The Ceyhan-Seyhan Coastal Plain (Cukurova). A Survey of its Structural, Marine, Terrestrial and Human ControlProcesses - Turkey

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The Ceyhan-Seyhan Coastal Plain (Çukurova)

A Survey of its Structural, Marine, Terrestrial and Human Control Processes

Catherine Kuzucuoğlu*

Abstract

A state of the art of ancient to recent publications and documents regarding the physical geography of the Çukurova Plain, allows the presentation of the physical forces at work in shaping the landscapes of the Çukurova area, from the Adana plain to the Ceyhan Plain, and the western coast of the Iskenderun Gulf, including the Yumurtalık delta. The forthcoming effects of these forces are also changing the life and future of the biologic species, ecosystems and inhabitants of the area. Four main controls are identified: (1) geological structure, especially tectonic structural organization and active tectonics; (2) marine currents, including newly evidenced whirling ones; (3) river hydrology; (4) and last but not least: human pressures on agricultural land, river channels, water resource and coastal lines. Among the remaining forcing factors, wind sediment transport is the least affected, for the time being, by changes. Regarding the main forcing factors, the review allows evidencing the long-term supremacy of tectonism, with the on-going partition of the Plain in two parts, increasingly separated by the Misis Highs. This SW-NE uplifting relief is rather rapidly rising, forcing the Seyhan lower course to slide westwards in direction of the central part of the Plain. This trend is already responsible for the avulsion of the Seyhan from the Gulf of Iskenderun basin to the Adana Basin in 1935. As a result, the Yumurtalık delta east of Karataş lacks sediment input for facing marine erosion, and is increasingly eroded. In addition, a trend of coastal retreat is easily evidenced in both river mouths since three decades. This latter phenomenon results from the too important dam construction on the main rivers providing sediments to the coast, especially the Seyhan River whose load has diminished by 90%. This impoverishment in river sediment loads will accentuate, in relation to the present sea level rise, the speed of on-going penetration of the sea inside the Plain, first underground and, later, overground.

Introduction

At the easternmost corner of the Mediterranean, the 120 km wide and 100 km large coastal plain of Çukurova (ancient Cilicia) in Turkey extends between the Taşeli metamorphic massif (west) drained by the Göksu river (outflowing to the sea at Silifke), and the Iskenderun Gulf (east) limited east by the steep slopes of the Amanos massif in Hatay Province. Seawards, the Çukurova plain ends with a worldwide-known magnificent delta built by the alluvium of two major Mediterranean rivers of Turkey: the Seyhan River and, mainly, the Ceyhan River (Fig. 1). Since the 1950's, the number of scientific articles concerning the delta, the mobility of its natural channels and of its coastal line, and their relationships with the riverine sedimentation input by the main rivers feeding the delta has been increasing (e.g. Erinç 1953; Gürbüz, 1999; Erol, 2003; Özpolat et al., 2021). Meantime, scientific and public interest grew also for the conservation of the dune and wetland areas related to the formation of the enormous delta east of Karataş (e.g. Altan et al.,

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2004). While the whole Çukurova alluvial plain is almost fully exploited by very intensive practices for agricultural production, the genuine environments in the coastal areas (coastal dunes, delta ecosystems) are threatened by impacts of the human activities on the coast and inland, and the sea-born dynamics which both act on the fragile equilibrium necessary for the perpetuation of deltaic ecosystems (e.g. Kuzucuoğlu et al., 1993; Altan et al., 2004; Ozaner, 2004; Isola et al., 2017). In this context and while the rise of the global sea level has started (Simav et al., 2013), the state of geomorphological knowledge presented here aims at exploring the processes controlling the dynamics of the Çukurova plain and coast, as well as of the Ceyhan delta.

1. Impacts of the Structural Framework on the Long-term (geological) Evolution of the Çukurova Plain

As evidenced by the geological map of the area, especially its tectonic components, the structural framework has an important control on the dynamics of the Çukurova plain and its delta, (Fig. 2A). This framework extends from the Mediterranean Sea floor in the vicinity of Cyprus, unto the Central Taurus highlands north of Kozan, and the Hatay-Kahraman-Maraş highlands (Fig. 2B) (Aksu et al., 2021). While a set of deep fractures forms a triangular peak-like pressure oriented toward the "Triple junction" near Karhaman-Maraş (Fig. 2A) (Aksu et al., 2021), a complex set of important regional faults also controls uplift *vs* subsidence dynamics of sub-basins. As a result, the Çukurova plain corresponds to an elongated tectonic depression bordered by the central Taurus Range to the west, north and northwest, and by the Karataş–Misis–Yumurtalık uplifting lineament to the east (Fig. 2B). This lineament extends from Northern Cyprus to the ridge which separates inland the Adana plain from the Ceyhan plain (Fig. 2A), while the İskenderun Basin lies east of the lineament. Thus, the "Misis Highs" separate the Cilician lowlands in two parts: (1) the proper" Cilicia' west of the lineament, (2) and a depression attracting the Ceyhan river east/north-east of the lineament. Noticeably, the tectonic activity of this "Misis lineament" continuously provokes destructive earthquakes, such as in 1998 when fatalities and damage occurred in Adana and in surrounding regions (Över et al. 2004; Ulusay and Turgay, 2004).

Presented here for the first time, the map in Fig. 3 inspired by Aksu et al. (2021), illustrates the major control of the sub-marine topography on the distribution of land-originating water and sediment flows. It illustrates also the control, by this topography, of the river frame organization inland, which outflows into three main sediment traps composed of deeper marine basins, through very steepy gorges providing the connections between the shelf areas and the deep sea.. The resulting picture provided illustrates the important role of the submarine geomorphology organized with the three basins clearly separated from one another, both in the sea and inland, by the Misis Highs. These tectonic disposal and resulting morphology, testify for a complex, intermingled, continental to marine sediment-trapping system in which the role of uplift movements of the Misis Highs is preeminent (Fig. 2B).

The geological control on the Çukurova plain organisation and dynamics is clearly illustrated by the separation, by the Misis Highs, of the water drainage in two different structural basins: west the Adana Plain mostly drained by the Seyhan river, but receiving today the Ceyhan river superimposed on the Misis Highs. As a result, the limestone ridge rising above the flat landscapes of the plain is not only the morphologic expression of a thrusted block, but also the backbone triggering (i) the separation of the river drainage toward two basins (the Adana plain and the Gulf of Isenderun), and (ii) the trapping, by submarine topographies, of the sediments produced by the erosion of continental reliefs both in Cilicia (Adana and Ceyhan plains), and the Iskenderun Gulf (Fig. 3).

Accordingly, the lowlands and marine basins are organized in three entities (and not two): the Adana and Ceyhan plains, and Iskenderun Gulf (Figs. 1, 3).

2. Agents Controlling the Delta front Dynamics Today

Within this well constrained structural frame (mainly active tectonics), the building of the coastal areas on land is also controlled by processes interplaying between the sea (air and sea currents), the sea-land interface (coastal areas), and the continent (land and stream).

2.1. Along the shore

Because of high evaporation rates during most of the year and of the low turnover of marine water, the salinity of the sea presents here the highest levels of the Mediterranean Sea (39‰) and a tidal range of 50 cm (to be compared with 100 cm at Gibraltar and 150 cm in the Gabès Gulf in Tunisia). The waters of the Iskenderun Gulf are also the warmest in the whole Mediterranean Sea. Currents, whether marine or winds, are important agents of the water and sediment circulation in and around the delta.

2.1.1. Winds

In Cilicia, winds reach strong speed for some 15 % of the year. According to their monthly distribution, the prevailing winds blow from N, NNE, and NE, but mainly during winter. Near the coast, prevailing winds blow from S and SSW (i.e. from the sea), and are more frequent during summer than in other seasons, both in frequency and in strength, (Altan et al., 2004; Özpolat et al., 2021). Along the coast of the plain, these winds weaken the stability of the dunes and of the shore line, particularly in summer when dune vegetation suffers from hot temperatures and salt concentration in the air (Özpolat et al., 2021).

2.1.2. Marine currents

Marine currents in the region belong to the main circum-Mediterranean westward circulation, originating here from the Levantine coast. This current turns north around the elongated relief formed by the Cyprus island and the submarine part of the Misis relief. Past this turn, it continues west along the Turkish Mediterranean coast. Superimposed on this general movement, vortex currents with high velocities occur in rather short distances from the coasts of the Iskenderun Gulf and Cilicia which favour their formation (Gérin et al., 2009) (Fig. 4). These whirling currents modify the paths and strengths of the main marine coastal current, as well as the salinity of coastal waters at places. Fig. 4 illustrates whirling currents in front of the northern Syria-Samandağ coastline. In the Iskenderun Gulf a similar vortex appear to also form, mixing both the highly saline and warm waters of the Gulf and Cilician coastal waters; vortex can also form along the Cilician coast west of the Karataş rock Point (Taupier-Letage, 2018). As a result of these events, the marine erosion of the coastal deposits may be much more important west of Karataş than east, while the western part of the Iskenderun Gulf may also receive sediments provided by westward-circling currents penetrating the Gulf (Taupier-Letage, 2018), that would feed the Ceyhan delta.

