Early Pliocene molluscs from the easternmost Mediterranean region (SE Turkey): biostratigraphic, ecostratigraphic, and palaeobiogeographic implications

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Abstract: The mollusc faunas from Pliocene deposits of the Hatay-İskenderun region were investigated at nine localities and complemented with three localities from earlier studies. The Pliocene units were deposited in three adjacent subbasins, Hatay-Samandağ (HS), Altınözü-Babatorun (AB), and İskenderun-Arsuz (IA); the first two are also known as the Hatay Graben. Basin configurations and shape, environmental evolution, and faunal compositions were affected by differential tectonic histories since the Late Miocene. In total 162 species (94 gastropod, 61 bivalve, and 7 scaphopod) are recorded, 80 of which are recorded for the first time from the region. The occurrence of tropical stenohaline benthic taxa (such as Persististrombus coronatus and some conid gastropod species) and a number of chronostratigraphically well-constrained mollusc species shows a Zanclean age. The base of the Early Pliocene is also shown by the occurrence of planktic foraminifer assemblages corresponding to MPL1 and MPL2 biozones and the nannoplankton Amaurolithus delicatus assemblage. The Early Pliocene Hatay molluscan assemblages allow for palaeobiogeographic comparisons across the Mediterranean. The Pliocene marine fossiliferous deposits are assigned to the Mediterranean Pliocene Molluscan Unit 1 (MPMU1) of the western Mediterranean and Atlantic regions. However, the eastern Mediterranean assemblages are notably poorer in species and in particular a number of thermophilic groups are lacking. This marine biodiversity gradient has been a characteristic feature of the Mediterranean ever since the Pliocene.

Key words: Zanclean, Gastropoda, Bivalvia, Scaphopoda, stratigraphy, palaeoecology, Hatay basin

1. Introduction
The Hatay Graben (HG) is an asymmetrical fault-controlled basin in the easternmost margin of the Mediterranean. Tectonic activity results from a complex interaction of several major regional fault systems including the East Anatolian Fault, the Cyprus Arc, and the Dead Sea Fault (Aksu et al., 2005; Boulton et al., 2006, 2007; Boulton and Robertson, 2007, 2008; Tarı et al., 2014) (Figure 1). The HG consists of several subbasins that have a Late Miocene-Pliocene fill. The basinal configuration, stratigraphy, and depositional environments of these subbasins were mainly affected by changing tectonic regimes from a late-stage continental collision phase in the Late Miocene (Messinian) to a westward tectonic escape during Early Pliocene (Zanclean) times (Boulton et al., 2006, 2016; Boulton and Robertson, 2007, 2008). The area consists of two tectonically originated NE-SW directed small subbasins, the Hatay-Samandağ (HS) and Altınözü-Babatorun (AB), and the neighbouring İskenderun-Arsuz (IA) basin. The latter is separated by the structural highlands of Amanos-Kızıldağ and the Misis complex, whereas the Ziyaretdağ-Kılıçdağ mountains separate the HS and AB (Kozlu, 1997; Tekin et al., 2010) (Figure 1).

A Late Miocene-Pliocene succession is exposed in these basins. It concerns mostly marine deposits, yet the basin fill has also been affected by lowstands of the Mediterranean Messinian Salinity Crisis prior to the Zanclean reflooding. Pliocene molluscs in the easternmost part of Mediterranean region have been reported since the early 20th century from Turkey and part of Syria and Lebanon (Daus, 1914; Dubertret et al., 1937; Roman, 1940). Erentöz (1955) described different lithological successions in the Samandağ region (Turkey), called “marl”, “marl and sandstone”, “sandstone”, “coral limestone”, and “pebble” series. She assigned Lower Tortonian, Upper Tortonian, and Mio-Pliocene ages to the different
units based on their foraminifer and mollusc content. Erünal-Erentöz (1958) made a comprehensive taxonomic documentation of the mollusc faunas as a part of her PhD thesis and assigned a Piacenzian age based on molluscs. In the 1980s these Pliocene deposits were described as the Samandağ Formation (Selçuk, 1981, 1985). A faunal assessment of these Pliocene deposits in the HS subbasin was made by Karakuş and Taner (1994) but it is in need of revision. Mollusc faunas from the Aktepe Formation of the IA subbasin were briefly reported by İslamoğlu et al. (2009). The newly collected material increases the regional coverage and enables to assess the palaeoecology, age, and biogeographic signature of the entire Pliocene fauna from the Hatay Graben region.

Pliocene-Pleistocene molluscan ecobiostratigraphic units (so-called MPPMUs) have been proposed for the western-central Mediterranean and the eastern Atlantic. These MPPMUs are bounded by a series of molluscan extinction events (Raffi and Monegatti, 1993; Monegatti and Raffi, 2001, 2007; Landau et al., 2011). The Hatay faunas are sufficiently preserved to make a comparison with these MPPMUs and allow for an extension of this scheme into the East Mediterranean area.

The aim of this work is 1) to describe the Early Pliocene molluscan assemblages obtained from the two subbasins (HS and AB) in the Hatay Graben and neighbouring IA subbasin, 2) to constrain their stratigraphic age and understand their palaeoenvironments, and 3) to compare our molluscan data with the western Mediterranean ecostratigraphic units of Monegatti and Raffi (2001) and to explore the biogeographic significance of these East Mediterranean faunas.

