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Reviewing the geomorphologic and neotectonic features of the Gönen Basin (NW of Turkey)

Recep Efe*, Abdullah Soykan, İsa Cürebal, Süleyman Sönmez

Balıkesir University, Faculty of Art and Science, Department of Geography, 10145 Balıkesir, Turkey

Abstract

The tectonic movements played a very important role of the formation of the Gönen Basin. During Quaternary period many dip and strike slip faults ocurred in the area. These faults affected the geomorphology and drainage system of the basin. The aim of this study is to determine the role of the tectonic activities occurred during the Quaternary period in forming the Gönen basin which is the one of the depressions on the southern Marmara Region on the northwest of Turkey. The tectonic movements formed the geomorphic units such as, depressions, scarps, off-set river channels, graben, horst, caused the deformation of surfaces. The faults affected the landscape and had important role the forming of the present drainage system. Hot springs came out along the fault lines. The down and up faultings accelerated the morphodynamics of the rivers, hence the erosional and depositional activities increased.

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Keywords: Turkey, neotectonics, Gönen basin, geomorphology

1. Introduction

In northwest Anatolia, there is a mosaic of different morphotectonic fragments within the western part of the right-lateral strike-slip North Anatolian Fault Zone. Most of these were developed from compressional and extensional tectonic regimes during the neo-tectonic period [1, 2, 3, 4].

The active tectonics of Turkey is governed by three major structures: the Aegean-Cyprean Arc, a convergent plate boundary, along which the African Plate in the south is descending towards NNE beneath the Anatolian Plate in the north; the dextral North Anatolian and sinistral East Anatolian intracontinental strike-slip faults zones, along which the Anatolian wedge in-between moves westward towards WSW away from the eastern Anatolia, the collision zone between the Arabian and the Eurasian plates [2, 5]. As a result of initiation of movement along the intracontinental strike-slip faults zones and their tectonic evolution, four major neotectonic provinces have formed in Turkey, each of which being characterized by a distinctive set

* Corresponding author. Tel.: +90-532-247-4807; fax: +90-266-612-1215.
E-mail address: recepefe@hotmail.com.

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of structures [6, 7].

The main geomorphological units in the study area are plains, valleys, hills, plateaus and mountains. The altitude increases from the center towards the outer part of areas. The two main parts of the unit, namely the basin floor and its margins, can be subdivided according to factors such as elevation and relief features. Gönen, Sarıköy and Tuzakçı plains in the center of the basin are formed by Pleistocene and Holocene alluvial deposits [8]. Close to the center are hills from the Pliocene formations. Farther out in the plateaus and mountains, we find older formations are found out ranging from the Miocene to the Paleozoic [9, 10, 11]. The research area is situated within the North Anatolian earthquake zone [5, 12, 13, 14]. The area has the characteristics of increased earthquake intensity by its differentiated Pleistocene and Holocene deposits.

2. Study area

The research area is located in the southern part of the Marmara Region (Fig. 1). The Gönen plain is found in the center of this area, and its boundaries are delineated by the Sea of Marmara in the north, the Manyas Basin in the east, Armutçuk mountain in the west and Delical mountain in the south. This morphological unit fits a tectonic basin with the Gönen, Sarıköy, and Tuzakçı plains on the floor surrounded by hills and plateaus. The basin is about 35 km long and 30 km wide. The whole area of Gönen basin is approximately 1050 km^2. The lowest point is 10 meters above sea level near Sarıköy locality.