2.1.3. Climate-forced sea level rise at the end of the Last Glaciation (since c. 16 ka years ago): timing and magnitude of induced changes in the Mediterranean

In the Mediterranean, the first significant addition of meltwater after the LGM about 19 ka, may have started with the world ocean level rising 10-15 m in less than 500 years (see references in

Benjamin et al., 2017). During the Bölling-Alleröd warming interval, an even more significant phase of accelerated sea-level rise occurred. The timing and magnitude of this rise in the global ocean vary according study places. Features collected by Benjamin et al. (2017) are:

- 16-24 m between 14.6 and 13.5 ka (Weaver et al., 2003), or

- 14-18 m between 14.65-14.31 ka (Deschamp et al., 2012), or

- 20 m between 14.3 and 13.8 ka (Bard et al., 2010).

From 12.8 to 11.7 ka ago (i.e. during the Younger Dryas cold event), the rate of sea-level rise slowed down, but with varying intensities (Carlson et al., 2008).

* During a first phase of the Early Holocene (11 to 8.8 ka cal BP) south of today's Po delta, the sea level rose with a peak around 9.5 ka BP (Correggiari et al., 1996). During the rest of the Early Holocene, the sea level rise was punctuated by smaller meltwater peaks due to episodic deglaciation episodes of the Laurentide ice cap. In several places in the Mediterranean, the 8.2 ka cold event that ends the Early Holocene, was preceded by a sea-level jump of one or two metres (Tornqvist and Hijma, 2012).

* During the mid-Holocene (after 8 ka cal BP), sea-level rise slowed down again, reaching its present level by 4 ka cal BP. In the Adriatic, this decrease in the rise rate led to the formation of a well-developed deltaic complex of the Po River, which is today partly preserved at a depth around -40 m between 40 and 60 km offshore of the city of Ravenna (Correggiari et al., 1996; Cattaneo and Trincardi, 1999).

* By 4000-3000 cal BP in tectonically stable regions, sea level remained close to present levels, with small fluctuations either below or slightly above the present. In the eastern Mediterranean however, as along the Turkish shore areas, significant regional and micro landscape changes occurred because of adjustment in land level caused by tectonic activity uplift *vs* subsidence (Pirazzoli, 2005).

Leaving aside the tectonic component of the forcing processes, one important conclusion must be retained from this post-glacial Mediterranean overview, that concerns the Cilician coasts. The Early Holocene climate-forced sea level increase in the Mediterranean sea, together with increasingly humid climate, led to the development of huge deltas over low-sloped sub-marine and continental areas fringing the mountain feet, fed by river systems inland delivering massive loads of sediments from deglaciating highlands. On the basis of this context -and whatever age is the pile of sediments of the Çukurova plain and delta developed in the NE corner of the Mediterranean sea, a gentle-sloped and thick Late Glacial and Holocene sediment coverage exists both above et below today's coastal line. In addition, we can expect that the most complete sediment record is over the continental "plateau" that is today marine, while sediments in the continental part (above today's sea level) correspond mostly to the Mid to Late Holocene period.

2.2. Inland

2.2.1. Climate on land

Climate in the Çukurova plain and surrounding areas is characterized by a very humid variety of the Mediterranean climate (Fig. 5). During summer, dry and warm summers generate a high humidity content of the air above the numerous wetland and humid ecosystems of the delta (Atalay et al. 2014); Yearlong, relief increases the precipitation amounts up to 1000–1200 m altitude, generating a subhumid-to-humid Mediterranean climate in the transitional highlands (Atalay et al. 2014). In autumn and winter, Mediterranean depressions, which have become colder when passing over Europe and the sea (Türkeş and Erlat, 2003), collide with the relatively cold air leaving Anatolia southwards and with the warmer Saharan air masses over Cyprus (Cullen et al. 2002). A front thus forms, that conducts the Atlantic-sourced Mediterranean depressions storms onto the land, triggering abundant rain and snowfall on the mountain slopes encircling the delta plain and the delta (LaFontaine and Bryson, 1990).

2.2.2. River network

All this rain-born humidity returns to the Çukurova plain and neighbour lowlands, through the water courses of several rivers, the main ones flowing from (i) the Central Taurus (the River Seyhan basin), and (ii) the highlands separating the Mediterranean basin from the Euphrates basin (the River Ceyhan basin) (Fig. 1).

Above the Adana plain, the Seyhan River drains water running from slopes facing the SE. Its headwaters are two rivers separated by the Tahtalı Mountains, which meet near the Gökçeköy village. In the northwest, the western branch originates from the Uzunyayla Plateau NE of Kayseri (at the eastern extremity of the Central Anatolian endorheic area). In the north-east, the other branch (Göksu River) originates from the Binboğa Mountains separating the Mediterranean and Eastern regions of Turkey. Downstream, part of the Seyhan River enters the Çukurova plain through the old Roman city of Adana.

Also flowing into the Çukurova plain, the Ceyhan River springs in the Elbistan plain, north of the Nurhak Mountains. Its eastern divide separates the Mediterranean basin from that of the Euphrates River. Strabo (xii. p. 536, in Karmer 1852) records that, before his time, the upstream part of the Ceyhan River used to flow underground and that it was navigable downstream the resurgence. Strabo also claims that, in some parts of the river course, the channel was so narrow that a dog or hare could leap across it. At present, these canyons are inundated by several dam lake reservoirs, with the exception of the Kısıklı Canyon south of the Menzelet Dam (Kuzucuoğlu et al., 2019: 71).

Profiles of these rivers are dominated by very steep slopes in the highest parts of the watershed, whether in the Central Taurus and Elbistan ranges, or in the Amanos massif. These systems collect high amounts of precipitation that they transport to the Adana and Ceyhan plains , as well as to the northern shores of the Iskenderun Gulf. Meantime however, part of the rain and snow falling over the highlands runs into karstic systems which may be deep and well developed because of the geological context (limestone thickness + uplift intensity) that occurred during and after the formation of the Taurus highlands and associated plateau reliefs. For this reason, the volume of sediment delivery by the rivers when reaching the lowlands and the sea, can be underestimated.

3. Recent Evolution of the River Paths in the Plain, Coastal Line and Delta

As underlined above, the sediment series accessible in today's Cilician plain and coastal areas, can only record Mid-to-Late Holocene environmental changes. Early Holocene remains (including Palaeolithic to Neolithic sites, if ever) are today buried below Mid-Holocene sediments. Early Holocene sediments resulting from highland erosion and coastal aggradation responding to the start of the Late Glacial and Early Holocene sea level rise (see the 0 to -100m bold black lines in Fig. 3), they may be found in today's plain only by very deep coring. When sea level stabilized ca. 6000-4000 years ago (end of Chalcolithic/early Bronze Age), the high sediment input discharged by rivers continued, building coastal areas and deltas seawards. According to data from similar large deltas in the Mediterranean, it is most probable that sea level stabilized, (i.e. the coastline altitude) to its present position c. 4000 years ago. In Cilicia however, it is also possible that subsidence continued at places controlled by recent tectonic movements. In this case, sediment input also continued over some coastal areas such as in the Ceyhan delta which prograded over the western submarine landforms of the Iskenderun Gulf.

As a result of the Mid-Holocene stabilization of the sea level, multiple and large-scale changes in the position of channels, back-swamp, oxbow lakes, as well as dune fields constructions occurred, evidenced today by remote sensing analyses of landscapes in the Çukurova. These landforms record translations of fluvial channel patterns, with river avulsions and consequent palaeomeanders, abandoned channels and suites of concentric features generated by progressive lateral meander migrations (e.g. Çetin et al., 1999; Gürbüz, 1999; Erol, 2003; Ozaner, 2004; Ataol, 2015; Isola et al., 2017).

3.1. From the Chalcolithic to the Iron Age

Deep cores as well as geomorphological and sub-surface sedimentological data studied by Gürbüz (1999) show that the Seyhan River was running from north to south-east, in direction of the Akyatan lagoon. Its mouth was located in the Tuzla area (i.e. ca. 10 km west and at least 4 km to the south of the present-day mouth). It was then a wave and wind constructed delta submitted to a strong erosion, today recorded by fossil flood plain muds on the present coastline. This erosion was caused by a succession of events: (1) decrease or stop of coarse grained sediment river input to the sea, followed by (2) sea currents forcing the migration of the channel westwards, causing (3) the sea to erode the delta previously built at the former mouth. Gürbüz (1999) does not produce any date précising the chronology of this evolution, nor any discussion about subsidence that could have caused the random depths and lateral locations of the many fossile coarse river channels recovered through the cores.

