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Geomorphology of Hereke-Körfez Area and its Relation to the Submarine Morphology of the Centre Basin of the Gulf of Izmit

Hereke-Körfez Arasının Jeomorfolojisi ve İzmit Körfezi Orta Çukurunun Denizaltı Morfolojisi ile İlişkisi

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Abstract

The present study is an attempt to interpret the geomorphology of the Hereke-Körfez area and the submarine morphology of the Gulf of Izmit. Geomorphological investigations have been carried out on the E-W trending normal fault, Hereke-Körfez fault, which constitutes the northern segment of North Anatolian Fault (NAF). Along this 10 km-long zone, the morphological features of this area have been considered according to the neotectonic features within and around the stream basins. Fault facettas, stream captures, deep dissection in young valleys, hanging valleys, en-echelon erosional surfaces, convexity and slope breaks in thalweg profiles indicate the youth phase in fluvvial geomorphological evolution. Active submarine landslides in front of the submarine deltas and the en-echelon erosional surface located at – 40 m to – 160 m imply the active tectonic in the Gulf of Izmit. The morphometric features of erosional surfaces indicate a collapse of about 190 m in the gulf. This result is supported by the deep valley form in the depression. It is concluded that this buried valley has been deepened by the en-echelon faultings.

The aluvvial cones developed along the Hereke-Körfez Fault. That there is no marine terrace in this zone appears to be related to the sediment input from north by the creeks, which covered the marine terraces probably. These terraces might have later been deepened by en-echelon faultings. Thus, the deep drill holes are needed to find out the vertical cross-section of these young deposits. This will

also reveal if the en-echelon erosional surfaces have been deformed by the activity of NAF.

Consequently, the hinterland morphology of the Gulf of Izmit could well be used as a reliable criteria to assess the morpho-tectonic features in this coastal area.

Keywords: North Anatolian Fault, Izmit Bay, neotectonic movements, fluvial geomorphology

1. Introduction

The Hereke-Körfez area constitutes the southeastern part of Kocaeli Peninsula (Figure 1). The conspicious landform feature in this area is characterised with an E-W trending fault scarp on land. So far, several geological investigatons have been carried out in and around the study area, (Erguvanlı, 1949; Abdusselamoğlu, 1963; Altınlı, 1968; Kaya, 1978; Bargu and Sakınç, 1990; Önalan, 1981; Seymen, 1995). Numerous studies have been performed on the geology, sedimantology and geophysic and tectonic of the Gulf of Izmit (Barka and Kadinsky-Cade, 1988; Sakınç and Bargu, 1989; Koral and Öncel, 1995; Akgun and Ergun, 1995; Barka and Kuşçu, 1996; Barka, 1997; Guneysu, 1999; Alpar, 1999; Alpar et al, 2001; Gökaşan et al, 2001; Gazioğlu et al, 2002) due to high earthquake potential. However, geomorphological studies including those coastal zone area are fairly scanty except those of Göney (1963); Güneysu (1986); Ertek (1995); Hoşgören, (1995); Alpar and Güneysu (1999); Erginal (2000). In addition, the mass movements in the eastern Marmara Sea were studied by Alpar (2000), who determined slope failures in the Çınarcık Basin and offshore Yalova.

The NAF is the main structural element controlling both onshore and offshore morphology around the Gulf of İzmit. Numerous studies have been carried out to enlighten the characteristics and activity of this major fault which has become active since upper Miocene (Barka 1992). This active fault follows the nearby place of the coast of the Gulf of Izmit. The highest part of the Kocaeli Peneplain is therefore on this fault scarp, where the watershed of the creeks draining the plateau passes of about 4-8 km distance from the present shoreline.