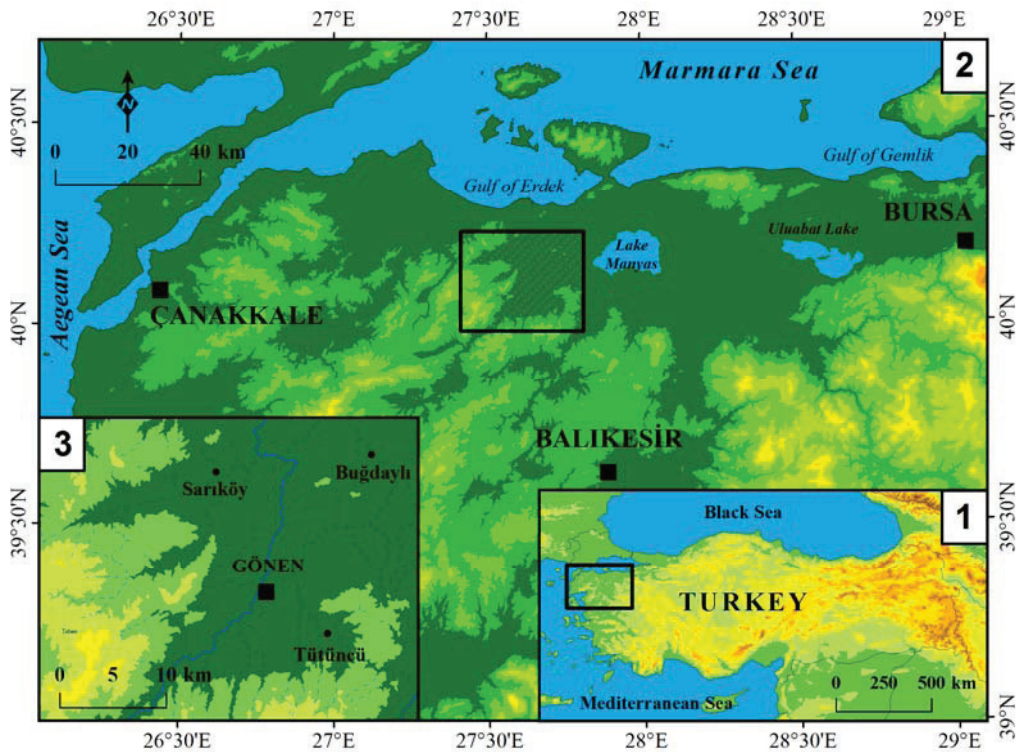

Fig.1. Location map of the study area.

2.1. General Geographic Properties

The basin has different formations ranging from the Paleozoic to the Quaternary. In the western part of the area, the Palaeozoic formations are found around the Hodul and Armutçuk mountains. But in the central area younger formations such as the Pleistocene and Holocene formations occur on the plains [15, 16].

The Paleozoic formations occur on the western part of the basin, around Hodul mountains. The sandstone is the most common rock type in the area, around the Armutçuk, Tahtalı mountains.