2. Geological setting
The Hatay Graben is bounded by the Dead Sea Fault Zone (DSFZ) and East Anatolian Fault Zone (EAFZ) in the east and the Cyprus Arc (CA) in the west. These have shaped the basin since the Late Miocene (Perinçek and Çemen, 1990; Boulton et al., 2006, 2007; Boulton and Robertson, 2008; Ediger et al., 1996 Tari et al., 2014; Boulton and Robertson, 2016). Late Tortonian normal faults with NW-SE directed right-lateral strike slip components are common. During the Tortonian, fine detritics (marls and sandy marls) of the Nurzeytin Formation formed while the basin underwent an extensional tectonic regime (Boulton and Robertson, 2007; Boulton et al., 2007). Marine Early Messinian deposits have
been reported from limited areas in the eastern part of the HG (Tekin et al., 2010). The Late Messinian is represented by evaporitic deposits (Vakıflı Formation), developed in the western and southern margins of the HG (Tekin et al., 2010; Boulton et al., 2016). Evaporitic sediments consist of two gypsum sequences, a lower interbedded unit and an upper chaotic unit (Tekin et al., 2010). During the Early Pliocene the HG consisted of three subbasins reflected in the deposition of three different units: the Samandağ Formation in the HS, the Aktepe Formation in the IA, and the (informal) Altınözü Formation in the AB subbasin. The latter is unconformably overlying Messinian units. Shallow and deeper marine sediments of the Samandağ Formation in the HS subbasin overlay the Tortonian, Messinian, and Mesozoic ophiolitic units (Tekin et al., 2010). Transitional levels from evaporates to non-evaporitic siliciclastic and carbonate units have been examined in several works based on the combination of planktonic foraminifer-ostracod and strontium isotope analyses (Boulton et al., 2007). They showed the resumption of marine deposition during the Early Pliocene. In the IA subbasin, the Early Pliocene shallow marine Aktepe Formation overlies Messinian evaporites (Haymaseki Formation) through a low-grade unconformity (Kozlu, 1997) but there is

Figure 1. (Continued).
3. Materials and methods
This study is based on newly collected mollusc material as well as material collected by Erünel-Erentöz (1958). The new material derives from sections and localities that were lithologically documented. Age estimates for these deposits were obtained from nannoplankton and planktonic foraminifer analyses performed on sediment samples from the sections. For mollusc analyses about 1 kg of sediment was processed per sample. Sediment was wet-sieved (diameter: 1 mm) in the Ankara University Geological Engineering Department’s sedimentology laboratory and at the General Directory of Mineral Research and Exploration (MTA), Department of Geology, Palaeontology Laboratory. In the residues, mollusc shells were sorted and documented by macroscopic photography (Leica MZ8 for shells of <2 cm and Canon camera for shells of >2 cm) in the Ankara University Geological Engineering Department. Mollusc shells are stored in the Geological Engineering Department of Bülent Ecevit University, Zonguldak (Turkey) and the PhD collections of Erünel-Erentöz (1958) reside in the Geological Engineering Department of Ankara University. Mollusc taxonomy for species that are extant follows WoRMS (www.WoRMS.org).

4. Results
In total nine stratigraphical sections were measured from the Early Pliocene deposits and samples were collected from mollusc-rich clayey-silty sands and mudstones of the Aktepe, Samandağ, and Altınözü formations (Figure 2). The sample coordinates and lithologies are given in Table 1.

A total of 162 species of molluscs are investigated in this work, 86 of which are recorded for the first time from the Early Pliocene of the eastern Mediterranean. Results of mollusc analyses are given in Tables 2–5. Specific nannoplankton and planktonic foraminifer species are only found in the HS subbasin (Samandağ Formation), supporting the Early Pliocene age of the deposits (Table 6; Figure 3). Some specific mollusc species are illustrated in Figures 4–9.

4.1. Litho- and biostratigraphy

4.1.1. Samandağ Formation (HS subbasin)
Six stratigraphical sections were measured and sampled (Figures 2 and 10). The earliest Pliocene Samandağ Formation consists of fossiliferous yellow sandstones and grey mudstones (Boulton et al., 2016). The unit overlays Messinian evaporites of the Vakıflı Formation that contain grey mudstone/marl interbeds in the Mızraklı-Kireçtepe section. The sections are rich in microfossils and molluscs.

Mızraklı-Kireçtepe section: In this section a combined micropalaeontological and mollusc inventory was made. The lowermost dark grey muds and marls (samples 08-11-28a–d) yield a very rich planktonic foraminifer fauna (Table 6). The sample is rich in Sphaeroidinellopsis species but Globorotalia marginatae is lacking. This corresponds to the lowermost Pliocene Sphaeroidinellopsis acme zone (MPL1 of Cita, 1973, 1975a, b; Meulenkamp et al., 1979, 1994). Upwards in the section marl intervals occur with abundant planktonic foraminifers (samples 08-11-30a, 08-11-30b, and 08-11-31; Table 6). The assemblage and especially the occurrence of Globorotalia marginatae are indicative of the MPL2 biozone (Cita, 1973; Lourens et al., 2004). The Early Pliocene nannoplankton assemblage of the Mızraklı section contains 13 species (Table 6) that are also indicative of a Zanclean age.

