BULLETIN OF THE MINERAL RESEARCH AND EXPLORATION INSTITUTE OF TURKEY

Foreign Edition October 1969 Number : 73

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Bu nüshada yazı işlerini fiilen idare edenler - Editors :
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THE RIFT SYSTEM OF THE WESTERN TURKEY; THOUGHTS ON ITS DEVELOPMENT

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ABSTRACT.— An earthquake of magnitude 5.5 occurred in Alaşehir (Manisa Province) region on March 28, 1969. Partly because of the use of improper building materials and construction processes, and partly because of incoherent ground, this low-magnitude earthquake caused great damage. Several ruptures developed on the ground, parallel to the trend of the Alaşehir Valley. Dip-slip displacements took place along these breakages. The sense of slips suggests lowering of the Alaşehir Valley. Geological studies support the view that the Alaşehir Valley is a graben. There is strong evidence indicating uplift of the entire region as a whole. It is proposed that grabens developed on a spreading rise at regions of tension. This hypothesis is supported by the tectonic style of the main geological features at the north and south of the Menderes Massif.

INTRODUCTION

Existence of grabens in the Ege (Aegean) region of Turkey has been discussed by several authors (Philippson, 1920; Salomon-Calvi, 1940; Pınar, 1950; Zeschke, 1954; Ketin, 1966; Bingöl, 1968). Büyük Menderes, Küçük Menderes, Alaşehir, Simav, Bergama and Edremit basins are the main sinking areas. We obtained the opportunity to study in detail the Alaşehir basin, during our investigation on the March 28, 1969 earthquake which occurred in this region.

THE ALAŞEHİR EARTHQUAKE OF MARCH 28, 1969

An earthquake of magnitude 5.5 occurred in Alaşehir (Manisa Province) region on 28 March, 1969. Partly because of the use of improper building materials and construction processes and partly because of the unstable ground, this low-magnitude earthquake caused great damage: reportedly, 49 people were killed and 4,651 buildings were demolished or heavily damaged.

Several ground ruptures developed during the earthquake. At least six of them were continuous in long distances. The longest one we had seen was over 12 km long. Two of the ruptures are numbered 1 and 2 on the accompanying tectonic map (Levha I), and they can be seen on photos (Photos 1 to 9). They are tension fractures. The movement along them is in the direction of the dip and suggests subsidence of the valley side. No. recent movement is observed along the previously existing, faults at the valley boundaries.

SHORT NOTE ON THE GEOLOGY OF THE ALAŞEHİR VALLEY AND THE SURROUNDING AREA

The studied area is a part of the Menderes Massif. The valley (average height 150 m) which contains Salihli, Alaşehir and Sarıgöl is bordered by high mountains (up to 2000 m) generally made of metamorphic rocks. Low areas are covered by young sedimentary deposits of detrital material.

Metamorphic rocks

Gneiss, augen-gneiss, mica-schist, greenstone and marble cover large areas. Besides these, quartzite, granite and Paleozoic and Mesozoic limestones are shown on the existing 1 : 100,000 - scaled maps of the region.

Young sediments group (possibly Pliocene)

This group is composed of conglomerates, sandstones, siltstones and, in smaller amounts, of limestones. The total thickness of this group is 1,375 m at least.

The limestone is often conglomeratic . and grades to a calcite-cemented conglomerate. It contains siliceous concretions, in places. It is white-colored, thick-bedded (75-150 cm) and quite porous. Thickness of this unit is about 20 m at the south of the valley and increases to 90 m at the north.

Limestone unit is followed upward by dark-red-colored conglomerates and sandstones; pink-white-colored conglomerates, sandstones and claystones; yellow-colored coarse elastics, and orange-colored coarse elastics, in that order. These units are composed mainly of subrounded or angular fragments of metamorphic rocks. Sorting is generally poor. Cementing is weak. Iron oxide, thin mica flakes and clay are the main cementing matter. The uppermost levels are almost uncemented. We were not able to find any determinable fossil in this group. But, Pliocene fossils were found in similar lithologies at the east.

Young volcanic rocks, known as «Kula basalts», cover rather a large area, at the north of the valley. Cinder cones, fresh lava surfaces, lava flows in present-day's valleys can be seen between Kula Village and Demirköprü Dam. No volcanic activity of Quaternary or Tertiary period is seen at the south of the valley.

TECTONIC OUTLINE OF THE REGION

Alaşehir Creek flows from SE toward NW in a valley about 5 km wide. Gediz River enters this valley through a narrow strait, near Salihli. From there the general trend of the valley changes to E-W.

