Institute of Earthquake Engineering and Engineering Seismology
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SEISMOTECTONIC INVESTIGATIONS IN SERBOMACEDONIAN MASSIF AND SURROUNDING AREA (GREECE)

By

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Thesis

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To my beloved parents Nikos and Maria
and to my sister Dora

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A B S T R A C T

The Serbomacedonian massif and surrounding area is characterized by intense recent vertical movements. The result of these movements is the creation of many uplifting and subsiding areas with a large range of altitudes. Around those areas, a great number of faults have been created. The faults have two main directions, the N-S or longitudinal and E-W or transverse faults. The longitudinal faults are the old ones which follow the main direction of the geotectonic zones. The transverse faults cross the previous ones and they are very new. Studing the neotectonic units with the two type of faults, we distinguish some fault crossing areas (junction zone).

Applying the Gutemberg-Richter cumulative frequency-magnitude relation (log $N=\alpha-bM$) for the earthquakes which have occurred during the last 185 years and 85 years, we determine the seismicity of the area. The values of "α" and "b" are in agreement with the values of previous studies. Combining the seismicity with the tectonic-neotectonic data we present a seismotectonic map which correlates the high seismicity and the junction zone.

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INTRODUCTION

The Northern part of Greece and the Southern part of Yugoslavia and Bulgaria is an area of high seismic activity. In this area, neotectonic movements, active faults in different directions and many strong earthquakes have been observed. One of the strongest shallow earthquake in Europe during the present century occured in this area and is that of 1904 in Kresna region (41.8°N, 23.1°E) with surface wave magnitude equal to 7.7.

In the present thesis, we attemped to consider the seismotectonic regime of the Serbomacedonian massif which is bounded by 42°N latitude and the Northern Aegean sea and longitude 21.5°E up to 25°E.The geotectonic evolution and seismicity of this region have been discussed by several authors by the use of various methods. In order to get information about the most hazardous zones, a correlation of the geological, tectonic ,neotectonic, morphostructural and seismological data have been made. Many parts of this area have been investigated during the disastrous earthquakes of the previous decades.

Therefore, the subsequent presentation includes the following topics :

a. Geological-Geotectonic setting of the region.
b. Neotectonic investigations and observations of the studied area.
c. The seismicity of the region.
d. The seismotectonics of the region.
e. Correlations and Conclusions .

In the first chapter, a review in relation to geology and tectonics of the area is made. The geological setting of the surrounding area and its evolution is presented. A geological description of the main geotectonic zones, which are related to the studied area is given.All the geological and geotectonic characteristics and previous studies are also referred, in this chapter.

The second chapter contains the neotectonic and other features observed in the area studied. All the results from the fieldwork ,as well as personal observations are given. The observed morphostructural elements are separated and an attempt is made to classify the faults in various categories. All these data are used to give some maps which contain descriptions of the faults, morphostructural elements i.e uplifting and subsiding areas, and the various juction zones (knot-faulting areas).

In the third chapter, the seismological data which have been obtained from Catalogues, papers etc, are given. Furthermore a catalogue of earthquakes is prepared for the area studied, which is bounded by 39.5°N-42°N latitude and 21.5°E-25°E longitude ,with historical and present century data. In addition, a seismological review of the area studied is given.

The fourth chapter includes the correlation of the Neotectonic and Seismological data. All these available information is mapped on a Seismotectonic map for the correlation between faulting zones and epicenters of the earthquakes, implying the determination of the Seismotectonic Source zone. At the end, the analysis of the Strong Earthquake zones, the collection of the information regarding the earthquake origin zone, maximum expected earthquakes and the elaboration of the Seismotectonic Map of the Region is attempted

The last part comprises the correlations between recent tectonic activities (faulting maps) and Seismicity. A correlation of the Strong Earthquake origin zones with neotectonic conditions, is finally discussed.

1. GEOLOGICAL-GEOTECTONIC SETTING OF THE AREA

1.1 Geological-Geotectonic Conditions of the Area

The area studied is located in the Balkan peninsula on the European continent. It is important to know how this area was formed during the geological time. This formation has taken place during the Alpine orogeny in the Alpine geosyncline.

The Alpine geosyncline was a large linear trough which was extended from the Atlantic to the Pacific ocean and was covered by deep waters, which were called Tethys sea. The activations of the Alpine geosyncline started in the beginning of the Triassic era and continued till the Kainozoic. During the various orogenies,the deposited sendiments on the geosyncline were affected by these orogenies,and gave rise to new formations.

All the formations which were uplifted during the Alpine orogeny,gave rise to a complex mountain system which is called Alpine. In Europe, two branches of this mountain system can be distinguished : 1) The Alpine branch that includes the Helvetides,Pennides,Carpathian,Balkan and Pondides mountains 2)The Dinatic branch that includes a part of Appenine mountains,the Southern part of Alps,the Dinarides,Hellenides,the Taurides in the Turkey territory and Zagros in Iran. Among them,there are crystaline masses and basins.

These Alpine branches can be divided into secondary geotectonic units which are called geotectonic zones. The area studied is surrounded by the Hellenides and Balkanides.The Hellenides can be divided into the following zones; Paxos zone, Ionian zone, Gabrovo zone, Pindos zone, Parnassos zone, Sub-Pelagonian zone,Pelagonian zone and Axios-Vardar zone. The Balkanides (Alpine Branch) are separated in the zones; Kraisthides,Stredna Gora, inner Balkan zone (or Stara Plannina) and the outer Balkan zone, and the Hercynian mass of the Meso-Europe (BRUNN 1960) (Fig 1.1)

Considering the two branches of the Alpine system and specially the Dinaric Alps and Balkan mountain ranges, both of them contain a great number of secondary geotectonic units.The Dinarides (Fig 1.2)including the Dinaric Alps in Yugoslavia and Albania

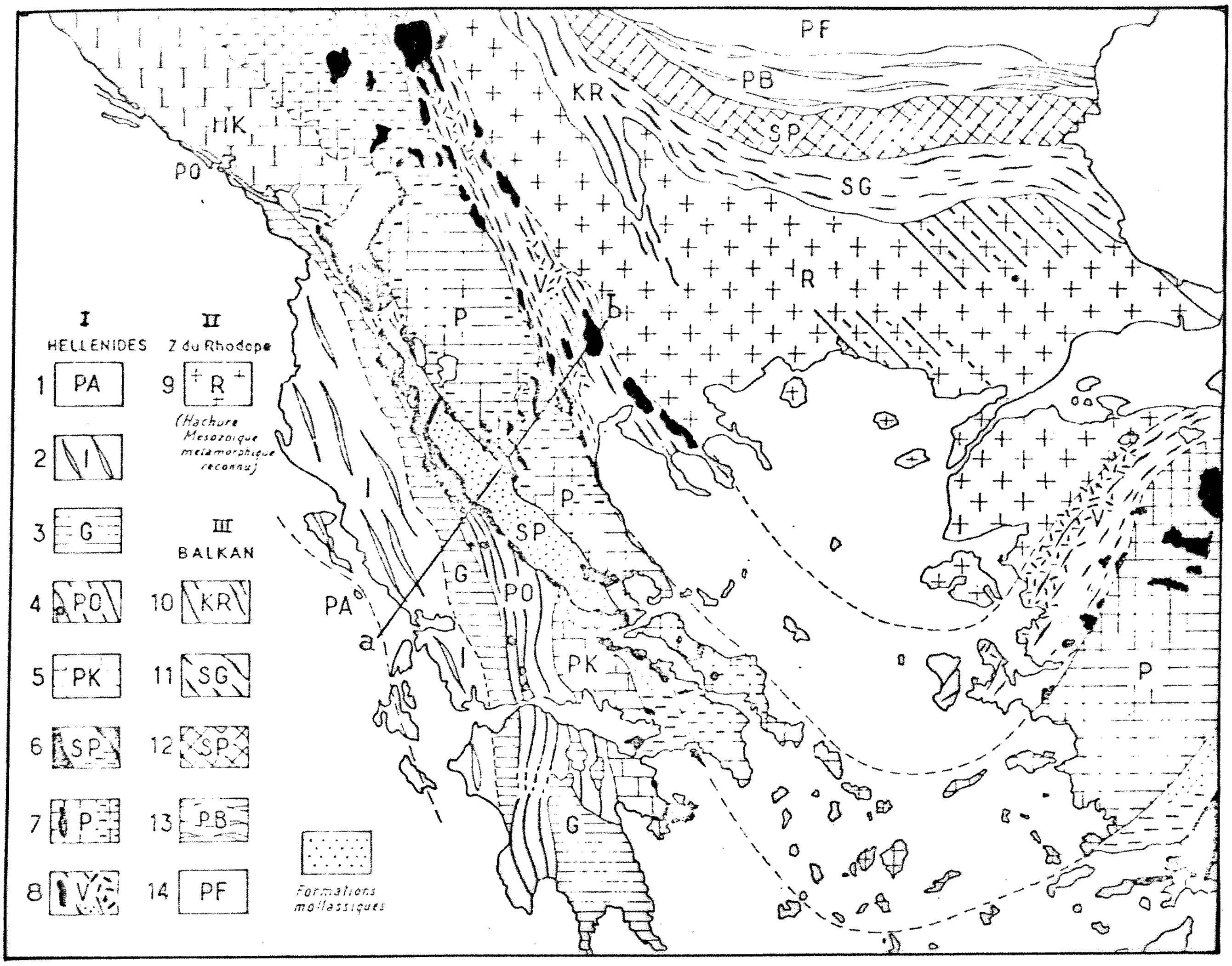


Fig. 1.1 Geotectonic regionalization of the Hellenides and neighbouring areas (BRUNN 1960)