The abundant mollusc fauna contains 48 species indicative of an Early Pliocene (Zanclean) age (Tables 2 and 3). The faunal community represents shallow marine conditions with the grazer Thericium crenatum indicating the presence of (some) sea grass.

Kuşalanı section: The mollusc fauna (39 species: Tables 2 and 3) is composed of shallow marine species with three cerithid gastropods species (Bittium latreillei, B. reticulatum, Thericium crenatum) indicating sea grass habitats to be present.

Sutaşı section: Here a very similar shallow marine mollusc fauna (25 species: Tables 2 and 3) was found, slightly less rich in species and more dominated by bivalves.

Kecesik/Karlısuyu section: The 9 species (Tables 2 and 3) indicate slightly deeper depositional depths than the previous sections with more common scaphopods, Anmusium cristatum and Nucula placentina.

Telliturna section: Three shallow marine species and 1 subtropical gastropod (Oliva sp.) were found in the section (Tables 2 and 3).

Karaali section: In the lower part 12 marine mollusc species were found, including the subtropical Conus antidiluvianus (Table 2). In the upper part 14 marine
Figure 2. Geological map of the region and localities of the measured stratigraphical sections (1: Mızraklı-Kireçtepe section, 2: Kuşalanı section, 3: Sutaşı section, 4: Kesecik/Karlısuyu section, 5: Telliturna section, 6: Karaali section, 7: Babatorun section; 8: Büyükdere section, 9: Aktepe section) (modified from Tekin et al., 2010).
Table 1. Sample numbers, coordinates, and lithologies of the fossiliferous levels.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>SAMPLE NUMBER</th>
<th>GPS COORDINATES</th>
<th>Altitude</th>
<th>LITHOLOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altınözü-Babatorun (AB) Subbasin (Altınözü formation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kesecik/Karlısuyu</td>
<td>10_06_14</td>
<td>3999653 N - 370233850 E</td>
<td>132 m</td>
<td>sandstone-marl</td>
</tr>
<tr>
<td>Kesecik/Karlısuyu</td>
<td>10_02_14</td>
<td>4019083 N - 37246839 E</td>
<td>134 m</td>
<td>dark grey colored marl</td>
</tr>
<tr>
<td>Kesecik/Karlısuyu</td>
<td>10_02_15</td>
<td>4015668 N - 37241087 E</td>
<td>237 m</td>
<td>dark grey colored marl-claystone</td>
</tr>
<tr>
<td>Mızraklı/Kireçtepe</td>
<td>13_10_06b</td>
<td>4001363 N - 37231157 E</td>
<td>110 m</td>
<td>dark grey colored mudstone - marl</td>
</tr>
<tr>
<td>Mızraklı/Kireçtepe</td>
<td>13_10_07</td>
<td>4001363 N - 37231157 E</td>
<td>110 m</td>
<td>dark grey colored mudstone - marl</td>
</tr>
<tr>
<td>Mızraklı/Kireçtepe</td>
<td>08_11_38</td>
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</tr>
<tr>
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<td>4001257 N - 37232813 E</td>
<td>79 m</td>
<td>marl-claystone</td>
</tr>
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<td>Mızraklı/Kireçtepe</td>
<td>13_10_07</td>
<td>4001363 N - 37231157 E</td>
<td>110 m</td>
<td>dark grey colored marl</td>
</tr>
<tr>
<td>Sutaşı</td>
<td>09_06_17</td>
<td>3997484 N - 372329996 E</td>
<td>32 m</td>
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</tr>
<tr>
<td>Sutaşı</td>
<td>09_06_19</td>
<td>3990557 N - 37229730 E</td>
<td>143 m</td>
<td>marl-mudstone</td>
</tr>
<tr>
<td>Sutaşı</td>
<td>09_06_24</td>
<td>4006698 N - 37241416 E</td>
<td>81 m</td>
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<tr>
<td>Sutaşı</td>
<td>10_11_02</td>
<td>4006698 N - 37241416 E</td>
<td>80 m</td>
<td>marl-mudstone</td>
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<tr>
<td>Sutaşı</td>
<td>10_02_01</td>
<td>3997838 N - 37232813 E</td>
<td>47 m</td>
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<tr>
<td>Sutaşı</td>
<td>10_02_25</td>
<td>3991870 K - 372329306 E</td>
<td>143 m</td>
<td>sandstone-mudstone-marl</td>
</tr>
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<td>Kanaal</td>
<td></td>
<td></td>
<td>134 m</td>
<td>dark grey marl</td>
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<td>Kanaal</td>
<td>10_02_23a</td>
<td>4014845 N - 37241722 E</td>
<td>216 m</td>
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<td>Kupaşlı</td>
<td>Kup1</td>
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<td>370 m</td>
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</tr>
<tr>
<td>Kupaşlı</td>
<td>Kup2</td>
<td>4006234 N - 372770303 E</td>
<td>370 m</td>
<td>dark grey colored marl-mudstone</td>
</tr>
