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Late Holocene faulting events on the İznik-Mekece fault in the western part of the North Anatolian fault zone, Turkey

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Abstract : The İznik-Mekece fault is one of the branches of the North Anatolian fault in northwestern Anatolia, Turkey. We investigated the geology and geomorphology of the İznik-Mekece fault to know its recent activities. On an outcrop of faulted alluvial fan deposits south of Geyve near the east end of the fault, we found a colluvial soil wedge which indicates recent activity of the fault. Based on the geologic structure and the fault topography, two last faulting events were recognized. The penultimate event is likely to have occurred in the third or fourth century B.C. The recurrence interval of this fault is 1700 to 2200 years based on the previously estimated age of the last event.

1. Introduction

The North Anatolian fault is a transform plate boundary between the Eurasian Plate on the north and Anatolian Plate on the south. The fault runs latitudinally across northern Turkey for over 1200 kilometers with consistent right-lateral strike-slip deformation. The seismicity along the fault zone is intense and destructive. The fault is well known for the westward epicentral migration of large earthquakes occurred in 1939-1967 period. This series of earthquakes ruptured about 800 kilometers continuous portion of the fault between 30°30′E and 39° 30′E (Fig. 1). This migrating sequence, however, did not reach the westernmost part of the North Anatolian fault where no large earthquake with surface breaks has occurred in this century. Toksöz *et al.* (1979) supposed that this part of the fault might be a seismic gap. Based on this supposition, a lot of geophysical and geological investigations including trenching surveys have been done in and around this part of the North Anatolian fault zone (e.g. Honkura and Işıkara, 1991; Oshiman *et al.*, 1991). Notwithstanding all these efforts, very little is known about the paleoseismology of the area. Honkura and Işıkara opened the first trench on the North Anatolian fault only to estimate the age of the last faulting event to be between 200 and 500 years B.P. Hence, the recurrence interval of faulting events as well as the slip rate of the

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Keywords : İznik-Mekece fault, North Anatolian fault, Turkey, recurrence interval, fault exposure, fault topography, paleoseismology

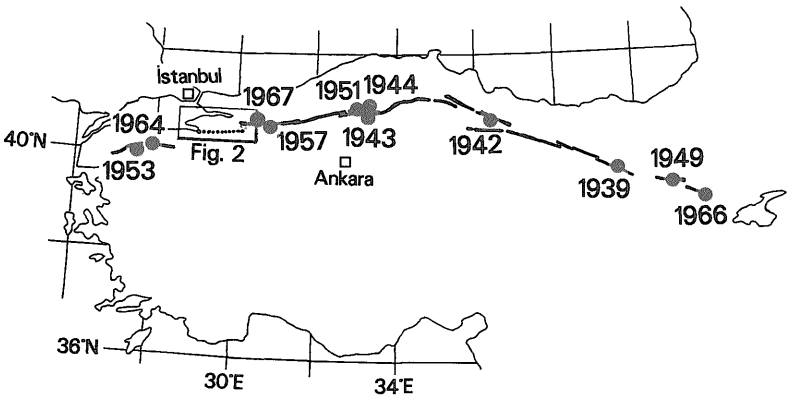

Fig. 1 Epicenter of major earthquakes (Ms $\geq$ 6.5) occurred on the North Anatolian fault zone during this century and accompanied surface breaks. (after Ambraseys, 1988)

fault in the recent time is not recognized yet to know.

The authors investigated the recent activity of the İznik-Mekece fault from geological and geomorphological points of view. The authors describe fault topography along the İznik-Mekece fault and a fault exposure indicating late Holocene activity and discuss the recent activity of this fault.