I. Hellenides(Dinaric Branch) 1.Paxos Zone,2.Ionian Zone, 3.Gabrovo Zone,4.Pindos Zone, 5.Parnassos Zone,6.S-Pelagonian Zone 7.Pelagonian Zone,8.Axios-Vardar Zone

II. Rhodope mass

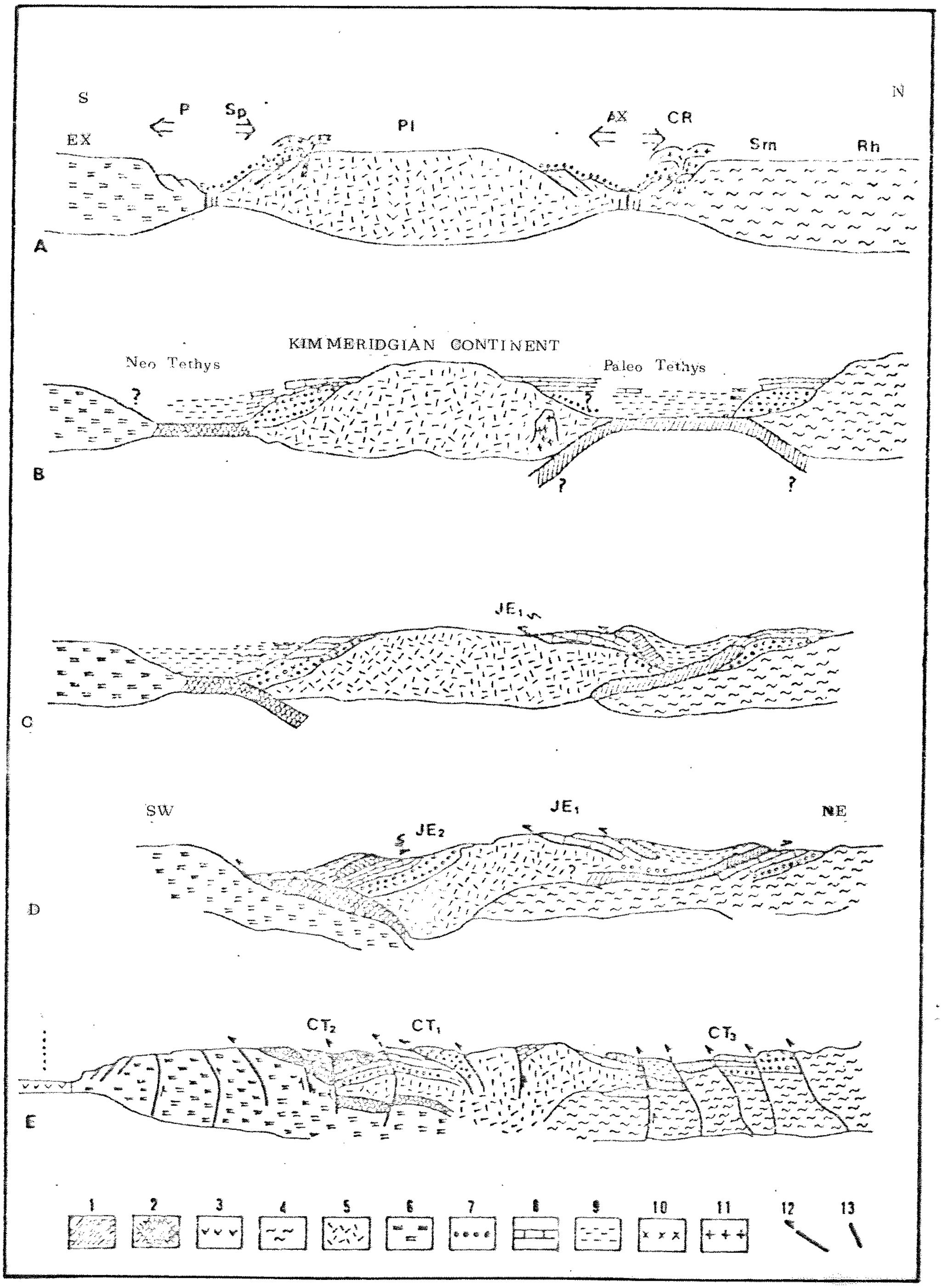
III. Balkanides(Alpine Branch) 10.KraishtidesZone,11.Stredna Gora Zone, 12.Inner Balkanides or Stara Planina,13.Outer Balkanides, 14.Hercynian mass of Meso-Europe extended Southwards, with the same orientation (NW-SE),by the Hellenides up to the Crete island. Then, this orographic axis is curved and is continued to the Taurides in Turkey. The Pelagonian zone and the inner Hellenides area extended in the same direction, and they are continued to the Menderes massif in Turkey.In this way ,two orographic arcs, which surround the crystalline Rhodope massif, are developed.

Patterns of geotectonic evolution of this region have been proposed by many geoscientists (AUBOUIN et al.1963, SMITH AND MOORES 1974, JACOBSHAGEN et al.1978,MOUNTRAKIS et al.1983 (Fig 1.2)

- Palaeo-Tethys is formed between Eurasia and Godwana during the Permo-Triassic age.
- After that, a crushing onto the Godwana gives rise to a new continental land, which is the kimmeridgian continent. Between them the neo-Tethys is extended during the Jurassic age.
- In the upper-Jurassic, the destruction of the Palaeo-Tethys ocean crust has been taken place and it is presented by the Axios-Vardar zone.
- Between the Jurassic-low Cretaseous, the neo-Tethys ocean crust(on the sub-Pelagonian - Pindos zone) is subsided under the kimmeridgian continent.
- Then, the inner and outer Hellenides have been collided causing various tectonic events which are obvious on the Axios-Vardar zone and on the Serbomacedonian massif. During the same period,the subduction of the African slab under the Eurasiatic and the creation of the Aegean arc are formed (MOUNTRAKIS 1983).

The intensive orogenies, the active tectonism and the sharp uplifting and subsidence movements are the main features of an active region with strong earthquakes. A combination of all these effects must be performed in order to get a better knowledge of the seismotectonic process in this area.

In the following texts , the geological,geotectonic and some geomorphological features of the main zones of the area will be discussed,i.e Rhodope massif, Serbomacedonian massif, Circum Rhodope massif, Axios-Vardar zone, and Kraishtides zone.



S
N
P
Sp
Pl
AX
CR
EX
Sm
Rh
A
KIMMERIDGIAN CONTINENT
Neo Tethys
Paleo Tethys
?
B
JE1
C
SW
JE1
NE
JE2
D
CT2
CT1
CT3
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Fig. 1.2 Phase of the Geodynamic and Geotectonic evolution of the studied area(MOUNTRAKIS 1983).
A:Permo-Triassic, B:Mid Triassic-Jurassic
C and D:Upper Jurassic-lower Cretaceous,E.Tertiary JE1,JE2,CT1,CT2,CT3;phase of orogenies.
Rh:Rhodope mass,Sm:Serbomacedonian massif
CR:Circum Rhodopen zone, AX:Axios-Vardár zone
Pl:Pelagonian zone, Sp:Sub-Pelagonian zone
P:Pindos zone, Ex:Outer (External)Hellenides
1:Paleo-Tethys ocean crust, 2:Neo-Tethys ocean crust
3:Mesogea crust, 4:Europe-lithospheric continent
5:Kimmeridgian-lithospheric continent, 6:Africa lithospheric continent 7:Clastic sediments, 8:Neritic deposits of continental margins, 9:Ar-Si ocean sediments, 10:volcanic material, 11:Granite , 12:Thrust faults and various deformative movements, 13:Normal faults.

