RELATIONS BETWEEN GENERAL TECTONIC FEATURES AND THE MAIN EARTHQUAKE REGIONS OF TURKEY

İhsan KETİN

Technical University of İstanbul

-_A -

The geological structure and the tectonic evolution of Turkey, which is part of the Alpine belt, took mainly place during the Cenozoic Era. At that time, the Central Anatolia, the Taurus Mountains and the Southeastern Anatolia were developed. On the other hand the evolution of the northern and northwestern regions, which are called Pontids, took place during the Paleozoic and Mesozoic Eras.

The following structural elements in the tectonics of Turkey can be distinguished:

1. Metamorphic - crystalline massifs,
2. Folded Paleozoic mountain chains,
3. Folded mountains of Mesozoic and Tertiary age,
4. Major faults and overthrusts,
5. Grabens and depressions,
6. Active faults and main earthquake zones.

Let's describe these structural forms briefly:

1. Metamorphic - crystalline massifs

These massifs, that played an important role in the evolution of tectonics of Turkey, form a kind of geologic skeleton of the country. They are formed of rocks that were subject to varying degree of metamorphism, and of crystalline rocks of basic and.acid composition. From the viewpoint of structure, they form large masses (massifs), and they respond as rigid bodies against tectonic deformations.

The more important ones of these massifs that outcrop in a great- number of places and in various sizes are from west to east: Istranca, Armutlu, Bolu, Kazdağı, Uludağ, Menderes, Sultandağı, Kızılırmak, Anamur, Ilgaz, Daday, Amasya-Tokat massife and in the east, Bitlis massif.

Some of the metamorphic series., in these massifs are of Paleozoic age and they were formed during the Caledonian* or the Hercynian orogeny. The massifs in the Northern Anatolia and in the Marmara regions belong to this group. Others are of Lower Mesozoic age and were developed during the early stages of the al-

pine orogeny (Kimmerician and partly Austeric), e.g. Menderes, Kızılırmak, Ilgaz and Daday massifs.

The age of formation of the Sultan Dağları, Anamur and Bitlis massifs is not yet known exactly. But they are mostly accepted as being of Paleozoic age.

2. Folded Paleozoic mountains

The folded mountain chains of Paleozoic age are found in Northwestern Anatolia, in the area surrounding the Marmara Sea, in the region of Ereğli-Zonguldak - Amasya, and in the vicinity of Ankara. Triassic or Lias and in some cases Lower Cretaceous beds overly these rocks transgressively and there is an unconformity between them. Typical examples of the structure just described are found in the Istanbul - Kocaeli Paleozoic massif, Alaplı - Yığılca massif, in the Paleozoic rocks of Ankara and İzmir (Karaburun), in the Amanos Mountains and in the Anamur massif.

In Southeastern Anatolia the old core-massif, that consists of Cambrian, Ordovician and Silurian formations overlain unconformably by Triassic and partly Cretaceous beds that are observed in the Mardin - Derik region, can be included in these Paleozoic folded mountain chains.

3. Folded mountain chains of Mesozoic -Tertiary age

The mountain chains in this group, that comprise the majority of the folded mountains of Turkey, are Black Sea Coastal Mountains in the north (Pontids), and the Taurus Mountains together with the individual mountain groups in the south. The time of their formation starts during the Jurassic, i.e. Kimmerician stage and continues up to the end of Pliocene; thus the youngest mountains of Turkey are in this group. Border folding of Souteastern Turkey can be given as an example.

An important feature of the Alpine mountain chains in Anatolia is that the basic and ultrabasic rocks like gabbro and serpentine have taken part in the evolution of these structures. These ophiolitic green rocks, that are accompanied by radiolarite and submarine lava flows at some places, form the host rock of some important mineral deposits like those of chromite, copper and manganese of Turkey and extend over large areas, especially in Central Anatolia and in the Taurus region.

4. Major faults and overthrusts

Examples for large dip-slip faults are found within the Sea of Marmara and also around it, in the vicinity of Gulf of Edremit, in the valleys of Büyük Menderes, Küçük Menderes and Gediz in Western Anatolia on eastern side of Tuz Gölü, and in the south, on the eastern slope of Amanos Mountains, between Antakya and Maraş and also on the south of Mardin-Derik uplift.

There are great number of smaller dimensions of dip-slip faults all over the country.

