# TECTONIC UNITS OF ANATOLIA (ASIA MINOR) *

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## SHORT HISTORY

The first subdivision of the Anatolian mountain ranges into tectonic units was made in 1896 by E. Naumann, and his classification was later developed further by Alpine geologists such as E. Argand (1924), R. Staub (1924, 1928), v. W. Seidlitz (1931) and L. Kober (1931).

In this first period the orogenetic belts of Anatolia were divided from north to south into three units, namely: Pontids, Intermediary massifs and Taurids, which were believed to be comparable to units in the Alps. The Pontids were connected to the Alpids by means of High Balkans and Carpathians; and in the same way the Taurus Mountains, by means of Hellenids, to Dinarids.

In 1939, P. Arni divided the Anatolian mountain ranges into more units, based on his geological and paleontological researches in East and Southeast Anatolia, and comparing Eastern Anatolia with the mountain belts in Western Iran. He joined up the units which show similarities in tectonic development in both countries. P. Arni, in his paper (4), divided Eastern Anatolian and Western Iranian ranges, from north to south, into following tectonic units :

- Pontids
  - Northern Branch
  - Southern Branch
- Anatolids
- Taurids
- Iranids (Zone of dislodged slices = Schuppenzone of Anatolia and Iran)
- Border folds
  - Inner folds
  - Outer folds
- Syrian - Arabian blocks

M. M. Blumenthal (1946) has accepted the previous tectonic units, the classification of P. Arni in principle, but has made some innovations: He has seperated the Paleozoic or the crystalline massifs from the Mesozoic-Tertiary series, present in each unit, and has shown the unit boundaries and the extensions of these in East and West in different ways. In Southeast Anatolia he establishes a new unit named Iraqid, containing petroleum-bearing anticlines.

In 1947, N. Egeran also accepted the units established by P. Arni in 1939, but divided these into secondary units, thus increasing the tectonic units to ten. Egeran

* A summary of this paper was communicated at the international conference on «The tectonics of the Alpine folded regions of Europe and Asia Minor» held in Tbilisi (U.S.S.R.), September 23-October 8, 1965.

has taken the magmatic intrusions and the metallogenic provinces into consideration when dividing the extra zones. He names his units, from north to south, as follows:

Pontids
Anatolids
Ortailids
Intermediary massifs
Içilids
Taurids
Önilids
Aegean-Iranids
Border folds
Arabian block

P. de Wijkerslooth (1942) and W. E. Petrascheck (1954), when comparing the metallogenic provinces in Southeast Europe with those of Turkey, separated those countries into great tectonic units (51 and 40). Wijkerslooth has used the chromium ores of Anatolia and the Balkans for comparison; and Petrascheck compared the copper, lead, zinc and antimony-molibdenum ores in Southeast Europe and in Anatolia.

In 1952, at the International Geological Congress in Algeria, N. Pınar and E. Lahn (İlhan) pointed out the effects of young post-orogenic movements and epeirogenic faulting. They also showed the unit of Pontids as «Outer Anatolids», and the Iranids as «Outer Taurids».

A few years ago (1960-1961), E. W. Petrascheck and J. H. Brunn compared the Alpine ranges in East Europe where Turkey is situated, with each other and separated various tectonic units. They demonstrated the similarities of these units (41, 12 and 13).

Also in 1961, A. Ten Dam and N. Tolun separated such units as Pontids, North Anatolian Ranges and Taurids; but on their tectonic map the boundaries are drawn differently from the earlier ones. They have also separated the crystallines, Paleozoic massifs, and plutonic rocks in each unit. The region of border folds is named «instable platform» and «Mardin uplift». In the Pontid region a new unit, named «Kocaeli - Ereğli» has been separated.

Here I have to mention the valuable colleagues who had written in detail about the tectonic characteristics of Anatolia during the last 25-30 years. Among these are : E. Chaput (1931-1936), K. Leuchs (1943), W. Salomon-Calvi (1940), E. Paréjas (1941), and lastly M. Mouratov (1960-1964). The above-mentioned authors have examined the orogenic development of Anatolia and its tectonic structure from various points of view, and published quite complete papers (14, 34, 43, 39, 37).

After this short historical summary, let us now turn to our studies :

In 1959, I have divided the mountain ranges of Turkey into tectonic units on the basis of the orogenic development (29). In this work I showed the boundaries and the tectonic histories of these units differently from the earlier ones.