<tr>
<td>Kupaşlı</td>
<td>Kup3</td>
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<td>370 m</td>
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<td>Kupaşlı</td>
<td>Kup4</td>
<td>4006234 N - 372770303 E</td>
<td>370 m</td>
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<tr>
<td>Kupaşlı</td>
<td>Kup5</td>
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<td>370 m</td>
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<td>Kupaşlı</td>
<td>Kup6</td>
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<td>370 m</td>
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</tr>
<tr>
<td>Kupaşlı</td>
<td>Kup7</td>
<td>4006234 N - 372770303 E</td>
<td>370 m</td>
<td>dark grey colored marl-mudstone</td>
</tr>
<tr>
<td>Kupaşlı</td>
<td>Kup8</td>
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<td>370 m</td>
<td>dark grey colored marl-mudstone</td>
</tr>
<tr>
<td>Kupaşlı</td>
<td>Kup9</td>
<td>4006234 N - 372770303 E</td>
<td>370 m</td>
<td>dark grey colored marl-mudstone</td>
</tr>
<tr>
<td>Kesecik/Kaşafusuyu</td>
<td>09_12_14</td>
<td>3996653 N - 372033850 E</td>
<td>132 m</td>
<td>sandstone-mudstone</td>
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<tr>
<td>Kesecik/Kaşafusuyu</td>
<td>09_12_14</td>
<td>4018683 N - 37248839 E</td>
<td>134 m</td>
<td>dark grey colored marl</td>
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<tr>
<td>Kesecik/Kaşafusuyu</td>
<td>10_02_15</td>
<td>4016668 N - 37241897 E</td>
<td>237 m</td>
<td>dark grey colored marl-claystone</td>
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<tr>
<td>ALTAÇ-SUBATLAR (AS) Subbasin (Altaç formation)</td>
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<td></td>
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<tr>
<td>Babatorun</td>
<td>10_12</td>
<td>3995779 N - 37256516 E</td>
<td>470 m</td>
<td>yellowish sandstone</td>
</tr>
<tr>
<td>Babatorun</td>
<td>10_12a</td>
<td>3995779 N - 37256516 E</td>
<td>470 m</td>
<td>yellowish sandstone</td>
</tr>
<tr>
<td>Babatorun</td>
<td>10_03_14a</td>
<td>3995779 N - 37256516 E</td>
<td>473 m</td>
<td>yellowish sandstone</td>
</tr>
<tr>
<td>Babatorun</td>
<td>10_03_14c</td>
<td>3995779 N - 37256516 E</td>
<td>473 m</td>
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<td>3995780 N - 37256517 E</td>
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<td>cream colored clayey limestone</td>
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<td>Babatorun</td>
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<td>3995781 N - 37256512 E</td>
<td>465 m</td>
<td>cream colored clayey limestone</td>
</tr>
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<td>Babatorun</td>
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<td>465 m</td>
<td>cream colored clayey limestone</td>
</tr>
<tr>
<td>Babatorun</td>
<td>10_09_13</td>
<td>3995783 N - 37256520 E</td>
<td>463 m</td>
<td>dark grey colored marl</td>
</tr>
<tr>
<td>Babatorun</td>
<td>10_08_14</td>
<td>3995784 N - 37256514 E</td>
<td>453 m</td>
<td>dark grey colored marl-claystone</td>
</tr>
<tr>
<td>Babatorun</td>
<td>10_08_15</td>
<td>3995785 N - 37256522 E</td>
<td>453 m</td>
<td>yellow colored sandstone</td>
</tr>
<tr>
<td>Babatorun</td>
<td>11_03_14a</td>
<td>3995774 N - 37256520 E</td>
<td>443 m</td>
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<tr>
<td>Babatorun</td>
<td>11_03_14b</td>
<td>3995784 N - 37256521 E</td>
<td>478 m</td>
<td>grey colored marl-claystone</td>
</tr>
<tr>
<td>Babatorun</td>
<td>11_03_14c</td>
<td>3995794 N - 37256511 E</td>
<td>470 m</td>
<td>dark grey colored marl</td>
</tr>
</tbody>
</table>
mollusc species were found. Both intervals are dominated by bivalve species (Table 3).

4.1.2. Altınözü Formation (AB subbasin)
One stratigraphical section (Babatorun) was logged and sampled assigned to the Altınözü Formation (Figures 2 and 11). Unlike the other subbasins, the assemblage includes mixed marine and reworked brackish water fossils.

Babatorun section: Theodoxus cf. mutinense (D’Ancona 1869), Erobria sp., Gyraulus sp., Melanoides sp., and Mytilopsis sp. are oligohaline-mesohaline species that represent latest Miocene anomalohaline lacustrine conditions. These lake intervals are overlain and partially mixed with a shallow marine fauna (Tables 2 and 3), indicating the rapid environmental change from anomalohaline lacustrine (latest Miocene) to shallow marine (early Pliocene) settings.