2. Recent activity of the İznik-Mekece Fault

The İznik-Mekece fault (Sipahioğlu and Matsuda, 1986) comprises the southern branch of the western North Anatolian fault zone. About 100 kilometer long fault trace appears between near Geyve and Gemlik Bay passing by Lake İznik (Fig. 2). The eastern end is located southwest of Geyve, about 20 kilometers southwest of the western termination of the surface rupture in the 1967 Mudurnu earthquake (Ambraseys and Zatopek, 1969). The fault consists of three major portions separated by right stepovers. On the north side of these portions, three topographic depressions of Pamukova Plain (Basin), Lake İznik, and Gemlik Bay are located from east to west.

Topographic map along the İznik-Mekece fault between Lake İznik and Geyve are shown in Fig. 3. Recent right-lateral strike-slip activity of the İznik-Mekece fault is distinct for displaced alluvial fan surfaces though the topographic expression is not obvious and continuous owing to human activity and erosion. Followings examples, however, clearly indicate recent activity of the fault:

In the south of İznik (loc. 1), a pair of fault trace runs sub-parallel to each other. One trace lies just on the piedmont line of the mountains to the south, and the other lies about 1 kilometer north of the piedmont line. The latter one displaces recent alluvial fan surfaces forming continuous fault scarplets of 1 to 1.5 meter high.

Between İznik and Mekece, a 15 kilometer long linear valley trending E-W is lying on the fault zone. The eastern half of this valley is about 1.5 kilometers wide, but there is no river that can dissect this wide valley. Tectonic movement must have formed this valley as a graven.

In the west of Mekece (loc. 2), a series of offset streams run across the piedmont line at the bottom of a distinctive north-facing fault scarp about 3 kilometer long. Topography of these offset streams are sharp and clear. The accumulated offset ranges 50 to 100 meters with consistent right lateral displacement.

Along the southern rim of Pamukova Plain, the fault passes along the linear piedmont line of the mountains. In the western part of this line, two lineaments trending ENE-WSW are passing through mountain slope. A fault exposure of displaced Tertiary sediments and overlying late Quaternary deposits reported by