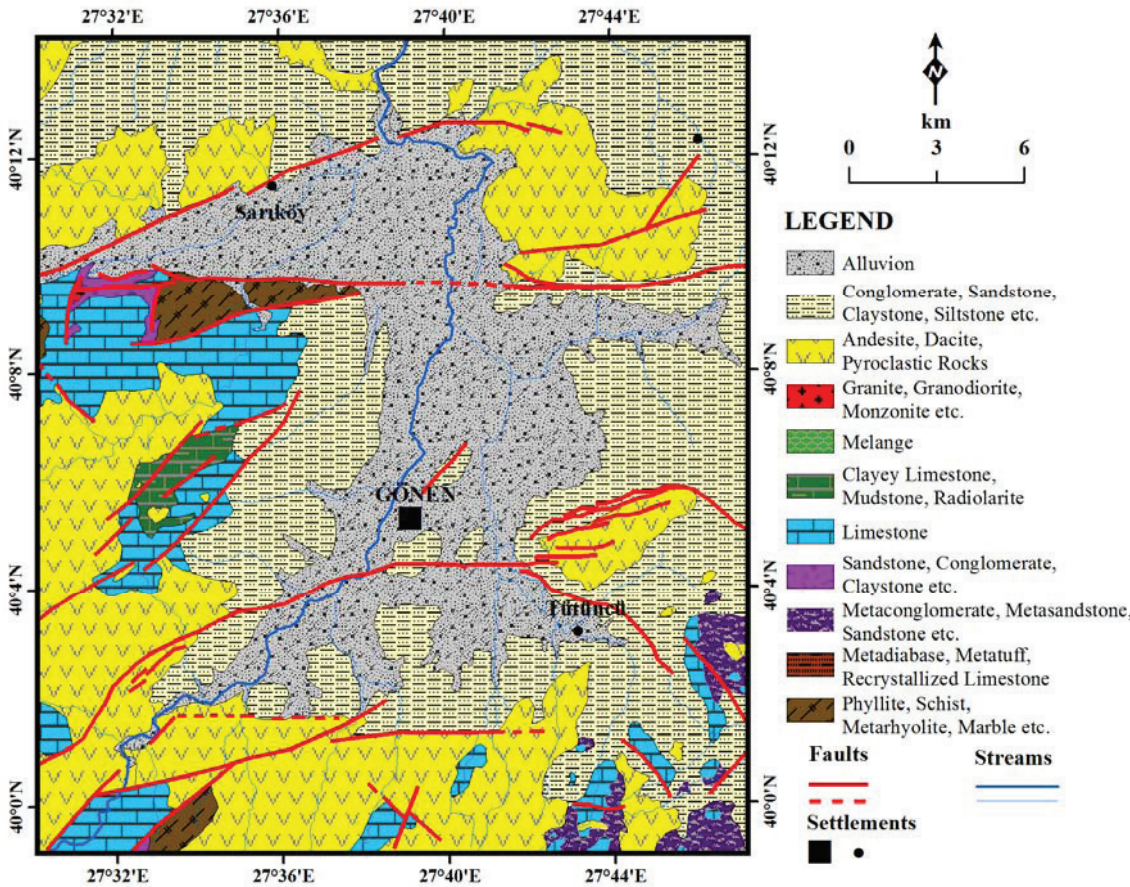

Fig. 2. Geological Map of the study area.

The western part of Sarıköy plain is covered by Mesozoic limestones which form the eastern slopes of Hodul mountain. These formations occur on the west of Çınarpınar, Atıcıoba and Alacaoluk villages. Mesozoic formations are also found on the Delical mountain and in the valley. The Upper Jurassic limestones are seen around Fındıklı and Sebepli villages as well as on Dikmen, Boğaçal and Akçal mountains.

Cenozoic is represented by Tertiary and Quaternary formations occur on a very large area in the basin.

The Miocene and Pliocene formations cover quite a large area in Gönen Basin. These formations start from the Gönen River Gorge in the north, and overlay towards the east and the south. The Neogene formations have been cut by volcanic formations to the north of Taştepe village. In the east, near Ilıcak and Üzümlü villages the threshold, which separates Gönen Basin from Manyas Basin, is an old plain floor, which was uplifted by tectonic movements during the Pliocene.

The Pliocene formations cover a very large area around Eriklioba and Tütüncü in the east and Kavakoba, Çınarlı, Üçpınar, Hacıvelioba and Güneşli in the south. The Pliocene formations do not show a straight stratigraphy due to tectonic movements.

The quaternary deposits, which fill up the plain, consist of clay, silt, sand, pebble and gravel. This material which form Sarıköy, Gönen and Tuzakçı plains have been transported from adjacent higher areas and deposited on lower basins. So that, they reveal the characteristics of these adjacent areas.

The volcanic formations in the basin consist of andesite, trachyte, syenite, tuff and agglomerate. Granite and rhyolite are found around Armutçuk mountains in the west of the basin. These formations cover the older formations in the west and spread out over a very large area in the south around Deliçal mountain.

They make contact with Mesozoic limestones and overlay them in some areas. The volcanic formations

start from the Gönen River Gorge in the north and overlay westwards. The formations consist of andesite, trachyte and volcanic tuff and are spread out over a very large area.