When the new geological map of Turkey was completed, on scale of 1:500 000, the tectonic units were again examined, and named, from north to south, as follows :

I. North and Northwest Anatolian Ranges, or Pontids in broader sense.

II. Inner Anatolian Ranges, or Anatolids, in limited sense.

III. South and East Anatolian Ranges, or Taurids, in broader sense.

IV. Southeast Anatolian Ranges, or Region of Border folds.

Now let's us explain the geologic-tectonic characteristics of these units one by one, as proposed by different authors (Table 1) :

**Table - 1**

**Tectonic units of Anatolia proposed by different authors**

| *P. Arni (1939)* | *M. Blumenthal (1946)* | *N. Egeran (1947)* | *I. Ketin (1961 - 1965)* |
|---|---|---|---|
| Pontids { North. P. / South. P. | Pontids<br>Anatolids | Pontides<br>Anatolides | Pontids |
| Anatolids | Intermediary massifs of Central Anatolia | Zone intermédiare<br>Ortaïlides<br>Massifs interm.<br>Içilides | Anatolids |
| Taurids<br>Iranids | Taurids<br>Iranids | Taurides<br>Egée-Iranides<br>Önilides<br>Egée-Iranides *s.str.* | Taurids |
| Anatolian-Iranian Border folds (Randfalten) | Irakids<br>Syrian-Arabian block | Plis bordiers<br>Anatoliens-Iraniens | Border folds |

## I. PONTIDS IN BROADER SENSE

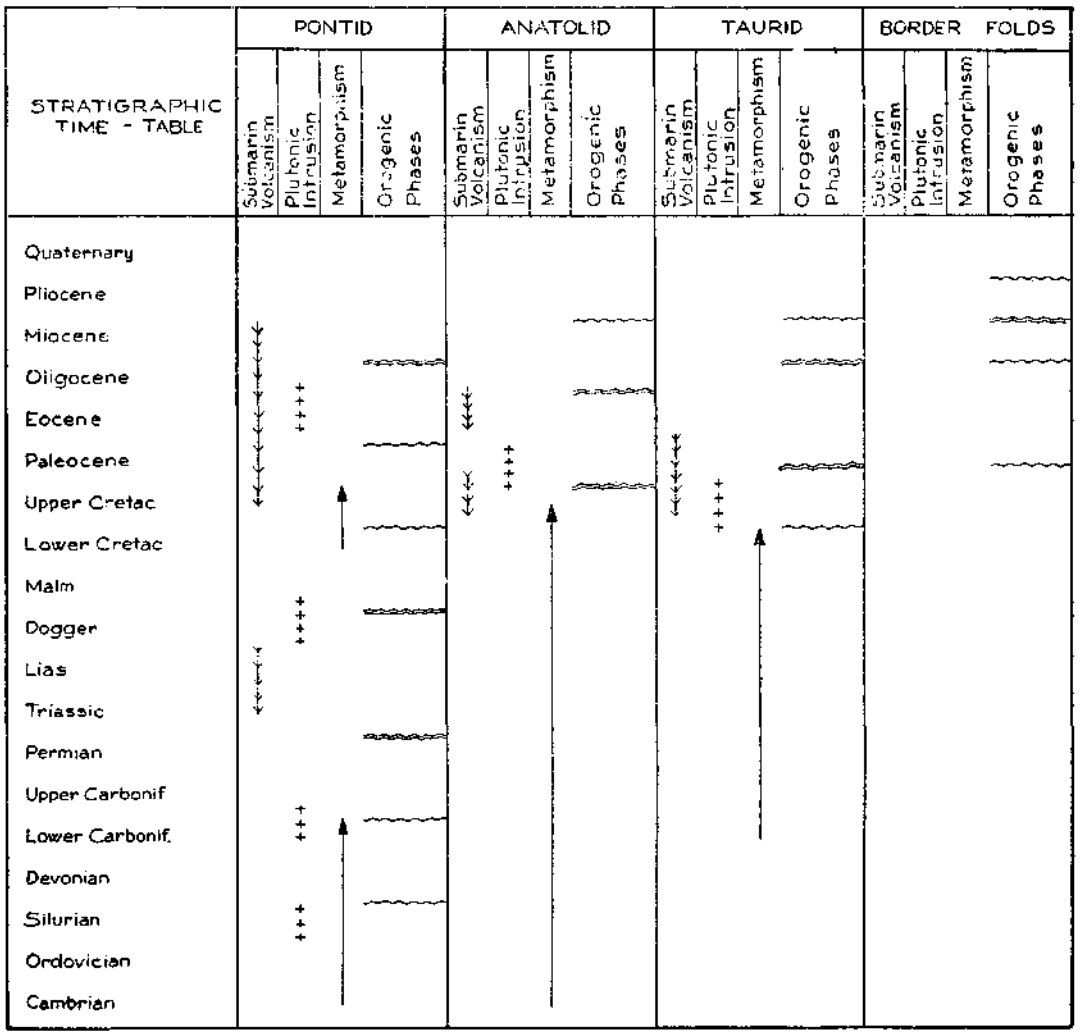
This unit contains the coastal range of Black Sea and Marmara, and Aegean coasts which extend to the peninsula of Karaburun. In this way, this unit possesses the greater part of «Anatolids» as described by P. Arni, M. Blumenthal and N. Egeran (Plate II).

