Traces of Mediterranean origin Holocene transgression in the drainage basin of Riva-Çayağzı Creek of the Black Sea (northeastern İstanbul-Turkey)

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Abstract: The Riva-Çayağzı Creek (İstanbul, Black Sea) pours into the Black Sea from the coasts of Turkey. In the drainage basin of this creek, both deep and shallow drillings were undertaken, and the minimum thickness of Holocene stratigraphy was determined as 30 m. The Holocene young deposits are mainly composed of fine-grained sediments and clay, which has the most prominent thickness. The energy of water during the sedimentation process was low and stagnant in the Riva-Çayağzı Creek basin. When the marine mollusc fossils obtained from the shallow boring cores are evaluated, it can be deduced that the sea level in the study area had drawdown to –21 m in elevation. Ostracod, foraminifer, and diatom fossils determined in all cores of shallow borings are the same or similar to Mediterranean origin euryhaline forms. According to this outcome, the presence of brackish water in the study area is the result of the sea level rise that occurred at ca. 9.4 ka due to the Mediterranean origin fluctuations passing through the Dardanelles and Bosphorus straits into the Black Sea. Thus, it is understood that the sea level entered from the present Riva (İstanbul)-Black Sea coastline to at least 13 km south of the Çayağzı Creek drainage basin. The Early Holocene transgression has been defined for the first time here in the specific location of the Black Sea coast of Turkey. Accordingly, in the Riva-Çayağzı Creek basin, a lagoon sedimentation environment with low energy and stagnant water, having mainly brackish water with partial seasonal change and sea connection, was determined.

Key words: Riva-Çayağzı Creek, transgression, mollusc, foraminifer, ostracod, diatom

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1. Introduction
The study of the Mediterranean transgression into the coasts of the Black Sea has been carried out by geoscientists for a long time. The coasts of the Black Sea have been subjected to transgression in different ways and on different scales (Martin and Yanko-Hombach, 2011). The Western Black Sea basin is located within the Ponto-Caspian basin groups. Transgression areas associated with tectonic activity on the southern margin of the Black Sea were also identified (Koral, 2007). The sea level in the north of the Black Sea has changed up to ~60 m in the last 10 ka (Nevesskaja, 1974; Tchepalyga, 1980; Voskoboinikov et al., 1982). The biodiversity content of climatic changes has become an important parameter to describe the sea level changes in the Holocene in the Black Sea. Consequently, sea level and fresh water changes and mixtures were determined according to foraminiferal and molluscan assemblages (Yanko, 1990a; Mayewski et al., 2004; Balabanov, 2007; Konikov, 2007; Martin and Hombach, 2011). According to the Late Quaternary stratigraphy of the Black Sea, during the last glacial melting period (about 13,000–160,000 years ago), fresh waters flooded into the Caspian Sea, Black Sea, and Sea of Marmara with the melting of some main rivers such as the Bug, Danube, Dniester, and Dnieper due to the melting of Scandinavian glaciers, and the complete region became a partly interconnected freshwater lake system before the Mediterranean transgression. The first Mollusca community is the representative community of this period and the stratigraphic correspondent of this period is called Neoeuxinian (Late Pleistocene) (Görür et al., 2001; Yanko-Hombach, 2007; Büyükmeriç et al., 2018). Some rivers flowing into the Black Sea deposited sedimentary lithological materials in the areas where rivers meet the seas. These deposits, which accumulate at different thicknesses due to different stream flow rates and water energy, are generally disturbed by climatic changes, sometimes by landslide type mass movements and erosion. Transgression can be explained by the “Noah’s flood” hypothesis suggested in the 1990s, whereby Mediterranean waters reached the Black Sea via the Dardanelles and Bosphorus straits in the Early Holocene (Yanko-Hombach

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et al., 2014). Records of Mediterranean waters in the Black Sea have been determined to be 9300 calendar BP (Yanchilina et al., 2017). Marine life in the Black Sea, which is in the form of a large lake, is determined as 9.4 ka according to biodata data (Soulet et al., 2011).

The aim of this study is to investigate the existence and the source of the marine sea level changes around the channel of the Riva-Çayağzı Creek (İstanbul), one of the important rivers discharged into the Western Black Sea (Figure 1). For this purpose, deep borings in the region were evaluated to determine the thickness of Holocene sedimentation (Figure 2). Additionally, shallow drillings were completed in some parts of the Riva-Çayağzı Creek channel and Holocene sedimentation was evaluated together with fossil findings in the cores obtained from these drillings (Figure 3). As a result, the reasons for the presence of transgression in this drainage basin are explained.

