b. Caledonian Orogenic Movements

The effects of the Caledonian orogenic movements are observed in the Paleozoic rocks of İstanbul-Kocaeli region, south of Ereğli, and north of Mudurnu-Göynük (2).

In the Paleozoic of İstanbul, the existence of an angular unconformity between the Upper Silurian and the Devonian has been described several times by the writer himself (1. Ketin, 1953,1959). There is an orogenic disconformity present between the arkose-graywacke-quartzite series and the Lower Devonian quartzitic limestones and the fossiliferous shales, both at Büyük Ada and Çamlıca, Pendik-Gebze regions. In those areas the direction of folding of the Silurian beds is generally E-W, while the general direction of folding of the Devonian rocks is N-S.

In the İstanbul and Kocaeli areas at the base of the Devonian, there are no conglomerates present. Instead there is a sandy, quartzitic band (Çamlıca and Pendik). This implies that during the Caledonian movement, the folding was not intense enough to lift the sediments above the surface of the Devonian sea; hence no erosion has taken place. However, there is a transgressive conglomerate-sandstone-limestone south of Ereğli (on the Black Sea coast) at the base of the Devonian shales, and on top of the Hamza-Fakılı sandstones of Gotlandian age (M. Tokay, 1952). On the other hand, at the base of Almacıkdağ Devonian, in Mudurnu-Göynük area, a basal conglomerate is observed by Şakir Abdüsselamoğlu (Thesis, 1958). In view of this, there is no doubt that in the İstanbul-Kocaeli area, and in general throughout the Pontids,. Caledonian orogenic movement took place.

c. Hercynian Movements

The effects of the early Hercynian orogenic movements are observed in the Carboniferous rocks of Zonguldak (3). Here folding and erosion have occured during the Dinantian - Namurian, and Namurian-Westphalian time, and coal pieces of Namurian age are found in the Westphalian conglomerates (W.E. Petrascheck).

It has long been known that at Kocaeli there is an angular unconformity between the Devonian and Triassic, and that the Triassic starts with a basal conglomerate. Recently the relationship between Devonian and Triassic has been studied in detail by F. Baykal in the Şile region and by K. Erguvanlı in Gebze (F. Baykal, 1943; K. Erguvanlı, 1949). At the road cut of the new highway between Istanbul and İzmit, to the east of Gebze, the red-colored basal conglomerates of the Lower Triassic overlie the Upper Devonian limestones and graywackes with an obvious angular unconformity (4). Also at Edremit, to the north of the villages of İnönü and Sarnıç, the Triassic sediments overlie the crystalline basement rocks with a basal conglomerate (V. d. Kaaden, M.T.A. Report). In the Balya region the Triassic is transgressive over the older rocks, particularly the Permian and it is unconformable.

On the eastern sides of the northern Anatolian mountain ranges and extending into Central Anatolia, the Liassic is transgressive over the Paleozoic and overlies it unconformably with a thick basal conglomerate. In the Ankara region, near Hasanoğlan village, the basal conglomerates of the Liassic rest upon Permo-Carboniferous rocks; between Gümüşane-Bayburt the basal conglomerates of Liassic rest on the Paleozoic (İ. Ketin, 1950 and 1958).

The effects of the Hercynian orogenie movements are also observed on the west, at Karaburun peninsula. Hence, there is no doubt that the Hercynian movements occurred throughout north and northwestern Anatolia.

There are slight evidences that the Hercynian movements have also affected the Toros Mountain region.

ALPINE MOVEMENTS

a. The earliest effects of the Alpine movement are again observed in the northern Anatolian ranges. It is noted by F. Baykal that an orogenic movement has taken place in Şile region between the Virglorian and Ladinian during Triassic time. It is believed that this movement is of a local nature, and it has been identified as the Şile phase (F. Baykal, 1943).

b. The movement following the Şile phase is observed between Kastamonu-Abana, near the village Mazrup (Blumeiithal, 1948; İ. Ketin, 1958) (5). In this area the Malm-Lower Cretaceous limestones overlie the Liassic series with red-colored basal conglomerates containing pebbles and boulders of Liassic and Paleozoic rocks. A similar situation is present in the Ponticls between Boyabat and Sinop. These are believed to be good examples testifying to the effects of the Kimmoian on the northern ranges.