In Pontids, beginning from Silurian and going up to Pliocene, non-metamorphic fossiliferous marine formations occur. In addition to these, metamorphic massifs are also seen in some areas. We will not discuss the details about the lithological and stratigraphic characteristics, or the areas occupied by these formations; but it will be useful to mention some classical outcrops of these formations :

i) Silurian and Devonian from the Bosphorus,
ii) Graptolite-schist from Ereğli of Black Sea,
iii) Coal-bearing Carboniferous from Zonguldak,
iv) Marine Permo-Carboniferous from Balya,
v) Triassic in Kocaeli (Bithynia).,
vi) Lias and Jurassic around Bayburt and Amasya,
vii) Upper and Lower Cretaceous, which has different facies in North Anatolian ranges,
viii) Eocene, both in flysch and in volcanic facies,
ix) Miocene sediments of Thrace and of Inner Anatolia.

**Table - 2**

**Comparison of tectonic units**




The orogenic evolution of Pontids is as follows :

Here, the Caledonian, the Hercynian, and the early Alpine (Kimmerian) movements have been active. Laramian phase, on the contrary, seems to be lacking. Pyrenean and Helvetic phases, the followers of the above ones, have been strong and effective. They correspond to the paroxysm of the Alpine orogeneses. The movements during and after Miocene were rather slight.

The important transgressions, related to above-mentioned orogenetic evolution, occurred during Triassic, Lias, Malm, Barremian, Cenomanian, Turonian and Lutetian. They produced the frequently changing paleogeography of this belt.

As to magmatic activity, there have been continuous magmatic intrusions during the Paleozoic, Mesozoic and Tertiary time, which were related to the orogenetic movements. These intrusions had resulted in the formation of well-known copper and lead ore deposits in Northern Anatolia (Murgul, Gümüşane, Küre).

The eastern extension of Pontids corresponds to the lower and middle belts of Anti-Caucasus, as mentioned by A. H. Gabrielyan in 1964. The western extention of them have been connected to Carpathians by means of High Balkans.

## II. ANATOLIDS IN LIMITED SENSE, OR THE INNER ANATOLIAN MASSIFS

This unit contains the Middle and the West Anatolian crystalline massifs or alpine metamorphosed scries, and Upper Cretaceous in ophiolitic facies. Both of these have been overlapped unconformably by Tertiary formations.

Anatolids, named by us in limited sense, correspond to the median massifs, or intermediary zones, so called by other authors (Plate II).

The geological and tectonic features of Anatolids, as shown by our investigations, are:

a) All the formations of Paleozoic and of Lower Mesozoic up to Upper Cretaceous are a more or less continuous scries.

b) Upper Cretaceous, which is partly in volcanic and partly in ophiolitic facies, overlies the metamorphic series conformably, and there was no erosion phase between them.

c) Only Lower Eocene covers unconformably the Cretaceous and the older metamorphic series.

d) In general, Lutetian developed in shallow waters or in volcanic facies. During this process thick flysch sediments, submarine lavas, and tuffs were formed.

e) Upper Eocene, Oligocene, and Miocene developed in continental or in lagoon facies. At the same time the gypsiferous and the salty formations of Inner Anatolia were deposited.

f) In Upper Miocene surface volcanism was active, related to the epeirogenic uplift, especially in southern border region (the volcanoes of Erciyas and Hasan Dag).

g) The Mio-Pliocene beds are generally flat, but in some places they have been tilted.

h) There is no orogenic unconformity between the Paleozoic and the Mesozoic. No traces of the pre-alpine movements can be observed anywhere.

i) The first strong and effective orogenic movement began at the end of Cretaceous, during the Laramian phase. This was followed by Pyrenean and Helvetic phases. The folding action was completed by the Miocene.

j) Magmatic activity occurred during the Laramian orogeny; and the basic and acidic intrusions of the Middle Anatolian region cut the Maestrichtian beds. These are covered transgressively by Lutetian. This has been observed at Çiçekdağ massifs between the vilayets of Yozgat and Kırşehir (25, 27).

k) The monzonitic granite specimens from Kaman - Kırşehir, examined in the laboratory of the University of Nancy in France by M. Ayan, have yielded 54 million years absolute age (5). This 54 million years absolute age of the Middle Anatolian crystalline rocks corresponded exactly to their geological position between Maestrichtian and Lutetian. In other words, the Middle Anatolian crystallines belong not to the

Paleozoic or Precambrian, as supposed up to now, but in reality are the Alpine intrusions of Eocene age.

The above-mentioned geological, tectonic and magmatic features of the Anatolid unit are based on the geological researches and personal observations. But these results and events do not correspond to the previous ideas and opinions expressed on the matter.

According to the present literature, the Middle and West Anatolian crystallines, or the Kızılırmak and Menderes Massifs, are «Median Massifs» (Zwischengebirge) or «Precambrian core» (K. Leuchs) between the northern Pontids and the southern Taurids. They did not participate directly in the Alpine movement, on the contrary they were passive (4, 8, 32, 33, 34).