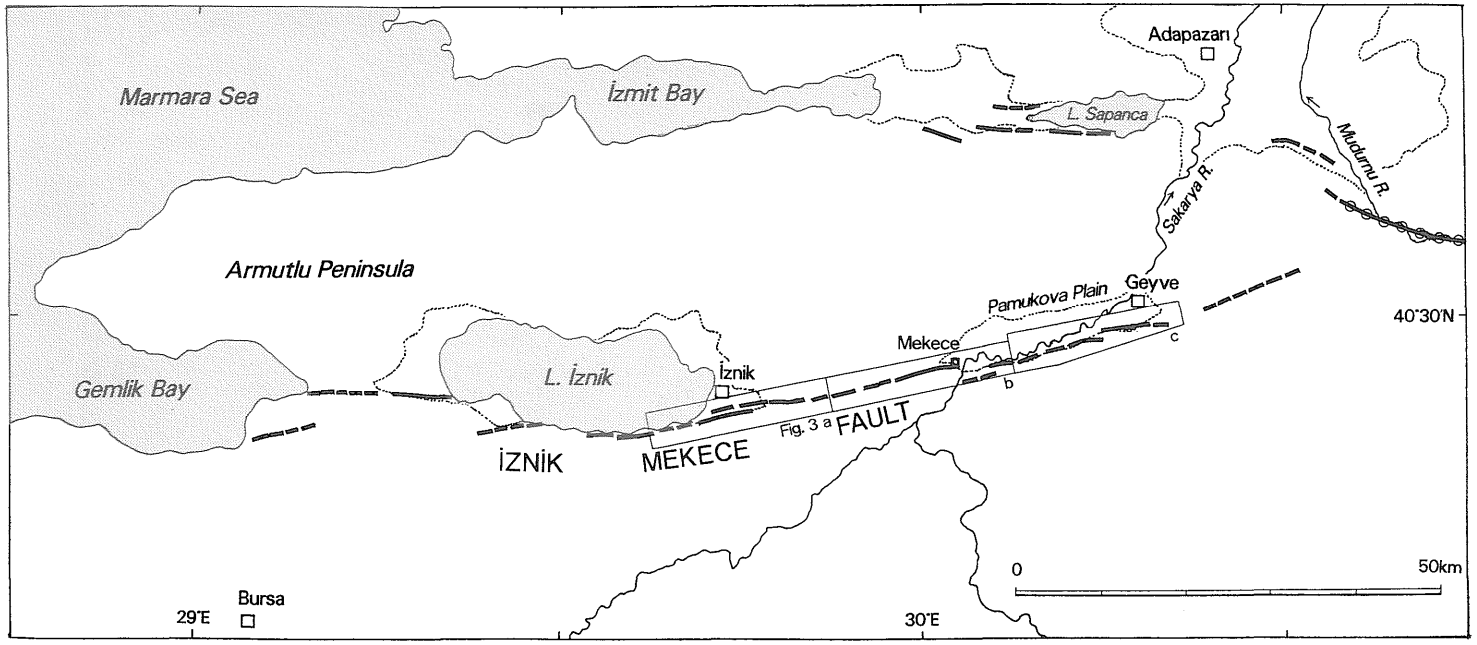

Fig. 2 Active faults in the western part of the North Anatolian fault zone. Active faults are shown in bold lines. Bold line with circles indicates the surface break associated with the 1967 Mudurnu earthquake.