1.2 Phodope Mass

The Rhodope massif (Fig1.3) includes a very extensive area, comprising the Thracian territory, eastern Macedonia, Samothraki, Lemnos and the southern part of Bulgaria. In the foregoing chapter, it has been reported that this massif is surrounded by the Dinaric and Alpine branch and it is a mid-branch or a middle core of the Alpine system. KOBER (1931) characterized the Rhodope territory as "Mid range" (Zwischengebirge), while BONCEV (1946) put the Rhodope massif to the Dinaric branch of the Alpine system. BRUNN (1960) defined it as a mid branch of this system. According to DIMITROV ´s view(1955) the Greek and Bulgaria ranges must be named Rila-Rhodope massif.

Metamorphic and igneous rocks, dominate on the Rhodope territory, while the sedinentary formations are absent, causing many problems for a complete study and determination of the massif. Many investigations have been made about the lithological evolution of the Rhodope massif and its total depth was estimated about 12-20 km.

JARANOV (1938) carried out studies on the Bulgaria Rhodope and divided the crystalline rocks into two series.

a. The lower series which is consisted of gneisses, amphibolitic schists and the marbles of a large depth, and of Palaeozoic age.

b. The upper series that is consisted of the muscovite and biotite gneisses and a large depth of the marbles, of Algonkian age.

DIMITROV (1959) defined a similar order of the crystalline rocks in the same territory.

OSSWALD (1938) studing the Greek Rhodopian massif has divided the mass into four subzones.

a. E-series of the gneisses ,which covers the western Rhodope with a depth about 7 km.

b. F-series of the marbles, which covers the Eastern Macedonia till Nestos river. Main characteristic rocks are the marbles with various types of schists.

c. G-series of the mica schists, which is extended to the Nestos river area. Its depth is about 5 km.

d. H-series of the schists and marbles that is appeared in NE direction of the Nestos river and its depth is about 3 km.

The E and F series are Algonkian age while the G and H are

HELLENIDES AND THE STUDIED AREA

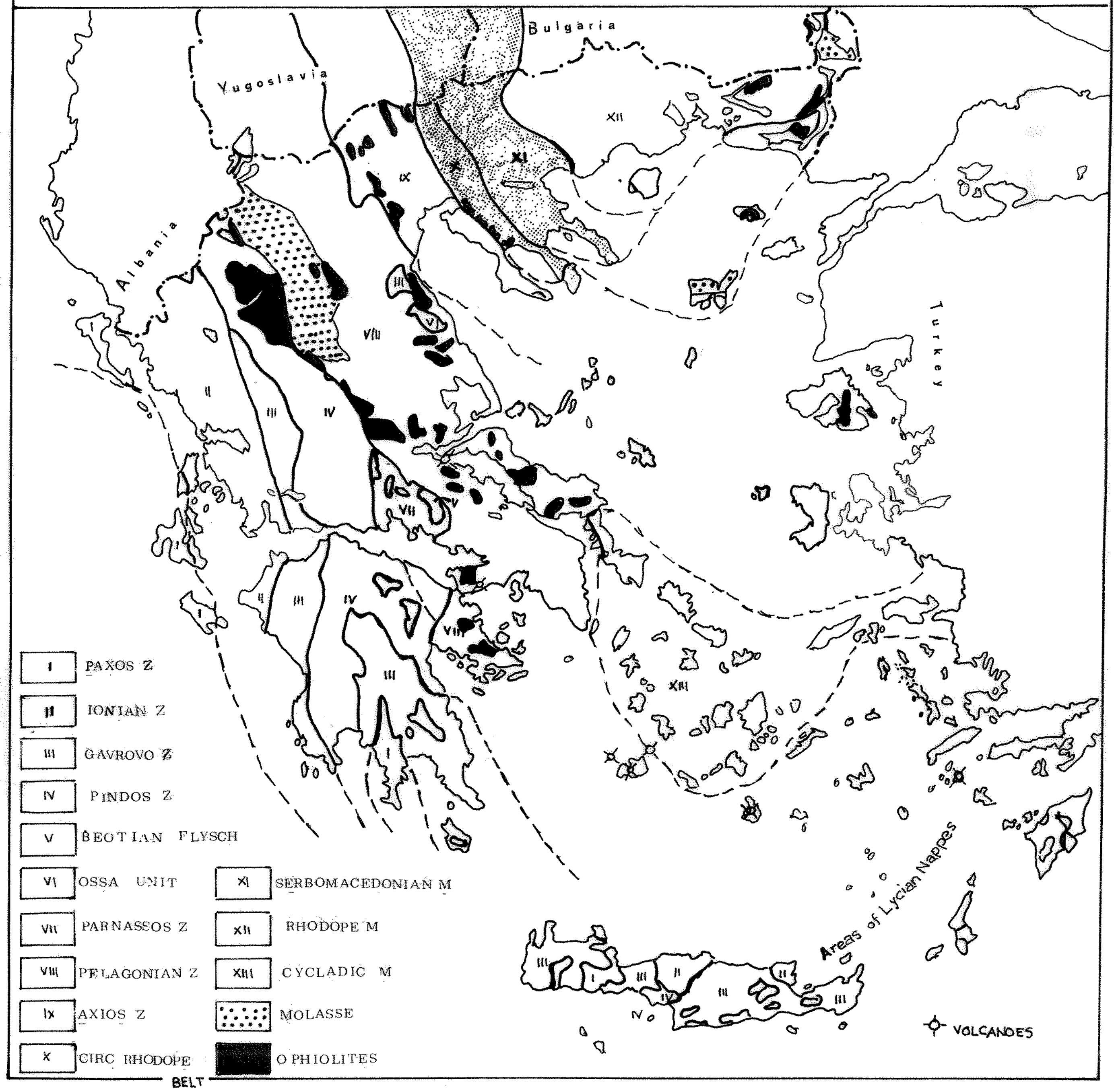


Fig 1.3

FROM THE GEOLOGICAL MAP OF GREECE

IGME (Geological Maps Publication Department)

lower Cambrian age.

The igneous rocks (mica-biotitic granites, granodiorites and etc) are Eocene-Oligocene age (PAPADAKIS 1965,MEYER 1968, SKLAVOUNOS 1981).The volcanic rocks (Rhyolites, dacites, andesites) are Oligocene age (RENTZEPERIS 1965, SOLDATOS 1961, KOPP 1965).

KRONBERG and his colleagues (1970) considering the metamorphic rocks of the massif, they found influences of the Alpine orogenies on those. They discovered two phases of the orogenies the first with strike 50°NE on which the big syclines and anticlines were formed and the second one with strike 120°NW. The two phases have simultaneously been generated during the Alpine orogenies (KROMBERG et al.1970). Taking into consideration the metamorphism of crystalline rocks and the igneous rocks age, they concluded that the metamorphism, folding and plutonism have Alpine age. From some observations in the Bulgaria Rhodope massif, they showed that some crystalline rocks were Pre-Cambrian up to lower-Palaeozoic age. KRONBERG and his colleagues (1970) formulated the following aspect: northern Rhodope massif (Bulgaria) was formed during the Calidonian-Hercynian orogenies or the Palaeozoic age. Around that, new crystalline masses were formed of Alpine age which were named Neo-Rhodopian massif.

HSÜ and his colleagues (1977) studied the geologic evolution of Bulgaria territory, by using plate tectonic theory, and stated that the zone between Rhodope and Moesia has undergone extension during the early Mesozoic and compression during the late Mesozoic and Cenozoic. The compression followed the late Cretaceous consumption of the ophiolite trough which led to a collision of the Italo-Dinaridian and the Rhodope part of the Bulgarian micro-continents.

VAPCAROV and his colleagues (1973) regarded the Bulgaria Rhodope as an ancient consolidated massif in the Alpine geosycline. They showed the existence of morphographic ,morphostructural and morphogenetic features, typical of an ancient consolidated and recently activated structural region. On the territory of Bulgaria,the massif includes fragments of the complex arc-block morphostructure of the Serbomacedonian block, the Rila-Rhodope arc-horst structure and the East Rhodope morphostructural complex. All these morphostructures are divided by a deep, crustal fault zone- the Struma and the Central Rhodope structure complex.