Tectonic movements, which occurred during Miocene and Pliocene, played very important role on geomorphology in the basin. As a result of this tectonic activity, the margins were uplifted and very intensive erosion started. A large amount of material was also deposited in the lower area. It is a progressive, but normally discontinuous uplift, its progress is interrupted or even reversed by periods of quiescence. It is virtually impossible to recognize such movement directly, except some scarps, which occur in the east and west of the Basin [17, 18]. The area changed in appearance because of the uplift and subsidence. We can infer these changes from the geomorphological features to which they give rise, especially valley terraces.

3. Findings and Discussion

3.1. Local Morphotectonics

Several potential seismogenic faults pass through or near the Basin. Many extensions of these faults are found in the basin (Fig. 3). Some of these are dip-slip faults and have very significant morphological forms in the study area. The fault on the north of Balcıdede and Üçpınar villages forms a very steep slope and it separates the volcanic formations from the Pleistocene deposits.

Another structure produced by dip slip fault occurs in the west of Gönen river, between Çınarpınar and Babayaka villages. The elevation difference between upper and lower blocks changes from south to north.

Another morphological evidence of the faults is found in the south of Sarıköy plain, between Hafızhüseyinbey and Gündoğan villages. This fault makes up the southern border of Sarıköy plain. The Kalafaköy fault is located in the eastern part of study area between Korudeğirmen and Saraçlar villages. There is about a 274 meters difference in elevation between Kurttaşı peak (374 m) and Saraçlar village (l00 m).

3.2. Geomorphology of the Gönen Basin

The geomorphological units in the study area are mountains, plateaus, hills and plains. The altitude increases from the center towards the outer areas. The two main parts of the unit, namely the basin floor and its margins, will be subdivided according to factors such as elevation and relief features. Gönen, Sarıköy and Tuzakçı plains in the center of the basin are formed by Pleistocene and Holocene alluvial deposits. Close to the center are hills from the Pliocene formations. Farther out in the plateaus and mountains, we find older formations ranging from the Miocene to the Paleozoic. The research area is situated within the earthquake zone. The areas has the characteristics of increased earthquake intensity by its differentiated Pleistocene and Holocene deposits.

The classification of landforms greatly facilitates the description of the landscape of the study area. Landforms are dependent on rock type and deposits. Indeed physical and chemical composition of the rocks determines whether disintegration or decomposition is the predominant form of weathering. In the study area, five main units are recognized. The Lower-Middle Miocene etchplane (DI, Armutçuk denudational surface - Higher plateaus) and the Upper Miocene erosional surface (DII, Akçalı surface - Moderate plateaus) take place in the margin, high plateaus and several peaks on these plateaus. On the margins of the above-mentioned units the Pliocene (DIII, Üçpınar surface - Lower plateaus) surface occurs which is a transitional unit between basin bottoms and plateaus. The other geomorphological units, which complete the basin, are ‘valleys’ that cut these surfaces, plains and ‘*river terraces’* occur on both sides of the Gönen River. Between the Armutçuk Mountains in the west and the Manyas low dividing ridge in the east is a vast lowland area.

3.2.1. Armutçuk Denudational Surface

Due to the volcanism, which started in the Late Lower Miocene in the Biga Peninsula, some isolated fault-bounded lacustrine basins were formed. Later, these basins filled with alluvial deposits and depositional and erosional surfaces developed. This surface is found between 700-960 meters in the south

and southwest of the study area. We call it as 'Armutçuk Denudational Surface' because it occurs in several places such as the peaks on Armutçuk mountains. The western margin of the basin is formed by the Armutçuk and Karlık mountains. These extend from Denizkent on the Sea of Marmara coast southwards for some 30 km to the east of the Armutçuk mountains and vertical to them lie the Deliçal mountains contain a series of volcanic ridges and plateaus.