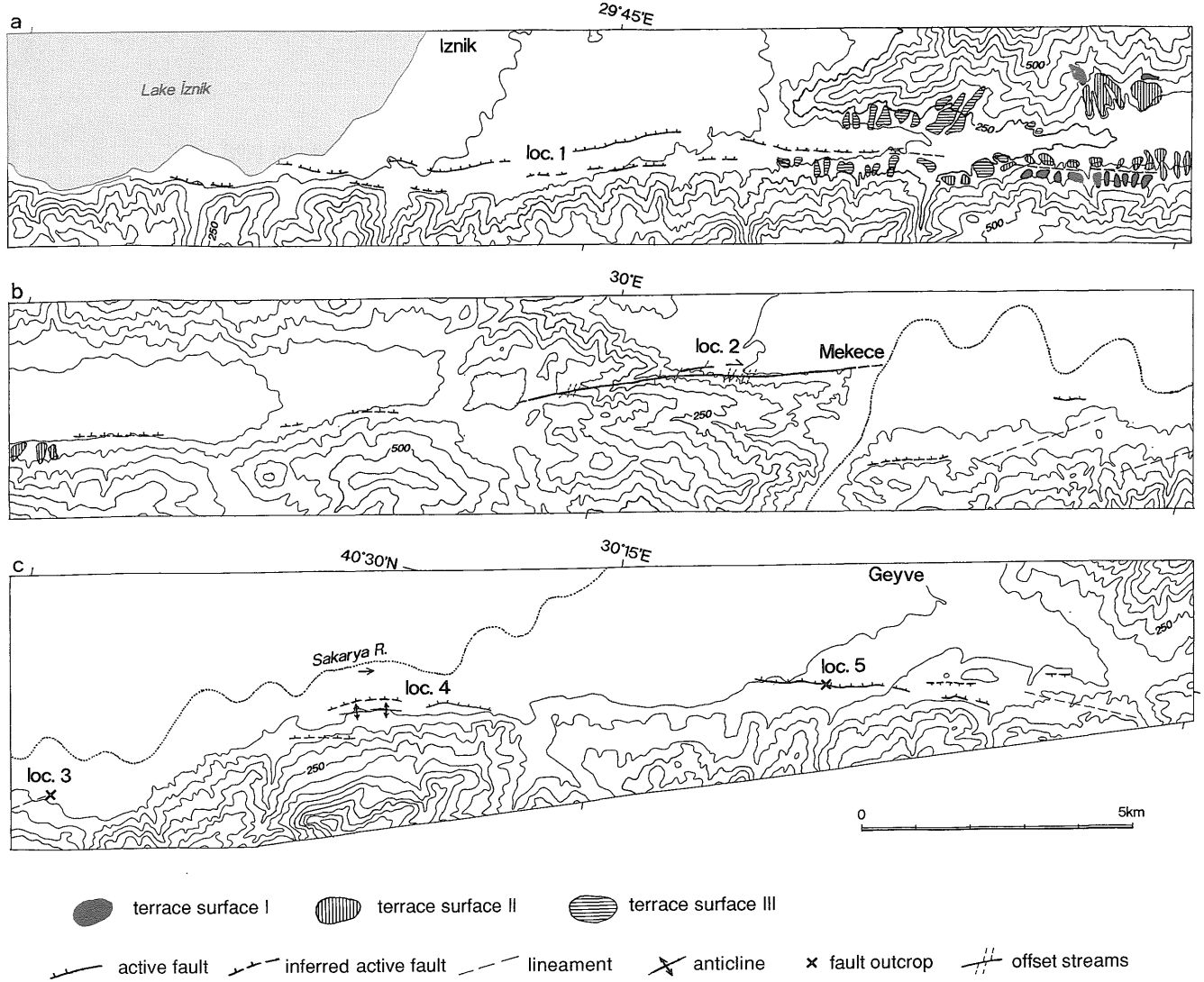

Fig. 3 Topographic map of the İznik-Mekece fault between Lake İznik and Geyve. Contour interval is 50 meters.

Tsukuda *et al.* (1988) coincides with one of these lineaments (loc. 3). These lineaments do not deform the late Quaternary deposits and topographic surfaces. The active trace of the fault may pass through the flood plain of the Sakarya River with its fault topography eroded away by the stream. In the middle part of the piedmont line, the fault deforms an alluvial fan surface with anticlinal fold (loc. 4). In the south of Geyve, the east end of pamukova Plain, the fault formed continuous sharp scarplets of 1 to 1.5 meter high on terrace surfaces (loc. 5).

In the westernmost part of the İznik-Mekece fault, fault topography on land is not clear. Ikeda *et al.* (1991a) supposed that the bottom topography of the lake, with the deepest part located near the south coast, was controlled by the fault. To the west of Lake İznik, the fault cuts alluvial fans mostly of Holocene age, and tilts the lower lacustrine terrace surfaces (Ikeda *et al.*, 1991a).

3. Fault exposure near Geyve

The fault exposure is located at about 2 kilometers south of Geyve, near the southeast corner of the Pamukova Plain (Loc. 5). A linear, probably tectonic, scarp of about 500 meter high borders the plain from mountains on the south composed of Cretaceous to Paleogene sedimentary and volcanic rocks. Along the foot of the scarp, alluvial fans formed by streams running down from the mountains have extensively developed. Fig. 4 shows the topography around the fault exposure. The alluvial fan surfaces around the exposure are classified into two levels based on interpretation of aerial photographs and field survey. Between these two levels, a linear scarplet of 1 to 2 meter high trending N50° to 65°W bounds these two surfaces.

The İznik-Mekece fault displaces these surfaces with north-facing scarplet which strikes N80° to 85°E. The height of the scarplet is 1 to 1.5 meters on the fan I near the exposure.

