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Geomorphological evolution and sedimentation characteristics of Biga plain (NW Turkey)

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Abstract

The purpose of this study is to define the geomorphological features, formation, and development of the Biga Plain. The study is based on field observations, sand and gravel analyzes, and literature review. A digital elevation model was produced by using 1/25000 scaled toposheets. Satellite images were used to interprete the present geomorphological features. The plain base is composed of dendritic elements belonging to the Quaternary Period. In this low-inclined area rivers disappear in alluvium in some places. There schist, andesites, and granodiorites around the plain. Factors controlling the formation are fluvial processes and tectonism. Gravel has low flatness ratio and medium roundness ratio. This indicates that materials do not go far and undergo little processing, yet are carried by a flood river, deposited, and that fluvial processes prevail over the area. Many faults in the area, other fragments, and tectonic lines limiting the Biga Plain constitute various parts of the North Anatolian Fault Line. These factors have affected the drainage in the area.

Keywords: Geomorphological evolution; sedimentation; Biga plain; Turkey.

1. Introduction

The coastal plains are the world's most important agricultural and residential areas. A large portion of the world's population lives in the coastal zone. Coastal plains are very widely used since they are accessible low areas, and

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they are the places most exposed to the effect of people. The coasts are in the first places among the most affected parts by the sea-surface fluctuations (Amorosi et al., 2008), and climate changes that occur in Quaternary period. It is expected that the melt down of glaciers due to global warming will result in increases in sea levels, which will lead to significant changes in the coastal plains (Efe, 1993b; Davidson-Arnott, 2010).

Turkey, surrounded by the sea on the three sides, coastal plains have great importance in terms of agriculture and settlements. Most of the coastal plains are sites that have materials such as sands, pebbles and silts deposited by streams. In time, entisol soil has been developed on the accumulated material, and turned into fertile areas. There are a great number of plains in southern Marmara Region formed by fluvial and tectonic processes (Ardel et al., 1957). Tectonic movements occurred in the Neo-tectonic period had a significant role in forming these plains (Şaroğlu et al., 1987; Herece, 1990; Okay et al., 1990; Efe, 1993a; Yaltırak et al., 2002). In the result of these activities, some sites have uplifted and some sites lowered (Ardel, 1965; Ardos, 1973; Ecevitoğlu and Tok, 2003). The changes occurred at the base levels have affected the erosion and deposition processes. The erosional force of the streams from the higher parts have increased and the deposited materials have formed large plains on the sites where the slope decreased (Erinç and Bilgin, 1956; Erinç, 1988). Again in the result of same processes, terraces have been formed at various levels around the coastal plains. These terraces are seen on the south coasts of Marmara Sea at 2-3m, 8-10m, 15-20m, 50-60m and 80-100m, and even at 180-190m (Erol and Nuttall, 1975). It has been assumed that some of these terraces were formed by tectonic and some by eustatic activities (Erinç, 2001; Ertek and Yıldırım, 2001; Ardel 1967-1968; Bilgin, 1969; Erol, 1980; Erol, 1981; Ardos, 1984; Köpük, 1987; Erol and Şencan, 1996; Şencan, 2007). Many coastal plains were formed by neo-tectonic movements. Many of these plains have been shaped by the tectonic activities and the fluvial processes (Ardos 1985; Erinç 1988; Efe 1994; Soykan and Cürebal, 1999).

2. Material and Method

The study area is located in the northeast of the Biga Peninsula in western Turkey. The objective of the study to define the geomorphological features of the Biga Plain, and to set out the effective factors in the processes of morphological evolution and development of the plain. In this study, previously published research studies were evaluated and assessed. A digital elevation model was created utilizing the 1/25.000 scale topographic map. In order to explain the relationship between lithology and geomorphological units, General Directorate of MTA and DSI resources were utilized.

3. Findings

The Biga Plain located in the northeast of the Biga Peninsula is the sedimentation site formed by the materials deposited by the Biga Stream and its tributaries (especially the Koca Stream) flow from the plateau site in the north. The sediments deposited in the floor of the plains are being drained by the Biga Stream (the Kocabaş Stream, Granicos) like a big bowl and carries the feature of a rift plain with alluvial fill.