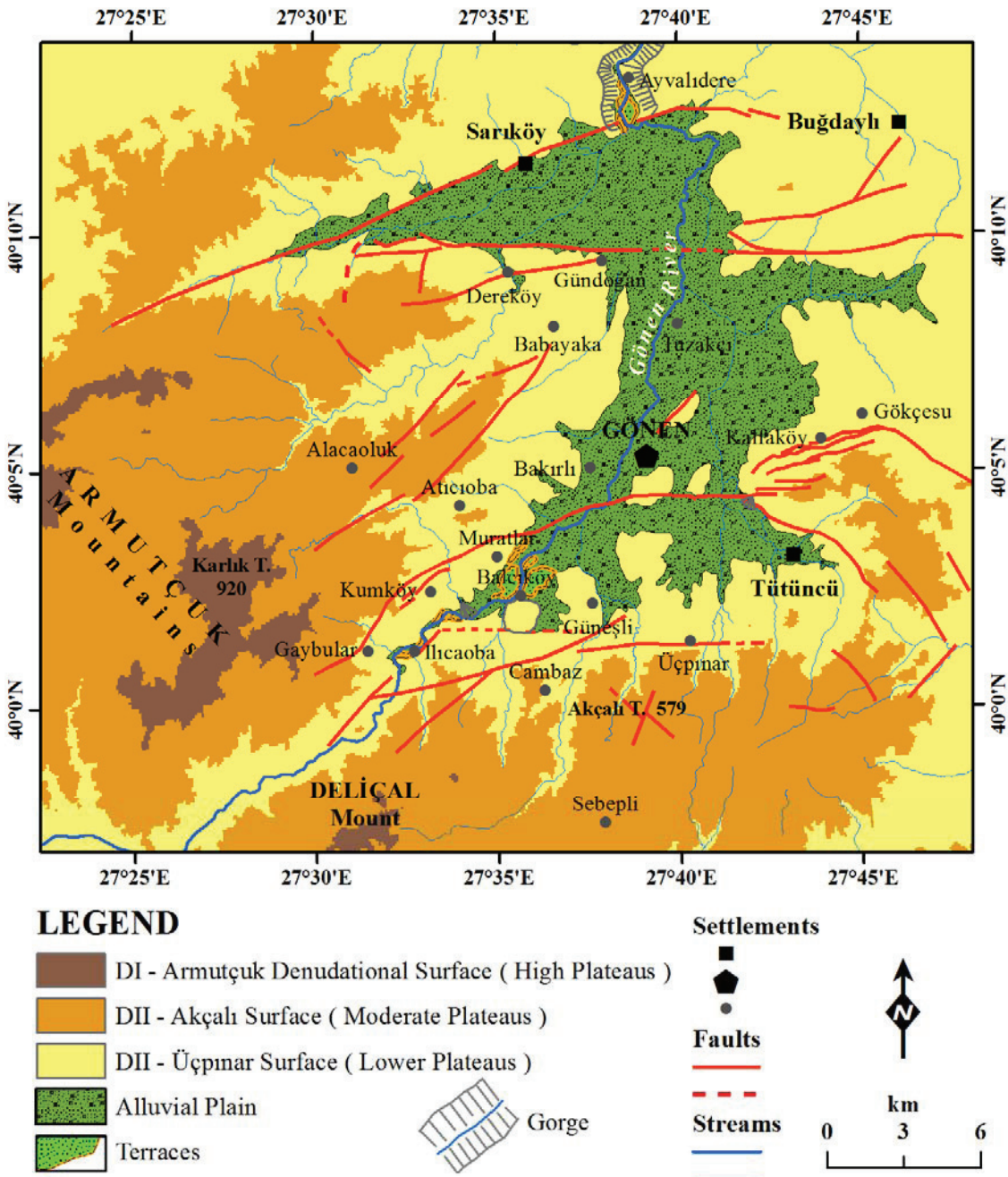

Fig.3. Geomorphological Map of the study area.