Figure 1. (a) Morphological map of Anatolia and its surrounding seas (https://earth.google.com). (b) Geological map of Riva-Çayağzı Creek drainage area located to the east of the Bosphorus (Özgül, 2011).
Figure 2. Flood plain morphology of Çayağız Creek near Paşamandıra village and the thickness values of the Holocene deposits and the locations of the deep drillings in the study area.
Figure 3. Depth and distribution of fossil contents along with the detailed lithologies of the cores obtained from four shallow borings (SK 1–4) drilled in the Holocene deposits around the Çayağzı Creek channel (location image taken from https://earth.google.com).
2. Sea level changes around the Black Sea
The Black Sea is one of today’s remaining seas of the Paratethys and is located in the Ponto-Caspian corridor along with the Caspian Sea (Yanko-Hombach, 2007). The stratigraphic equivalent of this period is named Neoeuxinian (Late Pleistocene) (Andrussov, 1896, 1900; İslamoğlu and Chepalyga, 1998; Çağatay et al., 2000; İslamoğlu, 2002; Bahr et al., 2005; Hiscott et al., 2007; Badertscher et al., 2011; Taviani et al., 2013, 2014; Büyüksümer, 2016; Huvaj and Huff, 2016).

The Neoeuxinian lake water levels in the Ukrainian and Romanian shelves were compared before and after the transgression (Ryan, 2017; Lericolais et al., 2010). In the Ukrainian shelf and in the Bosphorus deltas (Sakarya Delta) of the Sea of Marmara, the salinity change data show that Mediterranean-based brackish water mixed with the Neoeuxinian lakes due to sea level rises (Manheim and Chan, 1974; Soulet et al., 2010; Mertens et al., 2012).

Also, the presence of the Mediterranean transgression was determined based on the contents of bivalves, gastropods, and molluscs around the Black Sea (Yanko and Gramova, 1990; Stoica and Floroiu, 2008; Ivanova et al., 2012). In the late Quaternary-Holocene period of the Black Sea, after the last glacial period (approximately 13–16 ka ago), the melting of the Scandinavian glaciers and the glaciers in rivers such as the Don, Volga, Dnieper, and Dniester caused a freshwater flooding towards the Caspian, Black, and Marmara Seas and the region became a partly interconnected freshwater lake system before the Mediterranean transgression. In the northern shelf of the Black Sea, the “catastrophic flood” hypothesis was proposed according to the sapropelic mud layers (Ryan et al., 1997). It was found that these levels constitute a wide unconformity (Ryan, 2007). It was defined that the catastrophic/rapid/prominent flooding of the Black Sea was with the Mediterranean Sea water based on both salinity values and microfossil data, and the flooding continued until the Early Holocene (Hombach et al., 2014). These authors found marine environments in the Paleo-Dniester valley to the south of the Black Sea shelf.

The presence of Khvalinian transgression in the Black Sea was defined based on mollusc species in the Volga River and Kushum River deltas with increased salinity values and a sea level rise of about 20 m (Svitoch, 2010). The sudden increase in salinity on the northern coasts of the Black Sea and the Mediterranean Sea-based ostracod records indicate that the first sea level rise occurred around 9390 BP (Bricceag et al., 2019).

Transgressional fossils (mollusc) were determined in the cores taken from stratigraphic levels down to –20 m inside the sea during the drilling work along the southern shelf and the southern section of the Black Sea (Algan et al., 2007). On the other hand, in our study, the fossil data were discovered in the southern land part of the Black Sea and were compared with the transgression data of other studies. Additionally, traces of the sea level changes on the land part in the south of the Black Sea were determined.

3. Materials and methods
This study presents the Holocene young deposits in the Riva-Çayağı Creek basin to identify the sedimentologic environments based on lithology types and paleontological contents. For this purpose, drilling explorations were taken with deep and shallow boring cores. Deep drilling cores (Wells 1–8) have depths between 200 and 300 m and shallow drillings (SK 1–4) have depths of 12–32 m (Figures 2 and 3). Deep drillings were taken with a rotary air system and shallow drillings were obtained with a machine mounted on a truck with a hydraulic rotary system. The deep cores were drilled by the air-hammered method while circulating the foam. The shallow drillings were made by a rotary continuous coring method. The cores were preserved in the coring boxes, and samples were collected from fossiliferous and plant-containing levels. Samples selected from the soil levels containing fossils and plant remains were picked and sent for analysis to define the age and deposition environment of the deposits (Figure 4).