This record is completed by the spatial distribution of archaeological sites in the Cukurova plain (Seyhan and Ceyhan plains) distributed on satellite images interpreted by Rutishauser et al. (2017). The resulting map (Fig. 6) evidences, together with three distinct groups of river channels, the hydrographic evolution of the plain and delta areas during the Mid to Late Holocene. Remarks and discussions raised by these results can be summarized as follows:

a) An initial situation (Early Holocene?) can be described as a river flooding activity (in green in Fig. 6), with channels connected to west and east rivers were meeting some 30 km north from today's Karataş point. At the time, the sea coast was lower than today, and sediment accretion was produced by multiple river channels migrating laterally over a wide area developed at the western foot of the Misis Highs. The absence of Neolithic sites in this area suggests that this accretion period was the Early Holocene, when climate was the wettest of the Holocene (sedimention accretion associated with wetlands and surface meanders), and the coastline some 15 to 20 kms downstream today's shore.

b) During the Chalcolithic, a change in the river dynamics inland occurred. The Ceyhan channels concentrated in a valley-like corridor at the foot of the Misis Highs, while the Seyhan river channels moved westwards over a plane and wide area at the extremity of which today's fluvial corridor of the Seyhan river concentrated. This record may evidence a subsidence of the plain west of the Ceyhan "valley area" c. 6000-5000 years ago, which continued until the Roman and Medieval epochs in the Seyhan "valley area" as shown by Özpolat et al. (2021). At the end of this period, archaeological sites identified were settled along a W-E pioneer (coastal?) track today positioned c. 18 km inland from today's coastline (Fig. 6).

The following periods of the Late Holocene, Roman and Hellenistic sites grouped in locations close to today's main Seyhan and Ceyhan rivers active paths, abandoning the area between both valley systems. The reason for this is probably that it was transformed into a wetland-rich area, subject to numerous and imprevisible floods, that was repulsive for agriculture and settlements). Nevertheless, while flood valleys concentrated human activities, a few sites started colonizing the "no-man's land" where green channels are concentrated in Fig. 6, indicating that, during Roman to Hellenistic period, a prioneer movement started the modern site distribution in the plain and its colonization by increasing human groups.

Regarding the evolution of the plain environments during the modern period, the maps drawn by 19th century travelers and historians of the main river paths in the plain, exhibit their still very pregnant mobility (Kuzucuoğlu et al., 2019) (Fig. 7). They illustrate, in particular (i) a sliding westwards of the Seyhan River, leaving the Akyatan laguna to develop at its former mouth (Gürbüz, 1999), while (ii) the Ceyhan River constructed east of the Misis High and Karatas rock point, a huge delta growing into the Gulf of Iskenderun.

However, stamps in Figure 7 also testify for some lack of knowledge about the coastline (e.g. the 1855 stamp).

Today

With a ~300 km length and a 20,670 km^2 catchment, the Ceyhan River used to be, in its natural state, a major source of sediment which contributed to form an enormous delta east of Karataş. In 1935 however, the apex event for mobility of rivers in the plain occurred, with the displacement of the Ceyhan river mouth westwards in direction of the Karataş rock point (Erinç, 1953; Russell, 1954) (Fig. 7). This catastrophic avulsion event occurred during a very important flood (Ataol, 2015). Changes in river paths during floods, was a current process forcing meander sliding over the plain surface since the start of the plain construction. In 1935 however, this change of direction was a "point of no-return" because it concerned the main sediment and water in-flow feeding the delta in the eastern part of the plain, emphasizing the hydrologic trend of water channels to slide westwards. Besides, this avulsion confirms the subsidence of the western part of the Cilician part, as well uplift impact associated to the Misis Highs that forced the Ceyhan River mouth displacement westwards. Meanwhile and according to Seyrek et al. (2008), this lateral variation confirms an "uniclinal" shifting of the river.

Since then, photographs from airplanes (Bal, 2000; Ozaner, 2004; Özpolat et al., 2021), completed by satellite imagery at various dates, have evidenced a see-saw trend (accumulation *vs* erosion) very dangerous for the preservation of the coastal areas of the Çukurova plain and delta. For example, the comparison of the 1947 air photograph with a 1995 Google Earth Imagery (Figs. 8) (Bal, 2000), as well as the comparison between a 1950 air photograph and a 2016 satellite imagery in Özpolat et al. (2021) together with chronologic comparisons of satellite imagery from 1985 to 2020 (Figs. 9, 10), illustrate a tremendous erosion of both the Seyhan and Ceyhan river mouths. From this set of figures (Figs. 8 and 9), it is easy to date the reversal of sedimentation/erosion trend after 1995, with the erosion clearly pregnant on river mouths since 2000. Before that date, at the beginning of the 1950's for example, Russell (1954) described the dramatic seasonal coastal progradation around the Ceyhan river mouth, that resulted from sediment transported each spring by the peak discharge following nival melting upstream. In the 1990's, Çetin et al. (1999) estimated that this process typically increased the land area by ~7.5 ha annually.

However, since the Aslantaş Dam was completed in the Ceyhan valley in 1984 (Figs. 11 and 12), and even more with the construction (starting in 1988) of four more dams, the river flow downstream to the Ceyhan plain has become virtually sediment-free. Consequently, coastal erosion around its mouth is now a significant problem (e.g. Çetin et al., 1999; Bal, 2000) (Fig. 9), which has considerably increased in the last two decades (Fig. 10).

Conclusion

If the human factor pressures on resources are not considered, **the main factors controlling the coastal dynamics (progression vs erosion) of the Çukurova delta is the structural context**, because (a) it accentuates the partition between a western and eastern parts of the Çukurova plain, (b) it succeeds to attract the Ceyhan river delta westward away from the Iskenderun Gulf, (c) the tectonic attraction of sediments in the subsiding western part of the Cilician basin is stronger than that of the Levantine basin. As a result, and in spite of the mobility of the low courses of the main river channels and of their multiple secondary channels, the structural context strongly controls the fluvial dynamics in the plain on the long term.

This evolution is articulated by the role of the Misis Highs whose uplift (whether noticeable or not on the short term) accentuates the partition with a sedimentation activity more dynamic, especially since 1954 –and even more since 1990- west of the Highs in the Cilician basin than toward the Iskenderun Gulf.

In the future, and as a result of this evolution, the geomorphogenetic role of the River Ceyhan would have increased in the Cilician plain, comforting the positive dynamics of the Çukurova plain. However and on the contrary, the impact of dams retaining dramatically its sediment load since the 1990's, reduces its impact on the plain construction whose coastal environments is thus being eroded away by marine processes becoming more aggressive with time.

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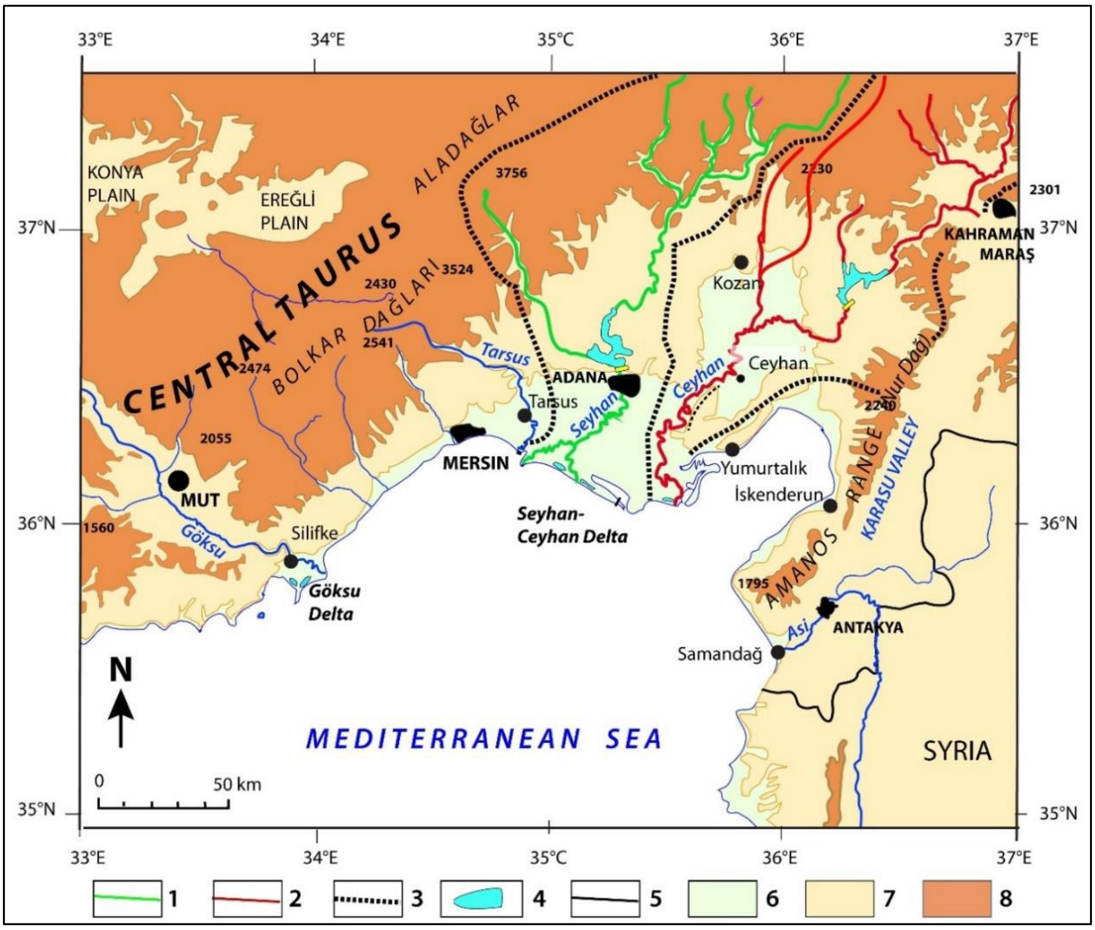