The Armutçuk denudational surface (DI) was deformed by faultlines during the Late Middle Miocene.

The Yenice-Gönen fault runs along the valley where the Gönen river flows in. Armutçuk surface occurs aroun Kocadikmen, Sakar, Deliçal peaks, and to the east of the Gönen river. There are other peaks on the Armutçuk erosional surface which occurs to the west of the Gönen river. These are Karlık peak (920 m), Makine peak (739 m), Deniz peak (722 m) and Akkabaağaç peak (963 m) on the Armutçuk mountains. To the south, beyond the Hacıvelioba village, lie the Deliçal mountains which were created by volcanic activity. The highest point in the Deliçal mountain is 741 m (Kocadikmen peak).

3.2.2. Akçalı Denudational Surface

In the Early Upper Miocene, the area was fractured by faultlines and erosion and deposition accelerated. In the result of this; a new denudational surface (DII) developed on the margins of the (DI) Armutçuk surface. In the beginning, the Akçalı (DII) surface began to develop under humid climate conditions, but in the late Upper Miocene the climate changed to sub-tropical conditions [19].

The effects of the tectonic movements occurred in the Tortonien are quite remarkable in the research area. The fluvial systems which settled into the fault lines began to cut the former Armutçuk (DI) denudational surface. The erosional material deposited all around the Armutçuk denudational surface and the Akçalı surface developed (Fig. 3). The elevation of (DII) Akçalı denudational surface changes between 300-600 meters due to deformations caused by tectonic movements. The mountain range in the south is cut by the three valleys of the Handere, Suçıktı and Obaköy creeks. Much of the northern side of the mountains is faulted, and is very steep in some parts. In distance, Akçalı peak to Obaköy is only 3 km, but the difference in elevation is nearly 500 meters. The altitude of Akçalı (DII) surface near Eriklioba, and Cambaz villages is around 350 meters, but it is more than 500 meters around Sebepli, Alacaoluk, in the west of basin. Rivers in many parts cut the erosional surface around Sebepli villages varying between 400-600 meters. The Deliçal mountains which extend on the southern section of the basin in a east-west direction, are composed of Tertiary sedimentary and volcanic formations. The Miocene and Pliocene erosional surface extends into the mountains at on elevation of 350 to 550 meters. The volcanic eruption covers a very large area in the south. Some Mesozoic sedimentary rocks (limestone) can be observed in limited areas, such as in the Akçal peak. in the north of Sebepli, around Fındıklı village near. These limestones are not so thick and they contain sand and silica so that they have no enough conditions for karst topography.

3.2.3. Üçpınar Surface

The base level was subducted in the Late Upper Miocene and Early Pliocene. This change started another erosional period, which cut "V" shaped valleys into the DII surface. The tropical and humid climate accelerated this erosional process, and in the end of Pliocene the fluvial deposits formed (DIII) Üçpınar in the margins of the Akçalı (DII) erosional surface. The Üçpınar (DIII) surface doesn't cover a large area and lies between the altitude 150-250 meters in some places around Kavakoba, Üçpınar in the south, Atıcıoba, and Babayaka in the west of the study area. The southern slope of the Armutçuk mountains continue with rolling hills towards the plain.

Some parts of Üçpınar surface occur on recent deposits of a mantle of often quite unconsolidated materials from mountains, transported and spread by the creeks. Only the effects of erosive agents upon it disturb this relatively smooth surface mantle. Running waters have cut deeply into the soft loose materials washed down from the mountains. The smooth hill-slopes cut by rain furrows can be observed around Havutça village.

Pliocene erosional surface appears on the volcanic formations in the north stretch from Ayvalıdere to Üzümlü village with the elevation 250-330 meters. The volcanic formations consist of trachyte, andesite and tuffs. In the east, a low ridge separates the Gönen and Manyas basins. The hills between Kalfaköy and Tütüncü have very steep slopes and they consist of volcanic formations. Some creeks flow from a low hilly area and join to the Gönen river around Muratlar and Bakırlı formed several breach valleys on the Üçpınar surface.