1.3 Serbomacedonian Massif

Originally this zone had been studied as the western part of the Rhodopian massif (KOSSMAT 1924,OSSWALD 1938,NEUBAUER 1957). Subsequent investigations in Yugoslavian and Bulgarian territory by DIMITRIEVIC(1959),JARANOV (1960) and ARSOVSKI (1961) divided the Rhodopian mass into the Rhodopian and Serbomacedonian massives, while KOCKEL and WALTER (1965,1968) and MERCIER (1968) regarded the Serbomacedonian massif as a separated zone with a NNW-SSE trend. Also, DIMITRIEVIC AND CIRIC (1966) and DIMITRIEVIC (1974) pointed out the significance of Serbomacedonian for the geology of this region.

The geological setting of the Serbomacedonian massif was formed during the Palaeozoic age and was metamorphosed during the Palaeozoic or Mesozoic. The crystalline setting is very difficult to be determined because there is no fossil.So, radiometric methods were applied (BORSI et al.1965,HARRE et al1968).A wide range of ages have been resulted between upper Palaeozoic till lower Kainozoic age.

KOCKEL and WALTER (1968) and KOCKEL and his colleagues (1971,1977) distinguished two crystalline series on the methamorphic bedrock of the Serbomacedonian as following:

- The lower-kerdilion sequence which is located at the eastern Chalkidiki between Stratoni village and Strimon river with the dominant rocks mainly being gneiss, mica-schists, bands of marbles, amphibolites and migmatites. The total depth is about 3 km.
- The upper-Vertiskos sequence is situated westernward of the Kerdilion series and includes the main body of Chalkidiki to the southern part of Yugoslavia and Bulgaria.The predominant rocks in the series are gneiss, mica-schists, amphibolites and metadiabases.

Both sequences have been metamorphosed during the Almandine-amphibolite phases. The contact between the two sequences is regarded normal (KOCKEL AND WALTER 1968) and tectonic (NEUBAUER 1957). A sedimentary sequence during upper Paleozoic-Lower Mesozoic had covered the western part of the massif and during the Jurassic tectonic phase was metamorphosed in green-schist phases . Fragments

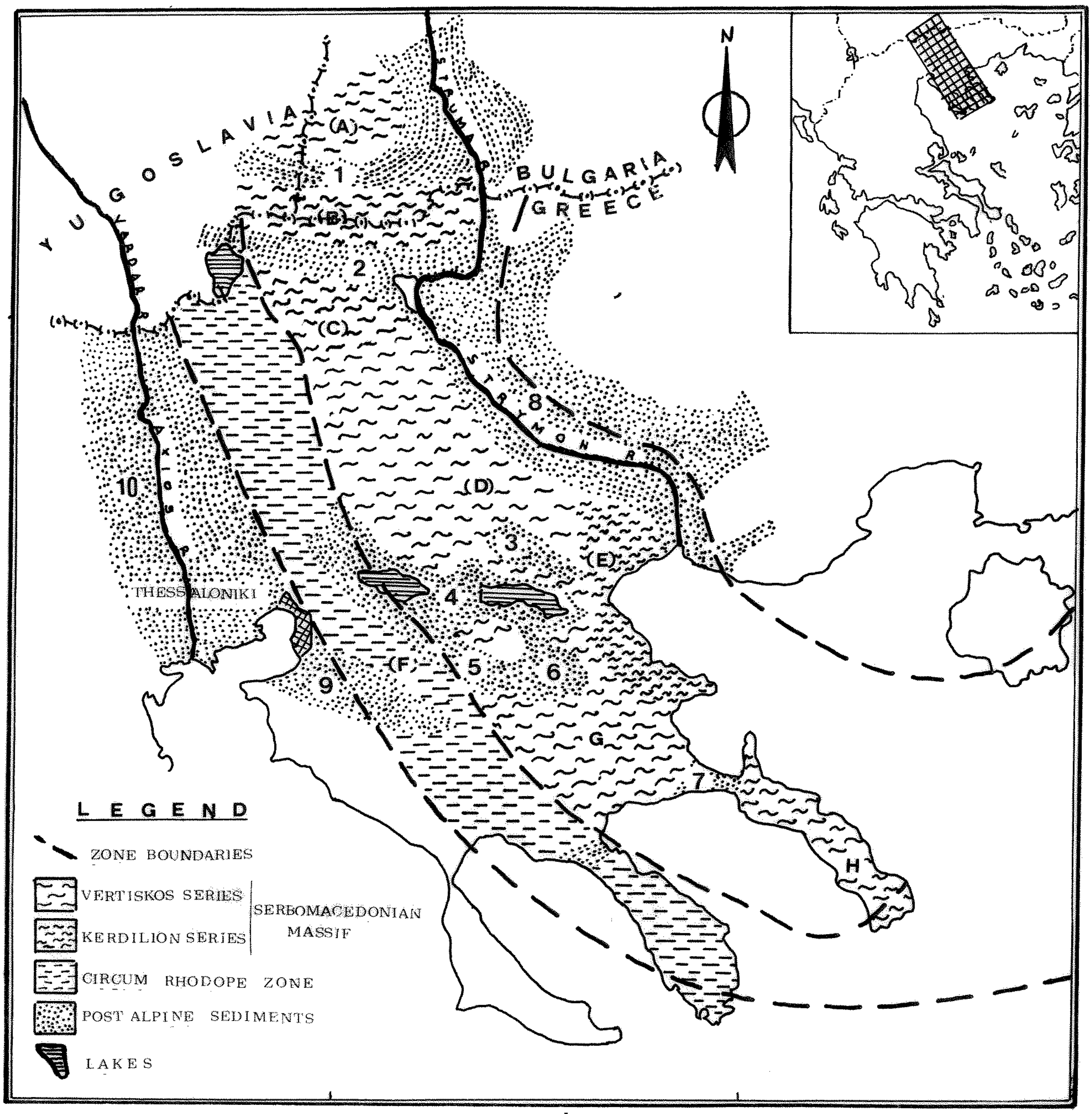


Fig. 1.4 Geological-Geomorphological map of the Serbo-macedonian massif and the surrounding area (MOUNTRAKIS et al.1983)

Basins		Horsts	
1.Strumeshnitsa	6.Marathousa	A.Orgazhden	E.Kerdilion
2.Rhodopolis	7.Nea Roda	B.Kerkini-Belassitsa	F.Chortiatis
3.Vromolimnes	8.Struma-Strymon	C.Krusia	G.Cholomon
4.Mygdonia	9.Anthemous	V.Vertiskos	H.Athos
5.Zangliveri	10.Vardar-Axios		

of this sequence were incorporated in the crystalline mass of the zone. During the Pre-Alpine(Caledonian or Hercynian) and Jurassic orogenies, granitic bodies were intruded into the crystalline series.

The Serbomacedonian boundaries with the surrounding zones have special geotectonic significance.

BONCEV (1958,1961) defined a geological contact of the Serbomacedonian and Rhodopian massif on the Bulgarian territory while KOCKEL and WALTER(1965) determined another contact along the Strymon river valley where the Serbomacedonian gneiss overlies the marbles-schists of the Rhodopian massif with an Oligocene eastwards overthrust . The same tectonic contact was observed by DIMITRIEVIC and CIRIC (1967) on the Bulgaria and Yugoslavia territory. Later on, KOUKOUZAS (1972) observed a contact near the Greek-Bulgarian frontier to the Promachon village. All these tectonic contacts were observed between the two massives consist the "Strimon line" or "eastern boundary" and probably represent an old (Alpine or Pre-Alpine) line, which has been reactivated during Tertiary and Quaternary times and created the Strymon neogene basin.

The"Western boundary" of the Serbomacedonian massif with the Vardar-Axios zone has not been clearly defined. KOCKEL and his colleagues (1971) suggested a tectonic line which crosses the Kilkis region and through the Volvi area is ended in the eastern Sithonia peninsula. Similar observations led Yugoslavian geologists to distinguish "inner" and "outer" western boundaries. (DIMITRIEVIC AND CIRIC 1967).Newest investigations in this area, by KAUFMANN and his colleagues(1967) and KOCKEL and his colleagues (1977) discriminated, a new zone called "Circum Rhodope Zone" which will be considered in the next paragraph. DIMITRIEVIC AND CIRIC (1976) and MERCIER (1968) have located and overthrust westwards of the Serbomacedonian massif. This is studied as a tertiary structure,but probably represents, a reactivated tectonic line, related to an old subduction of the Vardar ocean beneath the Serbomacedonian continental margin (MOUNTRAKIS 1983) (Fig 1.4).

