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Did *Amphistegina lobifera* Larsen reach the Mediterranean via the Suez Canal?

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ABSTRACT

It has been accepted by many researchers that *Amphistegina lobifera* Larsen migrated to the Mediterranean Sea via Suez Canal like many other Indo-Pacific originated foraminifers and organisms. This idea was also supported in the studies performed on the Turkish Aegean and Mediterranean coast in the last ten years, due to the discovery of alien benthic foraminifers. However, during field research in the Akkuyu (Mersin) region, a rich benthic foraminifera assemblage was found in the sediment samples, in which *Amphistegina lobifera* Larsen was abundant. In the present study, when and how *Amphistegina lobifera* Larsen migrated to the Mediterranean was investigated.

Most of the *Amphistegina lobifera* Larsen individuals observed are found to show similar morphological characteristics with recent samples collected from Turkish coastline, which at first indicated that the individuals from Akkuyu might also be of Holocene age, but the OSL method produced dates of 227.3 ± 17.8, 87.7 ± 9.6 and 6.0 ± 0.6 ka. These ages are Middle Pleistocene, Late Pleistocene and Holocene. In one sample, aged 427.5 ± 29.4 ka, *Spiroloculina antillarum* d'Orbigny, which was suggested to be introduced to Mediterranean via the Suez Canal, was found together with *Articulina carinata* Wiesner. The presence of *Spiroloculina antillarum* d'Orbigny with *Amphistegina lobifera* Larsen together with in an other sample, aged 227.3 ± 17.8 ka, indicates that these foraminifers have been introduced to the Mediterranean in Middle Pleistocene and they might have been living in the Eastern Mediterranean since then. As a result, these age data show that *Amphistegina lobifera* Larsen individuals did not migrate to the eastern Mediterranean via the Suez Canal which was opened in 1869, but much earlier than that via a different natural water way connecting Indo-Pacific to the Eastern Mediterranean.

1. Introduction

The species of *Amphistegina* are found in tropical and subtropical parts of the oceans (Langer and Hottinger, 2000). *Amphistegina lessonii* d'Orbigny and *A. lobifera* Larsen are widely distributed in the Indo-Pacific, including Red Sea (McCulloch, 1977; Hatta and Ujiie, 1992; Hottinger et al., 1993; Loeblich and Tappan, 1994). Both species have also been recorded in the Mediterranean shallow habitats, but it is distributed mainly in the eastern part (Weinmann et al., 2013). In the Mediterranean, *A. lobifera* Larsen is more abundant than *A. lessonii* d'Orbigny, and the westernmost limits of *A. lobifera* is Malta (Yokeş et al., 2007) and Pelagian Island (Sicily) (Caruso and Cosentino, 2014).

Many Indo-Pacific originated marine species have been introduced to the Mediterranean Sea via the Suez Canal, and most of them have also been reported from Turkey (Çınar et al., 2011).

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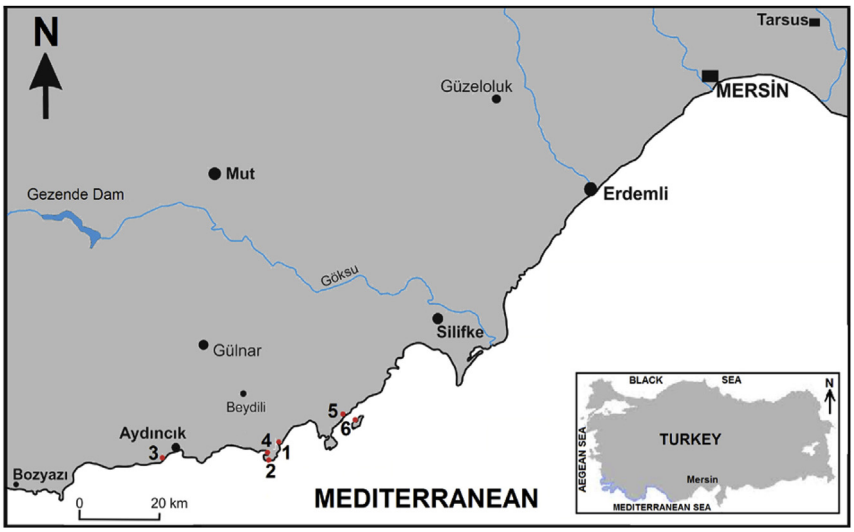

Fig. 1. Location map of study areas (1-Kusyuvasi, 2-Camalani, 3-Aydincik, 4-Mavi Cini, 5-Seal Cave, 6-Dana Island).