Figure 1. River network and watersheds contributing to the development of the Çukurova delta. Legend: 1: Seyhan River course; 2: Ceyhan River course; 3. Seyhan and Ceyhan rivers watershed limit; 4. Coastal lagoon; 5. Turkey-Syria border line; 6: 0-100m a.s.l.; 7: 100-1000 m a.s.l.; 8: > 1000 m a.s.l. Source: modified from Kuzucuoğlu et al. (2019), p. 83

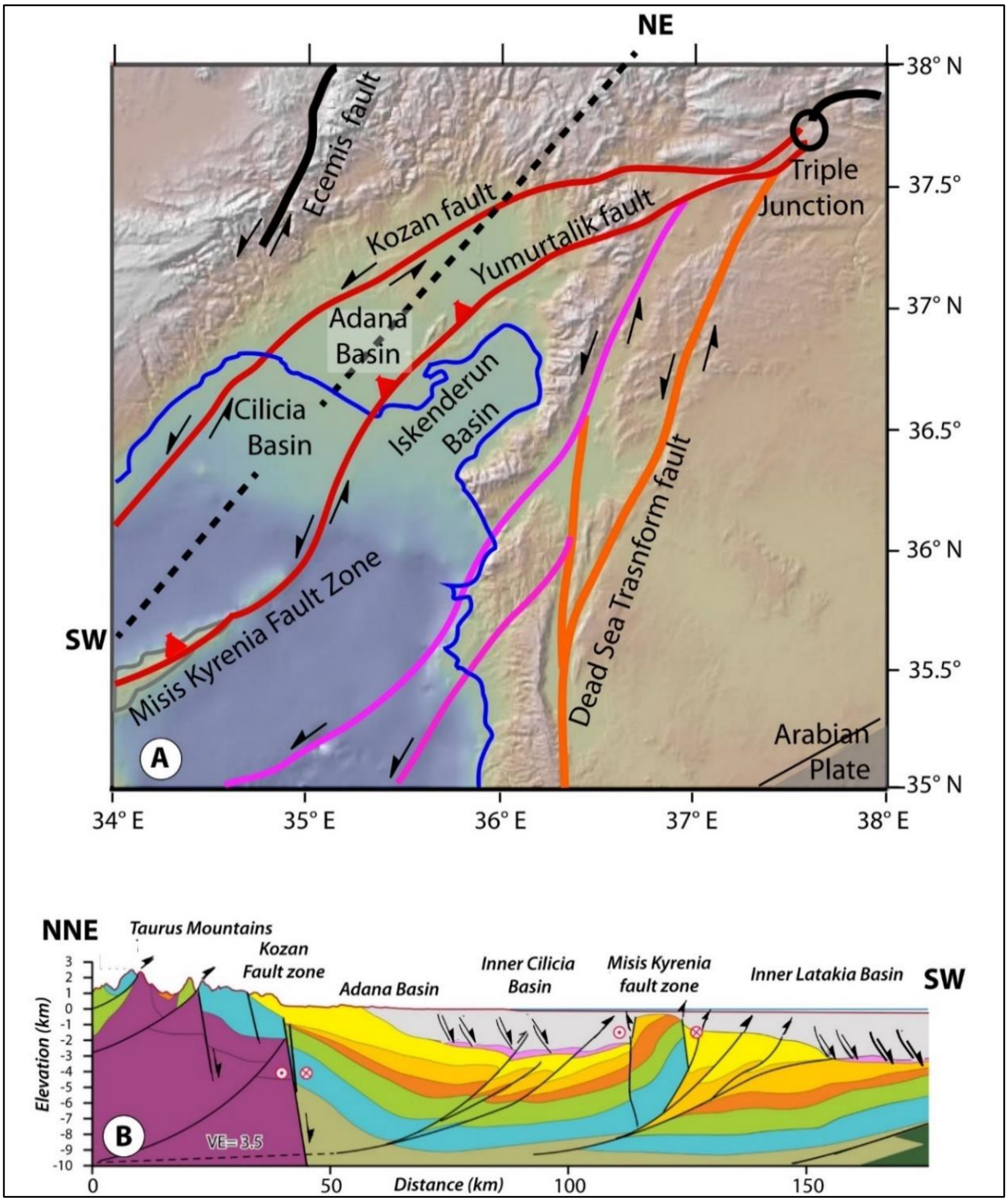

Figure 2. Structural constrains of the evolution of the Çukurova delta, from Göksu river mouth to İskenderun basin. A. Main fault lineaments (background map source: GeomapApp software), B. Geological cross-section from Kozan highlands toward Cyprus Sea. Source: modified from Aksu et al. (2021).

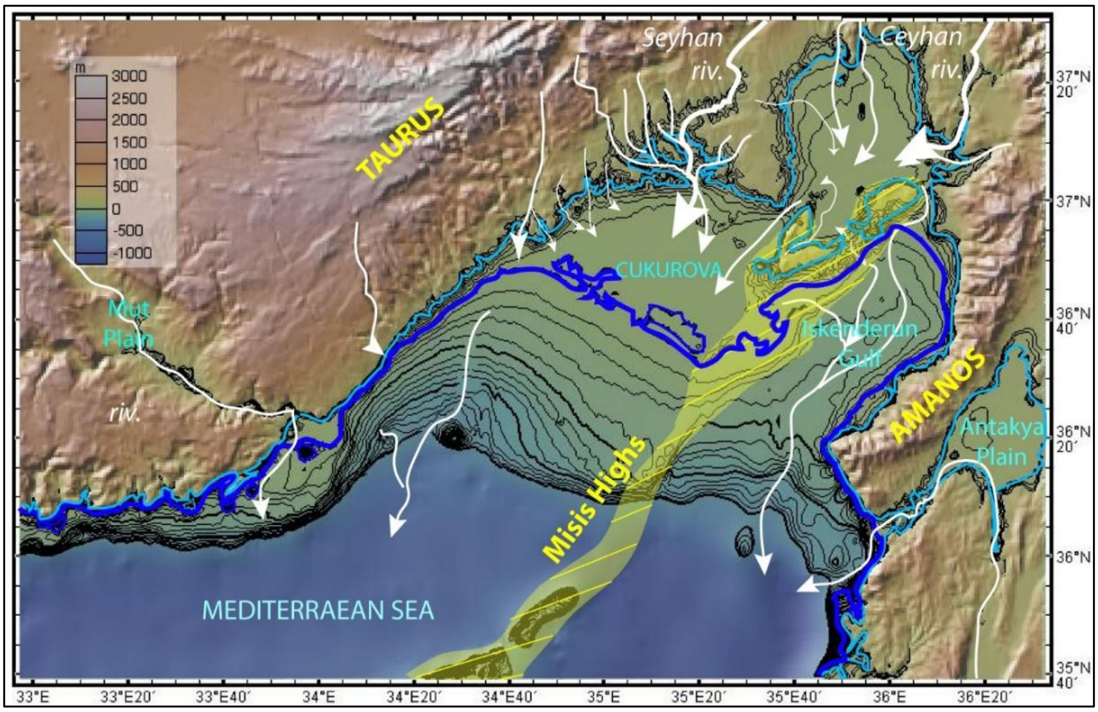

Figure 3. From the continent to the deep sea: topography and flow organization. Legend: White arrows: Erosion or structural features concentrating water flow originating from the continent; Light blueOld contour: 100 m a.s.l.; Dark blue contour: 0 m sea level; Bold black contours: every 100 m down to 300 m b.s.l. contours; Thin black contours: every 20 m. Source of contours map: GeomapApp.