4.1.3. Aktepe Formation (IA subbasin)
The lowest Pliocene mollusc-bearing unit comprises lagoon-beach and channelised tidal flat filled with conglomerate and cross-bedded sandstone deposits with interbedded channelised sandstones and conglomerates. Two stratigraphical sections were measured (Aktepe and Büyükdere sections) (Figures 2 and 12).
Table 3. Sample numbers and distribution of the bivalves.

<table>
<thead>
<tr>
<th>STRATIGRAPHICAL RANGE</th>
<th>Eastern Atlantic</th>
<th>Western Mediterranean</th>
<th>Central Mediterranean</th>
<th>E Mediterranean</th>
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<td>Miocene</td>
<td>Pliocene</td>
<td>Pleistocene</td>
<td>Holocene</td>
<td>Miocene</td>
</tr>
<tr>
<td>Bivalvia</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Anima ephippium</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Corbula gibba</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Büyükdere section: Only a few marine species were found (Anoma ephippium and Corbula gibba) in the Büyükdere section.

Akdere section: The Akdere section is rich in marine molluscs and nannoplankton. The unit is overlying a series of mostly dolomitic carbonates, clayey carbonate (attapulgite/palygorskite), and coal-bearing layers (Karakaş et al., 2009) containing plant remains but lacking mollusc fossils.

4.2. Palaeoecology and ecobiostatigraphy

The general preservation of molluscs is very good with very little abrasion, indicating deposition below the storm wave base. An exception is the basal interval of the Aktepe Formation of the İA subbasin that represents very shallow (possibly tidal flat) environments. Furthermore, some of the Altnözü faunas are a mixture of very shallow marine and oligohaline lacustrine biota. The studied faunas represent marine conditions and different depth ranges. The occurrence of sea grass-related species in several sections is indicative of relative clear water habitats in the photic zone whereas faunas with common propeamusiid bivalves, pteropod, and scaphopod species represent conditions well below the storm wave base and possibly even below water depths of 100 m. Especially within the Mizrakli-Kireçtepe section, the fossiliferous grey mudstones and marls rich in propeamusiid-scaphopod molluscs, planktic foraminifers, and nannoplankton show the rapid deepening at the onset of the Zanclean. Today, nuculoid-, propeamusiid-, and scaphopod-dominated faunas typically occur below water depths of 100 m in the Mediterranean (Büyükmeriç, 2016).
Within the Iskenderun subbasin a lateral relationship was observed at the base of the Pliocene succession: the lowest mollusc-bearing layer represents tidal flat deposits with the interbeds of channelised sandstone and conglomerates grading laterally into 10-m-thick marly shelf deposits with fossils of the Aktepe Formation. Upwards the unit becomes dominated by mudstones with abundant marine faunas containing Zanclean indicator taxa such as the gastropods *Nisco terebellum pygmaea* and *Cochlis epiglottina funicillata*. These faunas represent salinities of about 35 ppm or even slightly higher.

### 5. Discussion

The Hatay region is important to understand the Early Pliocene palaeobiogeography in the eastern Mediterranean region. A complete faunal recolonisation occurred in the Mediterranean after the Messinian Salinity Crisis and the succeeding brackish Lagomare phase (Hsü et al., 1978). At the onset of the Pliocene, Mediterranean basins were recolonised with marine biota from the Atlantic while many Tethyan taxa that were abundant until the Late Tortonian-Early Messinian were not reestablished (Harzhauser et al., 2002). The post-Messinian marine fauna represents a subtropical fauna that is the ancestor of the modern Mediterranean-Atlantic Region (MAR) fauna whose composition evolved through the cooling and further immigration events of the Late Pliocene and Quaternary. The Early Pliocene fauna studied here reflects the early recolonisation of the Mediterranean after the Messinian.
Biogeographical boundaries reflecting the latitudinal changes are determined by major changes in thermal gradients (Monegatti and Raffi, 2001). Mollusc assemblages, and thermophilic benthic molluscs in particular, are important proxies for the determination of palaeobiogeographical boundaries and the estimation of ancient shallow marine thermal conditions, as well as excellent ecosтратigraphic tools. Diverse faunas with common thermophilic taxa such as *Persististrombus coronatus* and species of Conidae, Terebridae, Cypraidae, and Veneridae are characteristic for Mediterranean Pliocene faunas of the Central Mediterranean (Landau et al., 2011). Based on the planktonic foraminiferal data (MPL1 and MPL2 biozones), the Hatay faunas are assigned an Early Zanclean age.

The total number of gastropod species from the Early Pliocene of the HG (94) is lower than that of the western Mediterranean and adjacent Atlantic. A total of 269 gastropod species were found in the Guadalquivir basin (SW Spain, Atlantic: Landau et al., 2011) that has a lower habitat diversity than the Hatay region, whereas more than 1000 species have been estimated in the Estepona outcrops that nowadays seem to have largely disappeared. The total number of gastropod species from the Early Pliocene of the HG (94) is lower than that of the western Mediterranean and adjacent Atlantic. A total of 269 gastropod species were found in the Guadalquivir basin (SW Spain, Atlantic: Landau et al., 2011) that has a lower habitat diversity than the Hatay region, whereas more than 1000 species have been estimated in the Estepona outcrops that nowadays seem to have largely disappeared. Based on the planktonic foraminiferal data (MPL1 and MPL2 biozones), the Hatay faunas are assigned an Early Zanclean age.