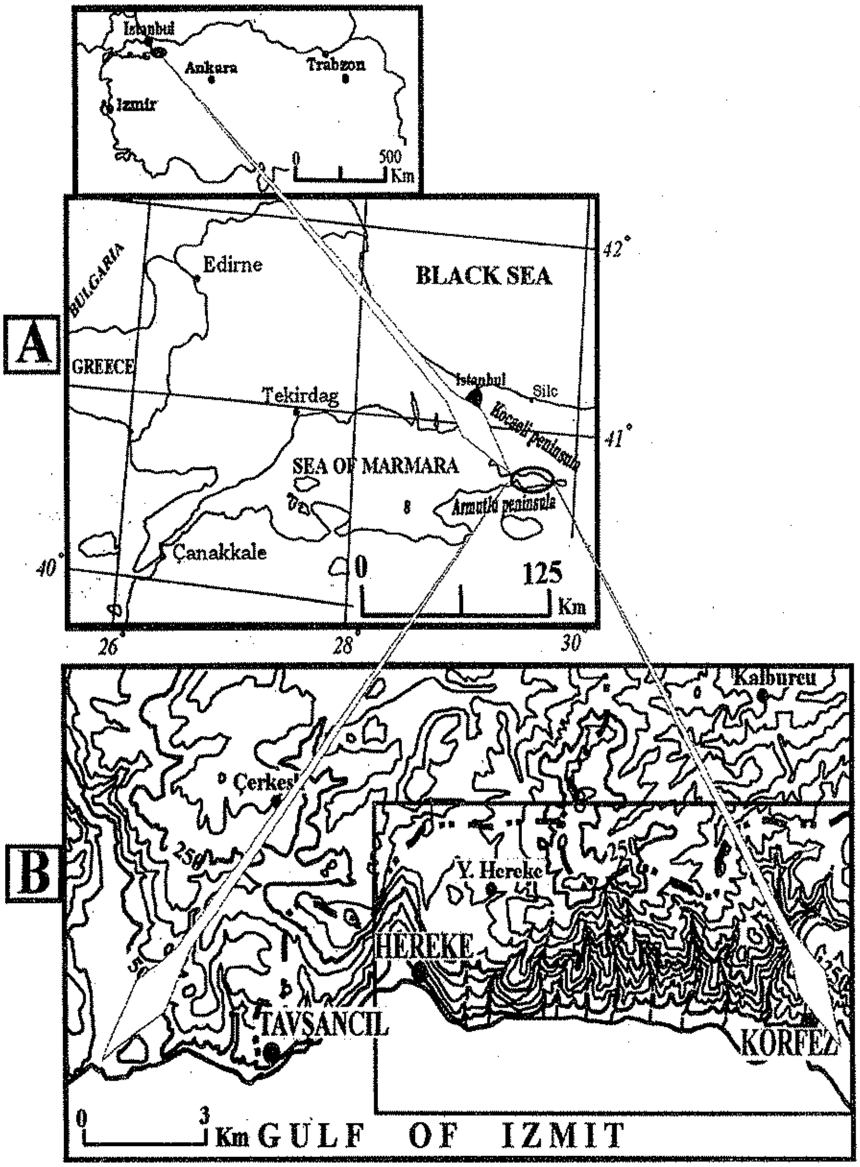

Figure 1. Location (A) and topographical map (B) of the study area and surroundings

Since our study area is situated in the fluvial morphogenetic region, the rivers are major factor on landform evolution under the control of climate and geologic factors. The present morphology of the area indicates that the dominating factor is likely to be neotectonic, whereas the other structural features, i.e. lithology and E-W trending foldings appear to be less important today, since the Kocaeli Peninsula has been eroded on a large scale in the late Pliocene. Resulted, which is resulted in the formation of Çatalca-Kocaeli Peneplain.

When compared with the ongoing activation of NAF, it is obvious that the morphology and formation of Kocaeli Peneplain, which makes the evolutionary mechanism of the gulf area is questionable due to a conflict between the peneplanation process and active faulting. Thus, geomorphological evidences are a correlation of these two opposite factors. The present study is an attempt to compare the morphologic and morphometric features of landforms both on land and in the gulf. In this respect, topographical maps with 1 / 25 000 scale and bathymetric map of the Gulf of Izmit formed by Güneysu (1999) was used both in field studies and relief analysis, and the area was digitised. The interval of contours were prefered by the slope gradient and finally digital elevation map of the area was produced using Surfer 8 software.

2. Geological Settings

The basement rocks of the area is formed by lilac-coloured arkozs which was distinguished by Altınlı (1968) as "Sopalı formation". The basement outcrops in an extensive area between Hereke and Körfez. This Ordovicien aged continental series are the prominent lithology except for the quarsits of Silurien around Serçe Hill (645 m) and greywake of Lower Devonien age to the north.

Mesozoic formations overlying the Paleozoic basement consist of the Triassic and Upper Cretaceous deposits. The latter consists mainly of limestone, limestone with clay, sandstone, which all are separated from each other by Paleozoic mass at two sides of the area.

The Quaternary formations are formed by the alluvial fan deposits, which are lined up to the east in front of the fault scarp. Delta deposits and beach sands form the youngest deposits in the area (Figure 2).

Because NAF is the prominent structural factor in developing of the three small submarine sub-basins of the Gulf of Izmit (Altınok et al. 1999, Alpar et al., 2001), E-W-aligned fault scarp should be associated with NAF as it extends close to the active fault. The fault that we named as "Hereke-Körfez Fault" starts from the east of Hereke Bay, and can be observed toward the east of Körfez 10 km back of the shoreline. The shoreline is controlled with that normal fault just as the Hereke coasts which is also associated with the segments of NAF (Barka, 1997; Bargu, 1997; Alpar and Güneysu, 1999). In addition, two lineaments were determined. Two stream channels forming the tributaries of Göksu follow these lineaments. But these are not important elements in recent morphology if compared to the E-W trending main fault.

The NAF in the Sea of Marmara has well been studied and the most recent studies explained this fault to be a relatively young active strike-slip fault zone (Le Pichon et al, 2001). The Gulf of Izmit has a great importance as its formation create a geomorphological controversy with the existence of Kocaeli Peneplain. Therefore, the faults that originate the depression should be correlated to hinterland morphology. According to Gökaşan et al (2001), three strike-slip segments of the NAF control the bottom morphology of the gulf. The middle strand forms a shear zone. This fault should be the eastern extension of the master fault in the Sea of Marmara.

Considering that normal faults in the gulf are associated with strike-slip faults (Bargu, 1997), the structure of the Hereke-Körfez escarpment becomes evident.