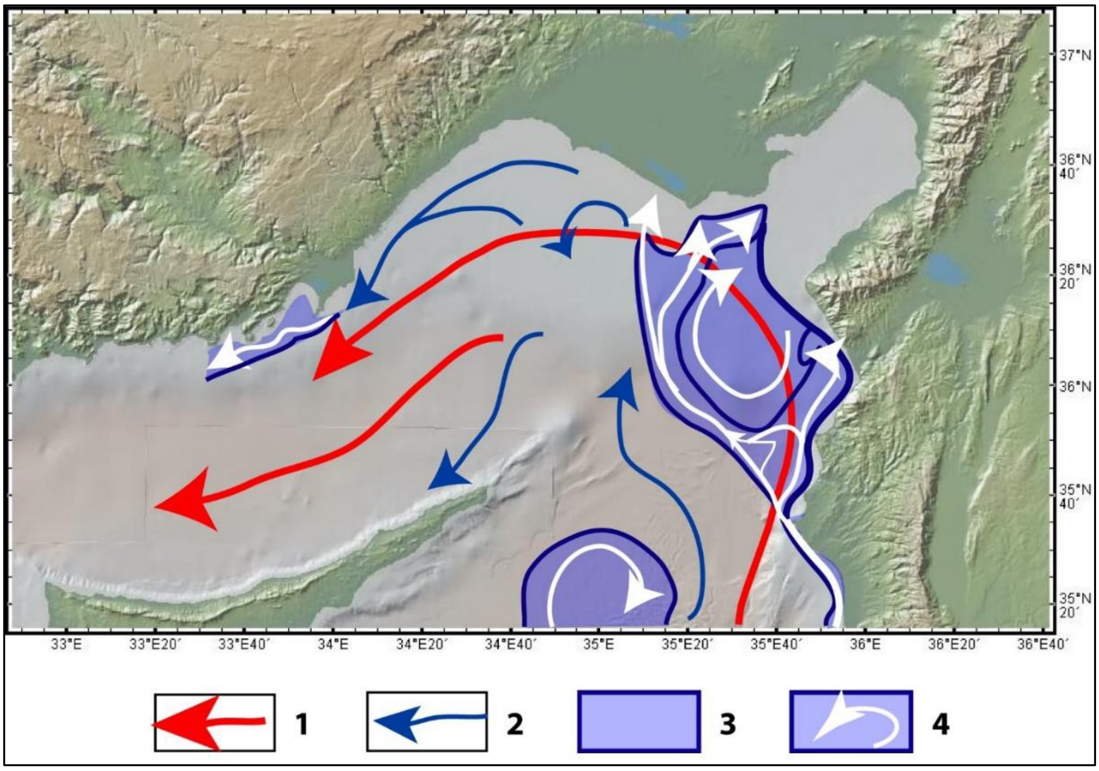

Figure 4. Marine currents in the Gulf of İskenderun and the Cilician marine Basin. Legend: 1. Mediterranean Basin-wide main current; 2. Secondary currents; 3. Whirling currents at sea: 4. Marine areas concerned by whirling currents. Source: modified from Gérin et al. (2004), and Taupier-Letage I. (2018).

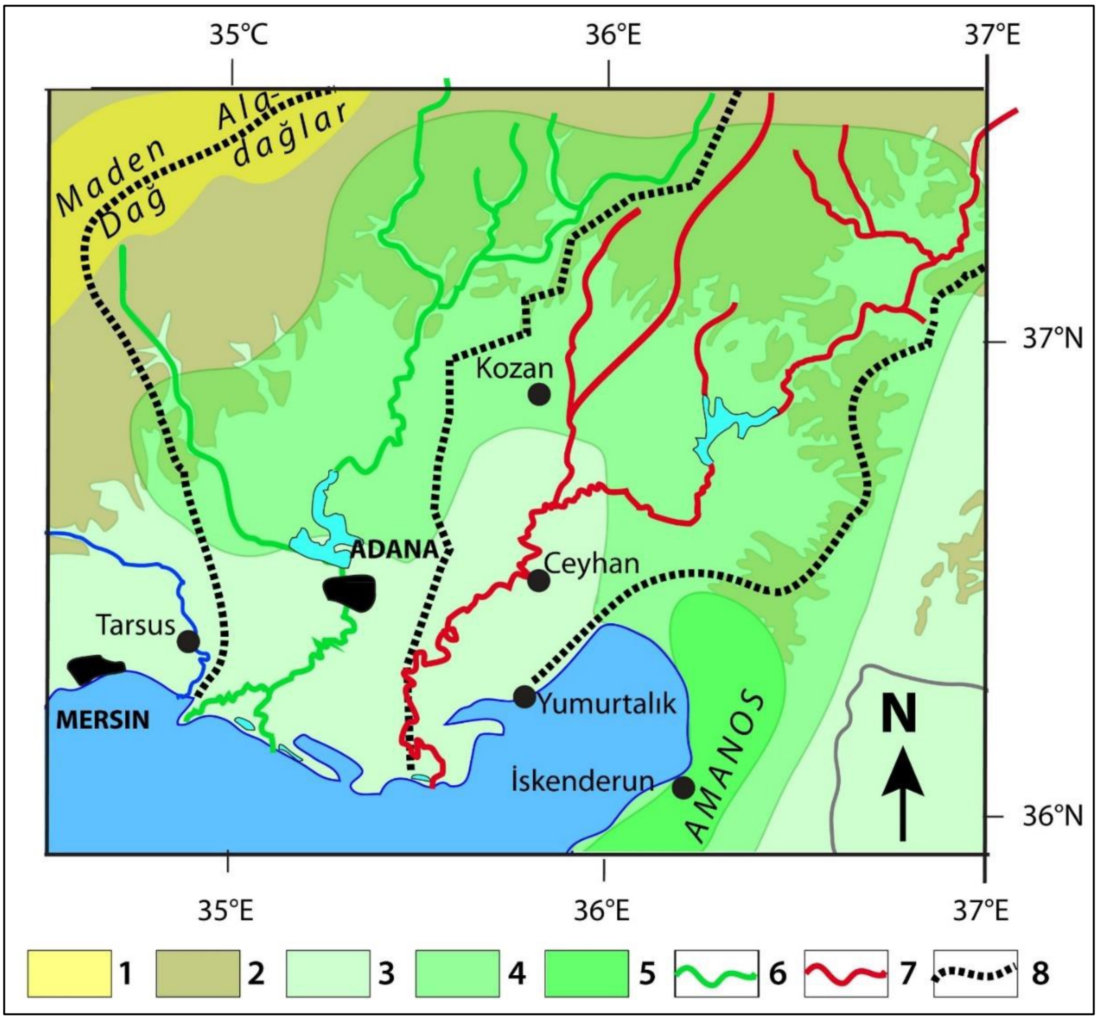

Figure 5. Mean annual precipitations over areas drained by rivers toward the Adana and the Cilician plain. Legend: 1. Area with P < 300 mm/yr; 2. Area with 300<P<600 mm/yr; 3. Area with 600<P<800 mm/yr; 4. Area with 800<P<1000 mm/yr; 5. Area with P > 1000 mm/yr. Source: modified from Atalay et al. (2014) and Sensoy (2016).

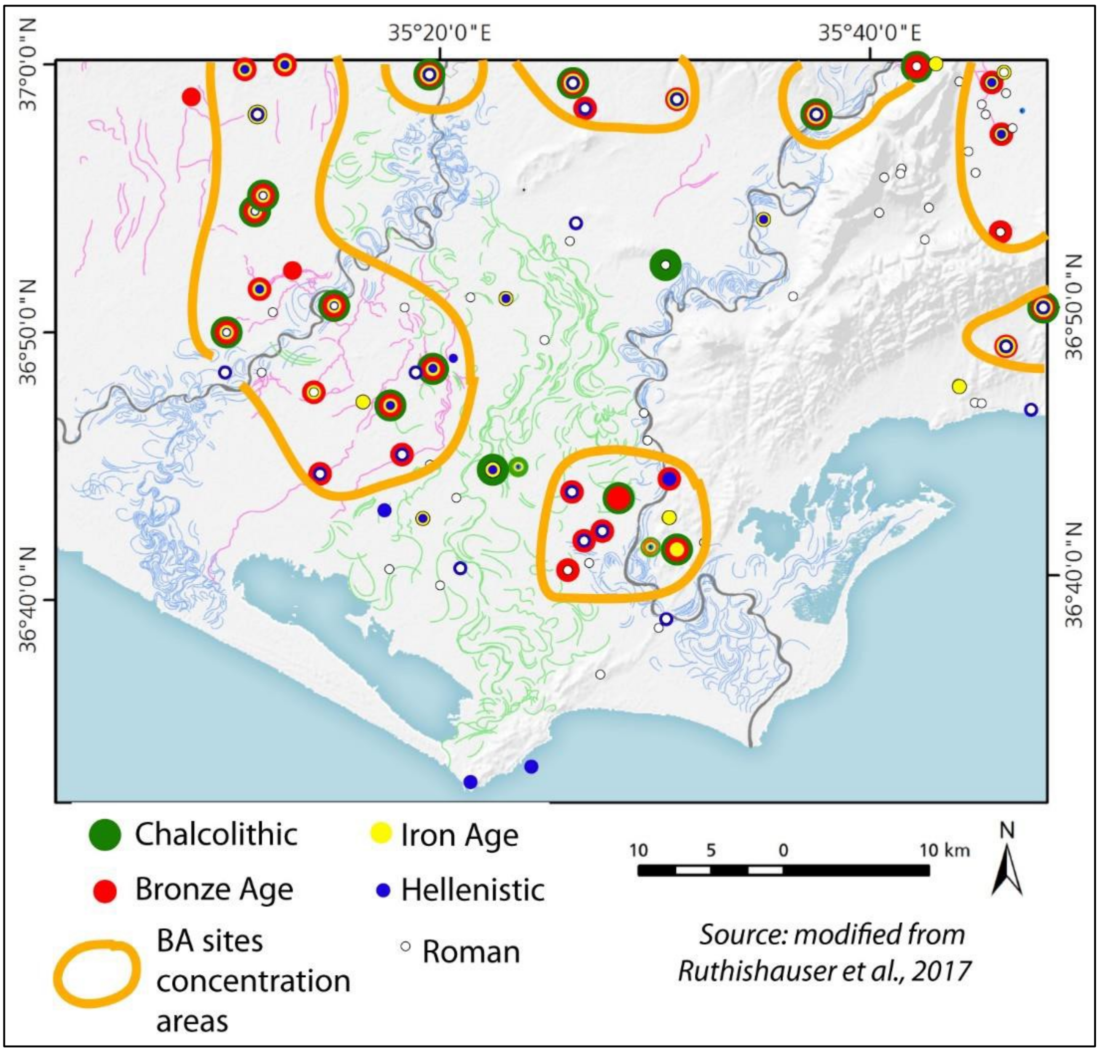

Figure 6. Archaeological sites identified by surveys in the Çukurova delta. Legend of background map: Black lines: Main beds of the Seyhan and Ceyhan Rivers (2015); Blue lines: Seyhan and Ceyhan Late Holocene divagation channels; Green lines: River divagation channels previous to Bronze Age; Purple lines: Relict canals. Source: modified from Rutishauser et al. (2017).