Around the Biga Plain, there are gently rolling sites which are not very high. These are fragmented by rivers and have a plateau like. The Biga-Danapınarı Plateau is located in the south, the Gürçesme-Kemer Plateau is located in the west and Karabiga-Karahamzalar Plateau is located in the north. In the low hilly site in the south and the west of the area lies detritals (sandstone) and andesites of Tertiary and Eocene period, and in the north lies Neogene formations.

To the east in the direction of Balıklıçeşme-Sevliköy, the Tertiary volcanic rocks (andesite, tuff) and detritals (sandstone) thrusting into the floor of the plains, and the geological structure formed by limestone with peninsula shape morphology, the extensions of the Gürçeşme-Kemer Plateau divide the Biga Plains into two separate parts (Bingöl et al., 1973). The first of these is a continuation of the Karacaali creek and the Geyikkırı creek directing to the east where the Biga Plain drains water in the west and north. The other half is the south and southeast of the Biga Plain where the Kocadere and the Koca Stream drain their waters. The river catchment boundary which divides the two catchment areas are separated with a threshold rising up to the west in the direction of the Taştepe (120m) and the Kaymakam Hill (120m), and with a line to be drawn to the east of the water section of the Karaboğa Hill (62m). In the east to the direction of southwest-northwest where the Koca stream, the Akkörü Village which own a drainage, it forms a tributary of Biga Stream, and the Geyikkırı creek indicating a west-east drainage is, today, dried up and used as an agriculture site the west of Lake Ece.

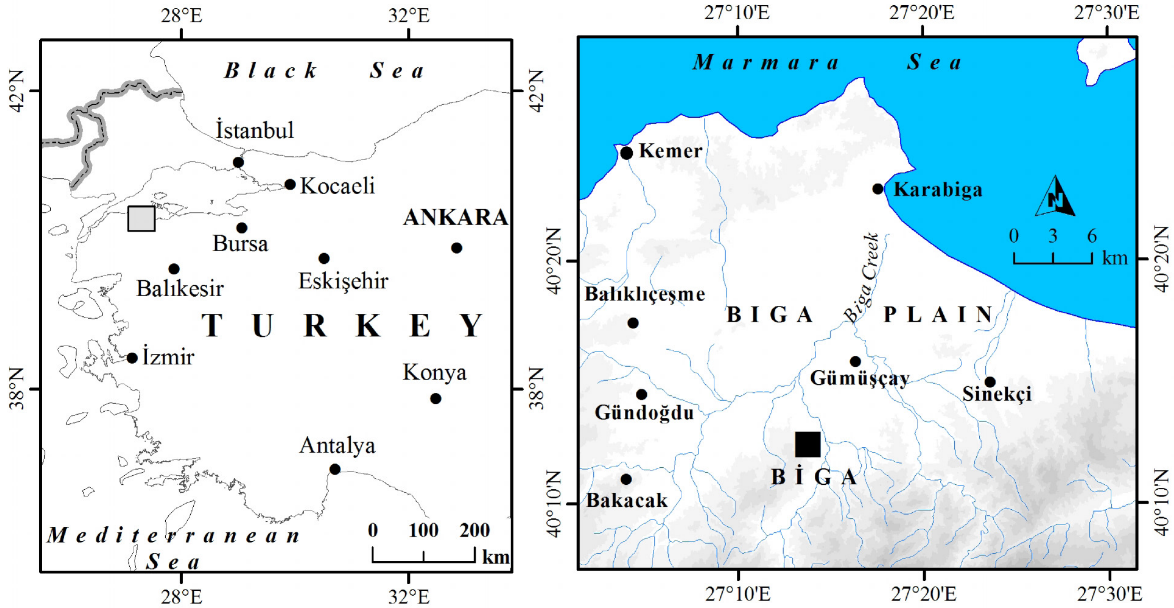

Fig. 1. Location of the study area

3.1. The West and North Sections of Biga Plain

The west and north section of Biga Plain are drained by the Geyikkırı creek and its tributaries. The stream fades away in the detritics in the floor of the plain before it reaches to the Biga Stream to the east of Yeniçiftlik. The weak streams in the north of the Geyikkırı and Karacali streams are thrust into the south inclined palteau sites. The slopes of the valleys in this site are not very steep and have created large alluvial floors in the basin.