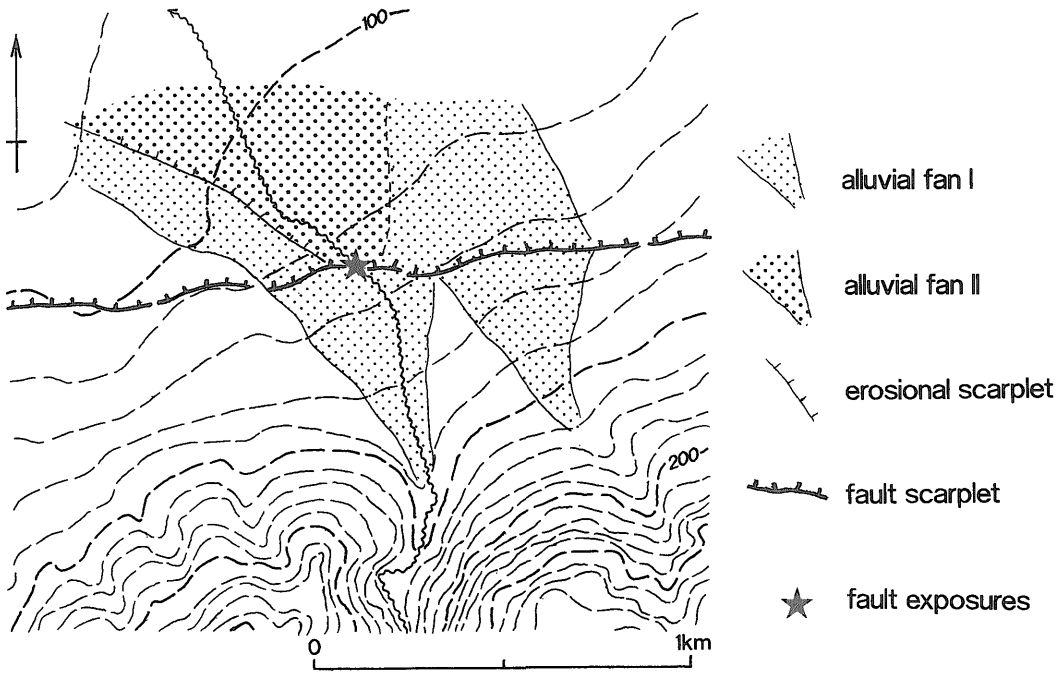

Fig. 4 Geomorphological map around fault exposure. Alluvial fans are divided into fans I and II. Contour interval is 10 meters.

Right-lateral strike-slip displacement of the fault is not evident around the exposure.

The fault appears along a gully incising the alluvial fans. Fig. 5 shows detailed logs of the exposure on the western and eastern walls. The western wall is sub-vertical and smooth but the eastern wall has a little irregular surface. The distance between two walls is about 10 meters. The eastern exposure is situated about 1 meter below the western exposure. A fault cuts gravel beds on the western wall. On the eastern wall, a thick pile of debris concealed the fault. The upper part of the fault plane is almost vertical. Some pieces of gravel are rotated along the fault plane to lay their long axes parallel to the fault plane. The rotation of the gravel is distinct in the upper part. We classified the exposed sediments on both walls into following four sedimentary units.

Unit 1 appears only on the western wall. This unit consists of subrounded to subangular pebble to cobble with intercalated coarse sand. This unit is about 2 meter thick and the deposition is restricted to the northern side of the fault.