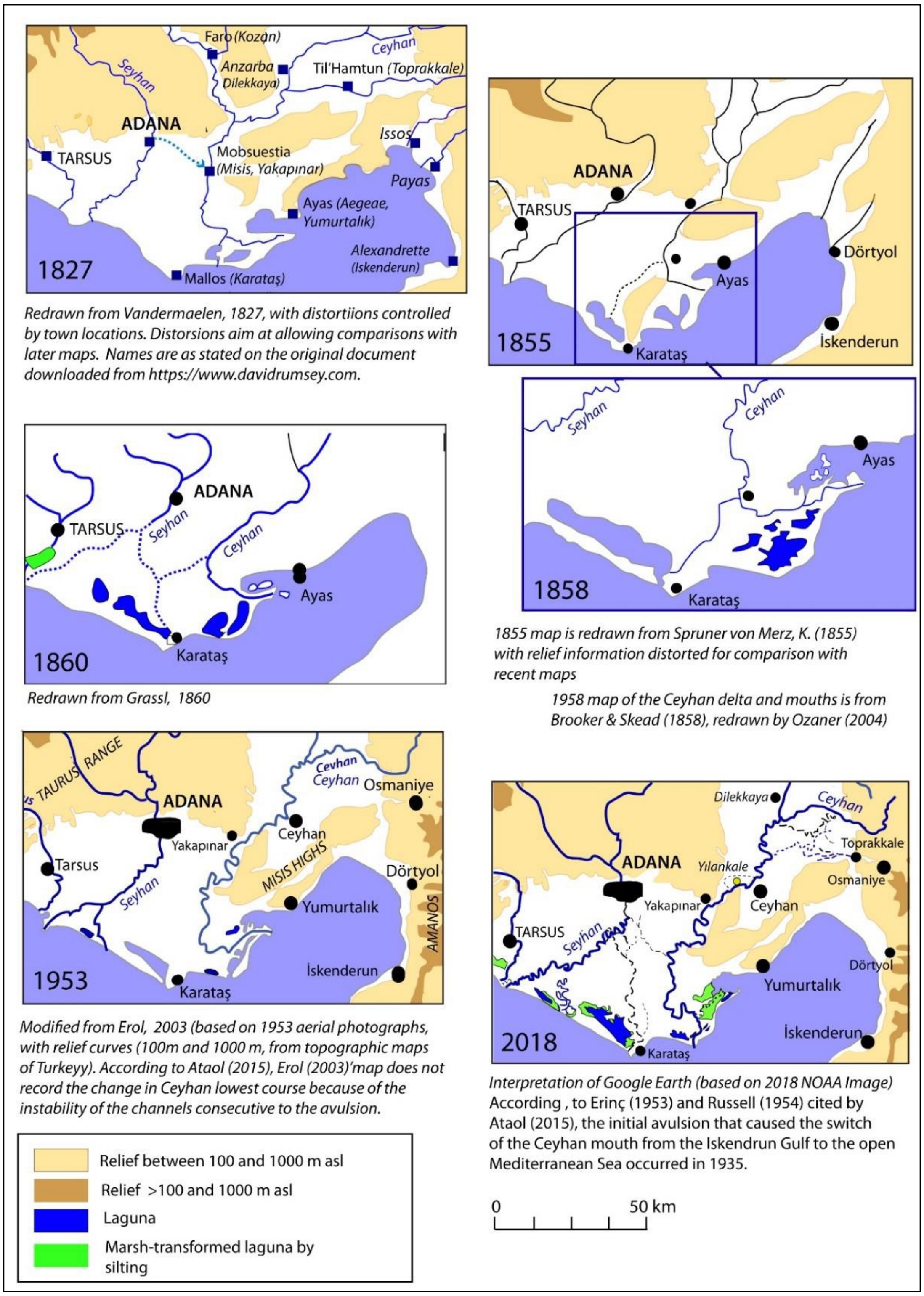

Figure 7. Changes in hydrographic patterns and coastlines since the early 1800's (1827-2018). Source: Kuzucuoglu et al., 2019 (p. 85). Figure based on Spruner von Merz (1855) map for 1855 stamp; Brooker & Skead (1858), redrawn by Ozaner (2004) for 1858 map; Grassl (1860) for 1860 map; Erol (1953) for 1953 map; and Google Earth imagery (NOAA) for the 2018. Note that the course of the Ceyhan River as drawn by Erol (1953) is the state of the art before the diversion in 1935.

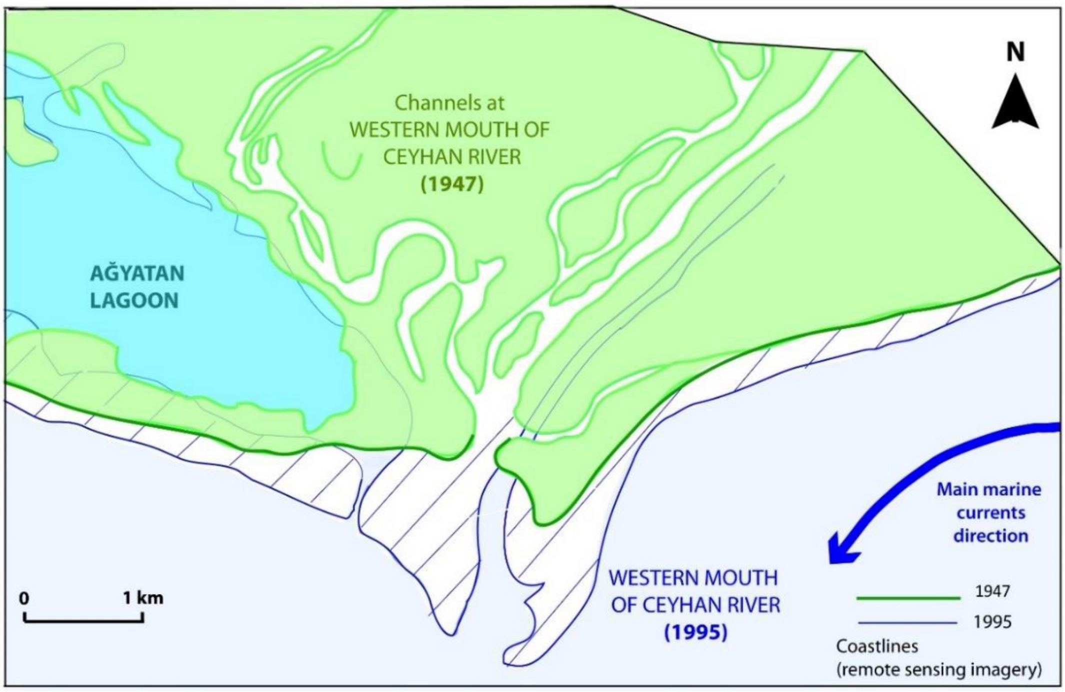

Figure 8. The Ceyhan River mouth at sea: comparison between 1947 and 1995. Source: redrawn from Bal, 2000.

Figure 9. Evolution of the mouth areas of the Seyhan and Ceyhan rivers from 1985 to 2020. Source: images available at Google Earth (2020).