The surfaces lined between the villages of Güleçköy and Çınarköprü match the former lake base level. The deposits reflecting a lacustrine sedimentation environment around the Güleç village was cut due to the changes of base levels and formed the former lake base status surfaces. Moreover, the systems lining up to Karabiga and Kocaada (12 m) and the surfaces of the Tokatkırı village to the east of İncirli Tepe (21 m), the Salkımlı Hill (15 m) and Kademlieneç Crest (24 m) carries the traces of the former lake as the levels formed up due to the cut of sedimentations which created the base of the former lake.

The elevation levels to the west of Lake Ece and to the east and south of Bağlar ridge and the Azaltı Çiftliği are the surfaces of the former lake base. The base of Lake Ece, which is now used as an agriculture site, forms the lowest area of the basin. While the former lake area was about 10 km², today it is decreased about to 1 km². The former lake level was about 3m whereas is is about 45m in the Adliye village. Karabiga and Karahamzalar are patched to Upper Pliocene surfaces cutting the depotists of Neogene in the low plateau. The Asar hill (26m) rising from the plain base to the south of Karabiga and to the west of the Biga Stream is an environment where fine clastic elements such as sand and clay are deposited. The deposits formed in the deposition environment matches the cut levels due to base level changes.

In order to determine the formation of the plain, pebble and sand samples collected from various sites were analyzed (Santana and Dumont, 2007; Lira and Pina, 2011; Jude et al., 2010). The curve drawn in the granulometric analysis of the sand sample collected from the sediments of 4m high under the 45m thick clay layer forming the wedge in the slopes of the medium value was found (Md)=0.36mm, the first quarter was found (Q_1)=0.48mm and the second quarter was found (Q_2)=0.20mm. These values indicate that storage is formed by medium sand sized materials, and the elements such as fine sized sand also exist in the environment. The deposition of the large sized elements in the sediments draws attention, too. The curve is of a sigmoid one, and such a curve indicates the environments where some certain sized elements are grouped. Since the middle part of the curve where medium sized sands exist is quite steep and the curve showing the deposition of large and small sized materials is low, it has a slight gradient. The percentage rates of large elements being low indicate that the force could not exceed a certain limit and help carry those. The fine elements being very small could deposit in the site and went on their ways. The medium sand size ratio in the storage is 51.23. Other ratios follow as 21.96% in coarse sand, 21.35% in fine sand 4.58% in very fine sand, 0.88% in very coarse sand. The deposition shows that the carrying factor is primarily powerful and medium size sand being plenty deposits by a sudden power lost; however, due to its effect gradually decreases, the fine elements are deposited. The bedding in medium and fine elements refers to materials are transferred with a slow tempo beside the weak transfer force.