As can be seen on the attached map (Plate I), many dip-slip faults take place between the valley and the mountains. Development of the valley can be explained by these faults and the valley corresponds to a graben.

Faults have affected mostly young sedimentary terrain. Many of them are parallel to the valley and follow each other causing stepping in topography. Intervals between faults are about 1 to 3 km. At the south of the valley the contact between metamorphics and the young group is faulted; but E-W faults are not numerous in metamorphic rocks. On the other hand, at the north of the valley metamorphic terrane, also, is greatly affected by E-W faults.

Fault planes dip toward the valley with angles of 30-60°. At the south, the fault plane between sedimentary group and metamorphic rocks dips less than 30°, in places. Foliations in metamorphic rocks generally dip toward the valley with low angles and influence attitude of fault planes. This control of young tectonic features by the olds ones is expressed in a larger scale by the asymmetrical shape of the Bozdağ horst. The southern face of Bozdağ Mt. is much steeper than its northern face. Foliations dip with high angles toward south at the southern face, and in accordance with this, dip angles of fault planes are high at this face of Bozdağ Mt. The asymmetrical shape of the Bozdağ horst could have been accentuated by tilting of the horst as a whole. Abnormal flat areas around the summit of Bozdağ Mt. could have been formed as a result of such tilting. The cited flats are those where Bozdağ Village and Gölcük Lake are situated. They are placed at the upper end of creeks flowing toward north in deep and narrow valleys.

Fault planes where they can be examined are generally planar; rarely they show a slight concavity.

Young sediment group of the blocks between faults is not folded, except a few large undulations. Sunken blocks are generally tilted toward fault plane. Due to drag, tails of downthrown blocks are slightly bended upward.

Vertical displacements at the faults are about 250-300 m. The presence of the limestone unit of the young sedimentary group at an altitude of 1220 m, 3 km south of Gökçealan Village, suggests for the valley base a minimum throw of 1500 m since the end of Pliocene. This amount can be reached by a subsidence of 1 mm a year.

N-S trending faults have also participated in the young evolution of the Alaşehir Valley. They are not numerous. They are old weakness lines and their role in the young tectonic is passive.

The south slope of the Alaşehir Valley is greatly shaped by a large mylonite zone in the metamorphic rocks. On the attached map (Plate I) a part of this zone is shown near Gökçealan Village. There, a nappe formed of marble and garnet-schists is placed on reddish colored mica-schists with a thick mylonite zone between. Similar thick mylonite zones are encountered between Horzumkeserler and Işıklar villages, among many other places.

Even «Kula basalts» are affected by faults. Two faults, with 1 m throw each, are exposed in basalt, near Demirköprü Dam.

Hot springs and cinnabar occurrences are placed along faults between the young sedimentary group and the metamorphic terrane. To name a few, are Çamurhamamı thermal, 92° C at exit, and cinnabar deposits at Işıklar Village and at 3 km south of Alaşehir.

COMMENTS ON THE GRABEN CHARACTER OF THE ALAŞEHİR VALLEY

Presence of several subsidence areas in Ege (Aegean) region of Turkey can be inferred through the outcrops pattern of metamorphic rocks and of young sedimentary terrane. Küçük Menderes Valley, Büyük Menderes Valley and Alaşehir-Salihli Valley are the greatests of those subsidence areas. Salihli-Alaşehir Valley, which we had opportunity to investigate in some detail, is a typical graben. As described in the preceding section, this valley has sunk about 1500 m through the end of Neogene period.

Our proposed evidences on the graben character of the Alaşehir-Salihli Valley are the following:

— Faults at both sides of the valley are normal faults and fault planes dip toward the valley. Faults generally trend linearly parallel to the valley. There is progressive subsidence toward the valley by sets of step blocks (Fig. 1 and 2).

— Folding in the young sedimentary group is uncommon. However, tilting of blocks toward the mountain side in agreement with graben morphology occurs at the south of the valley, in particular (Fig. 1).

— Cinder cones of Quaternary volcanic activity align parallel to the valley on the northern block.

— Present seismic activity coincides with the rift zone. The region is tectonically active. Quaternary volcanic terrane is also faulted.

— The valley sank, somewhat, during the last earthquake. The fractures developed during it are tensional features. The movements along fractures do not have lateral component. Several severe earthquakes occurred in that region during the historical times. The valley subsided sensibly in some of them.[1] (Ergin *et al.,* 1967).

— Gediz River flows in a valley 500 m higher than Alaşehir Creek, although it carries much more water. (Lateral distance between them is about 30 km.)