3.2.4. River Terrace Systems

During the Lower and Middle Pleistocene the tectonic movements accelerated again, and the middle part of the study area was subjected. Rejuvenated fluvial processes continued with different intensities depending

on varying climatic conditions of glacial and interglacial periods of the Pleistocene [11, 20]. In the Lower and Middle Pleistocene the '*Upper Terraces'* developed between 50-130 meters along the Gönen river valley.

Fig. 4. Fluvial terraces in the valley of Gonen River

The '*Lower Terraces'* between 10-40 meters developed during Upper Pleistocene due to sea level changes. These terraces depend upon changes in the energy of flowing water and result from changes in gradient as much as from changes in water volume. They are therefore just as easily the outcome of tectonic as of climatic changes, and can therefore be found in very diverse localities. There are several fluvial terraces on the both sides of Gönen River valley in the 'Gorge' near Ayvalıdere village. Some of these terraces had been deformed because of erosion, deposition and tectonic movements. The higher terraces are found in two levels, the first one is between 100-130 meters occurs near, Ayvalıdere, Kumköy, Güneşli, Balcı villages and on the south of Gönen. Ayvalıdere gorge which was cut on the Pliocene formations by Gönen river in the result of tectonic uplift of the western border of the basin. And the second one is between 50-70 meters and takes place on the both sides of Gönen river in the gorge, Balcı, Muratlar, Kumköy, Gündoğan villages. The lower terraces occur between 10-40 meters and are found near Ayvalıdere, Sarıköy, Dereköy, Muratlar, Balcı, Ilıcaoba and Gönen. Sea level changes and tectonic activity is responsible for the terraces along the Gönen river channel. Around Kumköy and Gaybular terraces extend along the sides of the valley.

3.2.5. Alluvial plains and valleys

Between the high plateaus there is broad plain where the surface is of loose sediment of Quaternary. This has been swept into the depressions adjacent to the mountains-stream action and sheet floods form here a vast flat surface. The quaternary formations, which form the plains, consist of detritus elements such us pebble, sand, silt and clay. This material was eroded from the rising mountains and accumulated on the lowland. The depth of the accumulation increases from south to north. Alluvial deposits cover the whole plain starting from Ayvalıdere in the north and continue until Kumköy and Balcı village in the south and

Tütüncü in the southeast. A small part of alluvial plain stretch in the west about 10 km along the valley of Çakıroba stream. The central lowland comprises several sections.

We can describe these as the Sarıköy plain in the north, Tuzakçı and Gönen plains in the middle, Tütüncü plain in the southeast and Balcı plain in the south. The plain roughly resembles an ellipse with its longer axis from the north to the south. It is approximately 18 km long and 10 km wide and the plain has an east-west width of between 10-30 km the whole plain and valley bottoms have been filled with alluviums, and their thickness ranges between 10-70 meters. The bottom of the basin contains three plains that extend from Ayvalıdere north until, narrowing between Gönen and Karalarçiftliği, it reaches the slopes of Deliçal mountains. The largest one is the Gönen plain, which is to the north and east of Gönen. The second one is the Tuzakçı plain close to Tuzakçı village. The last one is situated to the north of Gönen around Sarıköy. The altitude of the plain is 40 meters in the south and 10 meters in the north. The average altitude of the plain is 33 meter, and the gradient changes between 0.1 % and 0.5 % decreasing from south to the north.