From the geomorphological point of view, the Serbomacedonian massif is a strongly modified zone during the Neogene and Quaternary time. An important faulting on the massif is accompanied by intense tectonic activity. Two important directions of faults, crossed at right angles, cause many breakages of the pre-Alpine crust of the massif, while the subsequent vertical movements of the broken blocks contributed to its morphostructural differentiation (PSILOVIKOS 1984). The same researcher, considering the Serbomacedonian massif as a whole and applying geomorphological criteria, pointed out that the surface relief of an area expresses the balance between endogenic and exogenic processes, distinguisted three distinct morphotectonic units in the zone:

- The Northern unit which includes the Morava basin
- The Central unit forms a mountainous asymmetric ridge
- The Southern unit forms a complex area of the horstgraben structures.

The Central and the Southern units are bounded by the Struma Strymon basin and the Vardar-Axios basin (Fig 1.5) Along the Serbomacedonian massif many grabens and horsts have been produced as the result of the tectonic activity, while exogenic processes whith erosion on the horsts and sedimentation in the grabens have differentiated the morphology of the zone (Fig 1.5)

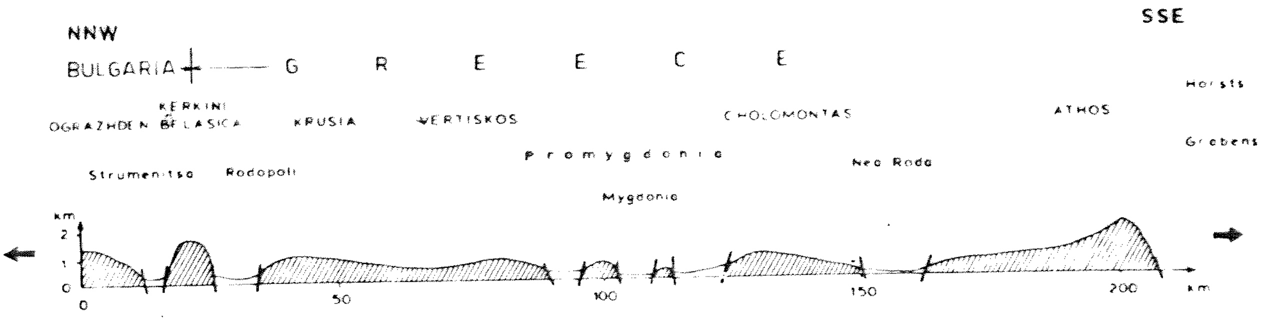


Fig. 1.5 Horst and Graben structures along the Serbomacenonian massif (MOUNTRAKIS et al.1983)

From the global tectonic viewpoint, PSILOVIKOS (1984) determined that the Northern part of the massif was affected by a Miocene extension in the Pannonian basin. There is evidence for compression, almost transverse to the long axis of the zone, while the southern part was related by an early Miocene extension and a late strong Quaternary extension to the Aegean region.

KARAGJULEVA and her colleagues(1973) during the proceedings of the seminar on the seismotectonic map of the Balkan region (UNDP-UNESCO), stated that the Serbomacedonian massif in Bulgaria territory is existed only in the Ograzden block which is made up chiefly of an Archean metamorphic complex. The block comprises two horsts, the Ograzden and the Belassitsa, separated by the Strumeshnitsa Neogene-Quaternary graben.

1.4 CIRCUM RHODOPE ZONE

As it has been stated (KAUFFMANN et al.1976) the Circum Rhodope belt is the innermost zone of the Hellenides (Fig 1.3,1.4)The formations in the innermost Hellenides, southernwards of the Greek-Yugoslavian frontier and on the boundary of the Vardar-Axios zone and the Serbomacedonian massif have been stratigraphically and petrographically studied by many investigators (MERCIER 1966-1973, MONOD 1965, MARATOS 1967,SAPOUNTZIS 1969, RICOU 1965, KOCKEL,MOLLAT AND WALTER 1971). However considerable discovery of new faunas and redetermination of some Mercier's findings by KAUFFMANN and his colleagues (1976) led to more exact stratigraphical processes of the Svoula formation (Megali Sterna formation, Melissochori formation).Based on these evidences, KAUFFMANN and his colleagues (1976) presented a new zone between the inner Hellenides and Serbomacedonian massif.

The eastern boundary of the Circum Rhodope belt follows the Serbomacedonian massif boundary, while the western and south-western boundary is covered by Neogene deposits.In Monopigado and Olynthos sites, the crystalline setting of the Serbomacedonian massif has been observed ,localizing the western boundary of the belt. The Circum Rhodope zone is extended southwards including the Sithonia peninsula , the end of the Athos peninsula and the southern

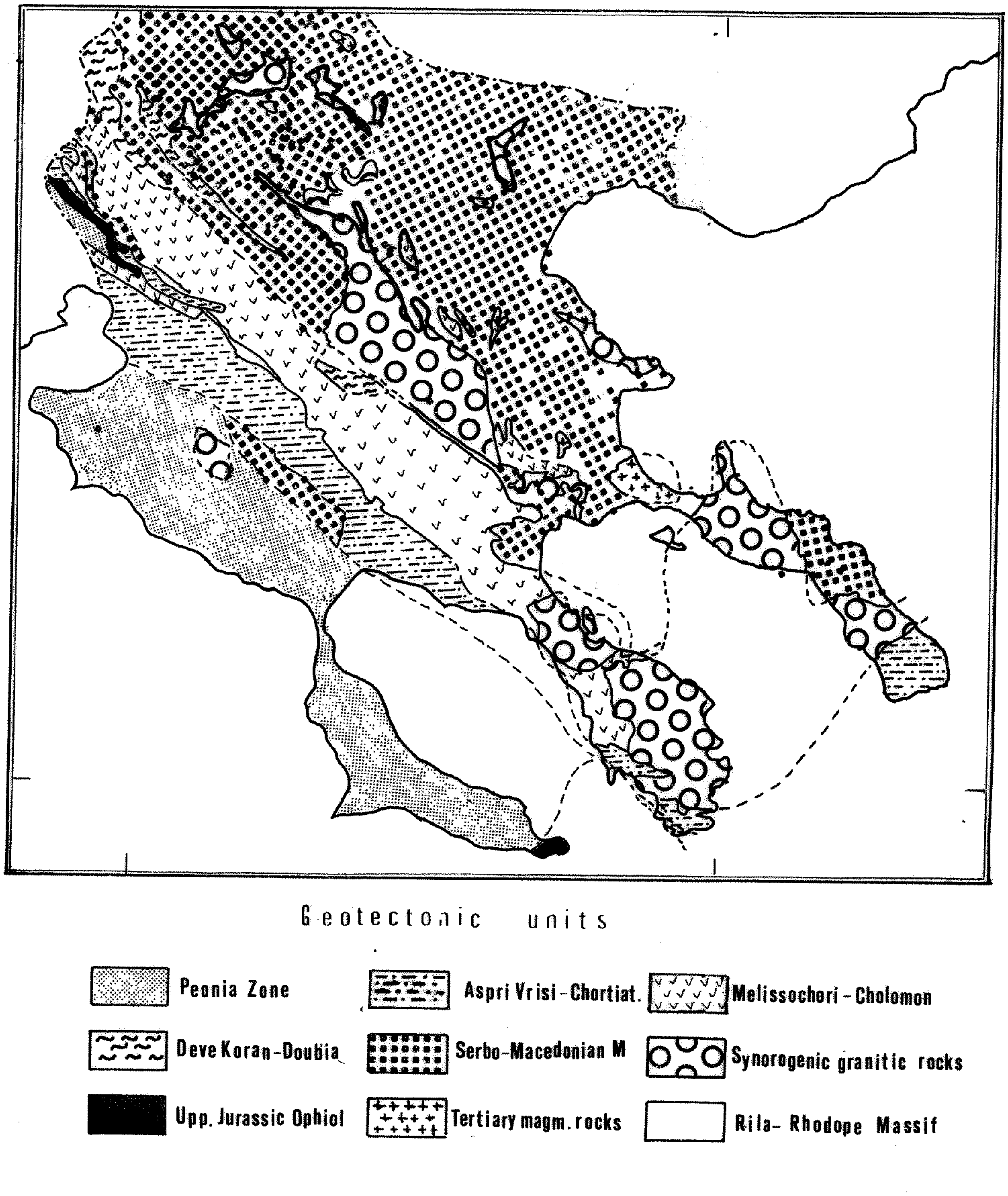


Fig. 1.6 Geological map of the Circum Rhodope zone and surrounding regions (KOCKEL et al 1977)

part of Evros region.