We will now give some geological observations and events because of the regional importance of this problem :

a) During geological researches in various areas (Kaman, Yozgat, Ilgaz. Muğla, Izmir, Denizli, Tavşanlı districts), an unconformity or a basal conglomerate had not been observed between the metamorphic and non-metamorphic series (Pl. I). In these regions all the formations up to Upper Cretaceous are a conformable serie.

b) The inner structure and the general trend of the metamorphic-crystalline massifs are more or less parallel to the non-metamorphic Mesozoic formations surrounding them.

c) The first basal conglomerates lying unconformably on the metamorphic massifs belong to the Eocene (Lutetian). No older ones have been observed.

d) At 5 km west of Kaman, the marble beds which form the highest levels of the metamorphic series have been covered by Upper Cretaceous in volcanic facies. Although these marbles do not contain fossils, they probably belong to the Lower Mesozoic (Jurassic or Lower Cretaceous) (Pl. I, Fig. 1).

e) The dioritic and syenitic intrusions of Çiçekdağ, near Yerköy, cut the Upper Cretaceous limestones and marls; and they had made termic influence on these beds (formation of calcite and garnet minerals) (27).

f) The sandy and marly limestones of Lutetian lie unconformably on the Upper Cretaceous in ophiolitic facies. This can be clearly seen near the village of Teflek, west of Yerköy.

g) The metamorphic series of Kastamonu - Daday massif contains green schist, serpentine schists, radiolarites, diabases and even red limestones. All these belong to the ophiolitic formations of Cretaceous age (mostly Upper Cretaceous). The red limestones and radiolarite beds, regularly interstratified with sericite- and chlorite-schists and marbles, are exposed on the Kastamonu - Araç road, at 18 km from Kastamonu (Pl. I, Fig. 2). Similar outcrops are encountered at various places along the same road. The red limestones and marls of this ophiolitic series contain Cretaceous foraminifera, such as *Globigerinella aequilateralis* Brady. It is apparent from the exposures that slightly metamorphosed serpentine and spilites also contributed to the composition of the metamorphic massif.

h) In West Anatolia, in the region Muğla - Yatağan, the metamorphic rocks, beginning with the gneiss, the fossilliferous limestones and quartzites of Permian age,

the Mesozoic crystalline limestones of Muğla, and serpentine-radiolarite-bearing Upper Cretaceous form a continuous, conformable series. It is very difficult to draw a border line between Anatolids and Taurids in this region. The ophiolitic Upper Cretaceous joins both units.

i) The gradual transition from the metamorphic series to the ophiolitic Upper Cretaceous can be clearly seen around Manisa, at the cross-section of Akhisar - Gördes, at Çaldağ and Palamut Dağı near İzmir (Pl. I, Fig. 3) and south of Tavşanlı. South of Denizli, the Paleozoic and Mesozoic formations passing into the Upper Cretaceous, form a continuous series; but here conglomerate occurs at the bottom of Upper Cretaceous limestones, on the way from Denizli to Acıpayam in km 36; this district, in fact, belongs mostly to the tectonic unit of Taurids.

It is possible to give more examples; new observations and geological events will be added in the future. We have demonstrated that the Middle- and West Anatolian metamorphic-crystalline massifs are not intermediary massifs (Zwischengebirgc) of paleozoic or of Precambrian age; but on the contrary they are Alpine ranges formed during the Alpine orogeny and were uplifted above the sea-level after the Laramian phase. They were islands only in the Tertiary oceans.

The last geological researches on the metamorphic and crystalline massifs, in Greece and in Iran, show that the Pelagonian and Central-Iranian massifs are not intermediary massifs as in Anatolia, but they are also Alpine mountains developed during the Alpine orogeny.

According to G. Marinos (35), the greater part of the metamorphic series of Eastern Greece (Attica, Cyclades, Euboea, E-Othrys) belong to Permian and to Lower Mesozoic; and the transition from the metamorphic series into non-metamorphic ones is gradual, as he mentioned below : «In allen Stadien kann der kontinuierliche Übergang von metamorpher zu nichtmetamorpher Fazies beobachtet werden.»

Ivan Godfriaux (1964), who had studied the metamorphic series of Olympus area in Eastern Pelagonian, expresses his views on this subject as follows :

«Le passage entre les schistes cristallins et les calcaires triasiques est lent et graduel et on n'observe jamais de discordance entre ces deux formations.» (20).

Also M. V. Mouratov, in his last publications (1960-1964), draws the attention to the new essays (of B. Mostafi & E. Frei, 1959; and A. Gansser, 1956) about Central Iranian massifs which are not intermediary ones (37, 19, 36).

After this detailed description of Inner Anatolian massifs we may pass to the next units.

## III. TAURIDS IN BROADER SENSE

The Taurus Mountains are a continuous but not straight belt. They are parallel to the Mediterranean coast in south, and have NE and W-E directions in east and in southeast. This unit is bordered by Anatolids in north, and by border folds in south; so it includes «Iranids» or «Aegean-Iranids» of P. Ami, M. Blumenthal and N. Egeran (Pl. II).