Mollusc-bearing sediment samples were collected from the SK-3 borehole. The samples were washed under pressured water through 200-mm mesh sieves and dried for small molluscs and microfossils (ostracods and foraminifers) at the Bülent Ecevit University Department of Geological Engineering (Zonguldak, Turkey) (Y. Büyüksümer, 2018, personal communication). Then the microfossil contents in the residue materials were picked out and identified using a stereomicroscope at the Çukurova University Department of Geological Engineering (Adana, Turkey). The microfossils (ostracod, foraminifer, and diatom) were put on stub and coated with gold for scanning electron microscope (SEM) images (Figures 5 and 6). Their images were taken from a Quanta 650 Field Emission SEM at the Çukurova University Central Research Laboratory. The ostracod and foraminifera specimens are housed in the Department of Geological Engineering of Çukurova University (Adana, Turkey). After defining the deposition environment of the deposits in terms of fossils in the study area, the result of this study were correlated with the previous studies presenting the existence of Mediterranean transgression in the northern coasts of the Black Sea.

4. Results
An effort was made to describe the development of Holocene Mediterranean transgression on the Black Sea coasts of Istanbul-Riva. Geochemical, stratigraphic, sedimentological, and paleontological evidence was
obtained from the current records of the land in the geological units deposited by the transgression in the northern Black Sea (Vinogradov et al., 1969; Degens and Ross, 1972; Ostrovsky et al., 1977; Arslanov et al., 1988; Danukolova, 1996; Ryan and Pitman, 1999; Balabanov, 2006; Yanina, 2012, 2014). Sea water level changes and the associated brackish water are especially identified in the northern shelf of the Black Sea (Kvasov, 1975; Fedorov, 1978; Fedorov, 1982; Kuprin and Sorokin, 1982; Svitoch et al., 1994, 1995, 1998; Selivanov, 1996). Results explaining the fossil species and facies analyses of deposits for the Riva-Çayağzı Creek basin are detailed below.

### 4.1. Fossils

Macrofossils (gastropods and bivalves) and microfossils (ostracods, foraminifera, and diatoms) were observed in the samples taken from the study area on the Black Sea coasts of Istanbul-Riva. The first group of molluscs obtained from the shallow drillings in the study area includes Theodoxus sp. (gastropod) and Dreissena polymorpha (bivalve) fossils discovered between 11–14 m and 17–20 m of the SK-3 borehole. The second mollusc community consists of Cerastoderma glaucum, Cerastoderma edule, Ecrobia maritima, Abra segmentum, and Bittium reticulatum marine fossils found between 20 and 24 m of the SK-3 borehole.

<table>
<thead>
<tr>
<th>SAMPLE NUMBERS AND THEIR LEVELS (m)</th>
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<th>F</th>
<th>D</th>
<th>M</th>
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<tr>
<td><strong>SK-1</strong> 1 (12.12.50) *</td>
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<td><strong>SK-2</strong> 1 (10.10-12.20)</td>
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<td>4 (14.50-14.70) *</td>
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<td><strong>SK-3</strong> 1 (8.50-9.00)</td>
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<td>6 (27.00-27.50)</td>
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<td><strong>SK-4</strong> 1 (7.00-7.75)</td>
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<td>2 (9.20-9.50)</td>
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<td>3 (10.30-11.00)</td>
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**Figure 4.** Distribution of fossil species, shells, and plant levels according to drilling depths in cores obtained from all shallow boring cores.

| O: OSTRACODA; F: FORAMINIFERA; D: DIATOM; M: MOLLUSC |
|----------------------------------|---|---|---|---|---|
| **BOREHOLE-A1:** | K20 | | | | |
| **BOREHOLE-A1:** | | | | | |
| **BOREHOLE-A1:** | | | | | |
| **BOREHOLE-A1:** | | | | | |
| **BOREHOLE-A1:** | | | | | |

