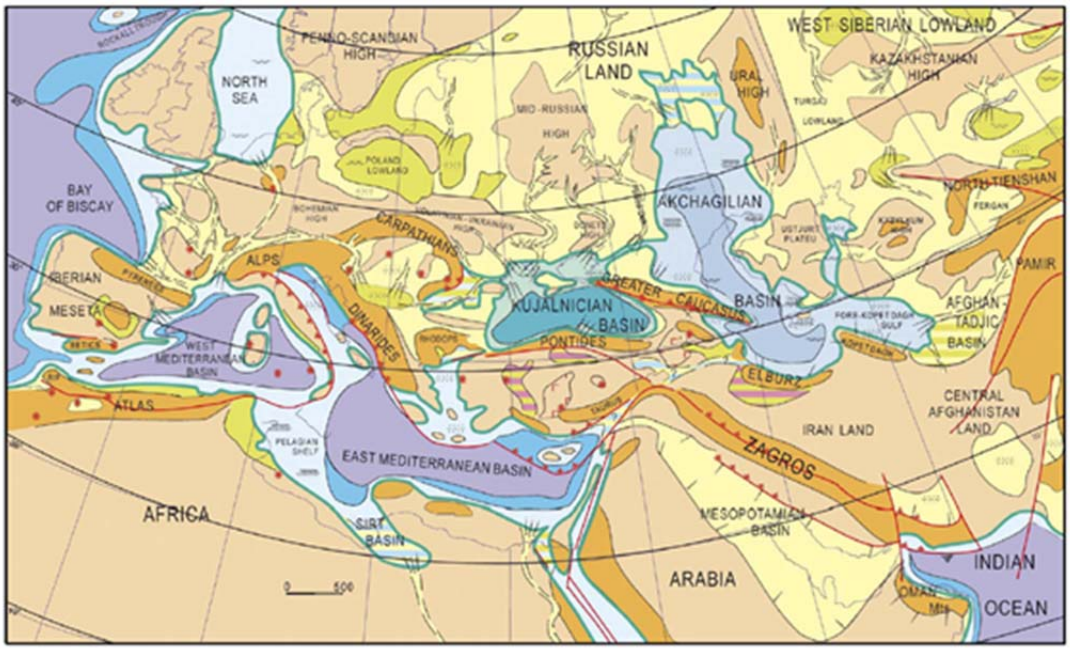

Figure 1. Late Pliocene-Early Pleistocene (Placenzian-Gelasian) lithological paleogeographic map of Paratethys (Popov etal. 2004, 2006).

Study Areas

The Indo-Pacific originated alien benthic foraminifers have been abundantly found in the surface sediment and drill samples on the Eastern Mediterranean coasts of Turkey, but they were also observed in the sediment samples from the north Aegean coasts and Sea of Marmara (Figure 2).

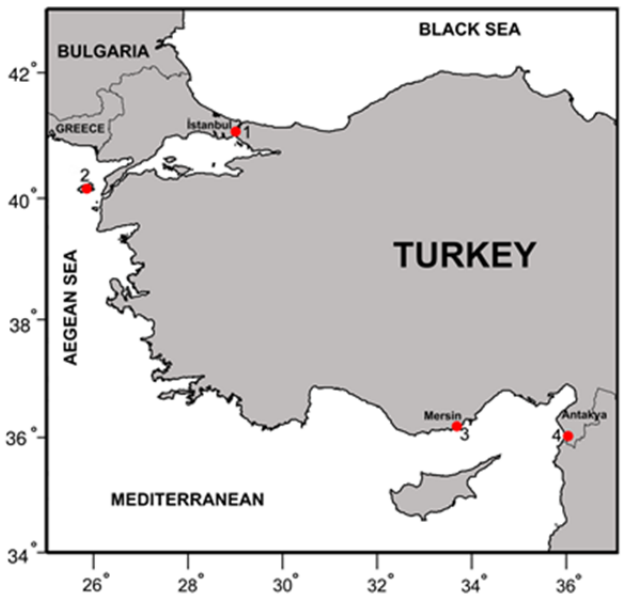

Figure 2. Distribution of Middle-Late Pleistocene and Holocene aged alien foraminifer observed in the drills from marine and coastal environments: 1. Golden Horn, 2. Gökçeada, 3. Akkuyu, 4. Samandağ.