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infralittoral and circalittoral environments are recorded from the Italian Pliocene (Marasti and Raffi, 1977, 1980). According to data available on the Italian Pliocene distribution of bivalves, *Aequipecten scabrella* (Lamarck, 1819) and *Flabellipecten flabelliformis* (Brocchi, 1814) are the most common and most representative of the Mediterranean Pliocene (Monegatti and Raffi, 2001). In the Hatay basin, 61 bivalve species have been determined. Although the species numbers are lower, the Hatay assemblage can be correlated to MPPMU1 of the Middle Mediterranean, having warm-water taxa, pectinids, glycymerids, *Acanthocardia*, and *Cardita* (Monegatti and Raffi, 2001; Raffi and Monegatti, 1993). This diversity trend exists even today with eastern Mediterranean faunas being less diverse than those in the central and western Mediterranean (Coll et al., 2010; Matalpa et al. 2011; Giacobbe, 2012). The relative low diversity of the Hatay faunas may be partially explained by the apparent lack of firm-ground habitats and the upwelling of well-ventilated oceanic water masses that in part explain the extreme high diversity in the western Mediterranean at the same time. However, the potential sea grass-related faunal component in the Hatay faunas consists of only 3 cerithiid and one *Tricoria* species and is lacking the highly diverse rissoid faunas that did occur within the western and central Mediterranean during the Early Pliocene. At this stage it is unclear why such large diversity gradients developed but it is likely that the location of the Hatay Graben farthest away from the source area of the post-Messinian recolonisation in the Mediterranean may explain part of the pattern. Furthermore, a relative low habitat diversity may contribute to the low number of species.
Figure 4. A1, A2- *Nassarius prismaticus* (Brocchi, 1814), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-32; B1, B2- *Nassarius semistratus* (Brocchi, 1814), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-31; C1, C2- *Nassarius semistratus* (Brocchi, 1814), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-31; D- *Nassarius elatus* (Gould, 1845), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-32; E1, E2- *Nassarius striatulus striatulus* (Eichwald, YB collection, 1829), HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-30a; F1, F2- *Bolma (Ormastralium) fimbriata* (Borson, 1821), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-32; G- *Turritella tricarinata* Brocchi, 1814, YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-38; H1, H2- *Nassarius cf. clathratus* (Born, 1778), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-32; I1, I2- *Clavatula* sp., YB collection, IA subbasin, Aktepe Formation, Aktepe section, 08-11-06c; J1, J2- *Ringicula (Ringiculina) auriculata* (Ménard, 1811), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-38; K- *Ringicula (Ringiculina) auriculata* (Ménard, 1811), HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, YB collection, 08-11-31; L1, L2- *Arcularia gibbosula phocallina* (Sacco, 1890), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-32; M1, M2- *Cochlis catena latostensis* (Sacco, 1890), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-32; N- *Cochlis pseudopigletina* (Sacco, 1890), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-38; O1, O2- *Antalis vulgaris vitreae* (Gmelin, 1790), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-32; P1, P2- *Dentalium sexangulum* Schröter, 1784, YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-30a; R1, R2- *Dentalium (Antalis) fossile* Schröter, 1784, YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-38; S1, S2- *Gadilina triguetra trigueria* (Brocchi, 1814), YB collection, IA subbasin, Aktepe Formation, Aktepe section, 08-11-06a; T- *Antalis vulgaris vitreae* (Gmelin, 1790), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-31. Scale bar: 0.5 cm.
Figure 5. A1, A2- *Niso terebellum pygmaea*, YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-32; B1, B2- *Mitrella (Clinurella) minima* (Sacco, 1890), YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-38; C- *Daphnella (Daphnella) textile* (Brocchi, 1814), YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-32; D- *Siphonochelus fistulosus* (Brocchi, 1814), YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-33; E- *Bela* sp., YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-31; F- *Turritella tricarinata* Brocchi, 1814, YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-38; G- *Vexillum ebens pyramidella*, YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-32; H- *Nassarius elatus* Gould, 1845, YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-33; I- *Nassarius plomagnum* (Sacco, 1904), YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-33; J1, J2- *Drillia* sp., YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-32; K1, K2- *Olivella* sp., YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-32; L- *Conus* sp., YB collection, HS subbasin, Samanadağ Formation, Mızraklı-Kireçtepe section, 08-11-38; M- *Turritella aspera* Sismoda in Mayer, 1866, YB collection, İA subbasin, Aktepe Formation, Aktepe section, 09-06-06; N- *Bullaria subampulla* d'Orbigny, 1852, YB collection, İA subbasin, Aktepe Formation, Aktepe section, 09-06-17; O- *Lyromangelia crassicostata* Scarponi and Della Bella, 2010, YB collection, İA subbasin, Aktepe Formation, Aktepe section, 09-06-06; P1, P2- *Clavatula ditissima* (Mayer, 1874), YB collection, İA subbasin, Aktepe Formation, Aktepe section, 09-06-06. Scale bar: 1 mm.