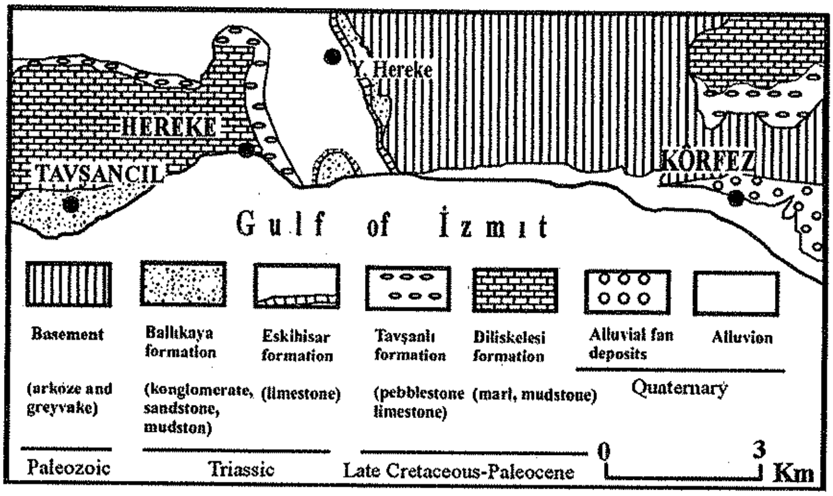

Figure 2. Geological map of the study area (partly modified from Seymen (1995)

According to him, the high angle secondary faults of NNW-SSE direction are dependent on the strike-slip faults. The E-W trending faults, within the gulf, were formed because of compressions, which create push-ups and depressions. The coastal faults are the evidence of the first opening of the Gulf of Izmit, as shown by Gökaşan et al (2001). Therefore, the morphological features of the Hereke-Körfez escarpment is very important in understanding the syntectonic morphology, both on this fault and on submarine morphology. We, here, suggest that the stepped slope morphology of the central depression is evaluated with the Hereke-Körfez Fault. Seismic sections presented by Gökaşan et al., (2001) indicates the morphological similarities between onshore and offshore morphology.

Tectonic depressions in the gulf are the result of E-W compressional and N-S tensional forces (Barka and Kadinsky-Cade, 1988,). The proposed pull-apart model is convenient for developing the three basins, we also think that the middle one is developed syntectonically with the Hereke-Körfez fault during the initial formation of the gulf as explained below.

3. Geomorphological Settings

3.1. Geomorphology of Hereke-Körfez escarpment and its surroundings

Kocaeli and Armutlu peninsulas are the horsts bounding the Gulf of Izmit, which is situated within an E-W trending active graben affected both from NAF and Marmara graben systems (Ketin, 1968; Seymen, 1995). Due to the erosion during Pliocene on the Kocaeli Peneplain, it is fairly difficult to observe the morphologic traces of the faulted blocks along the northern coasts of the gulf. However, the Hereke-Körfez area is a good reference to the impacts of NAF along the southern coasts of the peninsula. The characteristic landform features on the fault scarp are demonstrated in Fig. 3.

The E-W trending shoreline between Hereke and Körfez is fault-controlled and it is prograded southward the south depending on the stream activities. A mass with 450-500 m height extends along the coast, on which the highest peaks exceed 500 m at Eren Hill (583 m) and Serçe Hill (645 m) northwards. The Paleozoic basement rocks constitute the lithology of that step-sloped mass. The creeks on this fault scarp have deeply dissected their valleys from west to east (Köy Creek, Gicik Creek, Burma Creek. Domuzlu Creek, Zeytin Creek, Ayvacık Creek and Hamza Creek from west to east). Their length increase eastward as well as their deltas by the growing basin sizes of the creeks. These are all exhibit dandritic, sub-dandritic, parallel and sub-parallel drainage patterns connected with the actual slope conditions of the fault scarp. Each creek has already produced sloping alluvial cones in front of the fault scarp. These young deposits laterally pass into the deltas indicating a rapid progradation from the north to the south.

No creek in the area has ever reached their equilibrium profiles (Figure 4). This is because the fault scarp is morphologically so young that the drainage network is still dependent on the recent inclination conditions.