According to us, there are no geological-tectonic reasons for distinguishing the southern ranges of Taurids as a separate unit. The dislodged slices and ophiolitic facies

which are accepted as characteristic features of Iranids, developed in the region of Taurids as well. After this general view, we will explain the geological and structural peculiarities of Taurids :

a) This unit contains the non-metamorphic formations, beginning from Ordovician up to the end of Miocene, which developed in marine facies. The paleozoic segments of this formation occur in some places as metamorphic series. Bitlis massif in east, Anamur massif in south, and Sultandağ massif in northern border are good examples.

b) Paleozoic and Mesozoic sediments form a continuous, conformable series; neither an unconformity nor a disconformity has been observed between them. The «comprehensive series» in the western part of Taurids furnishes the best evidence of this kind of continuity. Similar cases were observed by us, all along the Taurids, but Amanos Mountain is an exception. This mountain range was part of the Taurus - system during Mesozoic, and its geological development in Paleozoic had been different from the proper Taurus. Generally speaking, a slight uplift occurred between the Paleozoic and the Mesozoic eras.

c) The first Alpine orogenic movement, in Taurids area, started with the Kimmerian phase and was followed by the Austrian one. At the southern border of Sultan Dağları, on the way from Akşehir to Karaağaç, the unconformity between the metamorphic series and the fossiliferous Upper Jurassic has been observed by Abdüsselamoğlu and Ketin. Traces of the Austrian phase are seen in the eastern Taurus, where the Upper Cretaceous with a basal conglomerate lies on the metamorphic Bitlis massif near Gevaş. (Z. Ternek, 1953).

The stronger and the widespread orogenic movement in this unit occurred during the Laramian phase at the end of Cretaceous; and the paroxysmal movement during the Oligocene. By Miocene time the orogenic movements were replaced by epeirogenic ones, and after this period all the Taurus Mountains were raised above sea-level. The upheaval of the whole mountain system continued till recent time, so that the marine Miocene beds between Silifke and Konya are now 950-1000 meters above the sea level.

d) Magmatic intrusions in the Taurus system were very active during the Cretaceous period, especially in Turonian and in Senonian. The peridotite - harzburgites of Elazığ - Tunceli and Ergani - Guleman, serpentines from Aladağ region, and Pozantı are examples. Older intrusions, such as Hercynian or Kimmerian, are unknown.

Although the peridotite-serpentine intrusions of the Taurus Mountains were accepted by G. Hiessleitner and K. Metz as of Paleozoic age, the last investigations by H. Borchert (1958-1960), L. Dubertret (1955) and I. Ketin (1964), show that this kind of intrusion belongs to the Cretaceous, and even to the Paleocene. The granitic-dioritic rocks from Elazığ - Malatya, and syenites of Divrik occur in Cretaceous beds and were covered by Eocene.

## IV. REGION OF BORDER FOLDS

This area is the foredeep of the Alpine geosyncline of Asia Minor, and contains Jura-type foldings. It can easily be distinguished from the other units by its tectonic features.

The region of Border folds developed as a continuous sedimentation basin, during all geological time, beginning with infra-Cambrian, ending by late Pliocene. All the formations were of shalllow-water facies; and they have not been influenced by metamorphism or magmatic intrusions. Also the orogenic movement was not so strong; but from time to time transgressions and overlapping occurred. The important ones had happened at the beginning of Cambrian, during Devonian, Permian, Turonian, Paleocene, and in Miocene.

The orogenic movements, in this region, started with the Laramian phase, were repeated during Oligocene; the strongest and the most effective folding and overthrusting occurred at the end of Miocene. The Mio-Pliocene beds generally form steep or overturned folds. The overturning of anticlines, to the south, mostly resulted in faulting (as in Raman and Garzan). The stratigraphic and tectonic features of this unit can be observed in Derik uplift, near Mardin, at Hazro anticline, and along the valley of Great, Zap, in the east. This area is being rapidly developed as a petroleum district of Turkey. Numerous drillings, durig last years, have enlightened us about the stratigraphy and tectonics of the region.

The geological boundary between Taurids and Border folds is an overthrust beginning at the south of Hakkari, in the east, continuing up to Amanos Mountains, in the west (Pl. II). As a result of this overtrusting was a displacement of 15-20 kilometers from north to south (F. Baykal, 1950; İ. Ketin, 1956). Along the thrust line small outliers (Klippe) occur.

The eastern and western parts of this region had developed in different ways. In the east, the formations arc a continuous series; but in the west, they have distinct unconformities. Mardin - Diyarbakır meridian separates the two districts. In the western part basalt flows occupy a large area, as in Karacalı Mountain, near Diyarbakır.

## CONCLUSION

When the above-mentioned four units are compared with each other it is seen that : In the Pontid region the oldest mountains, the Caledonian and Hercynian massifs of Asia Minor, appear. At the beginning of Mesozoic they were raised above sea level as islands, whereas the other parts of Anatolia were completely under water.