Unit 2 appears on the northern side of the

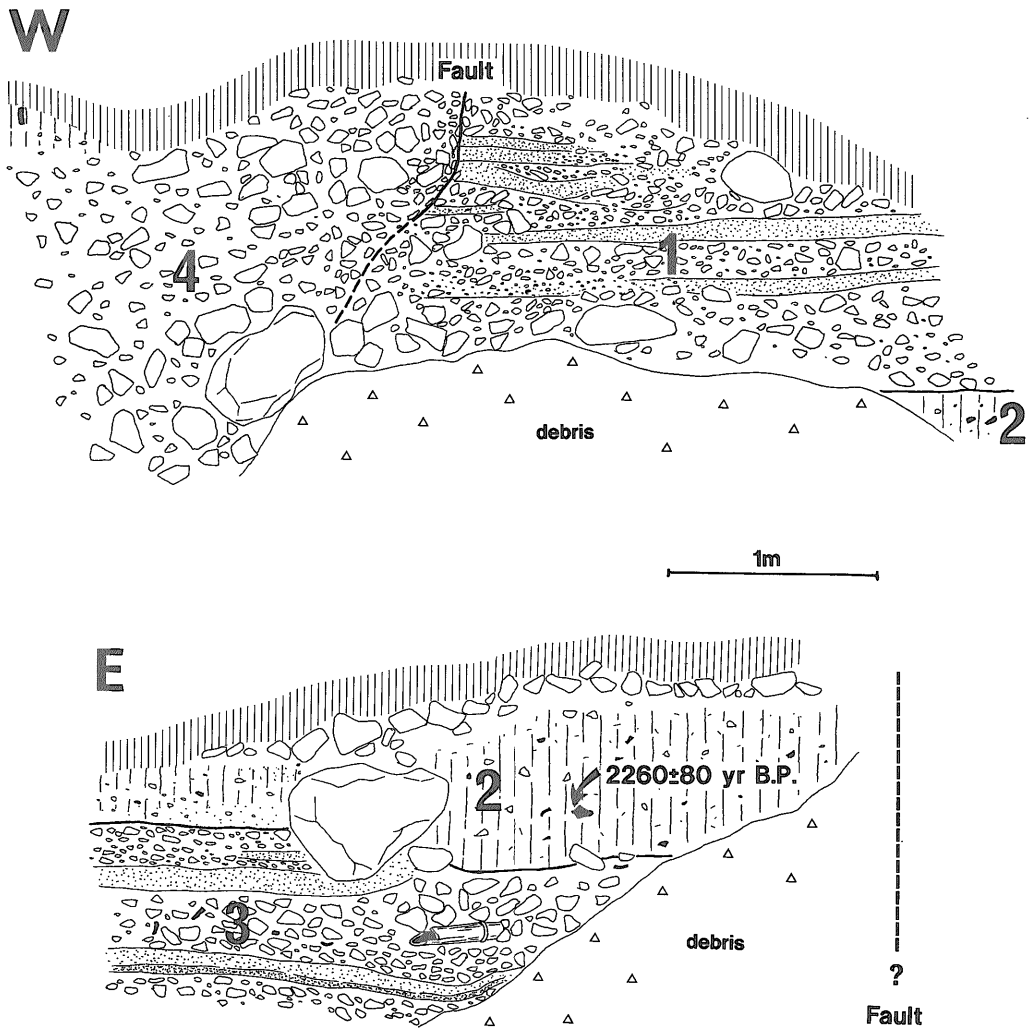

Fig. 5 Logs of fault exposure. Each number indicates a sedimentary unit. The eastern exposure (E) is situated about 1 meter below the western exposure (W).

fault on both walls. Its lithofacies vary across the outcrop. On the eastern wall, unit 2 is massive and unsorted yellowish brown loamy soil with many brick and pottery fragments near the fault. It gets thinner and changes into an unsorted silt and sand layer toward north. The thickness increases toward the fault to about 80 centimeters. On the western wall, unit 2 is an unsorted yellowish brown silt layer with brick and pottery fragments underlying the unit 1.

Unit 3 consists of subangular to angular pebble to cobble intercalating coarse sand and silt layers. This unit also contains many brick and pottery fragments with earthen pipes. Unit 3 is also distributed only on the northern side of the fault.

Unit 4 is composed of unsorted subrounded pebble to boulder. This unit is distributed only the southern side of the fault on both walls but concealed by debris on the eastern wall. Its thickness is more than 5 meters.

Judging from the distribution and lithofacies of these units, the surfaces of the alluvial fan I and II are constructional surfaces of the unit 1 and 4 respectively. The unit 2 is distributed only on the downthrown side of the fault and gets thicker and worse-sorted toward the fault. This lithofacies indicates the unit 2 is a colluvial soil wedge resulting from the collapse of the north-facing fault scarplet.