Figure 6. A1, A2 - *Strioterebrum pliocenicum* (Fontannés, 1880), YB collection, HS subbasin, Samandağ Formation, Kuşalanı section, Kuş-2; B1, B2 - *Terebra acuminata* Borson, 1820, YB collection, HS subbasin, Samandağ Formation, Kuşalanı section, Kuş-2; C - *Thericium crenatum* (Brocchi, 1814), YB collection, HS subbasin, Samandağ Formation, Kuşalanı section, Kuş-2; D1, D2 - *Conus* (*Chelyconus*) *pyrula mucronata* (Brocchi, 1814), YB collection, HS subbasin, Samandağ Formation, Kuşalanı section, Kuş-2; E1, E2 - *Persististrombus coronatus* (Defrance, 1827), L. Erentöz collection, HS subbasin, Samandağ Formation (scale bar: 1 cm); F1, F2, F3 - *Persististrombus coronatus* (Defrance, 1827), L. Erentöz collection, HS subbasin, Samandağ Formation (scale bar: 1 cm); G - *Gemmula rotata* (Brocchi, 1814), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14c; H1, H2 - *Nassarius nitidus* (Jeffreys, 1867), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 03-14c; J - *Petalocomehus intortus* (Lamarcq, 1818), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14c; J - *Raphitoma sp.*, YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; K - *Clathurella spreafici* Bellardi, 1877, YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; L - *Turbonilla rufa* (Philippi, 1836), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; M - *Thericium crenatum* (Brocchi, 1814), YB collection, AB, Altınözü Formation, Babatorun section, 11-03-14b; N - *Turritella erronea* Cossmann in Friedberg, 1914, YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; O - *Dentalium sexangulum* Schröter, 1784, YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; P - *Gadilina jani* (Hoernes, 1856), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; R - *Melanoidea sp.*, YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b (transported fauna from the lacustrine environment, possibly pre-Pliocene). Scale bar: 1 mm.
Figure 7. A1, A2: *Bulla ampulla* Linnaeus, 1758, YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; B: *Turbonilla* sp., YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; C: *Turbonilla densecostata* (Philippi, 1844), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; D1, D2: *Nassarius* (?) sp. - YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; E: *Conolites dujardini* (Deshayes, 1845), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; G: *Mangelia attenuata* (Montagu, 1803), YB collection, HS subbasin, Samandağ Formation, Kuşalanı section, Kuş-2; H: *Gyraulus* sp., YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; I: *Turbonilla* sp. 1, YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; J: *Oliva* sp., YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; K: *Turbonilla* sp. 2, YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; L: *Bittium latreillei* (Payraudeau, 1826), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; M: *Seila plioiberica* Landau, Perna and Marquet, 2006, YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; N: *Turritella spirata* (Brocchi, 1814), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-32; O1, O2: *Neverita olla* (De Serres, 1829), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; P: *Gibbula* sp., YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; Q1, Q2: *Tricolia pullus pullus* (Linnaeus, 1758), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; S: *Mitrella* sp. 1, YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; T: *Costellamussiopecten cristatus* (Bromm, 1827), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-32; U: *Corbula* (*Varicorbula*) *gibba* (Olivi, 1792), YB collection, IA subbasin, Aktepe Formation, Aktepe section, 08-11-06c; V: *Propeamussium* (*Parvamussium*) *duodecimlamellatum* (Bromm, 1831), YB collection, HS, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-37; Y: *Mitrella semicaudata* (Bellardi, 1848), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; Z: *Gadilina triqueta triqueta* (Brocchi, 1814), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-30a. Scale bar: 1 mm.
Figure 8. A1, A2- *Donax trunculus* (Linnaeus, 1758), YB collection, HS subbasin, Samandağ Formation, Kuşalanı section, Kuş-2; B1, B2- *Timoclea ovata* (Pennant, 1777), YB collection, HS subbasin, Samandağ Formation, Kuşalanı section, Kuş-3; C1, C2- *Mytilopsis* sp., AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; D- *Timoclea ovata* (Pennant, 1777), YB collection, HS subbasin, Samandağ Formation, Kuşalanı section, Kuş-3; E1, E2- *Acanthocardia echinata* (Linnaeus, 1758), AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; F- *Acanthocardia echinata* (Linnaeus, 1758), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; G1, G2- *Propemusium* sp., YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-33; H1, H2- *Anadara gibbosa* (Reeve, 1844), YB collection, HS subbasin, Samandağ Formation, Mızraklı-Kireçtepe section, 08-11-32; I- *Ostrea forskali* Chemnitz, 1791, YB collection, HS subbasin, Samandağ Formation, Sutaşi section, 09-06-17. Scale bar: 1 mm.
Figure 9. A- *Aequipecten cf. seniensis* (Lamarck, 1819), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; B1, B2- *Donax trunculus* (Linnaeus, 1758), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; C1, C2- *Lembulus pellis* (Linnaeus, 1767), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; D, E- *Yoldia nitida* (Brocchi, 1814), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 10-03-14a; F1, F2- *Corbula (Varicorbula) gibba* (Olivi, 1792), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; G- *Anadara sp.*; YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; H1, H2- *Barbatia empolesinis* (Micheli and Torre, 1966), YB collection, HS subbasin, Samandağ Formation, Sutaşı section, 09-06-17; I- *Ensis sp.*; YB collection, AB subbasin, Altınözü Formation, Babatorun section, 10-03-14a; J1, J2- *Gouldia minima* (Montagu, 1803), AB subbasin, Altınözü Formation, Babatorun section, 10-03-14b; K- *Pectinarca pectinata* (Brocchi, 1814), YB collection, AB subbasin, Altınözü Formation, Babatorun section, 11-03-14b; L- *Venus (Ventricoloidea) multilamella* (Lamarck, 1818), Babatorun section, 11-03-14b. Scale bar: 1 mm.
Figure 10. Mızraklı-Kireçtepe section, Kuşalanı section, Sutaşı section, Kesecik/Karlısuyu section, Telliturna section, Karaali section (HS subbasin).
**A-B SUBBASIN SECTION**