The classical and typical example of the strike-slip fault is the North Anatolian Earthquake Fault system. This system starts from the Biga Archipelago in the west and extends toward the east through Bursa, Yenişehir, Sakarya River,

Abant Lake, south of Bolu, Gerede, north of Ilgaz - Çerkeş, Tosya, Kargı, Havza, Ladik, Niksar and reaches the Kelkit River valley; it continues through this valley until Erzincan plain joins Varto in the southeast. After Varto it continues in the same direction through a line just north of Van Lake and enters Iran.

The North Anatolian fault that is presently active does not consist of a single line, but it is a zone or a system of several parts. During each destructive earthquake, part of this fault start moving and some horizontal surface displacements are observed. In fact, the horizontal displacements observed are illustrated by the following examples: Erzincan (1939), 3.7 m; Erbaa (1942), 1.75 m; Kastamonu (1943), 1.5m; Bolu (1944), 3.5 m; Yenice-Gönen (1953), 4.3m; and Abant (1957), 1.4 m. All these movements are right-lateral (like the San Andreas fault in California).

Another example of the strike-slip fault is observed in the south. This is seen in the Ecemi§ depression which extends across the Taurus Mountains. In fact, this linear depression zone was formed by strike-slip type faults. This fault zone was started during Tertiary and continued for a long time, which resulted in a horizontal displacement as much as 45 km. This strike-slip fault is different from the North Anatolian fault; it is left-lateral.

This fault has shown no activity during recent times.

Overthrusts

The overthrusting that took place during the last severe stages of the alpine orogeny are seen almost all over Turkey, but especially in Southeast, Central Anatolia, in the vicinity of Ankara-Yozgat, in the Western Taurus Mountains and between Kavaklar-Şile on the northern part of the Bosphorus. This type of movements are seen to be more severe and continuous in Southeastern Anatolia. Furthermore, they took place after Miocene. Metamorphic-crystalline series of the Bitlis massif together with the overlying ophiolitic Cretaceous beds were pushed over Miocene and partly Oligocene-Upper Eocene beds of flysch facies. The overthrusting was from the north to the south and the older beds were pushed over the younger ones as much as 15-20 km.

The overthrusting in this region is, in general, along the southern flanks of the Taurus Mountains. Starting around Maraş and Adıyaman in the west they continue to the east, passing around Çüngüş-Ergani-Lice-Kulp-Sason-Kozluk and Pervari. It is thus seen that the zone of overthrust separates the Taurus system from the tectonic unit of Border Folds or, in a broader sense, they correspond to the important geotectonic boundary that is formed between the Anatolian Geosyncline and the Arabian Platform.

The overthrust line that extends in E-W direction north of Yozgat brought the ophiolitic series of Upper Cretaceous over the Eocene flysch (from N to S). Furthermore, the serpentine and radiolarite series near Irmak railway station, east of Ankara, were pushed over the Eocene flysch (from W to E).

The overthrust line near Şile in the northern part of the Bosphorus first brought the Paleozoic masses over the Upper Cretaceous and later the Upper Cretaceous limestone over the shaly and marly Eocene beds. This time the movement was from S to N, as much as 4-5-km (F. Baykal, 1942).

In the Western Taurus Mountains, in the vicinity of Hadım, between Göksu River and the Suvla Lake, Paleozoic series were pushed over the Mesozoic and Tertiary formations over an 80-km-long line toward SW (toward the Mediterranean), as much as 20-22 km during- Lower Eocene (M. Blumenthal).

In the Eastern Taurus Mountains, thrusting to SE and S, and in the Eastern Pontids, such movements to NW and N are observed (l. Ketin, 1956).

5. Grabens and depressions

a. *Grabens.* — Grabens of different size and form were formed in those regions where dip-slip normal faults were developed on a large scale and they were filled with sediments of Neogene and Quaternary ages. The following are the more important grabens of Turkey: Gediz, Büyük and Küçük Menderes valleys, Gulf of Saros, Gulf of Edremit, Gulf of Kerme, Gulf of Gemlik and Gulf of İzmit, İznik Lake and the Sea of Marmara, Sapanca Lake and Düzce Plain, Tosya and Kargı Plains; Bayburt, Erbaa-Suşehri, Erzincan and Muş Plains, Burdur, Eğridir and Beyşehir Lakes, Amik Plain and its northern and southern extensions.

b. *Depressions.* — The depressions are mobile sedimentary basins and they are formed in connection with the epirogenic movements following the main orogeny. Typical examples are: Ergene basin of Thrace; Manyas Lake depression south of the Sea of Marmara; Bursa, İnegöl, Antalya and Tuz Gölü (Salt Lake) basins; Bafra, Çarşamba, Havza and Merzifon depressions; Denizli-Sarayköy, Erzurum-Pasinler, Muş-Bingöl, and Adana-Ceyhan basins.