4. Timing of the faulting events

The colluvial soil wedge of the unit 2 was most probably formed by a faulting of the İznik-Mekece fault. This soil must have been the surface soil when the faulting event occurred. The age of this event coincides with the age of the unit 2. A charcoal piece in the unit 2 was dated as 2260 ± 80 years B.P. (I-16928) by radiocarbon method using the Libby half-life of 5568 years. The dendrochronologically calibrated age for this radiocarbon date is 398 B.C. to 341 B.C. in the probability of 34.5% or 322 B.C. to 204 B.C. in the probability of 65.5% using CalibETH (Niklaus, 1991) with the original data by Stuiver and Pearson (1986).

The archeological age estimation of the pottery fragments from the unit 2 are the Hellenistic period (middle fourth century B.C. to late second century B.C.) (Omura and Matsumura, personal communication). These ages constrain the age of the faulting event prior to the last event, as the unit 1 overlying the unit 2 has been displaced by another event on the western exposure. The number of the events after the deposition of the unit 2 is not restricted to single by the geologic structure.

On the other hand, the vertical displacement of the fault scarplet on the alluvial fan I is 1 to 1.5 meters. This displacement is accumulated after the deposition of the unit 4. The maximum thickness of the colluvial wedge of the unit 2 along the fault is about 80 centimeters. This amount is approximately the amount of the vertical displacement during one faulting event. The 1 to 1.5 meter accumulated slip is probably the sum of two faulting events after the formation of the alluvial fan I. Accordingly, two faulting events occurred after the deposition of the unit 4. The timing of these events correspond to the deposition of the unit 2 and the deposition of the unit 1. The age of the penultimate event is 398 B.C. to 204 B.C, in the third or fourth century B.C.

5. Discussion and conclusion

The age of the last two faulting events on the İznik-Mekece fault are estimated. The penultimate and the last events occurred respectively in the third or fourth century B.C. and thereafter. Our present data do not allow to confine the age of the last event further than the current estimation of between third or forth century B.C. and 19th century AD.

Recurrence interval based on these dates is smaller than 2300 years. Honkura and Işıkara (1991) inferred the age of the last faulting event of this fault is between 200 and 500 years B.P. If this estimation is correct, the recurrence interval of this fault is 1700 to 2200 years. This recurrence interval is far longer than the estimates reported from more eastern part of the North Anatolian fault. Yoshioka *et al.* (1991) excavated an exploratory trench on the surface fault accompanied by the 1944 Bolu-Gerede

earthquake and estimated the recurrence interval as 220 to 280 years. Ikeda *et al.* (1991b) also estimated that the age of the penultimate event in the Mudurnu valley before the 1967 earthquake, is younger than AD 1480. The recurrence interval of the İznik-Mekece fault is more than five times longer than these estimates. The elapsed time after the last event is 200 to 500 years according to Honkura and Işıkara (1991). This corresponds only 10 to 30 percent of the recurrence interval. The İznik-Mekece fault might not be a seismic gap however there was no large earthquake with surface breaks in this century.

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トルコ，北アナトリア断層西部，İznik-Mekece 断層の完新世後期における断層活動

吉岡敏和・İsmail Kuşçu

要　旨

トルコ北部を東西に縦断する北アナトリア断層は，ユーラシアプレートとアナトリアプレートを境する右横ずれ活断層で，今世紀半ばに地表に地震断層を伴う一連の活動を起こしたことで知られている．その中にあって，北アナトリア断層の西部に位置するİznik-Mekece断層については活動の記録がなく，地震空白域と考えられてきた．İznik-Mekece断層東部のGeyveにおいて発見された断層露頭からは，断層運動によるとみられる崩積土層が確認され，過去2回の断層活動が解読された．活動年代については，放射性炭素同位体年代及び土器年代より，2回前の地震は紀元前3－4世紀に発生したと考えられる．また，既に報告されている最終活動年代に基づけば，再来周期は1700－2200年となり，北アナトリア断層主部の再来周期よりはるかに長い．最終活動以降の経過時間は再来周期の10－30％に過ぎず，今世紀の北アナトリア断層の一連の活動に際しİznik-Mekece断層が活動する可能性は非常に低いものと考えられる．