COMMENTS ON UPLIFTING OF CENTRAL PART OF EGE (AEGEAN) REGION

There are evidences implying uparching of the central part of Ege (Aegean) region of Turkey which contains the above-mentioned graben areas. These evidences are the following ones:

— Mesozoic cover has been removed by erosion from the massif and the surrounding areas.

— Augen-gneiss which has undergone high-grade metamorphism occupies elevated areas.

— Running water of the region has eroded much faster vertically than laterally: e.g. most of the creeks flowing S-N from Bozdağ Mt. to Salihli-Alaşehir Valley cut narrow, but 500-600 m deep valleys.

[1] No geodetic measurement is available.

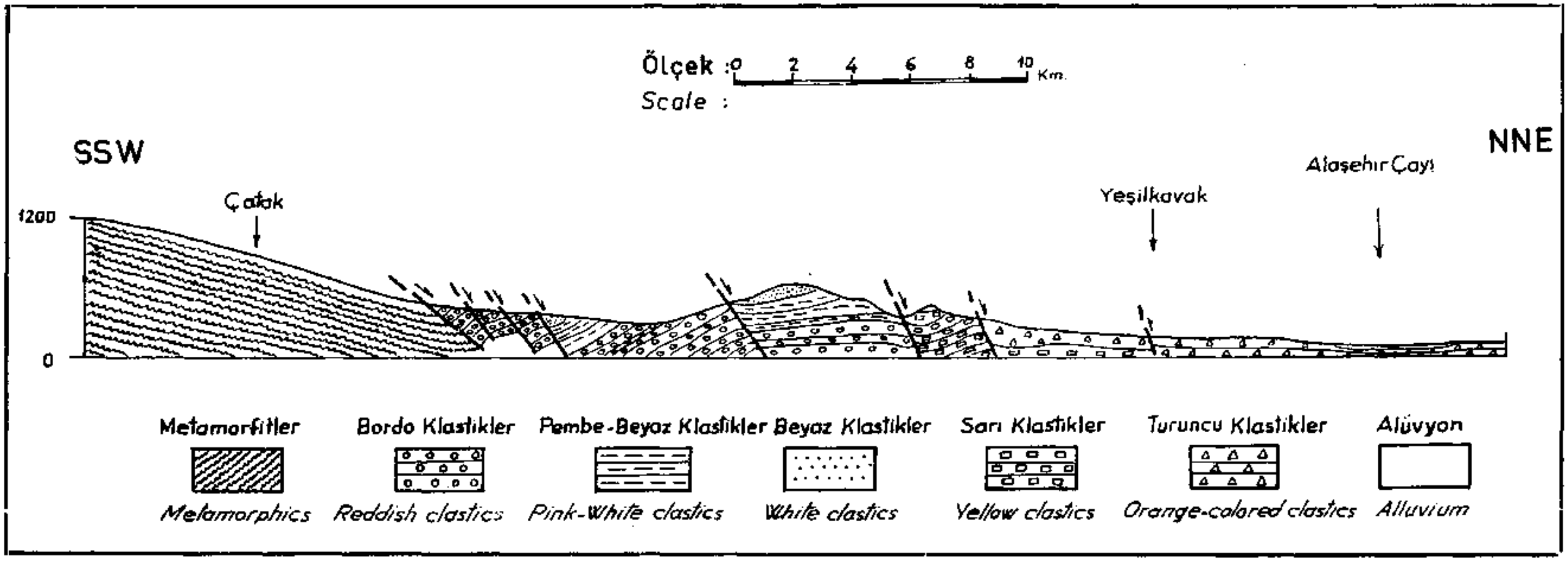

Fig. 1 - Geological cross section between Yeşilkavak and Çatak villages.

— Gediz River flows in an incised meander valley cut in metamorphic rocks, at NE of Kula Village. Cross profile 6f this valley shows no contrast between the slopes of the two valley sides of the meander curves. This pronounced symmetry of the cross profile suggests vertical uplift of the region rather than any other cause of rejuvenation; although this argument is not a strong one.

COMMENTS ON A POSSIBLE BROAD UPLIFT AS THE CAUSE OF THE EGE (AEGEAN) RIFT SYSTEM

There are rather strong evindences that the Ege rift system is developing under the tensional forces generated by a broad uplift of the crust. These evidences are the following:

— Areas of subsidence, such as Küçük Menderes Valley, Büyük Menderes Valley, Alaşehir Valley, etc., are grabens corresponding to release of tension.

— The Ege (Aegean) region of Turkey is rising as a whole.

— Geothermal gradient is abnormally high. The region has natural steam fields, many hot springs (up to 90°C). High geothermal gradient is also proved by several drillings.

— The region is very active seismically.