Some of these troughs are active and they are continuously and rapidly subsiding. The rate of subsidence is proportional to the amount of sediments being accumulated. Ergene basin, Adana-Ceyhan depression, Bafra and Çarşamba deltas are depressions of this type.

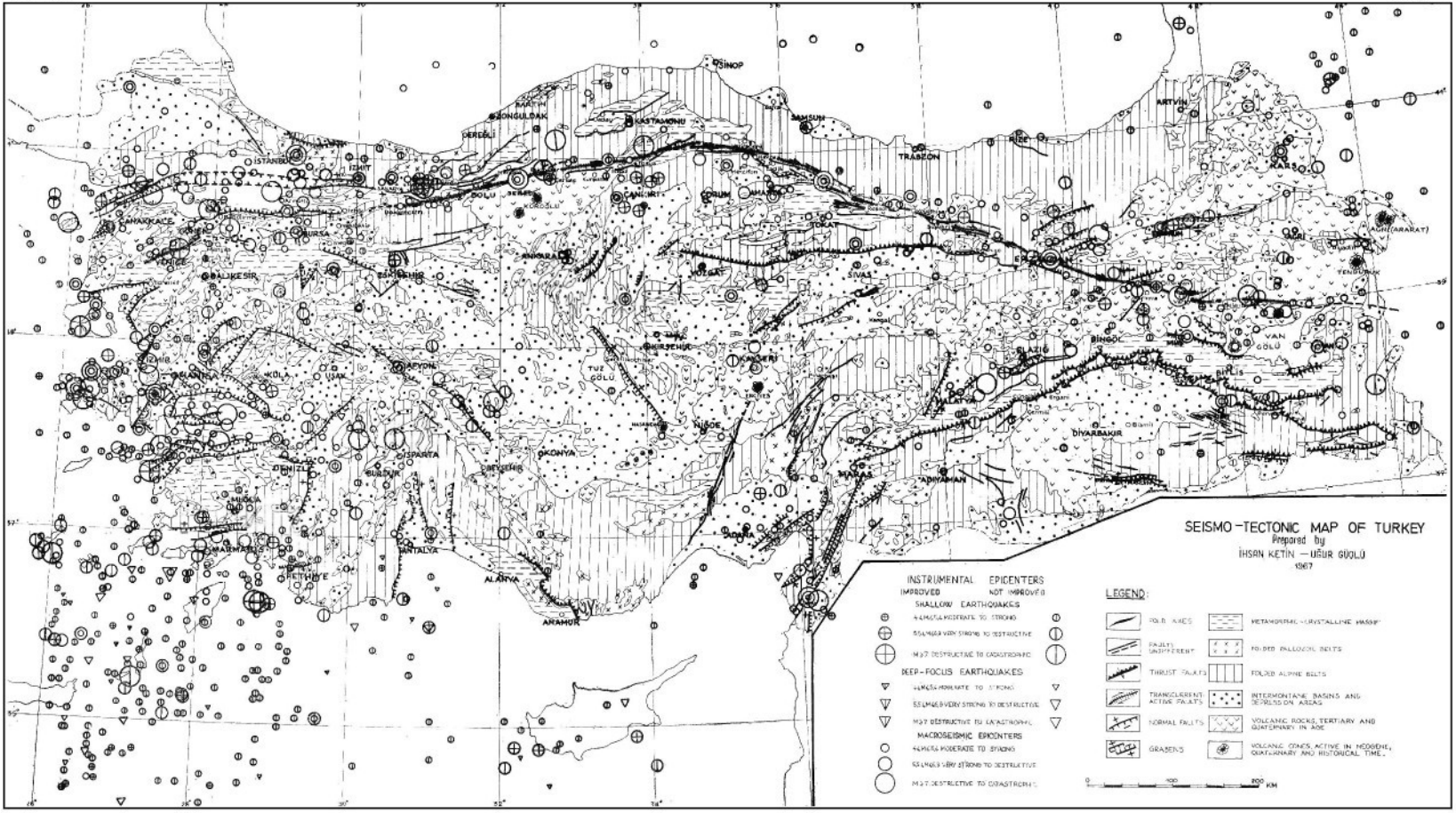
On the other hand, subsidence is either slowed down or completely stopped in some other basins (Acıpayam-Acıgöl, Diyarbakır-Bismil-Cizre basins are examples for this type).