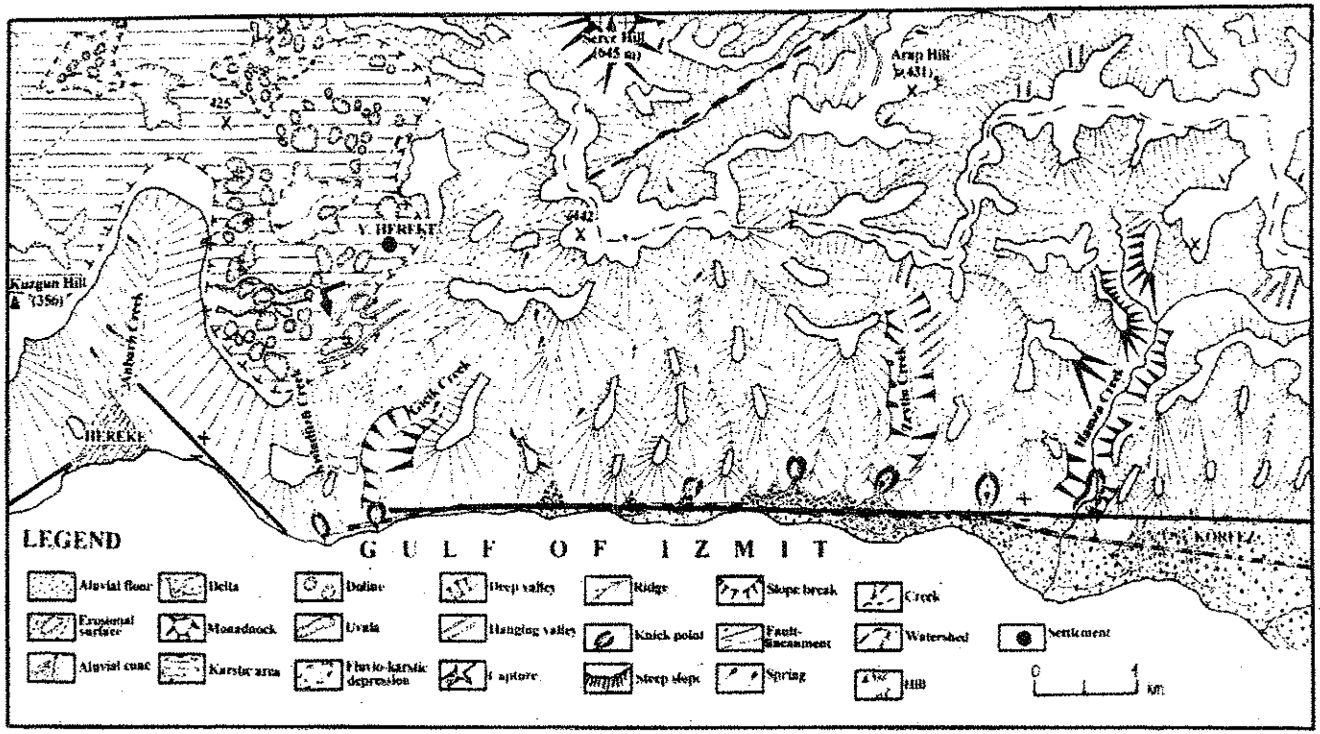

Figure 3. Geomorphological map of the study area and its surroundings.

Lithological or internal structural properties seem to be unimportant on valley morphology. The stepped thalweg line demonstrates the young reconstruction of the valleys. On the other hand, the intermittently uplift along the fault is comprehended by knick poits, starting from the fault line to the upper thalweg lines. The number of slope breaks in the thalweg profiles indicates the frequency of erosional cycle occured during morphological evolution.

We determined at least 2 – 3 slope breaks. The step rise of the profiles shows new profile construction. The profiles of Y. Hereke and Hamza creeks indicate equal and simetric uplifts of the area from west to east (Figure 4). This seems to be related with the same compressional force of NAF along the coastal zone.

Other morphological evidences connected with the young drainage network arises from the creek captures, and two captures were determined on the Paleozoic basement. These are interesting aspects in recent arrangement of drainage. The creeks dissecting the fault scarp increase their headward erosion. Here, an obvious capture at the east of Hereke has been fixed. Here, Kışladuzu Creek captured the west-oriented creek to form a tributary of Anbarlı Creek, where the karstic features are dominant at present, flowing on the plateau of 330 m. In this area, the surface drainage is fairly rare, indicating underground passasage. The creek responsible for capture dissected its valley about 80-90 m.

The rejuvanation of creeks on the escarpment is another morphologic indicator showing the dissection degree caused by base level changes. The changes are originated by two factors; eustatic and tectonic movements (Erinç, 2000) which increase the elevational discrepancy between construction of thalweg profile and sea level. Dissection degree along the thalweg lines reaches up to 150 m in the basin of Hamza Creek at the west of Körfez. This rate was measured about 100 m for almost all other creeks. Knick points at the back of aluvial cones of all creeks follow the extension of E-W trending fault. As a consequence, these creeks deepened their valleys due to the rapid uplift of the escarpment. A "valley in valley" topography observed in creek basins also denotes this escarpment to have been rised repeatedly.

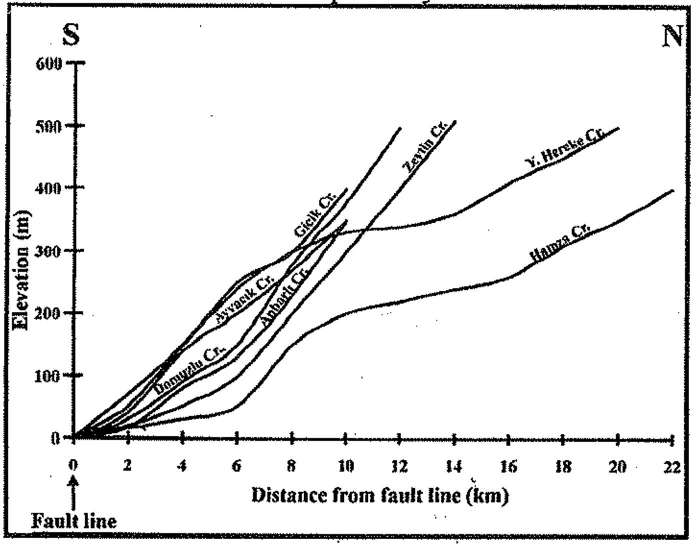

Figure 4. Superimposed longitidunal profiles of the creeks on the Hereke-Körfez escarpment

The areas on which "valley in valley" type of topography is a subcycle feature, are typically represented as submatured erosional surfaces. This cyclic feature is well observed in the valleys of Kışladuzu, Ayvacık and Hamza creeks, which supports the results obtained from curved valley profiles (Fig. 4).

In order to explain the cyclic normal erosion, a comparison of the erosional surfaces of the narrow area has been made with those situated in the central basin. As shown in Figure 3, the lowest one is situated at the heights of 100-110 m, 110-120 m, and 130-150 m. This southward slanted level extends over the fault facettas. The second surface placed at 230-240 m, 240-270 m also extends at the edge of deep valleys. The third level placed at 300-360 m, 350-360 m, 340-360 m elevations forms the lower step of the maximum level. Finally, the maximum surface level showed a great difference in elevation. It starts with 350-400 m level at the northwest Hereke and 330-360 m elevational area is occupied by karstic landforms on Triassic limestones (Fig. 3). The suspended valleys in this part are also characteristic and represent the old dandritic drainage area of Anbarlı Creek. Indeed, the creek was flowing from the south of Y. Hereke before it is captured by another N-S trending one on the escarpment. Thus, the old drainage area changed into a karstic surface, and the intense karstic dolines are related to the tectonic uplift.