c. The effects of the Austrian period are again observed on the northern mountain ranges and the eastern Toros Mountains in the Erzurum-Elazığ Bingöl area (İ. Ketin, 1945, 1955). To the south of Zonguldak and Amasra, in the Cretaceous, which usually has developed as flysch series, the Senomanian siarts with conglomerates and large blocks. There is a definite unconformity between the Lower Cretaceous ophiolitic beds and the Upper Cretaceous flysch in the Elmalı valley between Erzincan and Elazığ (5). The basal conglomerates of the Upper Cretaceous contain serpentine pebbles and boulders from the rocks underneath (t. Ketin, 1945). The same situation is observed by H. Pamir and F. Baykal in the Bingöl area (1943).

d. The effects of the orogenic movements (Sub-Hercynian period) that occurred during Upper Cretaceous time are observable on the border foldings (7) in southeastern Anatolia (N.Tolun, 1949,1951). Here, instead of an angular unconformity a rise of the sea bottom took place, causing the sea to become more shallow. Movements of the same type and stress are known to be present in the northern mountain ranges in Zonguldak-Amasra-Şile area. In these regions an uplifting took place between Campanian and the Maestrichtian (F. Baykal, 1943; M. Tokay, 1953).

e. The first strong phase of the Alpine orogenic movements in Turkey is the Laramian. The effects of these movements, which occurred between Upper Cretaceous and Eocene time, are observed especially in Central Anatolia (central and western parts) and the Toros Mountains. In the Pontids and the border foldings the effects are relatively mild. Between Yozgat and Çorum (8) at the base of the Eocene flysch series there is a conglomerate 200 m thick which contains many limestone and serpentine -Radiolarite pebbles and boulders of Upper Cretaceous age (İ. Ketin, 1956). The Laramian period at the same time corresponds to the time of intrusions of the crystalline massifs in Central Anatolia. These crystalline intrusions cut through the Upper

Cretaceous limestones and marls causing metamorphism (İ. Ketin, 1959). In the Toros Mountains the Eocene also usually starts with a basal conglomerate which contains rocks of Cretaceous age.

f. The strong orogenic movements that took place after the Laramian have occurred during the Pyreneean period. The paroxysm of the northern Anatolian mountains took place during that time. In the vicinity of Şile (9) this movement occurred between Ypresian and Lutetian, causing the thrust faults in the area (F. Baykal, 1943). Further to the east in the Cide-Sinop- and Gümüşane areas the strongest Alpine movements occurred before the Lutetian (I. Ketin, 1951).

g. On the Toros Mountains between Niğde and Adana in the Aladağ region (10), M. Blumenthal explains very clearly the presence of an unconformity and a period of folding which occurred between the Lutetian and the Upper Eocene (M. Blumenthal, 1941).

h. In the Bolkardağ area there is evidence indicating that strong orogenic movements took place between the Eocene and Oligocene— in a broader sense, the Pyreneean period (M. Blumenthal, 1955).

k. The paroxysm of the central and western Toros Mountains occurred between the Oligocene and Miocene. The Miocene transgressively overlies all the older formations with an angular unconformity and basal conglomerate. This is clearly observable at Beyşehir-Seydişehir (12), Antalya region, and north of Mersin, Tarsus, and Kozan (M. Blumenthal, 1947; E. Altınlı, 1945; Z. Ternek, 1953). These strong movements belong partly to the Savian and partly to the Helvetian

1. C. Erentöz (1954) mentions the occurrence of an orogenic movement between the Middle and Upper Miocene in the Aras valley at the northeastern corner of Turkey (13), during the Attican period.

m. The effects of the strong movements that occurred at the close of Miocene and beginning of Pliocene are observed in southeastern Turkey (14). Here the Miocene beds on the northern boundaries of the border folds have been subjected to strong folding, and the rocks older than Miocene have been thrust over the Miocene sediments for several kilometers (15-20 kilometers) (F. Baykal, 1950; İ. Ketin, 1955). The thrust faults have taken place particularly in the Van area and southern outskirts of Bitlis Massif (The old Iranid Belt). This period (Rhodanian) represents the main paroxysm of this area.

n. In the border folds (15) even the Pliocene sediments have suffered orogenic movements, and have been contorted and folded (P. Ami, 1939). The youngest movements (Wallachian) in Turkey occurred in this region.