Golden Horn (İstanbul)

During the subway line construction drill samples form Golden Horn have been investigated. In the 3 m and 9 m sections of HK-15 drill, *Sorites orbiculus*; in the 6 m section of HK-17 drill *Coscinospira hemprichii, Peneroplis pertusus, P. planatus* and *Sorites orbiculus* specimens were observed (Figure 2 and 3). Besides, in the 35.00-36.50, 36.50-38.00 and 68.50-68.95 m sections of HK-9 drill *Amphistegina lobifera* individuals were found. Except *Amphistegina lobifera*, majority of these specimens were having colored tests and gypsum crystals found in the sediment indicates the presence of hot water springs and special environmental characteristics suitable for these species (Alpar et al., 1997; Meriç et al., 2003; Burak et al., 2004; Önal, 2004; Suner et al., 2012).

The ESR (Electron Spin Resonance) analysis revealed the age of mollusk tests obtained from 38.70 m section of A-7 drill (New Galata Bridge) as 7.400±1.300 (Meriç and Sakınç, 1990; Göksu etal., 1990), indicating that these foraminifer species have lived in the Golden Horn about 6000 years ago.
b).

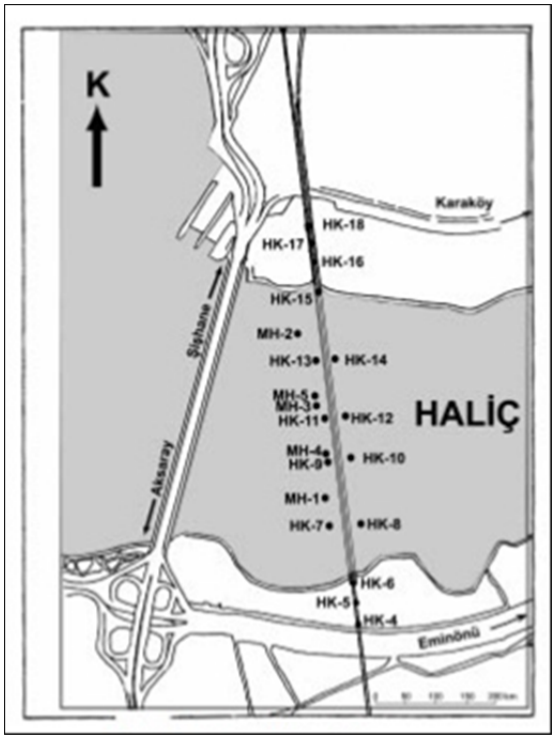

Fig 3. Location map of the drill stations of Golden Horn (from Meriç etal., 2003).

Gökçeada (Northeastern Aegean Sea)

A rich foraminifer fauna has been observed in the drill samples from Büyük Dere Valley (Northeastern Gökçeada), including Red Sea originated *Spiroloculina antillarum* in the 11.70-12.00 m section of GA-17 drill. Investigation of the gastropod *Cyclope donovania* tests from the 15.65-15.90 m section of GA-15 drill revealed the age of sediments as 8.194 ± 410 years (Figure 2 and 4) (Meriç et al., 2014).