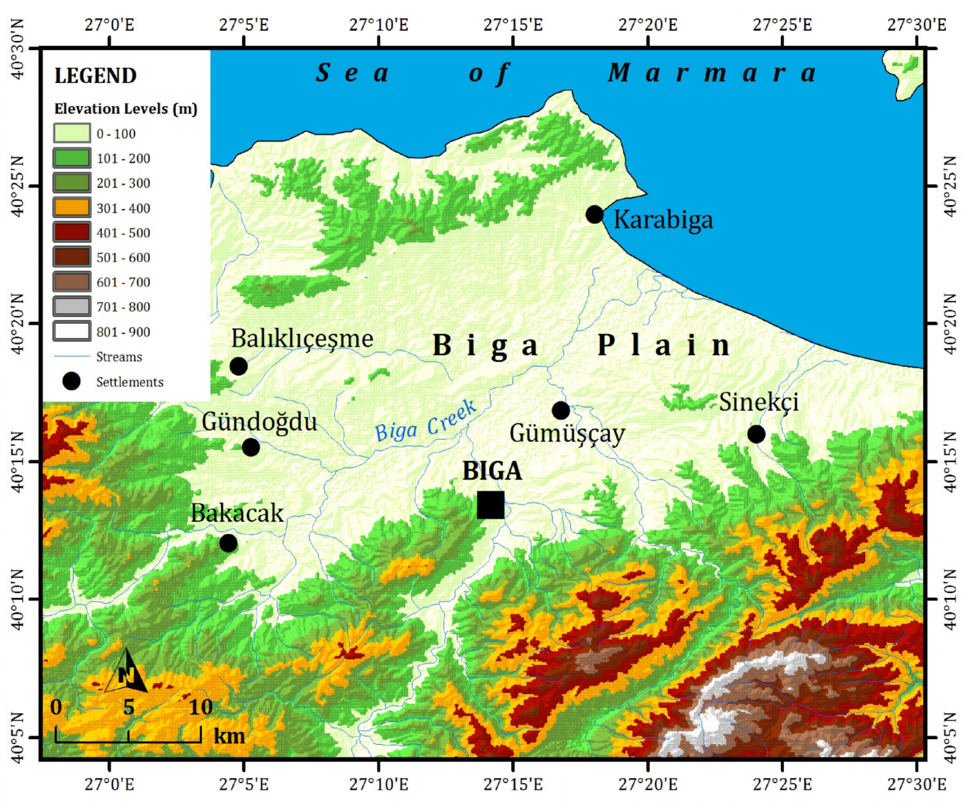

Fig. 2. Biga plain and elevation levels in the vicinity

3.2. The South and Southwest Sections of Biga Plain

The main stream of this section is the Koca Stream (the İpkaiye stream) which takes its sources from the mountainous part in southwest. The main stream enters the Biga Plain with the tributaries of the Kocaçay, the Doğandere and the Sarp stream. In the plain section, it takes the tributaries such as the Bakacak, the Çanboğazı and the Tekke stream. It changes its bed in the section called the Batak (marshy) plain. Farther it takes the Pekmezli creek, the Kocadere, the Uzgua creeks and the Kavak creek and reaches the Biga stream in the east of the Akköprü village.

The structure formed by Eosen flyshes (detritic - sandstone) in the southeast of the Danışment village where the Yeldeğirmeni hill (74m) is found is the continuation of the lithologic structure in the west, and it is originated by the collapse of the plain with neotectonic movements and the settlements of the Sazlıkdere, the Arılık creek and the Koca stream with their materials with "Adatepe" morphology in the base of alluvial plain.

The streams with north - south directions indicating a sub-parallel drainage structure such as the Uzgua creek, the Ayvalı creek, the Kuzgun creek and the Yolarası creek in the section among the villages of Ağaköy, Doğancı and Güleç enter the plateau section in the north with 0-5% slope to the south, and have fragmented in the forms of large surfaces on the plains formed by detritics and settled into the bases of alluvial plain. The bases of the valley are not very deeply cut, but the slopes are not steep. The streams in this section have a hooked drainage elbowing to the east because of the river bed migrations occurring under the control of with right lateral faulting. There has approximately been a 400m right lateral leap in the Kuzgun creek. The amount of migration in the Uzgua stream is 250m. The Yolarası stream, which reaches to the Biga Stream from the south of the Güleçköy village with a very large elbow, and the Ayvalı creek, is cut to the plateau 20m and 25m deep. The slope values of these streams change between 2.7% and 2,5.

The Biga Stream turns to the east with a sharp elbow between the villages of Güleçköy and Adliyeköy. It is possible to say that the right lateral faulting here has an effect in the occurrence of the elbow.

Resourced from the Biga-Danapınarı plataeu, the Çanboğazı creek, the Kösrelik creek and the Kavak creek making clear elbows around the tributary streams of the Kocaçay in the Biga Plain indicate rectangular drainage features occur in the fault-line topography which is controlled by the fault-line directed to northeast and southwest.

The pebbled deposits exist on the south slope of the Şaban creek, which is a tributary of the Kocaçay in the location of the Pürenlik hill in the north of Bakacak village. According to the index histogram in the metamorphic measurement result of the 50 pebbles of 4 to 7cm collected from the andesite - tuff pebbles at about the levels of 80m, the medium value of flatness index is Iys=1.53 and the medium value of roundness index is Iyv=261 (Fig. 3.4.). Whereas the flatness values gather around 1.25 or 1.75, the roundness values indicate rather separated features in the ratio. In accordance with this, the values of flatness being low and the values of roundness being medium indicates that the material was not transported long way, do not get processed and cannot get rounded, yet they were carried and deposited by a stream having a flood characteristic. When the index comparing diagram of the roundness and flatness of the sediment transported from the volcanic parts is viewed, and when the medium values of the index of roundness and flatness are compared (Iys=1.53; Iyv= 261), it is possible to say that the deposition is of a fluvial origin.