KOCKEL and his colleagues (1977) based on phase differences, on the rate of the metamorphism and on structural development during the mesozoic, justified a subdivision into three subunits (Fig 1.6).

- The Deve Koran-Doubia unit is known only from the northwestern section of the area and includes the lowermost parts of the upper Paleozoic-Mesozoic sequence. Metamorphism is low,intrusive rocks are absent.
- The Melissochori-Cholomon unit has a direction NW-SE and is extended from Melissochori village to the Cholomon mountain and the western side of the Sithonia peninsula.It comprises sedimentary rocks of the upper-Palaeozoic which were metamorphosed during the Mesozoic age.
- Further southwest, the Aspri Vrisi-Chortiatis unit is extended in the direction NW-SE. It´s presented northwards of Thessaloniki and is passing from the Chortiatis mountain and southernmost point of the Sithonia peninsula. The unit is characterized by a eugeosycline development during the lower-Middle Jurassic.

1.5 Vardar-Axios Zone

The Axios-Vardar zone (Fig 1.1,1.3) was primarily defined by KOSSMAT (1924) as a lineament orientated NNW-SSE and approximately 30-70 km wide.It is surrounded from the eastern and western by the Rhodopian and Pelagonian basement massifs,respectively. This belt extends through the whole territory of Yugoslavia,starting north of Belgrade and following southern direction along the Vardar river valley up to Thermaikos gulf and disappears under the Aegean Sea(ARSOVSKI et al.1975).It also includes some islands of Sporades complex (Skiros and Alonissos) and then curving in the direction W-E through the island Chios appears in Turkey.

The first systematic study was performed by OSSWALD (1938) on the basis of tectonic characteristics. He distinguished three branches from east to west : (1) Doiran branch, (2)Paicon branch, (3) CHERNA-REKA branch.

A different distinction was made by PETKOVIC (1956)who separated the belt into four subzones: 1) the inner Palaeozoic zone (the ended western part of the Axios-Vardar zone), 2) the inner Dinaric zone (the western part of zone), 3)the inner ophiolitic zone and 4) the Axios-Vardar zone(only to the eastern part of the zone) The same author (1958)modified his separations and he named the end of the western part "inner Dinaric zone" and the other part "Vardar-Axios zone".

KOBER (1952) regarded the Vardar-Axios zone as a whole,characterizing the zone (NARBEN LINIE)only for Cretasic formation.

AUBOUIN,BRUNN and MERCIER using tectonic criteria and paleogeographic observations tried to divide the belt into subzones. However, they used different names for the various regions of the Axios-Vardar zone. AUBOUIN (1959) used the term "Axios zone" for the eugeosycline and the term "pre-Pelagonian zone" to state the slope between Pelagonian platform and Axios trough. BRUNN (1961) named the same slope "Extra - Pelagonian zone".

The most important researcher of the Greek Axios zone is Mercier (1960). He divided the Greek zone into three parts: The eastern, central and western margin. He presented a new division of the Axios-Vardar zone :a)Peonia trough b)Paikon platform c)Almopia trough (Fig 1.7).

On the basis of Mercier´s viewpoint (1968) the Peonia is considered as a Mesozoic trough. It comprises the western Chalkidiki and the Kassandra peninsula as well as the most western margins of Sithonia peninsula. The zone adjoins Paikon platform and the slope of the platform to the trough was named by Mercier Pre-Peonian subzones. In this zone ophiolites have been observed. These ophiolites are situated at the eastern border of the Vardar zone towards the Serbomacedonian massif and have NNW-SSE orientation in Chalkidiki.The study of the ophiolites plays an important role since they delineate ancient plate boundaries.Furthermore,ophiolites are by many authors considered as the rest of oceanic floor that has been obducted upon plate edges, providing the possibility to study their physical and chemical properties (MAKRIS et al.1977, KYRIAKIDIS 1984). In accordance with ZIMMERMAN and ROSS (1976), JACOBSHAGEN (1979) stated that within the fourth orogenic paroxysm during the Eocene,Vardar ophiolites were obducted onto the Pelagonian platform again. Also, deep-sea sediments, radiolarites,sandstones, marls and flysch of about upper Triassic-Jurassic age are the main petrographic characteristics(MERCIER

1968).

The Paikon platform is easterwards overthrusted by the Pre-Peonian formations ,while it is in tectonic contact westwards with the Almopias zone. Thrust faults have been observed by MERCIER (1968) in this contact. This platform separates the Almopia and Peonia trough. A sequence of neritic limestones denote that the Paikon region was a submarine platform in shallow waters. The dominant petrographic formation in this zone are neritic limestones, volcanic-sedimentary rocks and flysch.

The Almopia zone is also a Mesozoic trough and contains ophiolitic formations, neritic sediments of the Jurassic age and upper - Cretaceous flysch.

Two faulting systems can be distinguished in the Axios-Vardar zone.A system of transverse faults are oriented in NE-SW direction and a system of longitudinal faults are orientated in NW-SE direction and dip NE (MERCIER 1968, MOUNTRAKIS 1976,1977). These fault systems are related to upper Mesozoic-lower Kainozoic tectonic events and probably were reactivated during the Tertiary tectonism.

SIKOSEK (1973) during the Seminar on the Seismotectonic map of the Balkan region (UNDP-UNESCO) reported that the Axios-Vardar zone represents a very complicated geotectonic unit, which is located on the innermost part of the Dinaric orogenic branch, in the area between Belgrade and the Yugoslavian-Greek frontier. Important investigations were accomplished by ARSOVSKI for the Yugoslavian part of the Axios-Vardar zone. ARSOVSKI and his colleagues (1975) deduced that the origin of this zone was resulted from the breakage of the Pre-Palaeozoic setting and includes faults due to the intrusion of basic and ultrabasic magmas. The dominant sedimentary rocks of the geosyclinic formations are sandstone and of pelitic character intruded by basic and acid rocks. The Palaeozoic era was characterized by calcareous deposits .During the Jurassic, the intrusion of the basic magmas was very characteristic in the whole inner Dinarides area. Main feature during the Mesozoic was the transgression and regression of the Tethys sea. At the end of Jurassic there was manifested an intensive tectonism, creating numerous foldings and breakages. During the upper Cretaceous a division of the Axios-Vardar zone was accomplished by the two geosyclinal and two geanticlinal trenches in the central part. The flysch was the main sediment.