— Folding is very uncommon in young sedimentary group which, in places, is elevated up to 1300 m.

Further investigations, such as the following, may end with additional evidences.

— Determination of the thickness of the crust. An anomalously thin crust will be a positive evidence.

— Search for an anomalous upper mantle. A thick plastic zone will be a positive evidence.

— Systematic heat flow measurements at the Ege and the surrounding regions. High heat flow will be a positive evidence.

— Periodical geodetical surveys to check relative positions of valleys and mountains. Mesurements should be planned to verify uplifting and extension of the region. Measurements made before and just after an earthquake may give necessary parameters, such as the amount of elastic strain and ratio of the sunken and raised volume, to study the mechanics of the earthquake.

— Magnetic survey to investigate presence of intrusive bodies beneath the grabens. Rift underlain by igneous intrusion would indicate strong extension of the region.

— Radioactive age determinations to investigate the pattern of rejuvenation. The age of rejuvenation could be younger in graben areas due to presence of intrusive bodies.

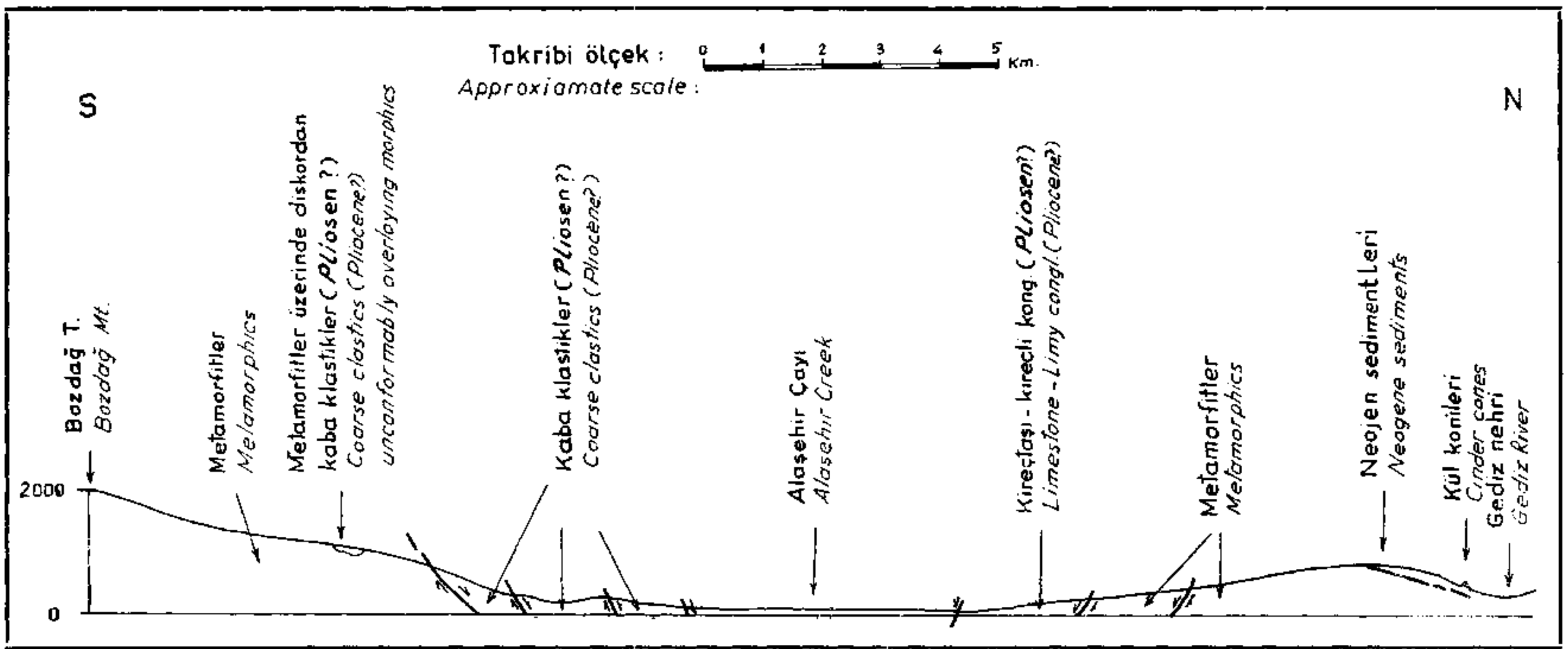

Fig. 2 - Schematic N-S section of the Alaşehir - Salihli Graben.