According to the index histogram in the morphometric measurement result of the 50 pebbles of 5,5 to 9cm collected from the quartz pebbles at about the levels of 3 to 4m form the Biga Stream in the south of the Akkayrak Village, the medium value of flatness index is Iys=1.71 and the medium value of roundness index is Iyv=270. The diagram indicates that the flatness index values are between 1.25 and 2.25, and the roundness index values are between 200 and 400 (approximately 70%). The roundness percentages refer to the sudden increases and decreases of the carrying force. In accordance with our observations, the flatness values being low and the roundness values being medium, and the features such as the random order of the pebbles in the storage indicate that these are the pebbles stored by the streams with flood characteristics which are with random flow in fluvial facies. However, when the diagram of roundness and flatness comparison index and their medium values index (Iys=1.71; Iyv=270) (Fig. 5 and 6), according to the distribution in the diagram, it can be said that the material might have been formed by the marine - lacustrine environment later on.

According to the index histogram in the morphometric measurement result of the 50 pebbles of 6 to 9cm collected from the quartz pebbles at about the levels of 2m form the Çınarlı creek, which is the tributary the Biga Stream in the south of the Apdiağa Village in the south of Biga, the medium value of flatness index is Iys=1.87 and the medium value of roundness index is Iyv=249. It is possible to explain the existence of a maximum in the flatness histogram with forming process primarily being powerful and its speed gradually decreasing. The values of flatness index indicate a bit higher values according to other sample pebbles. The roundness index value being medium and existing of two maximums in the histogram give the idea that these pebbles are the result of the flood character got decreased in time at fluvial facies with irregular flows; however, from time to time the flows got increased. Both the flatness and roundness indicate a quite messy classification index values. This situation gives the view of transported pebbles histograms. When the distributions in the roundness and flatness comparison diagrams are review and the medium values of flatness and roundness index are compared (Iys=1.87; Iyv=249) (Fig. 7 and 8), it could be said that the materials brought by the erosion from the south of the Biga Plain were later on formed under the control of marine - lacustrine environment.

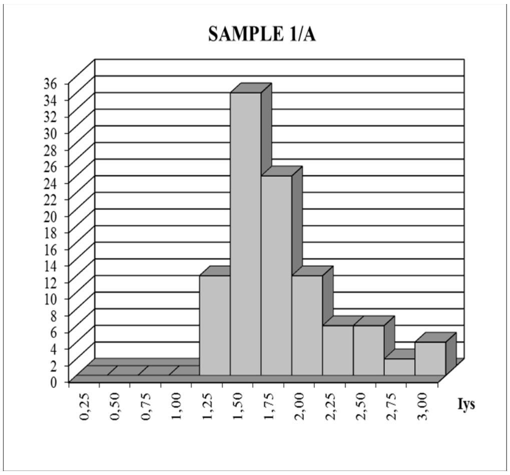

Fig. 3. The histogram (medium value Iys: 1.53) of flatness index of the pebbles collected form the Pürenlik Hill in the north of Bakacak

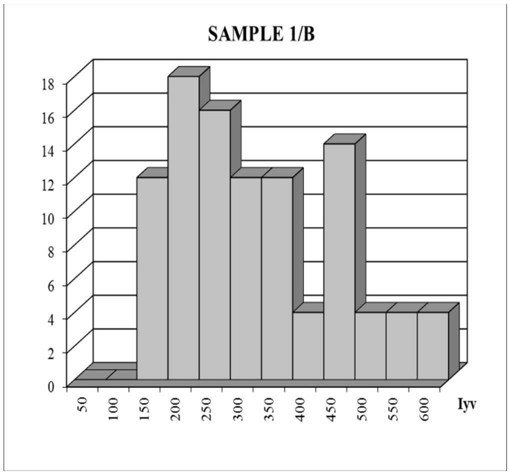

Fig. 4. The histogram (medium value Iyv: 261) of roundness index of the pebbles collected from Pürenlik Hill in the north of Bakacak