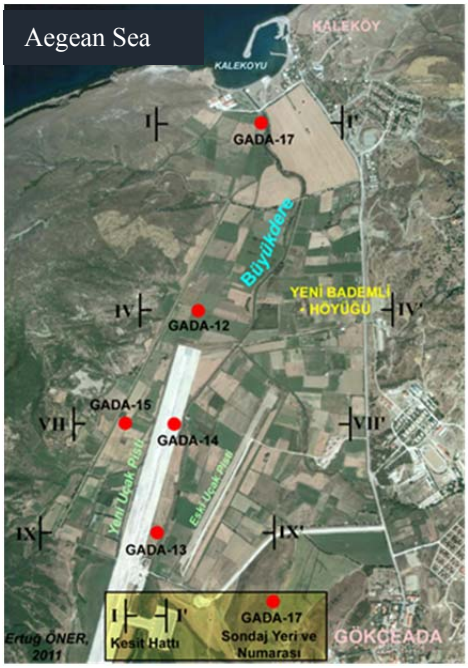

Fig 4. Drill stations in Büyük Dere Valley of Gökçeada (from Meriç etal, 2014).

Akkuyu (Mersin-Northeastern Mediterranean)

Surface sediment samples have been collected from Akkuyu (Figure 2). Amphistegina lobifera was abundantly observed, together with Spiroloculina antillarum, Peneroplis pertusus, P. planatus (Meriç etal. 2015a). With the OSL (thermoluminescence) method, the ages of sediments have been found as 227.3±17.8 (Middle Pleistocene), 87.7±9.6 (Late Pleistocene) and 6.0±0.6 (Holocene) thousand years before present.

OSL samples yielded 427.5 Ka (Middle Pleistocene) of age from AYD-1 sample (Figure 5). 24.00 m above this formation, alien species, such as Spiroloculina antillarum, Articulina carinata, Peneroplis pertusus, P. planatus were observed. This part of the sediments was suggested to have 300.0-350.0 years of age.

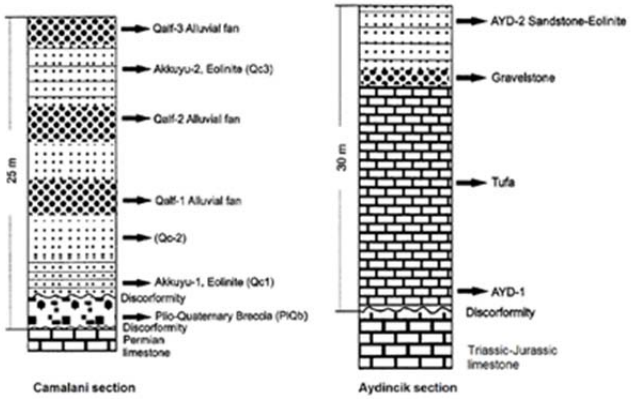

Figure 5. Generalized stratigraphical sections of Çamalanı and Aydıncık regions (from Meriç et al., 2016a).

Samandağ (Hatay-Northeastern Mediterranean)

The analysis of 5 drill samples taken from Asi Delta, west of Samandağ, Eastern Mediterranean (Figure 6 and 7) showed that Eastern Mediterranean- Red Sea connection has been still active 70,000 years ago (Late Pleistocene) through Red Sea-Dead Sea fault line (Meriç etal. 2015b). The presence of benthic foraminifer species, such as *Peneroplis pertusus, Astacolus insolithus, Siphonina tubulosa* and *Amphistegina lessonii* can be shown as proof of this hypothesis.

Amphistegina lobifera has not been observed in the 101 samples investigated. Numerous individuals of *Siphonina tubulosa* has been found in Asi-05 (1.20-13.00 m; 5 samples), Asi-06 (3.20-15.00 m; 13 samples), Asi-07 (2.80-14.70 m; 8 samples) and Asi-10 (1.50-8.00 m; 3 samples) drills. This species is known to inhabit Red Sea (Hottinger etal., 1993), but these findings indicate that it might have reached Samandağ via Red Sea-Dead Sea fault line (Meriç etal., 2015b). Today, it shows a wide distribution pattern along to Turkish coastline, from Samandağ to the depths of Sea of Marmara (Kırcı-Elmas, 2013; Meriç et al., 2016; Kırcı-Elmas and Meriç, 2016).