The second unit, or so-called Anatolids, developed at the end of Cretaceous, thus being the second to form in the orogenic evolution of Anatolia. The intrusions of this unit were completed at the beginning of Tertiary.

The main orogenic development of Taurus system occurred at the end of Oligocene, so it is younger than Inner Anatolian massifs.

The fourth unit, Border folds, are comparatively younger, and their development was completed during the Pliocene. Therefore they are the youngest mountains of Anatolia.

According to this explanation, the tectonic-orogenic evolution of Anatolia proceeded gradually from the North to the South. The first stronger and effective orogenic movements began in the northern ranges, then passed to the Central-Anatolia, afterwards to the Taurus, and at last to the southeastern Border folds-region.

*Manuscript received December 9, 1965*

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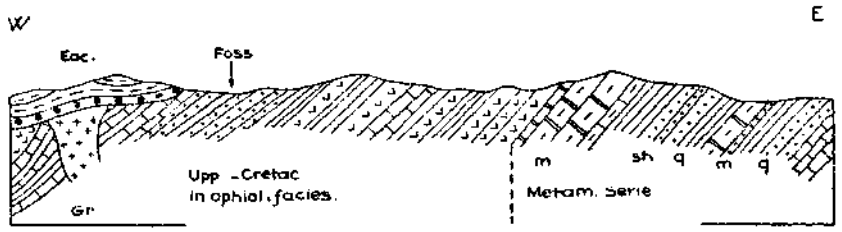