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Figure 6. Scaled images of benthic foraminifera species obtained from shallow drilling cores (1–10: Ammonia tepida, 1, 4, 6, 7, 9-spiral side; 2, 3, 5, 8, 10- umbilical side; 1–8: SK-4/3; 9–10: SK-4/2. 11: Ammonia cf. compacta, umbilical side, SK-2/3. 12: Ammonia ammoniformis, umbilical side, SK-4/2).
Borehole (Y. Büyükmeriç, 2018, personal communication; Figure 3)

A total of total 16 samples collected from the boreholes around Riva-Istanbul (2 samples from SK-1, 6 samples from SK-2, 5 samples from SK-3, and 3 samples from SK-4) were examined for ostracod fossils (see Figure 5). Ostracod species defined from the soil samples are Cyprideis torosa (Jones); Tyrrhenocythere amnicola donetziensis (Dubowsky); Leptocythere bituberculata Bonaduce, Ciampo & Masoli; Leptocythere rara (Mueller); and Loxoconcha elliptica Brady. Their distributions are given in Figure 4.

Cyprideis torosa is the dominant species in shallow cores. It is one of the widespread ostracod species and lives in both marginal marine environments and inland water bodies. C. torosa can adapt to very wide temperature ranges and different salinity (oligohaline-hypersaline), oxygen, and substratum conditions. Ecophenotypic specimens are observed especially in marginal marine environments (Klie, 1938; Bronshtein, 1947; Meisch, 2000; Pint et al., 2012). In this study, Cyprideis torosa individuals were found as smooth, rounded, and juvenile in the same samples, which is important for environmental interpretations. In addition, the shell ornamentations were observed as smooth and nodded (see Figure 5).

Tyrrhenocythere amnicola donetziensis was found only in one sample. It is a known species in the Black, Aral, and Caspian Seas. Recently, this species is found in salinity ranging from 12% to 13.5%, in sediments of less than 30 m in depth and usually 10–20 m (Chekhovskaya et al., 2014). Leptocythere bituberculata was found at depths of less than 50 m in the Adriatic Sea (Bonaduce et al., 1975; Breman, 1975) and at depths of 18–95 m in the Aegean Sea (Kubanç, 2005). Leptocythere rara was found at depths of less than 50 m in the Adriatic Sea (Bonaduce et al., 1975; Breman, 1975), the Black Sea (Kubanç, 2005), and the Levantine (Percin and Kubanç, 2005). Loxoconcha elliptica, together with Cyprideis torosa, is observed in swamps and estuary environments around Britain (Horne and Boomer, 2000), from oligohaline to polyhaline salinity on the Mediterranean coastline (Mazzini et al., 1999), Yumurtalık Lagoon/Adana (Nazik et al., 1999), Yumurtalık Lagoon/Adana (Şafak, 2003), Hersek Lagoon/Sea of Marmara (Mischke et al., 2012) and several euryhaline salinity and brackish environments (Altınsaçlı et al., 2018) in Turkey.

Benthic foraminifera were also found in the SK-1, SK-2, and SK-4 drillings together with ostracods. These species are Ammonia tepida (Cushman), Ammonia cf. compacta (Hofker), and Ammonia ammoniformis (d'Orbigny), and their SEM photographs are given in Figure 6. Ammonia tepida is found in brackish waters in the world. It can survive in a wide range of temperatures, salinities, and all negative environmental conditions and usually seeks out lagoon environments. Ammonia is common genus in the Black Sea and constitutes sometimes up to 99% of the total foraminiferal assemblages throughout the Quaternary period (Yanko, 1990a; Yanko-Hombach, 2007). In addition, it is commonly seen in the Mediterranean, Aegean, Azov, and Caspian Seas (Yanko, 1990b). Campylodiscus echensis Ehrenberg ex Kützing, 1844 from the diatoms is found in sample number 2 of borehole SK-4 (defined by Prof. Dr. Ayşegül Güney, Aksaray University). It is a universal species and known from fresh to marine environments.