**BABATORUN SECTION (7)**

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<tr>
<th>STAGE</th>
<th>SAMPLE NO</th>
<th>LITHOLOGY</th>
<th>EXPLANATION</th>
<th>ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Messinian - Lower Pliocene</td>
<td>13-10-12a</td>
<td>Dark grey coloured marly-sandstone</td>
<td>Lagoon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-03-14c</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>11-03-14b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>11-03-14a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-11-08a</td>
<td>Pelagic limestone with pelagic dyke and yellow shelly sandstone</td>
<td>Restricted marine - Lagoon - Open shelf</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-11-08</td>
<td></td>
<td></td>
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<td>10-11-06</td>
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<td>10-11-05</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>10-09-15</td>
<td>Pelagic limestone with pelagic dyke and yellow shelly sandstone</td>
<td>Shallow marine</td>
<td></td>
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<td>10-09-14</td>
<td></td>
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<tr>
<td></td>
<td>10-09-13</td>
<td>Yellow coloured, shelly sandstone</td>
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<td>10-09-12f</td>
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<tr>
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<td>10-09-12d</td>
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<tr>
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<td></td>
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<td>10-02-12</td>
<td>Light grey coloured marl-claystone</td>
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</table>

5m

**Figure 11.** Babatorun section (AB subbasin).

**IA-SUBBASIN SECTIONS**

**BÜYÜKDERE SECTION (8)**

<table>
<thead>
<tr>
<th>STAGE</th>
<th>SAMPLE NO</th>
<th>LITHOLOGY</th>
<th>EXPLANATION</th>
<th>ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Pliocene</td>
<td>13-10-12</td>
<td>Rhizolithic limestone</td>
<td>Shallow marine - Lagoon-coastal</td>
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<tr>
<td></td>
<td>09-11-11b</td>
<td>Red clastics</td>
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<td></td>
</tr>
<tr>
<td>Lower Pliocene</td>
<td>11-03-09</td>
<td>Yellow colored cross bedded and channelized sandstone</td>
<td>Shallow marine - Lagoon-coastal</td>
<td></td>
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<tr>
<td></td>
<td>08-11-10</td>
<td>Black colored mudstone</td>
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</tbody>
</table>

5m

**AKTEPE SECTION (9)**

<table>
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<tr>
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<th>SAMPLE NO</th>
<th>LITHOLOGY</th>
<th>EXPLANATION</th>
<th>ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Pliocene</td>
<td>08-11-05</td>
<td>Yellow sandstone, bioturbation and channelized structure massive mudstone with sandy injections.</td>
<td>Shallow marine - Lagoon</td>
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<td>08-11-05a</td>
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</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>08-11-06c</td>
<td>Cross bedded and laminated sandstone</td>
<td>Shallow marine - Lagoon</td>
<td></td>
</tr>
</tbody>
</table>

5m

**Figure 12** Büyükdere and Aktepe sections (İA subbasin).
6. Conclusions
In total 162 Pliocene mollusc species are reported from the Hatay Graben (southern Turkey). The stratigraphic age is constrained with microfossils to the Early Zanclean and the fauna represents the situation just after recolonisation after the Messinian Salinity crisis. Both the age of the fauna and the presence of various tropical taxa (such as *Strombus coronatus* and *Conus* species) show that the Hatay fauna is the easternmost Mediterranean MPPMU1 fauna. The faunas represent mostly fully marine upper infralittoral-circalittoral habitats with salinities of around 35 psu, although in one sample admixed anomalohaline lacustrine species were found. Species lived on sandy and muddy seafloors where some sea grass must have occurred, while firm-ground habitats appear to have been lacking. The Hatay faunas are diverse but harbour far fewer species than contemporary central and western Mediterranean faunas. This strong latitudinal diversity drop is attributed to relatively low habitat diversity in the Hatay region as well as its distal location compared to the western Atlantic that is the source of marine biota for the Mediterranean after the Messinian. The Hatay faunas do represent tropic-subtropic climatic conditions.

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References


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Vera-Pelaez JL (2002). Revision de la familia Turridae, excepto Clavatulinae (Gastropoda, Prosobranchia) en el Plioceno de las cuencas de Malaga y Vélez Malaga (Malaga, S. Espana) con la descripción de 26 especies nuevas. Pliocenica 2: 176-262 (in Spanish).