RELATIONSHIPS BETWEEN THE RIFT SYSTEM AND THE LARGE TECTONIC FEATURES OF THE SURROUNDING REGIONS

Central Anatolian region shows a similar uplift with grabens developed in its central parts. Dip-slip normal faults trend NW-SE in this region. The change of E-W trend of Ege region to NW-SE in Central Anatolia could be gradual or could have been arranged by some kind of transformed fault.

NE-SW structural trends predominate between the rift system and Karadeniz (Black Sea), and NW-SE trends between the rift system and Akdeniz (Mediterranean Sea). These trends are displayed by outcrop pattern of Neogene sediments, by general trend of Neogene volcanic activity and by drainage patterns. A larger zone having NE-SW trend extends between İzmir Karaburun and Manyas. This zone is especially characterized by widespread occurrences of Paleozoic and Mesozoic outcrops.

These NE-SW and NW-SE trends are older than E-W features. They are filled by felsic Neogene volcanic rocks (felsic Neogene volcanic rocks are not found in E-W features).

These older lines are zones of weakness in the crust. They participate sometimes in the activity of the E-W lines. In this way they cause block faulting.

The relationship of NE-SW and NW-SE lines with the younger E-W system is an important subject to be investigated.

Manuscript received January 12, 1970

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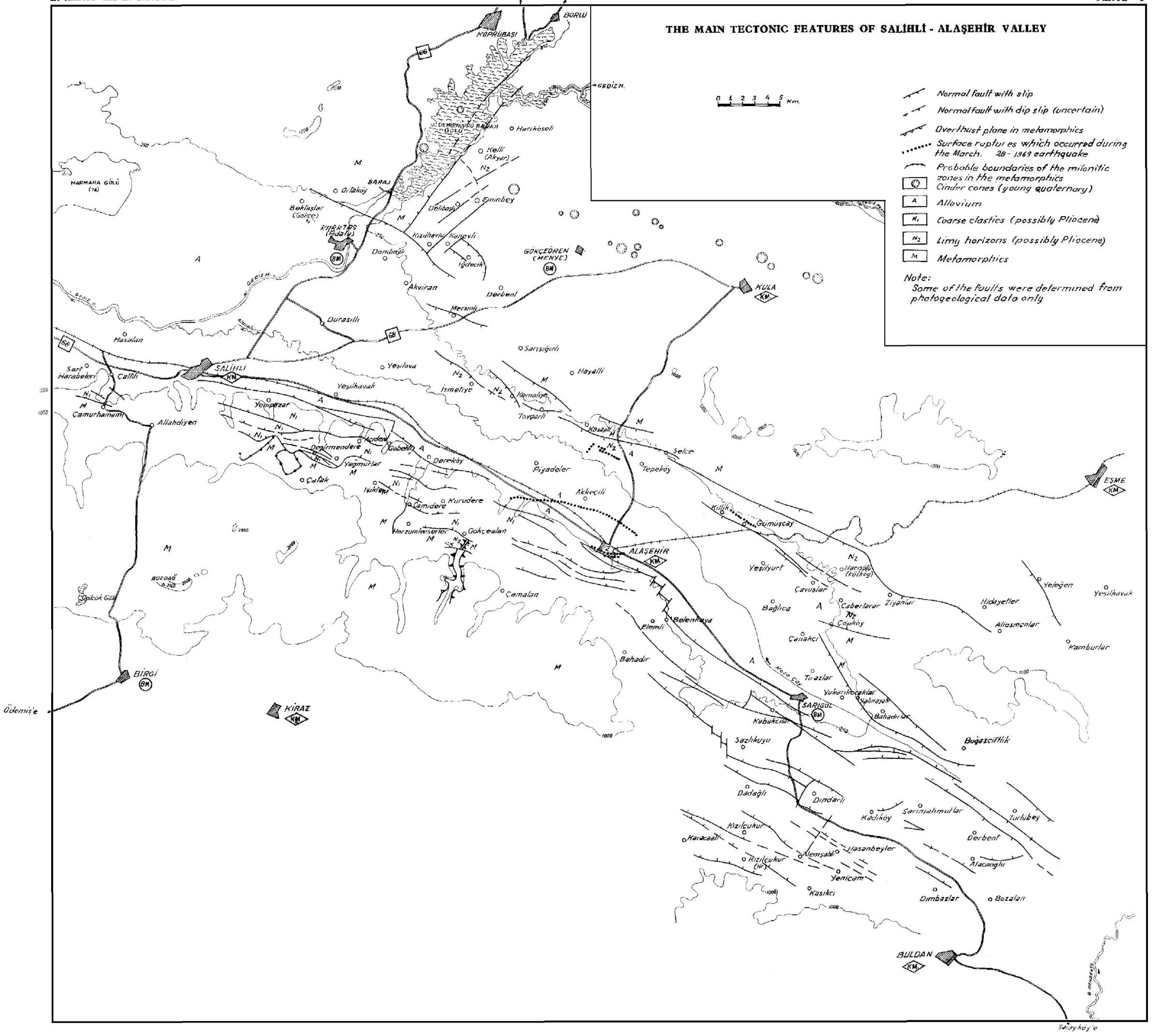
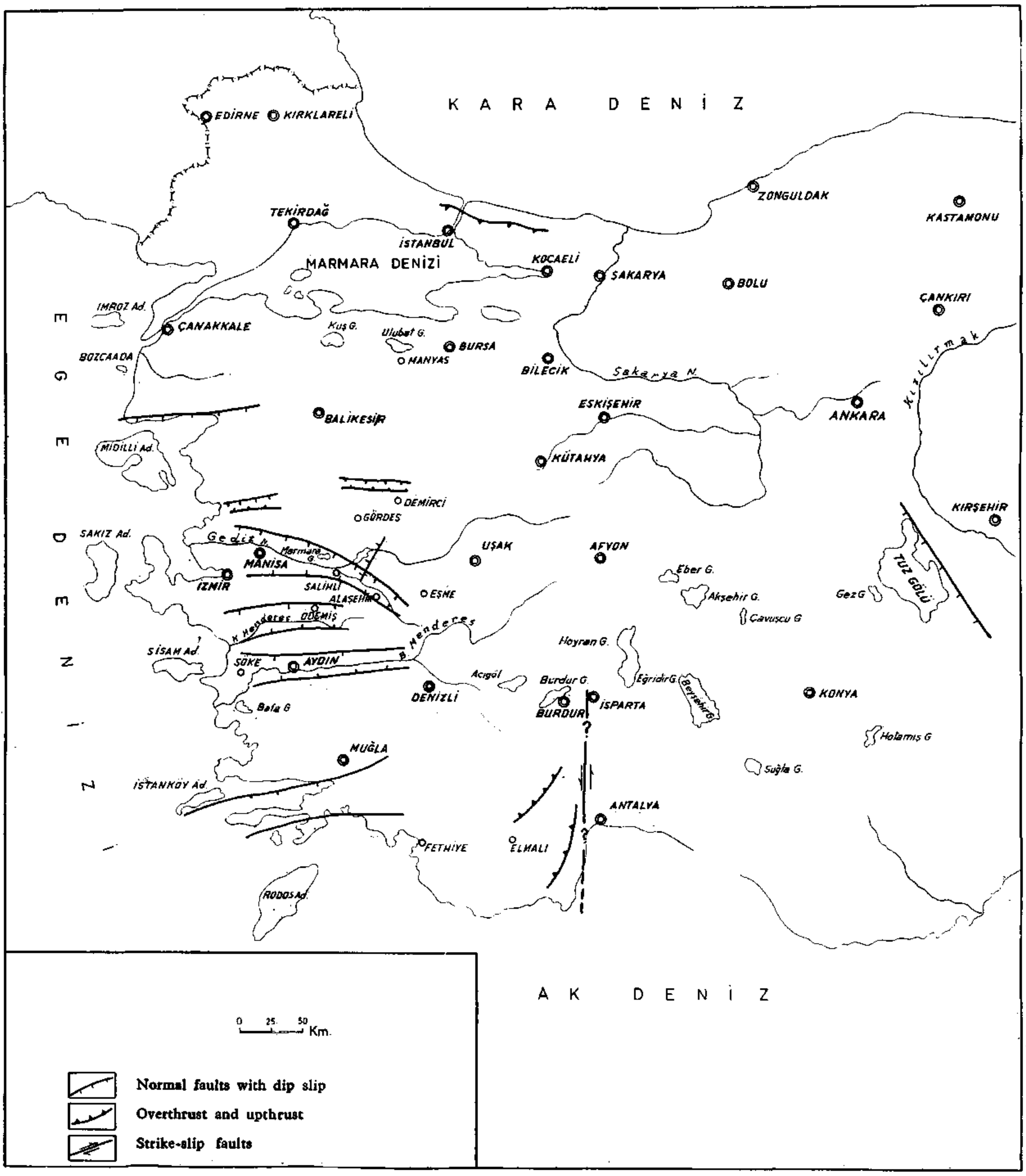