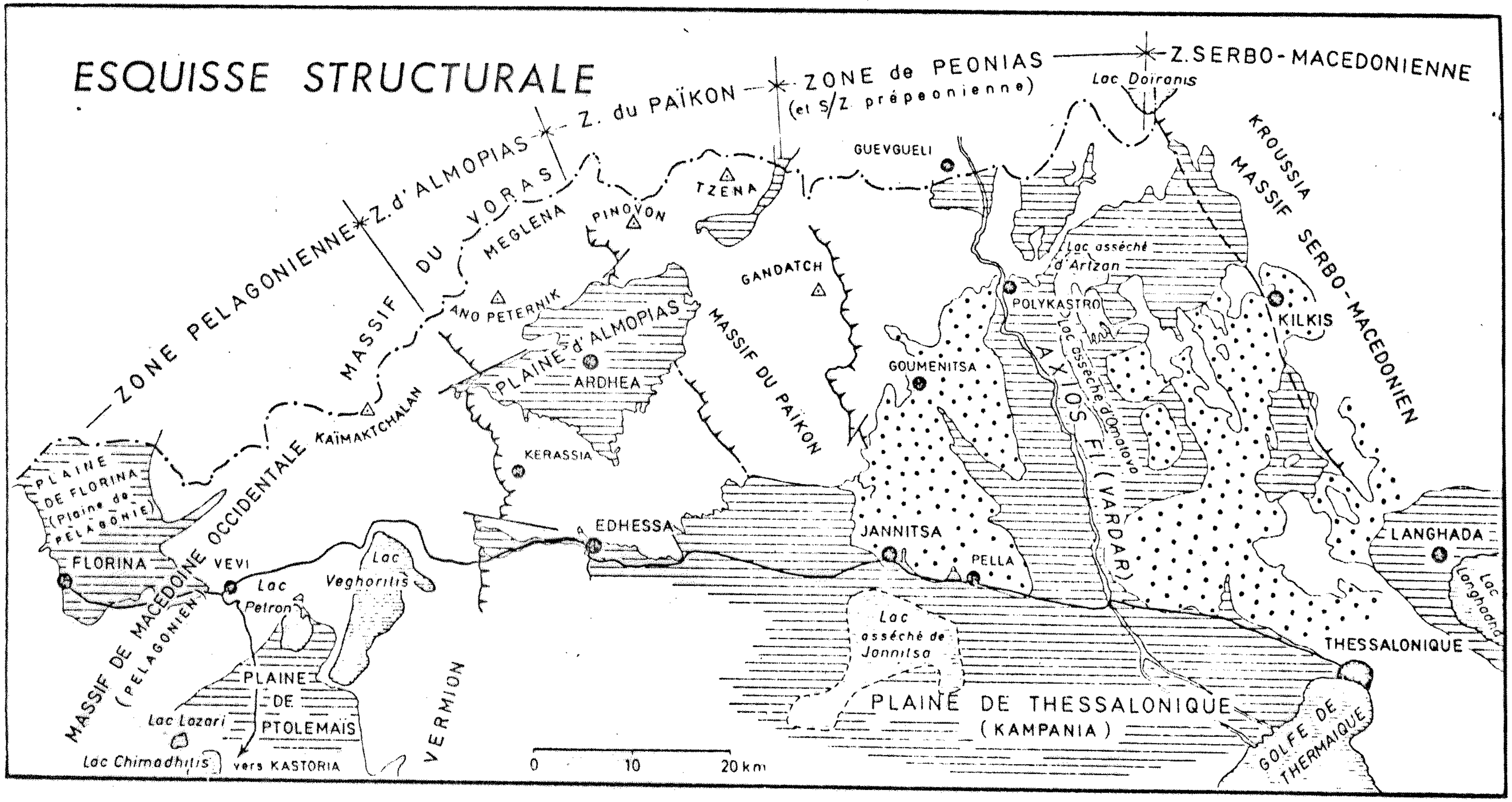


Fig. 1.7 Axios-Vardar zone (MERCIER 1966)

Fig 1.8 Tectonic Map of the Studied Area in Yugoslavia

from UNDP-UNESCO SEISMOTEC. MAPS

Fig 1.8 Tectonic Map of the Studied Area in Yugoslavia

frow UNDP-UNESCO SEISMOTECTONIC MAPS

BY M. ARSOVSKI, B. SIKOŠEK, M. VIDONIĊ, E. PRELOGOVIĊ

EDITOR : B. SIKOSEK, 1973

10 0 10 20 30 40 50km

EASTEPN ALPS

CK Crystalline of koralm

AD Alpine-Dinaric Boundary Zone

DINARIDES

JV Julian-Venetian Alps

HG Horst and Graben Zones

VU_3 Internal Unit

VU_2 Central Unit

VU_1 Inner Dinaric Unit

OF Ophiolitic Zone

CD Central Dinaric Zone

PH Pelagonides

KO Korab Zone

VK Visoki KRŠ Nappe

DA Dalmatiam Unit

BA Budra Unit

AJ Adriatic Ionian

IS Istria

MEDIAN MASSIFS

PM Pannonian

SHH SERBIAN MACEDONIAN

CARPATHIANS-BALKANIDES

GP Golubar-Penkovo Nappe

LU-SUP Zone of Lunica and Suva Plamina

K Kučaj Zone

T Timok Zone

TU Tupižnica Zone

SPS Poreč-Stara Planina Zone

MI Miroč-Zone

S Severin Nappe

KP Krajina Zone

M Moesian Platform

The Lamaride orogeny at the end of the Cretaceous created repeated dislocation of all complexes and the flysch was folded in narrow isoclinal foldings.

The Paleogene was characterized by the sea transgression that was taken place within the zone producing flysch with thickness about 2.700 m (PETKOVSKI 1974). A general uplifting of the zone accomplished during the Eocene, which subsequently was developed as a continent.

Finally, during the Neogene from the Miocene up to now, the Axios-Vardar zone has been suffered various movements. These neotectonic activities caused many breakages to the old structures and some of them were subjected to subsiding or uplifting movements. The natural boundaries of these morphostructural units are the faults (Fig. 1.8) and so the high seismicity of the Vardar-Axios zone is related to continuous tectonic processes producing the present structural formations (ARSOVSKI 1973).

1.6 Kraishtides Zone

This zone includes the South-western part of Bulgaria which is the Kraishtides lineament (Fig 1.9). The lineament as general characteristic of the kraishtides was defined by BONCEV (1961). The axial massives, the Macedonian - Pannonian (BONCEV 1940,1943) or the Serbomacedonian (DIMITRIEVIC 1959) and the Vardar (KOSSMAT 1924) and kraishtides (BONCEV 1963) structural zones, situated along either side of the massives, are included in this lineament. The kraishtides lineament has a North-western trend (150°-160°), passing through the center of the Balkan peninsula. The main faults, which are developed on the kraishtides, have the same tendency. Then, the zone continues south-eastwards in the area of the Aegean sea. To the North-west it is linked up with the major fault-line of Central Germany through the Pannonian depression. The kraishtides and Vardar zones are located almost symmentrically on either side of the massif as a result longitudinal deep faulting. The metamorphic rocks of the so-called Vlasina-Osogovo complex are considered to be the oldest in the kraishtides (DIMITROVA AND VERGILOV 1968)

The Kraishtides-Vardarides lineament is the unique axis of

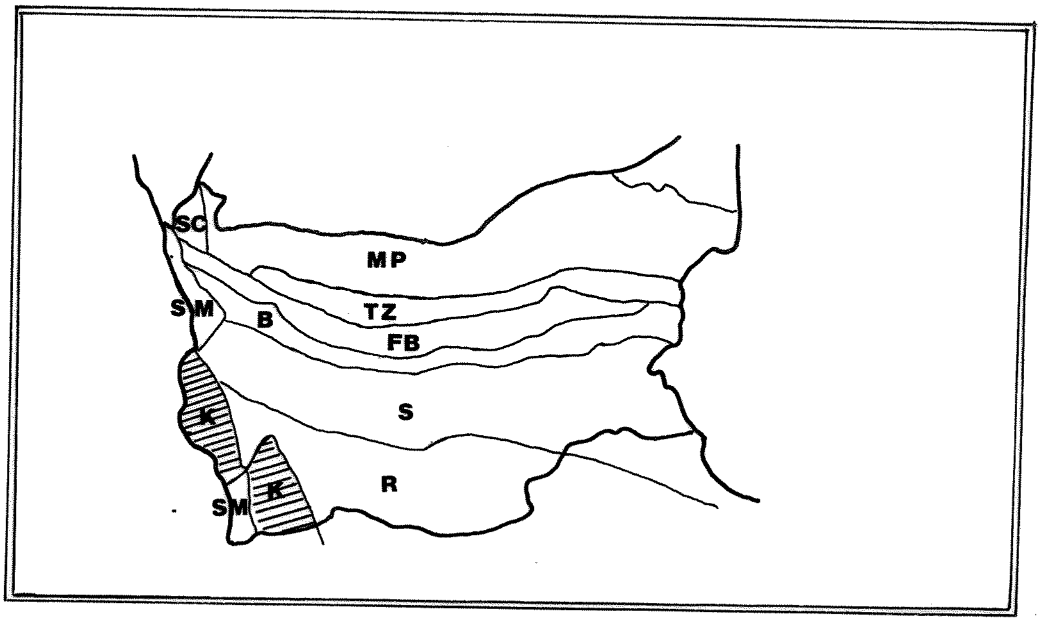


Fig.1.9 Structural zones of Bulgaria (BONCEV 1971)

MP- Moesian Platform
TZ- Trasitional zone
FB- Fore-Balkan
B - Stara Planina
S - Srednogorie
R - Rhodope massif
K - Kraishtides
SC- South Carpathian
SM- Serbo Macedonian massif