Various levels of 420-430 m, 440-450 m, 450-460 m and 510-520 m are observed on the maximum elevation zone. The above-mentioned different erosional surface levels prove the intermittent echelon faultings. Thus, the erosional surfaces of 100 m – 520 m base likely on active tectonic. This typical feature condition of Kocaeli Peneplain corrresponds to the partial peneplain surfaces determined by Ertek (1995) and Erginal (2000).

Eren Hill (584 m) and Serçe Hill (645 m), the monadnocks made up of Siluren quartsits are resistant to erosion. The upper limit of the surface morphology of the normal fault given lies along the Y. Hereke-Bağ Hill (444 m) line to the north, which represents the source areas of northward flowing creeks. Thus, a problem of drainage construction is likely to appear. Although the escarpment rises further north (Serçe Hill (645), and K. Kayalı Hill (643). No stream could ever pass southward. This might well be related to the northward tilting of the escarpment.

As known, the first drainage construction on the fault scarps depends on the primitive slope gradient of the first uplifting of the escarpments. The erosional cycle is established with regard to the balance between uplift and erosion. The morphologic evolution is resulted in the formation of a smooth planation surface if some interrupts occur, namely the rejuvanation of that fault. The first observable characteristic feature is "fault facettas" formed by dissection of V-shaped valleys (Erinç, 2000). The rivers in front of the fault scarps form aluvial fans and the fault line is covered beneath those young sedimments in a short period. The fault facettas are formed in front of the escarpment as seen in Figure 5. These side by side appearances between deep valleys indicate that the escarpment is very young in age. Hereke-Körfez escarpment is also typical for all the shoreline of the Gulf of Izmit. The nearest distance between shoreline and watershed line is also situated on this scarp. Thus, it is comprehended that the Hereke-Körfez fault plays an important role in the proximity of the watershed line to the gulf. No drainage channel is formed from monadnocks [(Serçe Hill (645 m), Kayalı Hill (643 m) and K. Kayalı Hill (647 m)] towards the south. This is aslo associated with the the fault. Indeed, the creeks springing from the basement rocks have been forced to deviate their routes at the north of escarpment. This is associated with its ongoing tilting to the north because of the compressive regime.

3.2. Submarine geomorphology of the center basin of the Gulf of Izmit

Macro-morphological sub-graben forms can be observed especially at the northern margin of the central basin of the Gulf of Izmit. The border faults of this E-W trending depression have contributed to the shape and geometry of the shoreline.

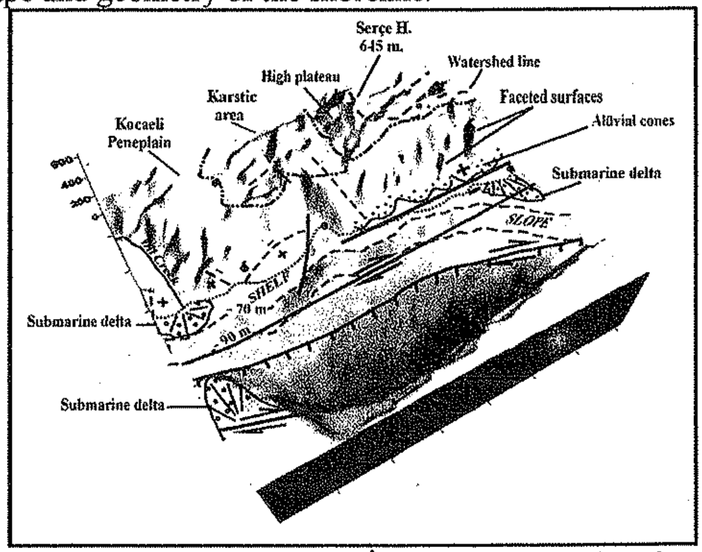

Figure 5. DEM of the study area (using bathymetric data from Güneysu (1999) and topographical map of 1/25 000 scale)

Rectangle shape of the gulf is associated with intersected faults which extend NW-SE at the west of Kaba Promontory, SW-NE and NW-SE at both side of Hereke Bay, and E-W between Hereke and

Körfez to the northern part. Southern coasts are related to the SW-NE trending dextral fault (Gökaşan,et al. 2001). The sea bottom topography of the gulf is deepened by normal faults extending E-W just like the Hereke-Körfez escarpment (Figure 6). But it is interesting that the southern slope is steeper than the northern one because of the extra activitiy of the south by NAF.

Apart from the broader deltas of Zeytin and Hamza creeks (Fig. 3), most of other creeks formed smaller-scale deltas along northern coasts,. They prograde until about -30 to -40 m isobath. This isobath is cut by an E-W trending fault. The distance from the shoreline to the-40 m isobath is 1 km, approximately. Around 0 to -40 m bathymetric interval terminates at the north edge of a shelf area. This shelf in seismic sections (Gökaşan et al. (2001) extends in an area of 2.5 km in average with a gradient of about 0.85 ° (1 %), towards the 200-m central pits.