€. Active faults and the main earthquake zones

Some of the fault systems mentioned above are active. They were active since Pleistocene or Pliocene and caused destructive earthquakes to occur. In such cases the morphology of the fault more or less preserves its original form and type of fault and the displacements along the fault are easily recognized at the surface.

The typical example of the active fault in Turkey is the North Anatolian fault. The morphological characteristics of this fault which is a right-handed strike-slip fault, can be observed and followed along a line 1100 km long. During the earthquakes that occurred between 1939 and 1967, different parts of the fault were slipped and horizontally displaced totalling to 18 meters. There is no doubt that a slip of 18 m in 28 years should be considered as a very fast movement and indicates the degree of tectonic activity of the region. The North Anatolian fault was probably subject to movements since the Pliocene (10-12 millan years).

A large number of grabens are also active. Their bottoms are slowly subsiding and their edges are rising relative to the bottom. The main dip-slip fault


SEISMO-TECTONIC MAP OF TURKEY
Prepared by
İHSAN KETİN — UĞUR GÜOLU
1967
INSTRUMENTAL EPICENTERS
IMPROVED NOT IMPROVED
SHALLOW EARTHQUAKES
4≤M≤5.5 MODERATE TO STRONG
5.5≤M≤6.9 VERY STRONG TO DESTRUCTIVE
M≥7 DESTRUCTIVE TO CATASTROPHIC
DEEP-FOCUS EARTHQUAKES
4≤M≤5.5 MODERATE TO STRONG
5.5≤M≤6.9 VERY STRONG TO DESTRUCTIVE
M≥7 DESTRUCTIVE TO CATASTROPHIC
MACROSEISMIC EPICENTERS
4≤M≤5.5 MODERATE TO STRONG
5.5≤M≤6.9 VERY STRONG TO DESTRUCTIVE
M≥7 DESTRUCTIVE TO CATASTROPHIC
LEGEND:
FOLD AXES
FAULTS (DIFFERENT)
THRUST FAULTS
TRANSCURRENT ACTIVE FAULTS
NORMAL FAULTS
GRABENS
METAMORPHIC-CRYSTALLINE MASSIF
FOLDED PALEOZOIC BELTS
FOLDED ALPINE BELTS
INTERMONTANE BASINS AND NEOGENE-QUATERNARY AREAS
VOLCANIC ROCKS, TERTIARY AND QUATERNARY IN AGE
VOLCANIC CONES, ACTIVE IN NEOGENE, QUATERNARY AND HISTORICAL TIME.
0 100 200 KM

and grabens that are active, are: area between İznik-Bandırma, Adapazarı-Düzce - Hendek grabens, central part of the Sea of Marmara, gulfs of Saros, Edremit and Izmir., the flanks of valleys of Gediz and Menderes, the Amik Plain grabens, etc.

The main seismic zones of Turkey are developed together with the fault and mobile depressions and are shown in detail in the accompanying seismo-tectonic map.

B

The enclosed map shows the tectonic features simplified as described in the foregoing pages. On this map, the epicenters of earthquakes of magnitude four and over, that occurred since 11 A.D. (up to 1964) were plotted.

An examination of the map indicates that: 1) the epicenters line up along the North Anatolian earthquake fault that extends from the shores of the Aegean Sea in the west through the Sea of Marmara, Adapazarı-Bolu-Ladik line, and Kelkit Valley and then through Erzincan and Varto plains and finally through north of Van Lake to Iran; 2) the epicenters lie in the grabens of Gediz, Büyük Menderes and Küçük Menderes valleys in Western Anatolia, and in the fault zones of the Gulf of İskenderun and Amik Plain in the southeast; 3) outside of this general distribution of the epicenters, we observe that there are epicenters in SW around the coast of the Aegean and Mediterranean seas, in the lakes region, and furthermore along a line that goes through Malatya-Varto (Karlıova) and Kars into the Caucasus. These last zones and regions are also one of the tectonically active regions of Turkey.

Earthquakes in Turkey are, in general, shallow, the hypocenter being in the crust. There are a few hypocenters, especially in southwestern part of the country that are probably below the Mohoroviçiç discontinuity. Deeper shocks occur off the southwestern coast, in the sea.

Manuscript received February 12, 1969