According to the occurrence of definite phases in certain regions, the mountain ranges of Turkey have been divided into four tectonic units, in which the orogenic evolution clearly differs from each other. These units are from the north to the south :

1. The North Anatolian Ranges or Pontids including the Marmara-Region, and the Northeastern Aegean Sea (I). **In** this unit the Caledonian and Hercynian orogenies have been active; there is an angular disconformity between the Upper Silurian and the Devonian on one side, and between the Paleozoic and Mesozoic on the other. The

important Alpine movements took place during the Eocene (Pyreneean phase) and Oligocene, and the paroxysm of the folding and thrusting ended before the Lutetian.

2. **The Inner Anatolian Ranges or Anatolids** (II). This unit contains the metamorphic and crystalline massifs of Central and Western Anatolia. The Paleozoic and Lower Mesozoic sediments are usually metamorphic and the Cretaceous has been developed in ophiolitic facies. The effects of the pre-Alpine orogenic movements are not visible; the transition from the Paleozoic to the Mesozoic took place without a disconformity. The Laramian phase of the Alpine orogeny was very strong and important for the region; the main folds and intrusions of the granitic and gabbroid magmas occurred during this time. It is followed by the Pyreneean phase and the paroxysm in the Oligocene. This unit forms the central part of the Alpine geosyncline in Anatolia, and has been a stable region throughout the whole Tertiary era. It also has a great influence on the trend of the southern ranges.

3. **South Anatolian Ranges or the Toros Mountains in the broader sense, including the Aegeo-Iranid chains, after N. EGERAN** (III). In this wide region the Paleozoic and the Mesozoic sediments often form a continuous series without any conspicuous orogenic interruption (Hercynian movements). But a few wide-spread transgressions have occurred during the Permo-Carboniferous and the Cretaceous periods. The Alpine orogenic activity began with the Austrian phase in the eastern part and with the Laramian in the west. The paroxysmal movements took place in the Toros proper at the end of the Oligocene, and in the southern ranges (Aegeo-Iranids) at the end of the Miocene.

4. **Southeast Anatolian Ranges or the Region of the Border Folds** (IV). This part of Anatolia has been the «foredeep» of the Alpine geosyncline. It consists of a continuous sedimentary series from the Cambrian to the Quaternary, without any violent orogenic interruption during the Paleozoic and Mesozoic eras. The important Alpine movements must have began in the Tertiary and the paroxysm has occurred at the end of the Miocene. The Pliocene beds have been folded and faulted during the last orogenic phase (Wallachian). In this tectonic unit we have the youngest mountains of the whole country.

If we correlate the four tectonic units described above, we can see, that the first unit, the North and Northwest Anatolian Ranges contain only Paleozoic massifs. At the beginning of the Mesozoic era they have been raised above the sea level as islands in the Mediterranean of that time (the Sea of Tethys). Other parts of Anatolia have been developed as basins for the Mesozoic sedimentation. The first tectonic region therefore comprises the oldest mountains of the whole country.

The evolution of the second unit, the Inner Anatolian Ranges, was essentially completed at the end of the Cretaceous, during the Laramian phase. It has, accordingly, the second place in the succession of the orogenic development of Turkey. The intrusion of the crystalline rocks of this region was finished likewise at the beginning of the Tertiary.

The Toros Mountains of the third unit ended their orogenic evolution at the Late Oligocene time; so they are younger than the second unit. On the