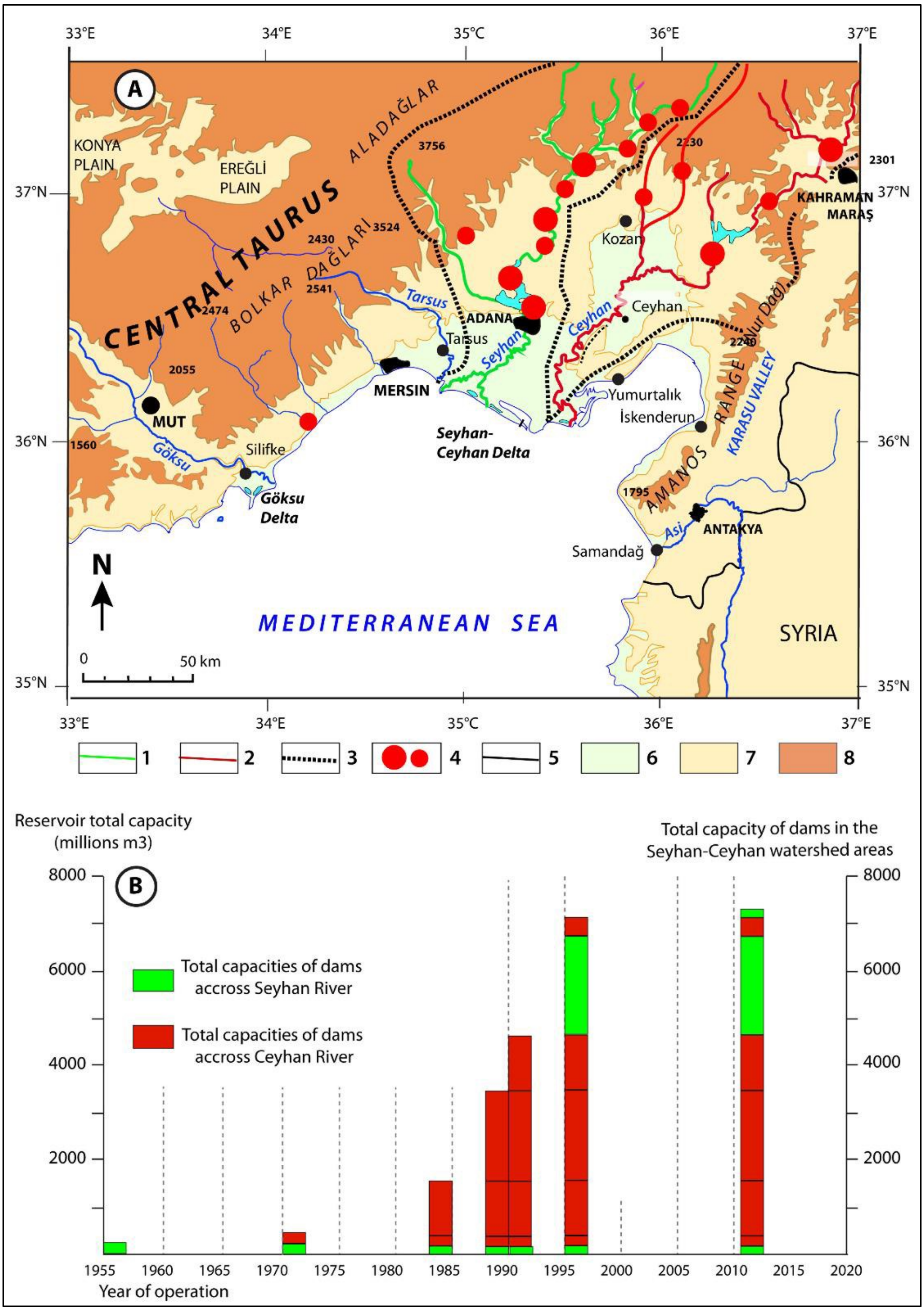

Figure 10. Dams in the watersheds of the Seyhan and Ceyhan rivers and the growth of water volume capacity retained in their reservoirs, from 1956 to 2013. A: Dam Locations. Sources: Background map is modified from Kuzucuoğlu et al. (2019), p. 83. Dam locations are from Google Earth (2020), with size of blue circles representative of small and large dams based on data from capacity of reservoirs list in Wikipedia. B: Growth of total dam reservoirs capacity, distinguishing Seyhan and Ceyhan Rivers. Source for dam operation year and capacity of dam reservoirs: https://en.wikipedia.org/wiki/List_of_dams_and_reservoirs_in_Turkey.

Urla Kıyı Düzlüğündeki Limantepe-Klazomenai'nin Paleocoğrafya ve Jeoarkeolojisine Paleontolojik Analizlerin Katkısı

Contribution of Paleontological Analysis to Paleogeography and Geoarchaeology of Limantepe-Klazomenai on the Urla Coastal Plain

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Özet

Batı Anadolu kıyılarında yer alan Urla Yarımadası, tarih çağları boyunca yerleşim için elverişli coğrafi şartlara sahip olmuştur. Yarımadaya adını veren Urla kentinin kuzeyinde İskele kıyı düzlüğü yer almaktadır. Urla'nın İzmir Körfezi kıyısındaki İskele Düzlüğü, batı kesimindeki Klazomenai antik yerleşme yeri ile tanınır. Limantepe, kıyıda 15 m kadar yükseklikte bir tepe olup batı eteğinde batık bir antik liman bulunur. Arkeolojik araştırmalara göre, burada ilk yerleşme Tunç Çağında (GÖ 4800-3900) Limantepe ve güney eteğinde başlamıştır. Gelişen yerleşme, batıya ve güneye doğru alanını genişletmiş, Arkaik ve Klasik çağların (GÖ 2800-2400) Klazomenai kentini oluşturmuştur. Helenistik Çağda da kullanılan liman daha sonra işlevini yitirmiş, kentin gelişimi sona ermiştir. Limantepe-Klazomenai yerleşmesinin kuruluş, gelişme ve sonlanmasında Holosen transgresyonu, bunu izleyen alüvyal dolgu süreci, küçük ölçülü son deniz seviyesi değişmeleri ve kıyı çizgisi değişmelerinin önemli etkileri olduğu dikkati çekmiştir. İskele mevkiindeki Limantepe ve Klazomenai antik kentleri de bu değişimlerden etkilenmiştir. Limantepe-Klazomenai yerleşmesinin kuruluş, gelişme ve sonlanmasında Holosen transgresyonu, bunu izleyen alüvyal dolgu süreci, küçük ölçülü son deniz seviyesi değişmeleri ve kıyı çizgisi değişmelerinin önemli etkileri olduğu dikkati çekmiştir. İskele kıyı ovasında Holosen doğal çevre değişmelerinin ve arazi kullanımına etkilerinin belirlenebilmesi için toplam 24 delgi sondaj gerçekleştirilmiştir. Delgi sondajlardan sağlanan sediman örneklerinin sedimantolojik ve paleontolojik analizlerine ve arkeolojik bilgilere dayalı jeomorfolojik değerlendirmelerin sonucunda Holosen transgresyonu ile ilerleyen denizin kıyı çizgisi, günümüzden 6000 yıl kadar öncelerde, İskele düzlüğünün orta kesiminde bugünkü kıyıdan en çok 1 km içeriye kadar sokulabildiği ortaya konmuştur. Limantepe batısında bu ilerleme çok daha dar alanlıdır. İskele düzlüğünde, Orta Holosen sonrası alüvyal dolguya bağlı kıyı ilerlemesinde iki büyük şekil birimi birlikte gelişmiştir. Bunlardan biri, çok sığ kıyı profili üzerinde yayvan ve geniş bir kıyı setidir. Bunun iç kenarındaki Arkaik Çağa ait nekropol, oluşumunun 3000 yıldır sürdüğünü göstermektedir. İkinci birim setin iç tarafındaki sulak alandır.

Anahtar kelimeler: Urla, Limantepe, Klazomenai, Paleocoğrafya, Jeoarkeoloji, Paleontoloji, Fosil

Abstract

The Urla Peninsula, which is located on the shores of Western Anatolia, has had favorable geographical conditions for settlement throughout the ages. To the north of the city of Urla, which gave its name to the peninsula lies the İskele coastal plain. On the shore of İzmir Gulf, the plain is renown with the ancient

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settlement of Klazomenai. Limantepe is a 15 m high hill on the shore, housing a submerged ancient port on its western skirt. According to archaeological excavations, the first settlement here started on Limantepe and its southern skirt during the Bronze Age (4800-3900 BC). Then-burgeoning settlement expanded to the west and south, resulting in the city of Klazomenai of the Archaic and Classical Ages (2800-2400 BC). The port, which was also in use during the Hellenistic Age, lost its function, putting an end to flourishing of the city. The ancient cities of Limantepe and Klazomenai in İskele region also suffered from consequences of such changes. It appears that the Holocene transgression, followed by silting up by alluvial deposits, final small-scale sea level changes and shoreline changes played an important role in foundation, development and decline of the Limantepe-Klazomenai settlement. A total of 24 core drillings were performed on the İskele coastal plain to determine natural environmental changes and their impact on land use during Holocene. The sedimentological and paleontological analyses of sediment samples from these drillings and geomorphological evaluations based on archaeological data showed that the shoreline, which advanced by Holocene transgression, was able to encroach up to 1 km at most from the present shoreline in the middle section of the İskele plain about 6000 years ago. To the west of Limantepe, this encroachment is much narrower. Two major geomorphological units developed together on the İskele plain following progradation due to alluvial deposits. One of them is a flat and wide coastal barrier on a very shallow coastal profile, where an Archaic necropolis on the inner side indicates that its formation has lasted for 3000 years. The second one is a wetland in the inner part of the barrier.

Keywords: Urla, Limantepe, Klazomenai, paleogeography, geoarchaeology, paleontology, fossil

Giriş

Klazomenai ve Limantepe, İzmir Körfezi güneyindeki Urla-İskele kıyı düzlüğünde yer alırlar (Şekil 1). Bu arkeolojik sit alanları antik çağlarda yörenin önemli liman kentleridir. Limantepe güneyindeki Tunç Çağı eserleri, yerleşmenin erken evrelerinin geliştiği yerleri işaret eder. Geçen sürede yerleşim alanı batı ve güneye doğru genişlemiş ve Arkaik Çağda Klazomenai kenti gelişmiştir (Bakır vd., 2000). Limantepe, kıyı bölümünde 15 m kadar yükseklikte bir tepe olup batısında su altında kalmış antik liman bulunur. Batık liman bu alanda jeoarkeolojik araştırmaların kıyı çizgisi ve deniz seviyesi değişmeleri konularında yoğunlaşmasını gerektirmiştir.