The shelf surface is covered with the Quaternary deposits, which have a thickness of about 25-30 m in the gulf (Özhan et al., 1985). An erosional surface cuts the basement under this thin cover. The erosional surface lies E-W parallel to the same-trending graben and was dislocated by an other normal fault. This fault caused the erosional surface separate into two fragments, (Es1 and Es 2 in Figure 6). Indeed, the inclinational break between - 70 to - 100 m indicates this fault. The gently inclined ridge lying from -100 m to -160 m might be the continuation of the erosional surface. It is thought that the surface starting from - 40 m is compound with this erosional surface. We concluded that the step-wise region between - 40 to - 160 m isobaths is due to vertical faulting (Figure 7).

This idea may also be supported by borehole data. Ediger and Ergin (1995) explained that just at ahead of Kaba promontory two close bore, one after the other, the basement is found to be in a 22 m difference due to the faulting. They also indicated the degree of faulting evidence. From the sedimentological data the latter that consecutive sand and well-rounded fluvial pebble levels were

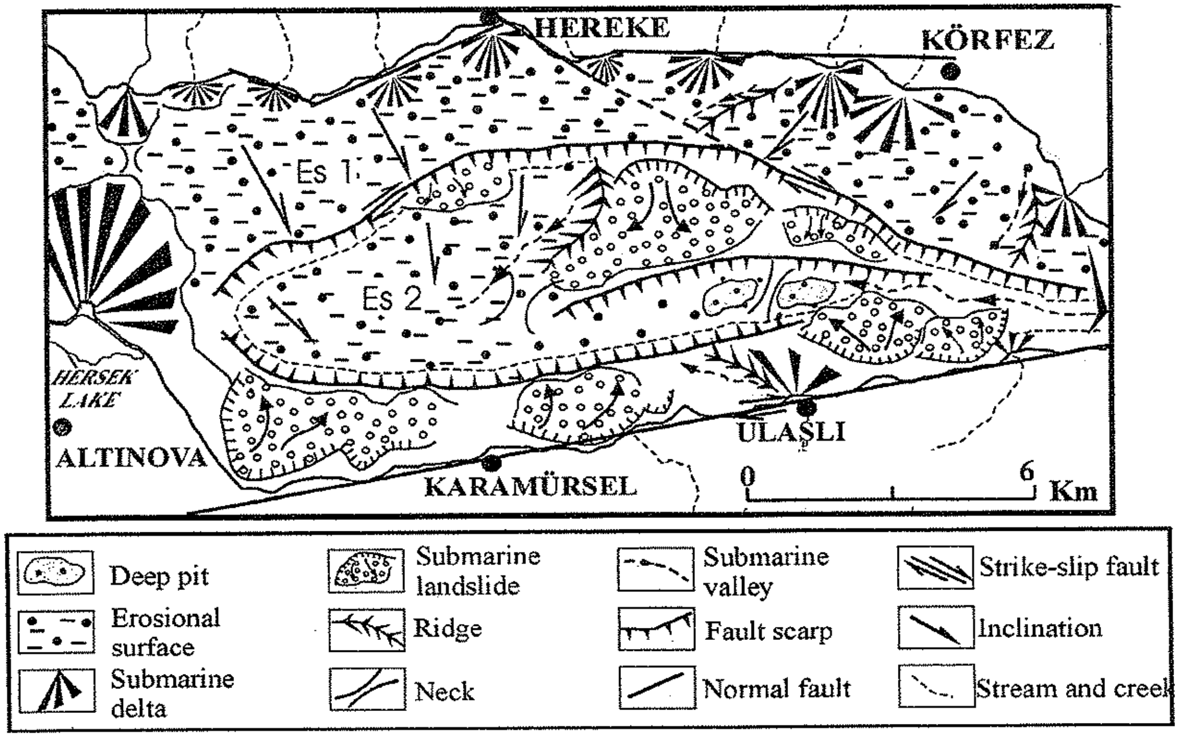

Figure 6. Submarine geomorphology map of the Gulf of Izmit

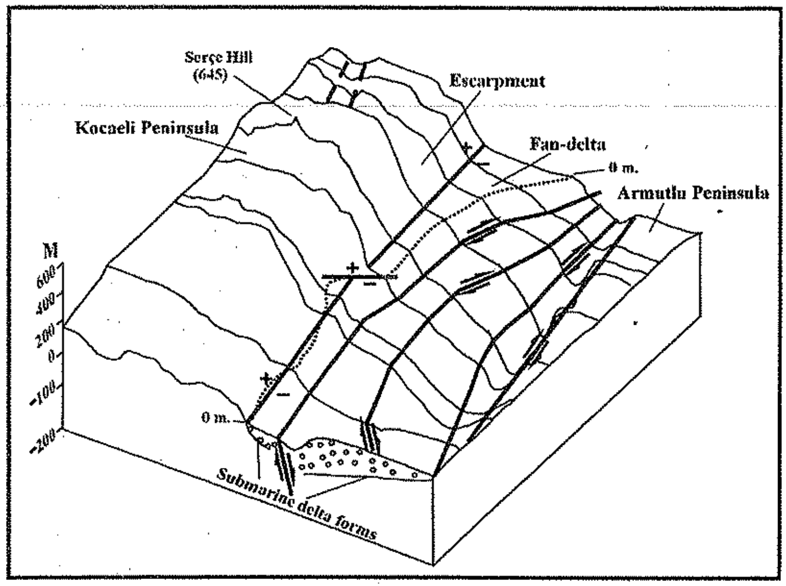

Figure 7. Topographic profile series showing echelon morphology on erosional surfaces in the study area