4.2. Facies analysis
The study area covers the drainage area of Riva-Çayağzı Creek, and for sediment investigation both deep and shallow drillings were conducted in the area. The boreholes are located approximately 9 km north of the Istanbul Ömerli catchment area and about 13 km south of the Black Sea coastline, near Paşamandıra village, as shown in Figure 1. A total of eight deep boreholes (Wells 1–8) show the thickness changes and types of sediments in the Holocene period in the region and also provide information on the general lithology of these units (see Figure 2). According to the findings, nearly all of the sediments obtained from the boring cores around the present Çayağzı River channel have fine grain sizes, and this type of sedimentation indicates that the water energy level, which is one of the most important parameters, was low when the sedimentation occurred (Folk and Ward, 1957). The thickness of the lithological level determined as Çayağzı Creek sediments and containing Holocene stratigraphy varies between 8 and 26 m. At the same time, the base of this level is the latest angular unconformity in the region. In all drillings, sands and silts were light yellow or brown while clays were blue, green, or gray in color. The high clay content in these drillings indicates that the sediments during the Holocene period were deposited in a very low water energy environment. In addition, this lithological distribution also shows that there is no difference in clay contents of Well-2 and Well-8 close to the creek channel and of Well-1 and Well-4 far away from the creek channel (see Figure 2). Furthermore, some fossil shell contents obtained in the boreholes were taken into consideration and shallow drillings were undertaken to distinguish the fossil shells within the drilled units (see Figures 3 and 5).

The lithological change around Çayağzı Creek in four shallow drillings (SK 1–4), which were performed on the base of the Holocene angular unconformity, was determined in more detail. Accordingly, it can be understood from the SK-3 borehole that the thickness of the fossiliferous deposits in the Holocene period was as high as 24 m (see Figure 3). The presence of vegetative
roots or remnants from all of these boreholes indicates that the deposition environment was covered with water in the near Holocene period. The clay lithology of 13 m in different colors was cut from the borehole ground surface elevation of +7 m to −6 m during the drilling of SK-1 located approximately 15 m northeast of the Çayağzı Creek. The marine fossils explained in the paleontology section of this study prove that the sedimentation environment was flooded towards inland by brackish water due to sea level changes. This situation shows that the sea level sill depth is about −7 m. Also, the benthic foraminifera found in the clay levels indicate the presence of sea water in the deposition environment. In the SK-2 borehole, which is about 21 m northeast of the Çayağzı Creek channel, clay lithology, which includes both marine fossils and plant composts, has been cut until the depth of 30 m. The thickness of the clay in this borehole is 27 m and the remaining deposits are sand and very little pebble. The SK-3 drilling is about 24 m away from Çayağzı Creek’s channel and was completed at a depth of 31 m. This boring contained a 6.5-m sand layer with very few pebbles in the upper part of the boring and an approximately 24.5-m clay layer with different colors beneath the sand layer. The SK-4 boring located 28 m northeast of Çayağzı Creek and at the point where the flood plain ends and the elevation begins has clay of approximately 9 m thick. The dominant content of clay deposition in all Holocene lithologies cut in all of these shallow boreholes indicates that water energy, which is the most important indicator in deposition, is quite low and there is a significant amount of sea water inundation in the sedimentation environment together with the determined marine fossils.

5. Discussion

Marine fossils found in the study area are mostly euryhaline forms of Mediterranean origin and these species still live in the Black Sea and the Sea of Marmara. Before the Mediterranean transgression in the region, the presence of fossils such as *Theodoxus* sp. (gastropod) and *Dreissena polymorpha* (bivalve) indicates the freshwater environment and Neoeuxinian (Late Pleistocene) period. The transgression that occurred by the 9.4–9 ka (Early Holocene) flooding and included the Mediterranean origin fossils first reached the Sea of Marmara over the Dardanelles and then reached the Black Sea through the Bosphorus. This flooding in the Holocene was proposed as the “Noah’s flood” hypothesis in the late 1990s (Ryan et al., 1997, 2003; Ryan and Pitman, 1998; Ballard et al., 2000; Görür et al., 2001; Major et al., 2002; Lericolais et al., 2007; Yanko-Hombach, 2007; Yanko-Hombach et al., 2007; Soulet et al., 2011). According to the fossil data between the Bandırma and Gemlik Gulfs, the youngest age of the Mediterranean origin transgression is 7.5 ka. Hombach and Kislov (2018) investigated three different paradoxes for the origin of the transgression in the Black Sea. The first one is the marine transition in the Late Glacial epoch after the Caspian Sea (~17–12 ka BP), the source of which is unclear. The second paradox considers the variations in sea level due to global climate changes around both the Caspian and Black Seas. However, this paradox was determined as weak in the correlation of climatic differences and sea level changes. The third paradox concerns the point that water passes through the Bosphorus to the Black Sea and the sea level fluctuations in the Black Sea are not synchronized.