**Fig. 1 - Diagrammatic section south of Kaman (Central-Anatolia).**

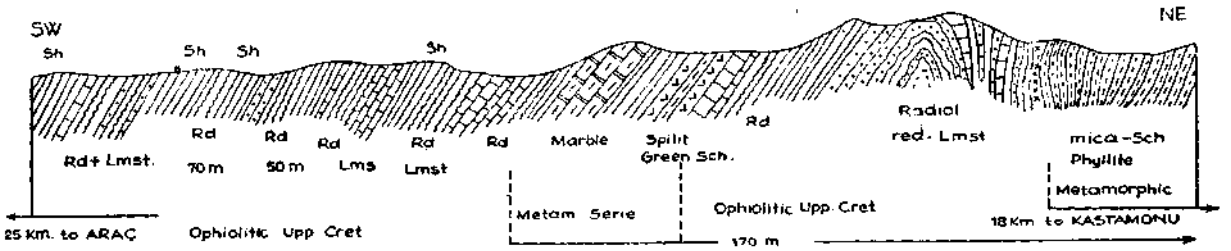



**Fig. 2 - Measured section along the highway Kastamonu - Araç (Northern Anatolia).**

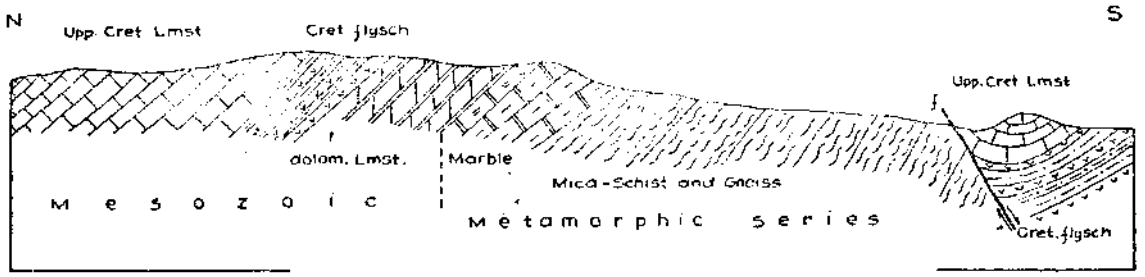



**Fig. 3 - Diagrammatic section through the Palamut Dağ, south of İzmir (Western Anatolia).**

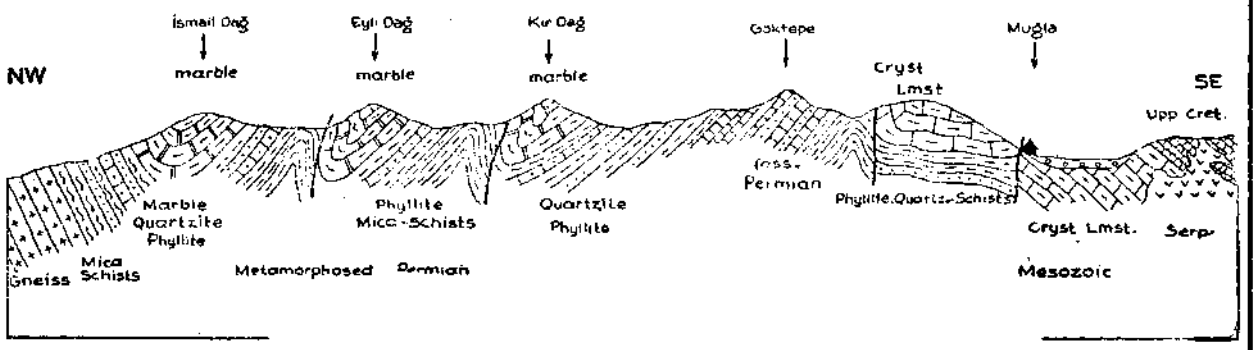
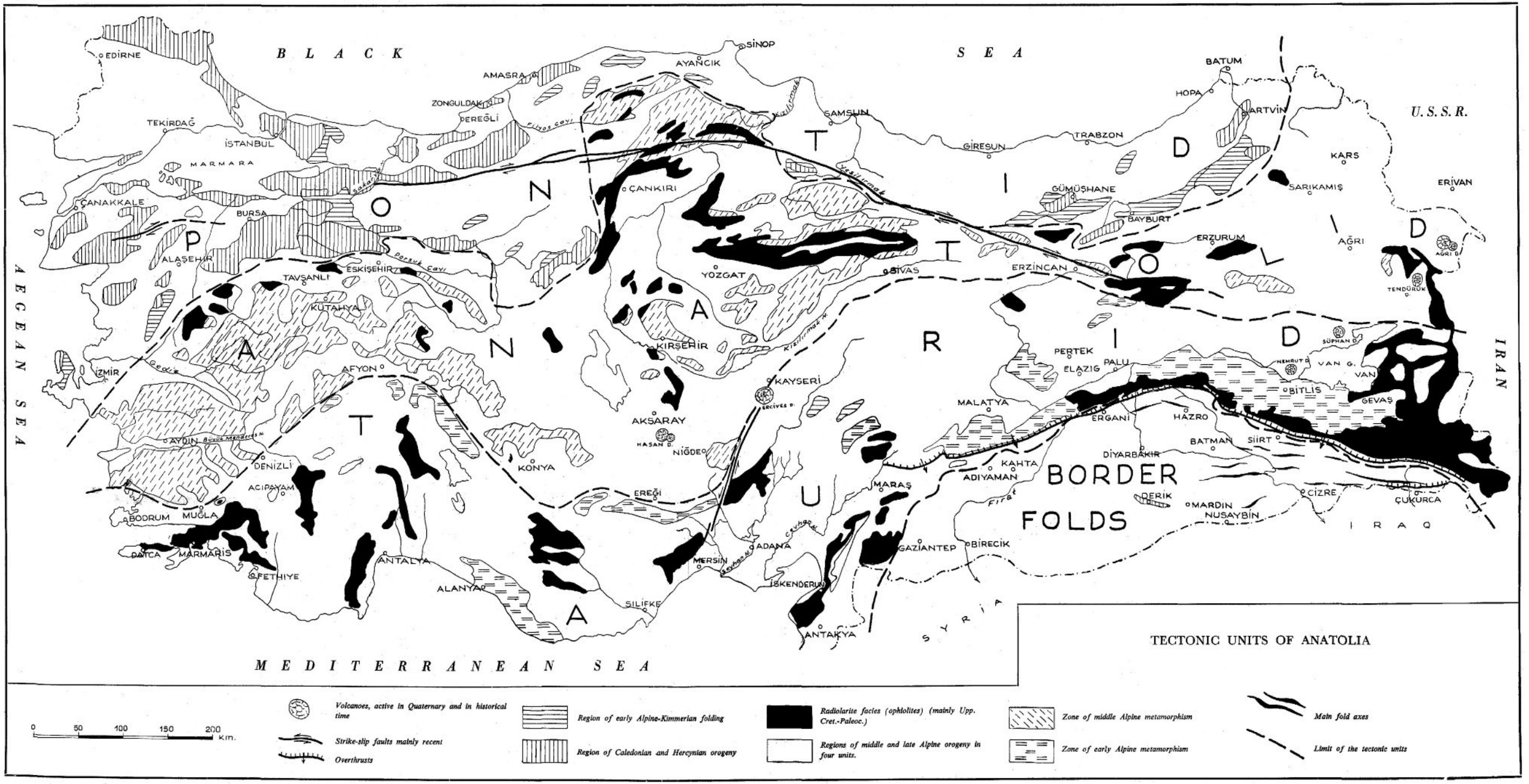
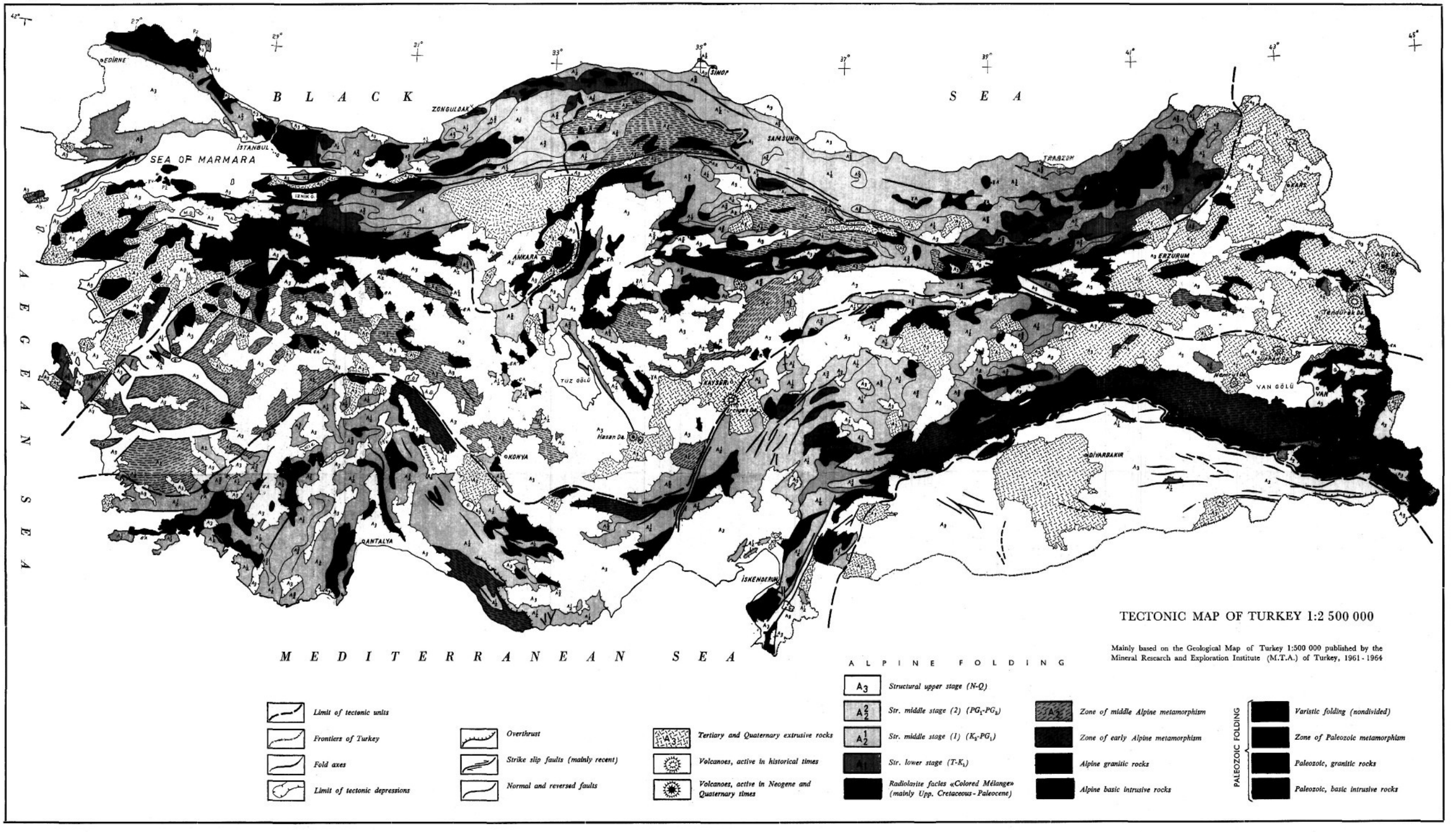