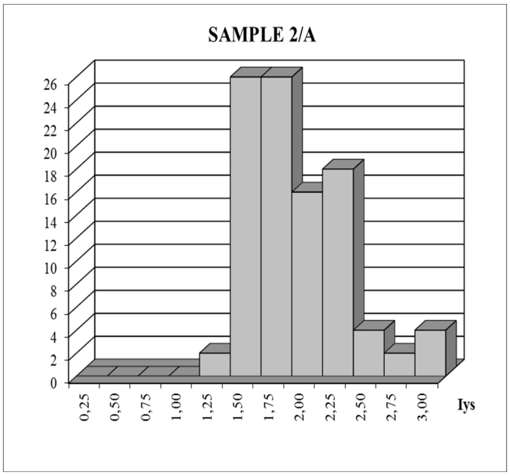

Fig. 5. The histogram (medium value Iys: 1.71) of flatness index of the pebbles collected from slopes of the Biga Stream in the south of the Akkayrak Village

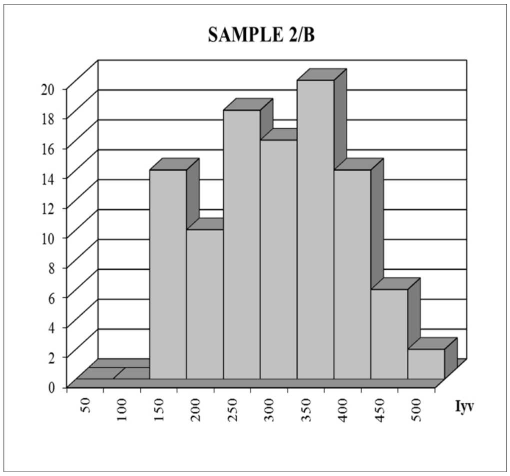

Fig. 6. The histogram (medium value Iyv: 270) of roundness index of the pebbles collected from slopes of the Biga Stream in the south of the Akkayrak Village.

The flatness index values of the pebble samples analysis being low and roundness values being medium indicate that the material was not transported long distance and shortly processed (flood characteristics streams) marine - lacustrine environment played an important role (Hoffmann et al., 2009). It is understood that the similar climate conditions to today occur in the period when the storage first formed in the area such as heavy rains and floods.

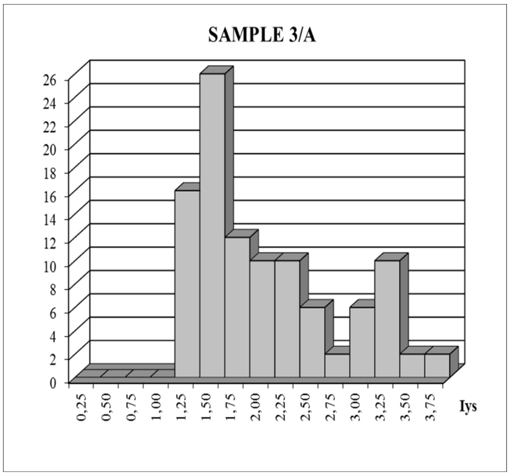

Fig. 7. The flatness index histogram of the pebbles collected from the terrace deposits at 2m hight of the Çınarlı creek in the south of Biga (medium value Iys 1.87).

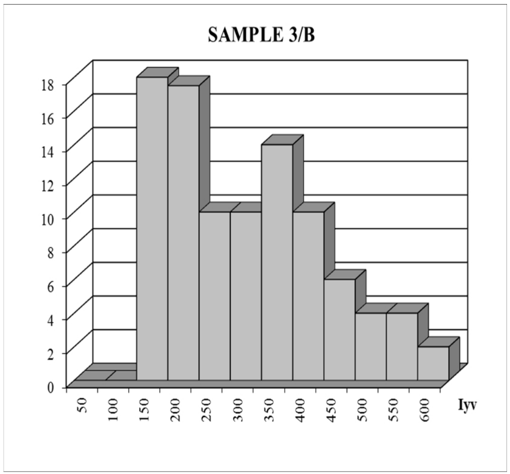

Fig. 8. The roundness index histogram of the pebbles collected from the terrace deposits at 2m hight of the Çınarlı creek in the south of Biga (medium value Iyv 249).