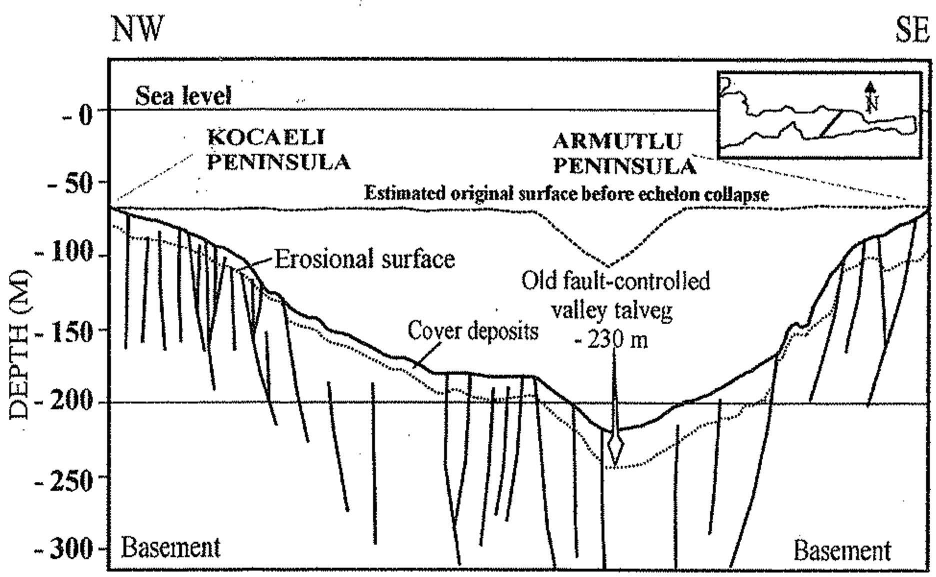

Figure 8. Seismic section of the Central Basin (modified from Gökaşan et al., 2001)

found between -58 to -73 m was associated with tectonic and paleogeographic history of the gulf. The deepest stratigraphic level, including pebble, has been found at -71.55 m. Examining the borehole profile, it appears that this level is found between -64.50 to -71.55 m. This study indicates an E-W flowing stream in the central basin. When considered the thalweg line of this old stream, the bathymetric data show this valley profile between -40 m and -100. But seismic profiles (Gökaşan et al, 2001) display an old valley placed in the the basement at -230 m (Figure 8).
It seems that the seismic section indicates a differeance at 190 – 200 m, by neglecting the cover young deposits 30 m thick. Hence, the collapse rate of the central basin could be estimated from this result to be 190 m. This collapse might have caused deepen both the old thalweg and en-echelon erosional surfaces.
From the evidences driven from en-echelon geomorphometry in the basin, it is likely that the gulf was opened as a graben between the Kocaeli and Armutlu peninsulas. For only northern margin, it seems that the erosional surface in the gulf is the continuation of Kocaeli Peneplain. Thus, both peninsulas ought to been contiguous before the gulf opened.

The pebbles of the Samanlı Mountains observed on Kocaeli Peninsula (Göney, 1963) indicate that these peninsulas were contiguous. Howevew, since the asymetric geometry of the gulf is a result of half graben formation (Altınok et al. 1999) tectonic deformation of NAF has also caused the erosional surfaces to have en- echelon appearance. The coastal slumps are also associated with faulting (Altınok et al. 1999). All segments combining at a few km below the sea bottom move when the northern branch of NAF activates. This causes slumps on both slopes of the basin (Alpar, 2000).

The bathymetric data expose submarine landslides over extensive areas. As seen in Figure 6, slidings extend southern slope of the depression, which is mostly related to the active northern segment of the NAF. The delta deposits form the slidable material in the basin in general. No deltaic or other deposits can remain stable on a normal fault scarp. The overall appearance in the gulf looks as if the landslide edges show correspondence with the fault scarps.

It is concluded that the Hereke-Körfez escarpment is a border fault which formed during the first opening of the gulf. Afterwards, the collapse of the gulf with an en-echelon geometry caused the southern part of smooth topography of the Kocaeli Peninsula decline 190 m, comprehended from fossil thalweg at -230 m. This subsidence, which occured intermittently, is also understood from the escarpment morphology. That is, the escarpment morphology also supports the intermittent subsidence. Rejuvenation of creeks show a 100-130 m dissection degree on the escarpment. On the other hand, the sudden changes shown by the tectonic uplift of the escarpment created the present position of watershed line. So the elevational amplitude, which reaches up to about 700 m, from the top of escarpment down to deep of the gulf gives the total level difference.

Finally, the coastal terraces have given relative information. At the north of Dilovası, three alluvial terraces were determined at elevations of 6-7 m, 25-30 m and 50-55 m, implying that the area have been uplifted 40-50 m (Erguvanlı, 1949). In additon, 25-30 m level is found in Hereke (Bargu, 1997). To the east of the area, Göney (1963) determined four levels located at 1.5-2 m, 7-8 m, 18-20 m and 40-42 m. Why these marine terraces are not found along the escarpment? (1) Is it due to tectonic uplift of the fault scarp? As seen along the sharp-edged façeted surfaces of the scarp, step coast profile is related to this condition. (2) Is it due to the effective sediment input from north by the creeks on the escarpment? Alluvial cones are ranked eastward. Especially the bigger cones reach a maximum thickness as as much 25-30 m level headwards. Thus, we think that the coastal terraces have been possibly covered by these alluvial deposits.