The plain covers a larger area to the east of Gönen river and overlays until Çınarlı, Tütüncü and Gökçesu villages. South of Gönen the central lowland is interrupted by a group of low hills called Beştepeler (Five hills) in the south of Gönen. These hills are formed by Pleistocene formations. The thickness of the alluvium layer on the plain is more in the Sarıköy plain. The Gönen river meanders along the plain as a result of its very low gradient. When the Gönen river reaches to Balcı village the valley broadens out towards east and west. To the southwest, the Gönen river channel was filled by sediments and along the valley between Ilıcaoba and Muratlar, several abandoned channel segments can be seen. Between the Gönen plain and Manyas basin lies the threshold which stretches for about 5 km from south to north. Deposits resulting from sea level changes during the Pleistocene and the Holocene formed these three plains, making up the basin floor.

The characteristics of landscape is entirely dominated by valleys the sides of adjoining valleys intersect the linear ridges which are no more than boundaries separating adjoining valleys. The difference in altitude between and valley bottoms that is intensity of dissection, depends initially on the amount of tectonic uplift. The greater the uplift the greater the power of water to erode. The faster rivers incise and approach the profile of equilibrium while interfluvial ridges are degraded at a much slower pace. The layout of the Sarıköy and Gönen river valleys are determined by the tectonic surface. Valleys were formed and developed progressively and continuously through different stages of life until they attain a permanent-state. In this permanent state, their floors display quite gentle gradients and their sides slope gently towards these. In the south of Kumköy, the Gönen river valley gains a "V" shape and the sides of valley rise directly or nearly so. This section of valley has been cut through volcanic formations and in some parts tectonic movements displaced the formations. This displacement can be observed around Karasukabaklar, Gaybular and Ilıcaoba villages. Some karstic caves can be found in the eastern facing slopes of the Gönen river valley. But there are not so well developed because of the thickness and quality of the limestone. The limestone layers are not so thick and they also contain sand and silica.

4. Conclusions

Gönen basin and its vicinity include active strike-slip faults. Correlations between tectonics and physiography are strong in the area. Tectonic events established the setting in which the present physiography of Gönen basin developed, but the landscape acquired its present form much more recently, in Pliocene and Quaternary time.

Holocene tectonic activity at the area is evidenced by significant seismicity, which has been documented over hundreds of years. Wide range of geomorphic features carry signatures of past tectonic events, the focus in this work is laid on fluvial geomorphology. The fluvial system in the area has been affected by a number of large-scale tectonic events since the late Miocene [19, 21]. The geomorphic data revealed no unambiguous evidence of recent tectonic activity on individual faults. The Sakarya zone is made up of the Triassic Karakaya Complex overlaid unconformably by the Jurassic Cretaceous Sedimentary rocks on the western part of the study area [22, 23]. The region which includes Deliçal, Karlık and Armutçuk Mountains was strongly deformed during the Late Triassic Karakaya orogeny. Due to a collision between Istıranca-Rhodope Massif and Sakarya Zone during the Early Eocene the whole region was uplifted and eroded [24,

25]. Following the deposition of a thick clastic sequence during the middle Eocene - Oligocene, there was a major uplift and erosion in the Late Oligocene. With the inception of the North Anatolian Fault in the Early Miocene, a large number of NE-SW trending dextral faults were formed in the study area. By the end of Middle Miocene, the area was fractured by faultlines, which are western extensions of the North Anatolian Fault Zone, and Armutçuk denudational surface developed [19]. By the end of Upper Miocene (Messinien) a new denudational surface (DII. Akçalı Etchplane) system developed on the margins of DI denudational system. During the Pliocene erosion, the transportation processes of the rivers increased because of tectonic movements and sea level changes [26, 27].

During the Lower and Middle Pleistocene the climate was sub-humid and temperate, and tectonic movements accelerated again. As the result of this, the middle part of the study area was subjected. The base levels of rivers were also altered and fluvial terraces developed as a result of these tectonic movements and climatic changes. These terraces occur on two levels. The higher ones are found between 50–130 meters, and lower terraces occur between 10-40 meters.

Rejuvenated fluvial processes continued with varying intensities depending on differing climatic conditions of glacial and interglacial periods of the Pleistocene.

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