The curve (Fig. 9,10) drawn in the granulometric analysis of the sand sample collected from the middle area of the sediments of 4m thick old bed on the east slopes of the Biga Stream, the medium value was found (Md)=0.172mm, the first quarter was found (Q_1)=0.194mm and the second quarter was found (Q_2)=0.130mm (Fig. 9 and 10). These values show that the storage has fine size elements are dominant. According to this, the curve is logarithmic since it reaches to the fine elements, it shows sudden leanings. Here, the fine elements traveled for a while with the effect of the stream and later on they were stored by the sudden force interruption. Structural elements being very little shows that the force could not exceed a certain limit, and the fact that a high percentage of fine elements shows that the storage might have occurred in a very quiet environment. This situation suggests that the stream transmitting the elements flows in a mature valley. The streams of which steepness reaches the base level and floods which reach to the flat area undergo a sudden change in speed in this way. In the storage, fine sand size is 62.76%, very fine sand size is 23.29%, medium sand size is 8.93%, coarse sand size is 3.89% and very coarse sand size is 1.1%. According to this, near the base level of the Biga Plain, the Biga Stream flowing in its wide based bed due to the decreased curve has gathered the fine elements in this area because of the force being very low. In the result of the stream settled in its current bed, the storages were cracked and the stream accumulation terrace was formed. The coarse size elements exist near the areas to the south of the study area close to the source.

3.3. The evolution and formation of the Biga Plain

Tectonic-geomorphological formation of basin of the Biga Plain has been due to various factors in geological times. The terrestrial and lacustrine Miocene and Pliocene sediments filled the Biga basin which collapsed before the Miocene in Neogene. With the Pliocene - Quaternary Neotectonic movements of the North Anatolian Fault and other related dislocations (tectonic lines bordering the plain in study area from north and southeast) re-collapsed and accordingly the terrestrial sedimentary were partly transported with erosion. These were replaced with the alluvial material brought by the streams from higher areas in the north. When the geological layers and the drilling data of the study area and the Biga Plain are analyzed, the material (sand-clay, pebble, silt, limestone, marl) brought by the linear and surfacing erosion effect from the high areas created by the plateaus around, it is seen that they created the terrestrial sedimentary of the origin of the Quaternary alluvials which are Miocene – Pliocene period. As the villages of Sarıca, Gemicikırı, Balıklıçeşme, Akyaprak, Karahamzalar and Hacıhüseyin Yaylası which are the villages situated on the same erosional surfaces. With the drills opened with different purposes in the base of the plain and around, levels of clay, sand, pebble, sand clay, pebble, sand, silty sand clay, pebbled clay, clayed sand and marl were formed. The thickness of sediment of the very fine elements such as clay indicates that lagoon facies were formed in the still water environment. From time to time it created the deposition of coarse elements of fluvial root with high energies from around.

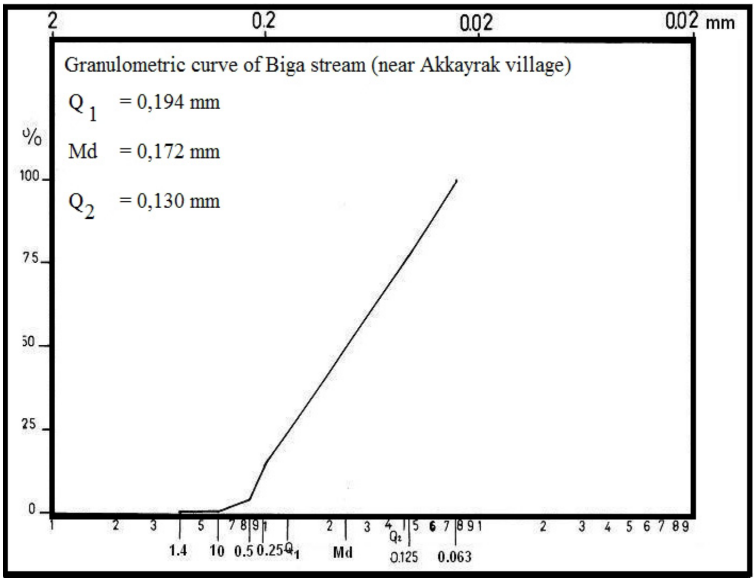

Fig. 9. Granulometric curve of Biga stream (Akkayrak village)