The Riva Çayağzı Creek flows into the Black Sea on the coast of Turkey. The brackish water and fossils in the drainage basin of this creek were investigated and the marine environment was detailed. The transgression occurring on the Turkish coasts that formed the southern border of the Black Sea in the Early Holocene period has been identified for the first time by this study. According to the mollusc content obtained from the shallow drillings in the study area, the region characterizes a fresh water environment prior to the Mediterranean transgression. Then, as the marine transgression coming from the Mediterranean Sea at approximately 9.6–9.3 ka BP (Early Holocene) first reached the Sea of Marmara and then the Black Sea by the Bosphorus, the Çayağzı Creek was one of the areas covered by the brackish waters (Figure 7). The mollusc and ostracod fossil species are seen from the ground surface to the 24th meter in SK-3, indicating the deepest level of the mixture of brackish waters. The presence of brackish water according to the distribution of ostracod, foraminiferal, and diatom fossil species in the other drilling cores is observed at the 18th meter of SK-2, 14th meter of SK-1, and 11th meter of SK-4. This indicates that sea level changes and the base of the brackish water in the Çayağzı Creek channel in the Holocene period had changed at elevations between −3 m and −21 m. This water energy, controlling the sea level and sedimentation environment, also suggests that the sedimentation occurred in a waveless and low-energy environment. Hence, fine-grained sediments (especially clay) are thicker and dominant in this period. In the north of the Black Sea, the depth of brackish water originating from the Mediterranean can go down to −45.9 m in Holocene (Mudie et al., 2014). The lithological and facies contents of the cores obtained from the shallow borings were determined by this study. The facies types and characteristics of sediments were affected by the annual climatic changes, brackish water level, and salinity ratio in the Çayağzı Creek channel. In the Holocene, all Ponto-Caspian Neoeuxinian lakes had at least 7 psu of salinity before the transgression in the Black Sea (Manheim and Chan, 1974). After the Mediterranean transgression, the rate of salinity increased continuously for at least 3600 years and reached 0.05–1.7 cm a⁻¹ (Hombach et al., 2014).
Fossils in this salinity rate (~ 25 psu) are also compatible with the fossils obtained by this study (Neveuskaja, 1965; Chepalyga, 1995; Büyükmeric, 2016). In addition, 9.5-ka-old mollusc species or similar species in the form of Mediterranean euryhaline species living in this salinity rate and determined by this study have been found in other countries along the Black Sea coasts (Yanko, 1990; Yanko-Hombach, 2007; Yanko-Hombach et al., 2007;

Figure 7. Model of a shallow lagoon environment with a marine connection formed between the Early Holocene period and present at least 9.4 ka (images taken from https://earth.google.com) in the study area.
Soulet et al., 2011). Also, during the pre-Boreal stage of the earliest Holocene, the shorelines of the Black Sea were somewhere between ~80 and ~90 m relative to the present coast (Lericolais et al., 2007, 2011; Ryan et al., 2014).

6. Conclusions
The presence of transgression in the Riva-Çayağzı Creek drainage basin is determined for the first time by this study for Turkey’s Black Sea coast and the fossil records found are of Mediterranean origin. In the Çayağzı Creek basin, the sea entered at least 13 km south from the current position of the coastline and made the fresh water combination suitable for the marine fauna. In the Çayağzı Creek basin, the lithology consists of fine-grained sediments, especially clay, which were dominant during sedimentation. The thickness of this lithology in all drilling cores indicates that the energy level in the region was low and a lagoon with marine connection was present in the Early Holocene. In Riva-Çayağzı Creek basin, the Black Sea level has fallen to elevation levels of ~17 m from at least 9.4 ka to present. The region includes both fresh water fossils with a Neoeuxinian lake environment that dominated in the Ponto-Caspian area and marine environment facieses containing Mediterranean origin fossils. In addition, the gravel lithology in the study area is very low (not exceeding 5% in all Holocene lithology) and the grain diameter is 2 cm at maximum, indicating that the energy at the time of deposition did not vary significantly. The fine-grained lithology in the Holocene stratigraphy containing fossil records during sedimentation indicates that transgression in the study area was related to the Mediterranean origin marine waters that flooded the southern shore of the Black Sea rather than tectonic origin or the mass movements that could occur due to the physical characteristics of any geological unit.

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