THE MAIN TECTONIC FEATURES OF SALİHLİ - ALAŞEHİR VALLEY
0 1 2 3 4 5 Km.
Normal fault with slip
Normal fault with dip slip (uncertain)
Overthust plane in metamorphics
Surface ruptures which occurred during the March. 28 - 1969 earthquake
Probable boundaries of the milonitic zones in the metamorphics
Cinder cones (young quaternary)
A Alluvium
N1 Coarse clastics (possibly Pliocene)
N2 Limy horizons (possibly Pliocene)
M Metamorphics
Note: Some of the faults were determined from photogeological data only
Gördes'e
Demirci'ye
BORLU
KÖPRÜBAŞI
DEMİRKÖPRÜ BARAJI GÖLÜ
Hacıköseli
Kelli (Akyar)
MARMARA GÖLÜ
Orlaköy
BARAJ
Beklaşlar (Gökçe)
Eminbey
Delibaşlı
KURTTAŞ (Adala)
Kızılhavlu
Kanevli
Dombaylı
İğdecik
GÖKÇEÖREN (MENYE)
Akviran
Derbent
KULA
Mersinli
Durasıllı
Hasalan
Sart Harabeleri
Çaltılı
SALİHLİ
Yeşilova
Sarısığırlı
Hayallı
Yeşilkavak
İsmetiye
Kemaliye
Toygarlı
Çamurhamamı
Allahdiyen
Yenipazar
Kasaplı
Selce
Acıdere
Değirmendere
Göbekli
Yağmurlar
Dereköy
Piyadeler
Tepeköy
Çalak
Işıklar
Akkeçili
Kurudere
Çamidere
Gümüşçay
Horzumkeserler
Gökçealan
ALAŞEHİR
EŞME
Yeşilyurt
Hacısüllü (Kolköy)
Yeleğen
Yeşilkavak
BUZDAĞ
Gölcük Gölü
Çamalan
Çavuşlar
Bağlıca
Cabertarar
Ziyanlar
Hideyeller
Çöpköy
Aliosmanlar
Elemli
Belenkaya
Çanakçı
Kamburlar
Bahadır
Tirazlar
BİRGİ
Yukarıkocaklar
Yalmayaz
SARIGÖL
Bahadırlar
Ödemiş'e
KİRAZ
Kabakçılar
Sazlıkuyu
Boğazçiftlik
Dadağlı
Dindarlı
Kadıköy
Sarıpehmutlar
Turlubey
Kızılçukur
Karacaali
Alemşahlı
Hasanbeyler
Derbent
Kızılçukur
Yenicami
Alacaoglu
Kasıkçı
Dımbazlar
Bozalan
BULDAN
Saraykoy'e



MAP SHOWING THE MAIN TECTONIC LINES DISCUSSED IN THE TEXT

Photo 1 - Fracture (developed during the earthquake of March 28, 1969) **crossing Salihli-Alaşehir road.** Locality is about 1300 m from Alaşehir. Photo is taken toward S. The northern block has sunk about 30-35 cm. This fracture line is shown with number 1 on the Plate I. (Photo was taken after the repair of the road.)

Photo 2 - Fracture number 1 crossing Alaşehir-Akkeçili road. Throw, here, is accentuated by unstable material filling the channel of a small creek. (Photo is taken toward S.)

Photo 3 - The fracture, number 1, crossing Alaşehir - Piyadeler road. Total vertical displacement is about 1 m. The southern block is depressed. (The locality is about 700 m W of the road shown on Photo 2.)

Photo 4 - Fracture number 1 at 2 km NE of Alaşehir. (Photo taken toward E.)

Photo 5 - Fracture number 2 (marked on **the map) crossing high school building in Alaşehir.** (Photo taken toward W.) Northern block is depressed.