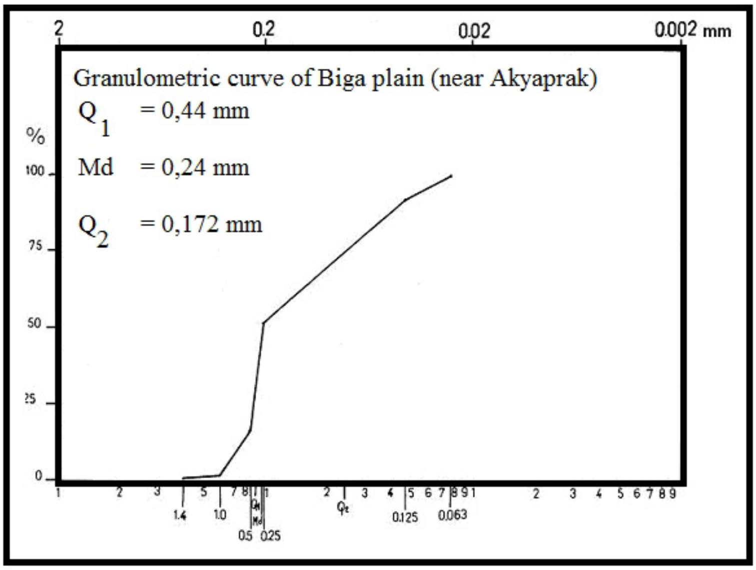

Fig. 10. Granulometric curve of Biga stream (Akyaprak village)

The Biga Plain, which is the local base levels for the sloped plateau sites around, is also a plain which carries the features of a delta. The Karabiga coasts where the plain connects with the Marmara Sea indicates a low lineal coastal features. Although having a delta feature, it did not form a ledge towards the sea. The main reason for this is that it indicates a subsidence feature in the result of collapses with the neotectonic movements before Miocene and Pliocene – Quaternary periods. Additionally, according to the changes due to the North Anatolian Fault and the eustatic movements, coast moves and corrosion and accumulation events occurring back to back are the factors affecting the delta ledge, thus the delta, not to progress towards to the sea.

In accordance with these pieces of information, the environment of deposition is the result of the alternating terrestrial sedimentation with the lacustrine - fluvial sedimentation, and progressed under the tectonic events creating the Marmara basin. The current view of the plain today is the result of the terrestrial sedimentation being partly swept by erosion and replaced with the alluvial fills of fluvial origin (Brown et al., 2009).

4. Conclusion

The strike-slip fault motions occurred during Alp orogenesis in the Tertiary period in the study area. The region uplifted and was eroded in the end of Early Eocene period. In the result of the transgression began in the Mid Eocene, the sediments started accumulating. The deepening and depositing storage went on in the Late Eocene and turbidities deposited in a large area.

Although the volcanic events lost their impacts in the Upper Miocene and Pliocene, the North Anatolian Fault went on its activities (Siyako et al., 1989). The intense tectonic events occurred in the Upper Miocene broke the Lower - Mid Miocene upper level which is the outline of the study area and caused the topographic structure to lower towards the north.

The events created the current morphologic features of the study area are the Neotectonic movements which continue up to today and fluvial processes started as of the Mid Miocene. Neotectonic activities, northwest - southwest, east - west, north - south directed structural lines, northwest - southwest, east - west, northwest lateral and vertical directed faulting, secondary faults, with the help of lateral pressure caused tectonic rises in the curves and embarkations, and plenty of morphological traces such as topographic discordance, tectonic slope, elbows and shifts in stream, lineal valleys, hanging valleys, asymmetric hills, stepped slopes, epigenetic straits, young V shaped valley, asymmetric valleys, embedded meanders etc. were formed.

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