Because of its absence in the Western Mediterranean and Eastern Atlantic, the Eastern Mediterranean population of *A. lobifera* Larsen has been generally accepted to have originated from Red Sea population and was introduced via the Suez Canal (Yokeş et al., 2007; Zenetos et al., 2008; Triantaphyllou et al., 2009). However, recently tests of this species have been observed in sediment samples from Akkuyu (Mersin, Eastern Mediterranean), which are much older than the Suez Canal, suggesting that *A. lobifera* Larsen might have been in the Mediterranean much before the opening of the Suez Canal. The aim of this study is to figure out possible scenarios for the presence of *A. lobifera* Larsen in the Levantine Basin.

2. Materials and methods

Sixteen sediment samples were collected in 2012 from Aydincik, Mavi Cini, Camalani, Kusyuvasi Dana Island and the Seal Cave (Silifke-Aydincik, west of Mersin) (Fig. 1). 15 g of dry sediment from each sample were treated with 10% H_2O_2 for 24 h, then washed with pressurized water over 0.063 mm sieve. The washed samples were dried in an oven at 50 °C and sieved with mesh sizes of 2.00, 1.00, 0.500, 0.250, 0.125 mm. Foraminifer and ostracod species were identified under a binocular microscope.

Ages of eight samples have been determined by OSL (Table 1). Optically Stimulated luminescence (OSL) analyses were conducted at ISIK University, Luminescence Research and Archeometry Laboratory, in Istanbul. Sample preparation and OSL measurements were performed under subdued red light. Samples were wet sieved first to 180–212 μm and then cleaned with HCl before H_2O_2 treatment. Quartz grains were extracted using a subsequent HF acid etch. Therefore, the alpha irradiated rind of the quartz was assumed to have been removed by HF etching. The grains were tested for the absence of feldspar contamination using infrared stimulation (IRSL) before OSL measurements. The OSL measurements were carried out on an automated Risø TL/OSL reader of model TL/OSL-DA-15 equipped with an internal $^{90}Sr/^{90}Y$ beta source (~0.1 Gy s^{-1}), blue light emitting diodes (LEDs) (470 nm, ~40 mW cm^{-2}) and IR LEDs (880 nm, ~135 mW cm^{-2}). Luminescence signal was detected using an EMI 9635QA photomultiplier tube, fitted with Hoya U-340 filters of 7.5 mm total thickness (Bøtter-Jensen, 1997).

Table 1
The OSL ages and paleodoses (equivalent dose) obtained for the samples taken from different profiles.

Lab. No.	Depth (cm)	Age (ka)	Dose (Gy)	(n)	Dose rate (Gy/ka)
Akkuyu-1	15	227.3 ± 17.8	100.9 ± 5.2	22	0.4 ± 0.0
Akkuyu-2	20	167.2 ± 20.1	61.4 ± 5.7	14	0.3 ± 0.0
Kuy-1	20	113.1 ± 15.0	47.9 ± 5.4	14	0.4 ± 0.0
Kuy-2	20	92.6 ± 7.6	47.0 ± 2.7	12	0.5 ± 0.0
Kuy-3	15	87.7 ± 9.6	49.8 ± 4.7	14	0.5 ± 0.0
MC-1	300	6.0 ± 0.6	1.9 ± 0.1	9	0.3 ± 0.0
MC-2	250	2.7 ± 0.3	0.9 ± 0.0	10	0.3 ± 0.0
AYD-1	25	427.5 ± 29.4	231.6 ± 9.2	24	0.5 ± 0.0
AYD-2	No results have been obtained since the sample did not include quartz.				

The paleodose or equivalent dose (D_e) accumulated in quartz grains was estimated using single-aliquot regenerative-dose (OSL-SAR) protocol (Murray and Mejdahl, 1999; Murray and Wintle, 2000). The protocol is basically based on the comparison of the natural OSL signal with the OSL signals produced by a known laboratory doses for each sample. Aliquots were first preheated at 260 °C temperature for 10 s and then recorded with blue light stimulation at 125 °C for 40 s to obtain OSL signals of natural and regenerative doses. The possible sensitivity change during measurements was monitored and corrected using a test dose administered (approximately 10–20% of the natural dose) to the same aliquots prior to heating to 190 °C to release electrons from shallow traps. Corrected OSL signals were used to construct a growth curve in which the sensitivity corrected natural signal is interpolated onto the growth curve to obtain the paleodose (*De*) estimate. The OSL measurements appeared reliable based on growth curves and dose recovery tests.

The dose rate of the natural environment was derived from U, Th and K concentrations obtained by ICP-ES/ICP-MS analysis. The alpha dose component was not considered due to HF etching treatment to the quartz grains by which irradiated rind of the quartz was assumed to have been removed. The β and γ dose components of natural dose rate were calculated using the conversion factors as presented by Olley et al. (1996). The cosmic ray contribution to the dose rate was found using the formula given by