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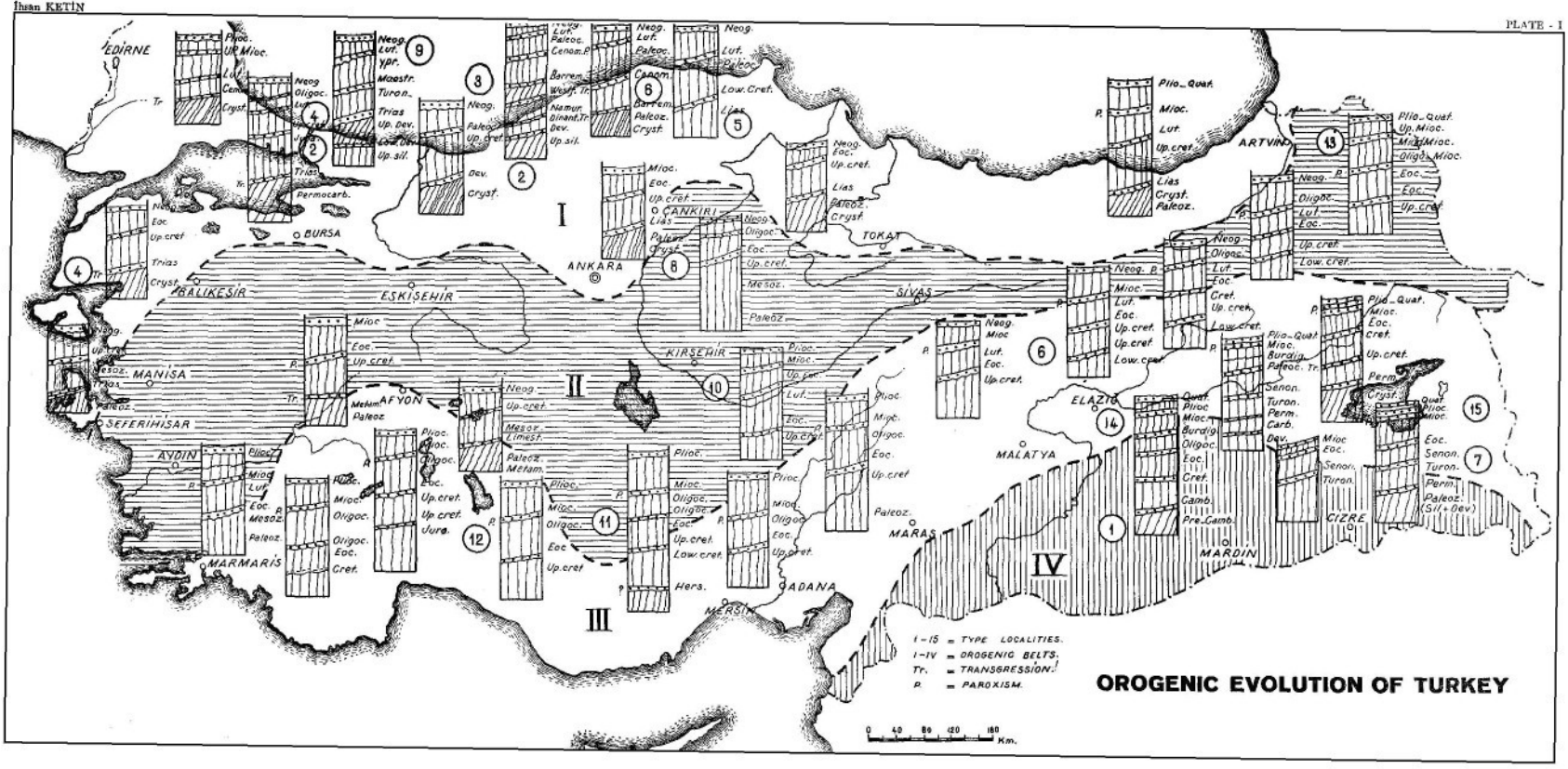

OROGENIC EVOLUTION OF TURKEY

other hand, the Southern and Southeastern Ranges (the Border Folds) form the youngest mountains of the country. Their tectonic development was finished at the end of the Miocene. Even the Pliocene beds of the fourth unit have been affected by the last folding.

As a result of the facts briefly summarized above, we can conclude, that the orogenic development of Turkey has proceeded from the North to the South: The main mountain chains of the Northern and Northwestern part of the country have been formed at the beginning of the Mesozoic; then followed the Inner Anatolian Region at the end of the Mesozoic; thereafter came the Toros-Mountains at the Late Oligocene time, the Southern Ranges at the end of the Miocene and finally the Southeastern Border Folds at the end of the Pliocene.

The effects of the pre-Cambrian movements occurring in the vicinity of Derik in the Southeastern border seem to be an exception. But the Cambrian and pre-Cambrian rocks of this region indeed belong to the Southern foreland of the Mediterranean Geosyncline, or to the Arabian Shield, which is most probably setting forward quite a long distance to the North under the Border Folds.

This brief paper is meant to be a tentative example of the kind of research work, which we hope will be carried on in the future.

The author is fully aware of the fact, that the boundaries and numbers of units, as well as the nature of the phases themselves in each unit would be changed by new facts and observations. But he is also convinced that, it is with this method of approach, that the tectonic and orogenic history of Turkey may soundly be based on fundamental geological principles.

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