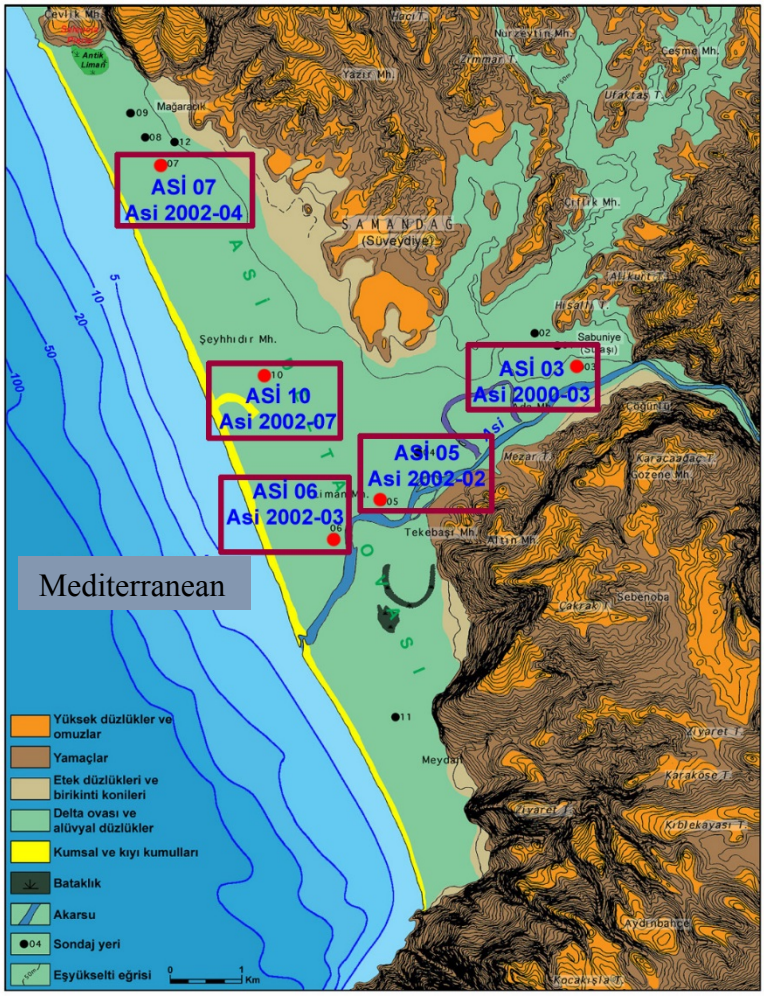

Figure 6. Location map of drill holes from P35 Maps of Turkey. Harita Genel Müdürlüğü (from Meriç et al., 2016b) .