**Fig. 4 - Diagrammatic section through the southern border of Menderes Massif (SW Anatolia) (S. Abdüsselâmoğlu).**




TECTONIC UNITS OF ANATOLIA

İhsan KETİN




# TECTONIC MAP OF TURKEY 1:2 500 000

Mainly based on the Geological Map of Turkey 1:500 000 published by the Mineral Research and Exploration Institute (M.T.A.) of Turkey, 1961 - 1964

- *Limit of tectonic units*
- *Frontiers of Turkey*
- *Fold axes*
- *Limit of tectonic depressions*
- *Overthrust*
- *Strike slip faults (mainly recent)*
- *Normal and reversed faults*
- *Tertiary and Quaternary extrusive rocks*
- *Volcanoes, active in historical times*
- *Volcanoes, active in Neogene and Quaternary times*

ALPINE FOLDING

- $A_3$ *Structural upper stage (N-Q)*
- $A_2^2$ *Str. middle stage (2) ($PG_1$-$PG_3$)*
- $A_2^1$ *Str. middle stage (1) ($K_2$-$PG_1$)*
- $A_1$ *Str. lower stage (T-$K_1$)*
- *Radiolarite facies «Colored Mélange» (mainly Upp. Cretaceous - Paleocene)*
- *Zone of middle Alpine metamorphism*
- *Zone of early Alpine metamorphism*
- *Alpine granitic rocks*
- *Alpine basic intrusive rocks*

PALEOZOIC FOLDING

- *Varistic folding (nondivided)*
- *Zone of Paleozoic metamorphism*
- *Paleozoic, granitic rocks*
- *Paleozoic, basic intrusive rocks*