Bu alanda, arkeolojik araştırmalara göre, ilk yerleşim Tunç Çağında (G.Ö. 4800-3900) Limantepe ve güney eteğinde başlamıştır. Gelişen yerleşme, batıya ve güneye doğru alanını genişletmiş, Arkaik ve Klasik çağların (G.Ö. 2800-2400) Klazomenai kentini oluşturmuştur (Erkanal, 2014). Helenistik Çağda da kullanılan liman daha sonra işlevini yitirmiş, kentin gelişimi sona ermiştir. Klazomenai ve Limantepe yerleşimlerinin bu alanda yer alıp gelişmeleri ve önemlerini yitirip günümüze arkeolojik buluntular halinde kalmalarında Holosen transgresyonu, bunu izleyen alüvyal dolgu süreci, küçük ölçülü son deniz seviyesi ve kıyı çizgisi değişmelerinin önemli etkileri olduğu dikkati çekmiştir. Bu gelişmeleri ortaya kayabilmek için 1990'lı yıllarda başlayan alüvyon sondajlarımıza ek olarak 2015, 2016 ve 2017'de olmak üzere yeni sondajlar gerçekleştirilmiş ve toplamda 24 adet sondaja ulaşılmıştır (Şekil 2, 3, 4 ve 5; Tablo 1). Bu sondajların ayrıntılı sedimantolojik ve paleontolojik analizleri yapılmıştır. Bunun yanında, yeni çevresel jeomorfolojik gözlemler ile bütün bu analiz sonuçları birlikte yorumlanarak arkeolojik bilgiler ışığında yeni paleocoğrafik-jeoarkeolojik değerlendirmeler yapılmıştır.

Urla Kıyı Düzlüğünün Jeomorfolojik ve Arkeolojik Özellikleri

Urla ve yakın çevresi Anadolu ile Çeşme-Karaburun dağlık alanı arasında bu iki bölgeyi birbirine bağlayan kıstak durumundadır. Bu alan, doğudaki İzmir Körfezi güneyindeki dağlık alan (1017 m) ile batıdaki dağlık alan (708 m-500 m) arasında, 100-300 m yükseltilerde, tepe ve sırtlardan oluşan arızalı bir rölyef gösterir (Şekil 1). Bu haliyle Urla kıstağı İzmir ve Kuşadası körfezleri arasında bir eşik durumundadır. Urla yerleşim merkezi bu eşiğin orta kesiminde, 100 m kadar bir yükseltide yer alır. Buradan güneye Kuşadası körfezine ve kuzeye İzmir körfezine doğru alçalan sırtlarla inilir. Kuzey bölümdeki sırtlar küçük ve kısa boylu derelerle aşındırılıp taşınan malzeme ile Urla-İskele kıyı düzlüğü oluşmuştur. Büyük bir akarsuyun bulunmaması nedeniyle Urla-İskele kıyı düzlüğünün gelişimi delta gelişiminden farklıdır (Kayan vd., 2018; 2019; Öner vd., 2019a; 2019b; Öner, 2020) (Şekil 6).

Urla ve çevresinde doğu ve batı bölümdeki yüksek kesimlerin yapısını Mesozoik yaşlı karbonatlı ve kırıntılı kayaçlar oluşturur (Şekil 5 ve 6). Dağlık alan arasındaki kıstak kesimi genç tektonik hareketlerle Miosen'de oluşan bir çöküntü -graben- alanı içinde şekillenmiş olup tektonik hareketler sırasında doğu ve batısındaki faylar boyunca volkanik etkinlikler gerçekleşmiştir. Bunların sonucu çevrede kırıntılı volkanik kayaçlar ile trakit ve dazit gibi asitik lavlardan oluşan formasyonlar yer almıştır. Çöküntü alanının ortalarında ise Orta-Üst Miosen'e ait gölsel, çoğunlukla kalker, marn ve yer yer kumtaşı, konglomera türünde tortul kayaçlar bulunur (Şekil 7 ve 8). Günümüzde meydana gelen depremler, bölgedeki tektonik etkinliklerin hala sürdüğünün işaretleridir.

Urla kıyı düzlüğü, 3 km kadar kıyı uzunluğuna sahip olup İzmir Körfezi dış bölümünün güneye doğru uzanan girintisi içinde gelişmiştir (Şekil 1). Güney kısmı küçük derelerin birikinti yelpazelerinden oluşan az eğimli bir etek düzlüğü şeklindedir. Buradan kuzeydeki kıyı düzlüğüne tedrici olarak geçilir. Güneydeki birikinti yelpazelerinde sel karakterli yağışlarla gelişen dere yataklarının izleri, geçiş bölümünden itibaren kıyıdaki düzlükte tamamen silikleşir (Şekil 6 ve 8). Bu durum kıyı düzlüğünde akarsu işleyişinin çok zayıf olduğunu gösterir. Bu yüzden kıyı düzlüğünün gelişimi akarsu ağızlarındaki delta gelişimlerinden farklıdır. Bununla birlikte düzlüğün gelişiminde denizel süreçlerin de etkisi yansır. Karantina adasını bağlayan yol nedeniyle batı ve doğu kıyı bölümlerinde bir farklılık bulunur. Karantina ada yolunun doğusunda, düzlüğün önünde, sığ bir kıyı profili üzerinde çok yayvan ve geniş bir kıyı seti bulunurken, batıda etek birikintileri önünde dalga aşınım şekilleri gelişmektedir (Şekil 2). Yaklaşık 2300 yıl önce yapılan bu bağlantı yolunun oluşturduğu engel, doğudan batıya kıyı boyunca taşınan sedimanın yolun doğusunda birikip sığlığa, buna karşılık batıda ise aşınmanın etkili olmasına neden olmuştur. Doğu bölümdeki sığlığın neden olduğu zayıf dalga etkisiyle, kıyı şekillenmesi yavaş ve dengeli olmuştur. Buradaki güncel kıyı setinin iç kesiminde Arkaik Çağa ait mezarlar bulunması, son 3 bin yıldır kıyı şeklinin çok fazla değişmediği, sadece deniz tarafında birikimle setin genişlediğini gösterir (Kayan vd., 2018; 2019; Öner vd., 2019a; 2019b; Öner, 2020).

Urla kıyı bölgesi kara ve deniz yönlerinde çok yatık bir profile sahip olduğu için kıyı çizgisi gelişimi bakımından deniz seviyesi değişmeleri önemlidir. Araştırmalar Ege kıyıları ile adaları arasındaki deniz ulaşımının Neolitik'e kadar gittiğini göstermiştir (Erkanal, 2014). Günümüzden 20 bin yıl önce son buzul çağı maksimumunda -130 metrelerde olan deniz seviyesi Holosen başlarında (12 bin yıl önce) -50 metrelere, 6 bin yıl önce ise günümüz seviyesine ulaşmıştır (Kayan, 1996; 2012; Waelbroeck vd., 2002; Brückner vd., 2010) (Şekil 9). Son 6 bin yılda küçük ölçülü deniz seviyesindeki yerel oynamalar sonucu oluşan kıyı çizgisi değişmelerinin sığ kıyılarda kıyıların kullanımını etkilemesi nedeniyle arkeolojik araştırmalar bakımından önemi fazladır (Şekil 9). Bu değişmelere ışık tutmak amacıyla 1990'lı yıllarda başladığımız alüvyon sondajlarına 2015, 2016 ve 2017 yıllarında da devam edilmiştir (Şekil 2, 3, 4 ve 5; Tablo 1). Bütün sondajların değişen birimlerine ait örneklerin sedimantolojik ve paleontolojik analizleri yapılmış ve Urla kıyı düzlüğünün jeomorfolojik gelişimi ortaya konmaya çalışılmıştır.

Urla Kıyı Düzlüğünün Holosen Stratigrafisi ve Paleocoğrafik Gelişimi

Urla kıyı düzlüğünün jeomorfolojik gelişimi ve özellikle son kıyı çizgisi değişmeleri ile Limantepe-Klazomenai liman ve arazi kullanımı arasındaki ilişkiler üzerine olan çalışmalarımız 1997 yılında Tabaklar kanalı batısında Cobra makinesi ile yaptığımız ilk sondajla başlamış, 1998 ve 1999 yıllarında yapılan 5 sondajla birlikte 6'ya ulaşmıştır. 1990'lı yıllardaki ilk çalışmalarımızda sağlanan verilerle ilk kesit çizilmişti. Uzun bir aradan sonra 2015 yılında yörede yapılan arkeolojik yüzey araştırması projesine katılmamız, Urla kıyı düzlüğünde yeniden çalışma olanağı sağladı. Bu aşamada 2015, 2016 yıllarında yeni arazi gözlemleri yanında, iki yılda toplam 15 yeni delgi sondaj yapıldı. 2017 çalışma döneminde ise yapılan üç sondajla birlikte ikinci dönem çalışmalarımız 18 sondaja ulaştı (Şekil 2). Böylece Urla-İskele kıyı düzlüğündeki toplam sondajlarımızın sayısı 24 olmuştur.