4. Comparison of Results and Discussion

In this work, the geomorphological relation between the Hereke-Körfez escarpment and the central basin of the Gulf of Izmit were studied. Norhward hinterland morphology of the gulf shows a young landform evolution since the activity of NAF beginning in the Upper Miocene. The present landforms evolved until present with the control of active tectonic, litologic and climatic factors. The relation between present Kocaeli Peneplain and the activity of the NAF starting from Upper Miocene is still a contraversy. Here, we should consider whether this planational process could occur or not with the activity of NAF.

Now that the cover deposits which are made up of clay, sand and pebble are cut by this erosioal surface, there is no doubt on the age of this peneplain, which was accepted of Pliocene age generally (Ertek, 1995; Erginal, 2000). This is possible either in a stable period or during a different mechanism of NAF. We here reckon that during the peneplanation, the activity of NAF was not so effective to interrupt the morphological evolution. In this period, the tectonic movements might be relatively quiet. But the following period indicates much more influential activity of NAF as seen both from rejuvenation by creeks on land and from the collapse of the Gulf of Izmit, as observed in the marine seismic sections.

Contiunation of the Kocaeli Peneplain might have not formed the narrow erosional surface in the bottom morphology of the gulf. Submarine surfaces with en-echelon morphology should have been remnants of the partial peneplain surfaces observed on the whole peninsula. This means that the erosional subcycles are important. Therefore, it seems that this erosional surface with E-W direction formed in front of the Hereke-Körfez Fault in a narrow area because of repetition of the sub-erosional cycles occuring after the formation of Kocaeli Peneplain. From this point, it appears that the forming of the central basin is after these short-timed erosional cycles. The number of en-echelon submatured surfaces gives the repetation rate of tectonic movements. In this respect, we determined 4 levels at least. The knick points observed in the thalweg lines also support this result as well.

Thus, the Hereke-Körfez fault, on which submatured surfaces take place apart from the main Kocaeli Peneplain cutting its upper part, was existent as a border fault before the collapse of the Gulf of Izmit. But this fault was non-active since it could have been flatted by normal erosion. This fault should have been reactivated by the

NAF. Before the colapse of the gulf, the narrow-area erosional surface with en-echelon morphology developed in front of this old escarpment. There should have been an E-W-oriented stream, which dissected the basement at – 230 m as observed from the seismic data. In this respect, it can be said that the narrow submaturated surfaces on the present escarpment formed parallel to the erosional cycles dominated on the area.

The river pebbles determined at - 73 m in deepest levels (Ediger and Ergin, 1995) seem to be very young for this old valley. Thus, we think that, in some stand-still times, new drainage channels have been constructed on this valley line. When NAF started its activation, one of its ruptures formed in front of the Hereke-Körfez Fault. The NAF cutted the erosional surface in front of the old stable Hereke-Körfez escarpment. Afterwards, the sub-graben faults evolved in the northern part of the gulf. Therefore, the pull-apart mechanism caused new collapses, as seen from the deep surfaces around 160 m. Each collapse or movement in the gulf, at the same time, corresponds with geomorphological changes as seen from drainage constructions, such as young thalwegs, stream captures, sediment input and mass movements in submarine environment.

A difference of 190 m in the submarine erosional surface demonstrates the collapse of the basin to be 190 m. This is a rather high value when it is compared with the 50-60 m uplift of coastal terraces at both sides of the gulf.

Özet

Bu çalışmada Hereke ile Körfez arasında uzanan, fakat gerçekte İzmit'e kadar çizgiselliği takip edilen fayın üzerindeki genç morfoloji ile, İzmit Körfezi orta çukurunun denizaltı morfolojisi arasındaki ilişki araştırılmıştır. Karada fay dikliği üzerindeki façeta oluşumları, drenajda kapma ve gömülme türünden değişiklikler, diklik önünde dar alanlı olarak korunmuş aşınım yüzeyi parçaları, fay dikliğine gömülen akarsuların kırıklı thalweg profilleri, delta istifleri üzerinde gelişen ve delta önü oyulmalarına karşılık gelen aktif denizaltı heyelanları ve en önemlisi deniz altında -40 – -160 m arasında kademeli faylarla kırılarak ayrılmış aşınım yüzeyi seviyeleri sahadaki aktif tektoniğin görünür delilleri arasındadır. İzmit Körfezi orta çukurunda 190 metrelik bir çökmenin

meydana geldiği sonucuna varılmıştır. Bu sonuç, depresyondaki kademeli çökmelerin derine indirdiği derin vadi formu ile de desteklenmektedir.

Hereke-Körfez fayı boyunca gelişen alüvyal yelpaze formları üzerinde dikkatle çalışılmalıdır. Bu zonda denizel taraçaların bulunmaması kuzeyden gelen malzeme ile mevcut olması muhtemel taraçaların maskelenmesi ve kademeli faylarla derine indirilmesini düşündürdüğünden derin sondajlarla fay dikliği önündeki güncel sedimentasyon ortamının derine doğru uzantısı ve stratigrafik dizilimi, dolayısıyla da ve fan-olası taraça ve temel istifi stratigrafik açıdan ortaya çıkmış olacaktır. Bu türde bir sondaj fan-deltaların sıralandığı kıyı boyunca derine indirilmiş olabileceğini belirttiğimiz aşınım yüzeyinin de mevcut olup olmadığını belgeleyecektir.

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