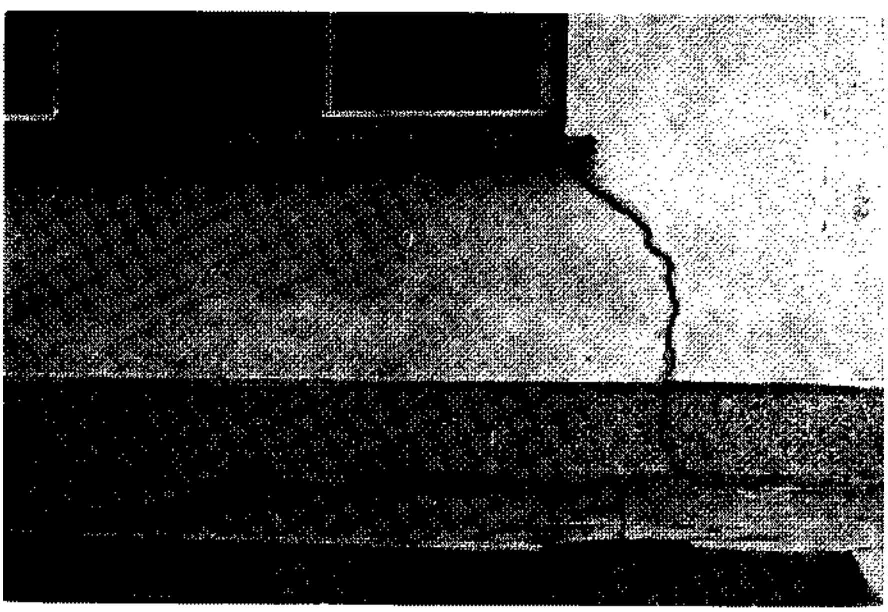


Photo 6 - View toward E to the rear of the school building shown on Photo 5. The nprthern block is depressed.

and

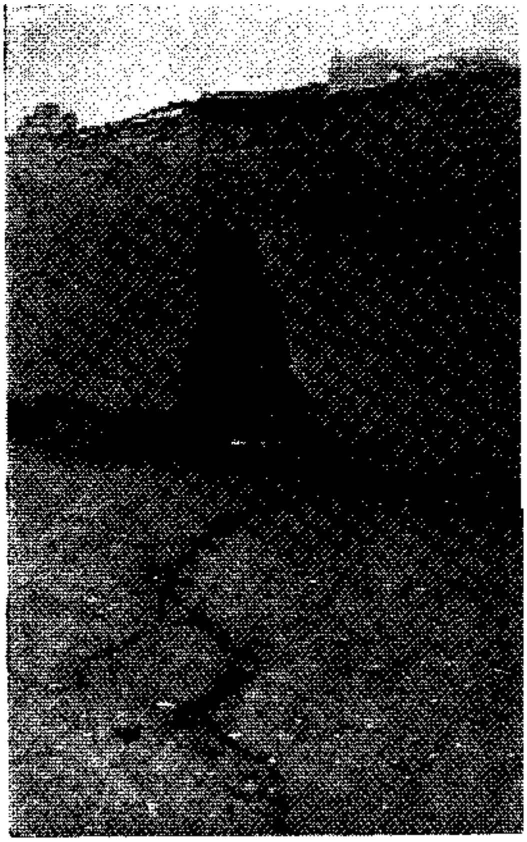


Photo 7 - Fracture number 2 crossing the wall of a house near the school building seen on Photos 5 and 6.

Photo 8 - Fracture number 2 crossing one of the main streets in Alaşehir Village. Northern block (left-hand side) is depressed.

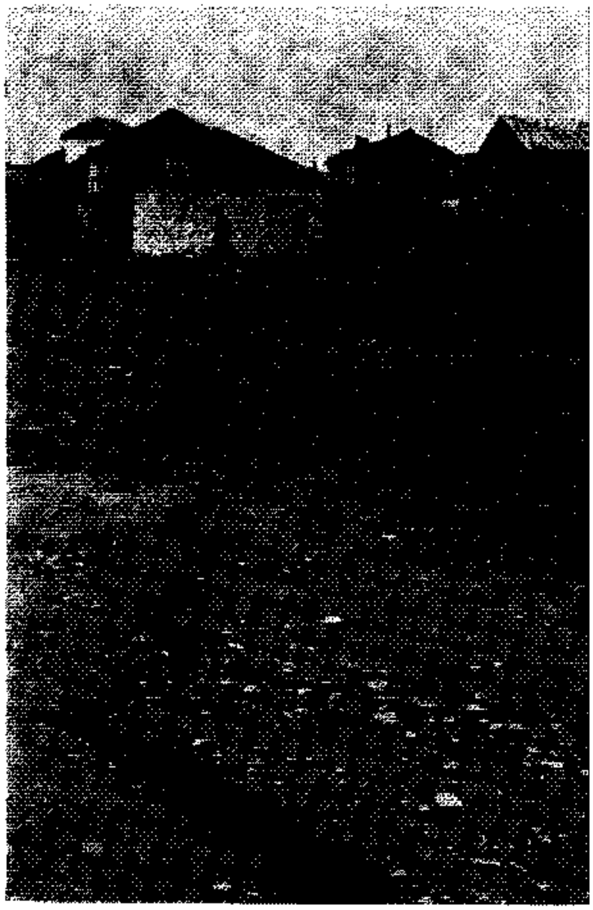


Photo 9 - A digitation of the fracture number 2, at 2 km E of Alaşehir, near Yeniköy. (Photo taken toward ESE.) Northern block is depressed. Note the fracture crossing the wall of the house at the foreground.

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