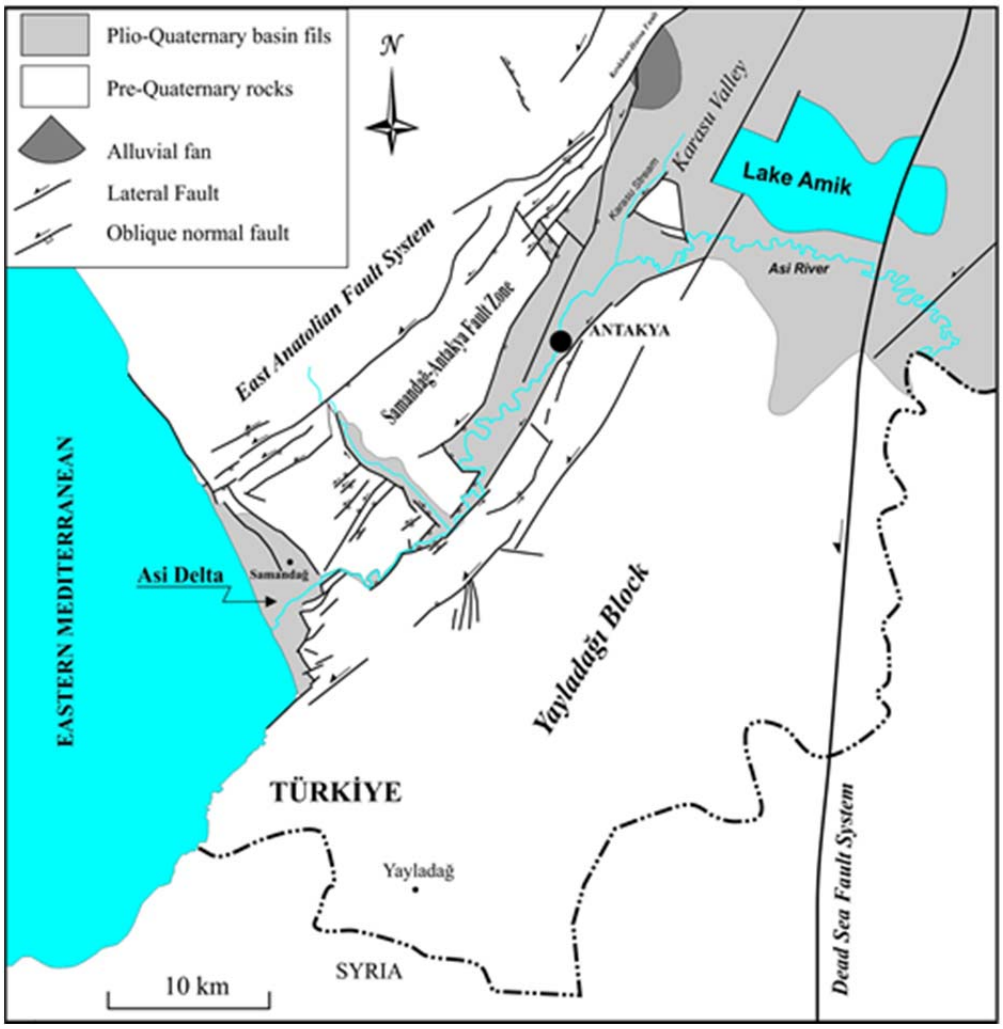

Figure 7. Fault and Quaternary map of Asi Delta Plain (Perinçek et al., 1987, Doğan et al., 2012).

Discussion

The alien benthic foraminifer species which are widely distributed in the Eastern Mediterranean, such as *Spiroloculina antillarum, Coscinospira hemprichii, Peneroplis pertusus, P. planatus, Sorites orbiculus, Astacolus insolithus, Siphonina tubulosa, Amphistegina lessonii* and *A. lobifera* are generally accepted to be recently entered the Eastern Mediterranean via Suez Canal (Langer etal., 2012; Weinmann etal., 2013). However, their presence in the sediment samples aged back to Middle Pleistocene-Late Pleistocene and Holocene, rules out the 149 years old Suez Canal to be responsible for their introduction. An introduction via the connection occurred on the Gulf Aqaba – Dead Sea Fault Line or Arabian Gulf – Mesopotamia Basin seems more probable (Figure 1) (Popov etal., 2004, 2006; Meriç etal., 2015b).

However, it was shown that recent populations of *Amphistegina lobifera* Larsen from the Eastern Mediterranean and Gulf of Aqaba are genetically identical (Schmidt et al., 2016), proving that the recent Mediterranean population has been introduced via Suez Canal. Thus, it is suggested that the population introduced via Gulf Aqaba-Dead Sea Fault Line has been vanished due to environmental changes occurred in the past, but the invasion

took place established once again after the opening of Suez Canal. Thus, the origins of the recent populations of *Spiroloculina antillarum, Articulina carinata, Peneroplis pertusus, P. planatus, Astacolus insolithus, Siphonina tubulosa* and *Amphistegina lessoni* found in the Eastern Mediterranean can be dated back to Middle-Upper Pleistocene, or they may be also recent introductions. Their status can be enlightened by more specific researches, mainly by genetic analysis.

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