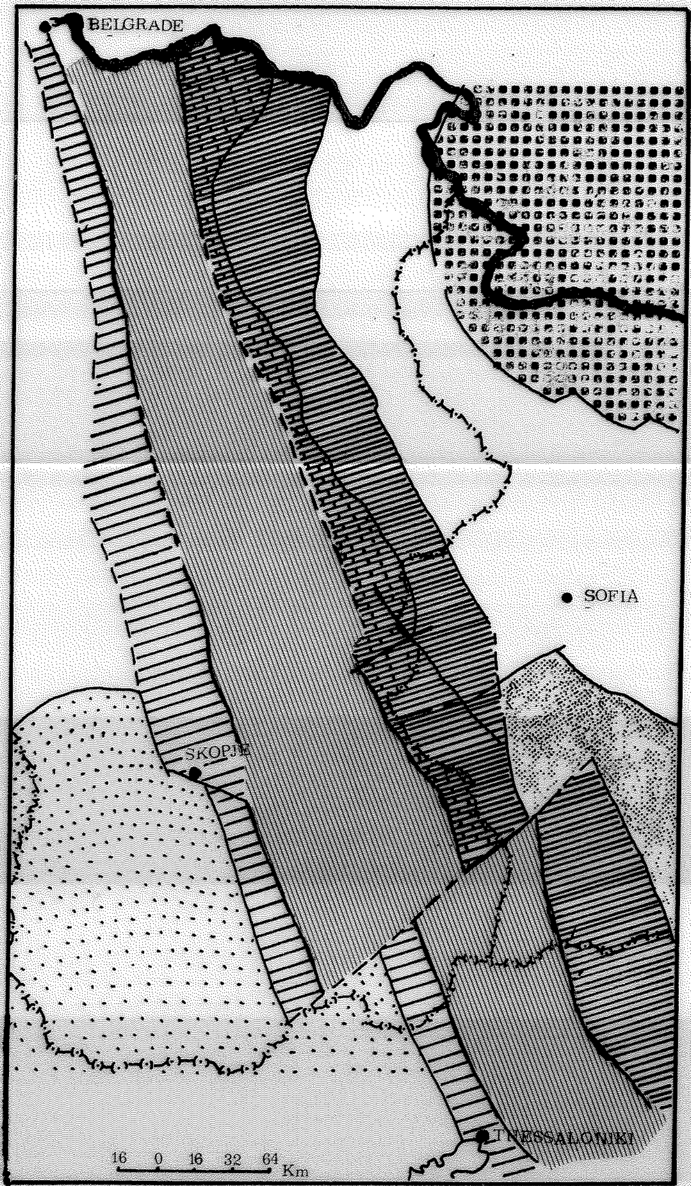
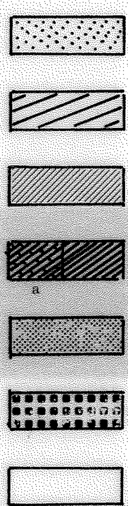


Fig 1.10 Kraishtide–Vardaride lineament in Balkan Peninsula (BONČEV 1974)



Pelagonian zone

Vardar zone

Serbomacedonian zone

Kraishtides zone (a– inner part)

Rhodope massif

Moesian platform

Carpatho–Balkan & Dinaride folded areas

symmetry in the Alpine tectogen in the Balkan peninsula. The structural zones of the Carpathides and the Balkanides to the East and the Dinarides and Hellenides to the west are located on its two sides. Two platforms, the Moesian to the East and the Ionian to the West, lie in the inner parts of the tectogen arcs. The other two large fragments of the Thracian massif the Rhodope to the East and the Pelagonian-Thessalian-Cyclades to the west, occupy a symmetrical position with respect to the lineament. This lineament is broken up by a number of transverse and diagonal faults,depending on the position of the network of regmatic faults in the peninsula. The horizontal displacement of the blocks,very conspicuous in places, was affected mainly along the diagonal faults (Fig 1.10).

KARAGJULEVA and her colleagues (1973) during the seminar on the seismotectonic map of the Balkan region, suggested that this belt is a prolonged development which started its activation in the late Riphean or the Cabrian. Various types of faults (longitudinal or transverse), which controlled the sedimentation and magmatism and determined the longitudinal zoning of the Kraishtides, played an important role in their development. Some long-living transverse and oblique faults are performed on this zone. The Kraishtides are related by repeated tectonic influence (different in individual blocks)by axial and lateral migration of the sendimentation troughs, by repeated migration of tectonic activity,by epianticlinal development of the grabens.

VAPCAROV AND MISHEV (1982) considering the dynamics of the morphostructures in Bulgaria, defined the Kraishtides as a mountain depression morphostructural area with a complex heterogeneous unit , which was developed in the place between the boundaries of the northern normal fault scarp of the Rhodope massif and the southern slope of the Stara Planina system. It consists of the mosaic block-fault structure.

Some hypotheses about the relations of the East Serbian mountain to the Kraishtides have been suggested by BONCEV.The structural units of the Kraishtides is the western zone of East Serbia. About the problems of genesis, and the time of origin and tectonic style of Kraishtides BONCEV (1936 1952) changed his views. Initially, he considered them as a young mountain system of a nape structure which originated through the reactivation of the older Carpathian-Balkan fold mountains. Some other aspects considered the

Kraishtides as an ancient lineament showing elements of hybric tectonics. The two opinions agree in that, this unit is an independent system. However, GRUBIC (1974) during the publication of the explanations of the Tectonic map of the Carpathian-Balkan Region did not agree with the BONCEV´ opinion. He presumed, based on the conditions in East Serbia, that, this region was separated by folding, shifts and overthrusts and even fractured in the vicinity of the Kraishtides and ,according to this finding, the structures of the Kraishtides are young and cannot be as a separate mountain system.

2. NEOTECTONIC CHARACTERISTICS OF THE AREA

In this chapter,an effort is made for the determination of the independent neotectonic units in the Serbomacedonian massif and in the surrounding zones(Rhodope massif and Vardar-Axios zone). The neotectonic zones are classified into various groups in relation to their characteristics,the vertical movements and the ground relief.Considering these features,a first faulting determination and classification is attempted. Geomorphological presentations,based on the neotectonics of the region studied is given.At the end, a neotectonic zonation and mapping is simultaneously represented by the morphostructural elements of the various neotectonic units.

2.1 Presentation of the Neotectonic Units

Taking into account the intensive tectonism and the geological deformation, we divided this region in distinct neotectonic units and we classified them into groups on the basis of their main geotectonic characteristics and morphological data.In the previous chapter,the geotectonic features have been determined. The field observations took place in two parts. The first one was aquired on the Yugoslavian territory,during the trainning trip of the IZIIS postgratuated students.The trip covered an extensive area from Skopje to Titov-Veles and an eastermost region. This area includes the Eastern part of the Axios-Vardar zone and the Western part of the Serbomacedonian massif. Some very characteristics places were studied and some interesting results were accomplished.

An investigation was carried out in Greek Serbomacedonian massif. This investigation included all the region of Chalkidiki, Kassandra and Sithonia peninsula, the central area of Chalkidiki, the region of Lagadas and Volvi lakes and all the area northermost of Thessaloniki up to the border with Bulgaria and Yugoslavia. During that time, many geotectonic characteristics and the surface relief were studied. Those data contributed to prepare the first tectonic mapping of the neotectonic units. A very significant factor which plays an important role in the neotectonic determination of a region is the surface relief.Steep relief in combination with neotectonic deformations characterizes intensive vertical movements.During the fieldwork,many subsidence and uplifting neotectonic areas were determined, and a faulting mapping was accomplished. These data are represented in a map and a first separation is performed in the uplifting and subsiding areas (Fig 2.1). Correlating the separation of the uplifting and subsidence areas with the morphostructural elements we have a clear perception of the relation between neotectonic formations and surface relief (Fig 2.2).

It is meaningful to notice that a basic role of the uplifting and subsidence areas and the neotectonic mechanism is established by the faults. During the field work, our effort was the recognition of the faults, as clearly manifested on the relief or the slightly manifested or assumed or covered by the neotectonic deposits. After the first mapping and separation of the uplifting and subsidence areas we symbolized the uplifting regions with the Roman numbers (I,II,...) and an index plus (+), while the subsiding areas are symbolizedby the capital letters A,B,....(Fig 2.1,2.2).

Now, concerning the uplifting areas, some main characteristics are discussed, while the subsidence areas will be subsequently described.

2.1.1 Uplifting Morphostructures

The first great uplifting region is the Rhodope massif I^+ and especially its Western end which is adjacent to the Serbomacedonian massif. The geological and geotectonic characteristics of this region have been reported in the previous chapter. In the Greek-Bulgarian border and in the South-Western Bulgarian part, recent vertical movements of (+5)-(+6) mm/year have been observed (CHRISTOV et al.1973).In the Eastern Greek Rhodope massif, vertical movements at amplitude up to 100-500m have been reported (BORNOVAS 1973).The Pirin Planina is the predominant mountain in the Western Bulgarian Rhodope mountain range at the altitude of about 3000 m. In the Greek territory the Orvilos, Menekion and Falakron mountains at altitudes of about 2200m, 2000m and 1800m, respectively, are observed. PSILOVIKOS and his colleagues (1981) investigated this area and especially the Vrontou mountains for core-stones and tors.They found core-stones and tors on the top surface of ridges at altitudes of 500-1200m and also within the neogene and

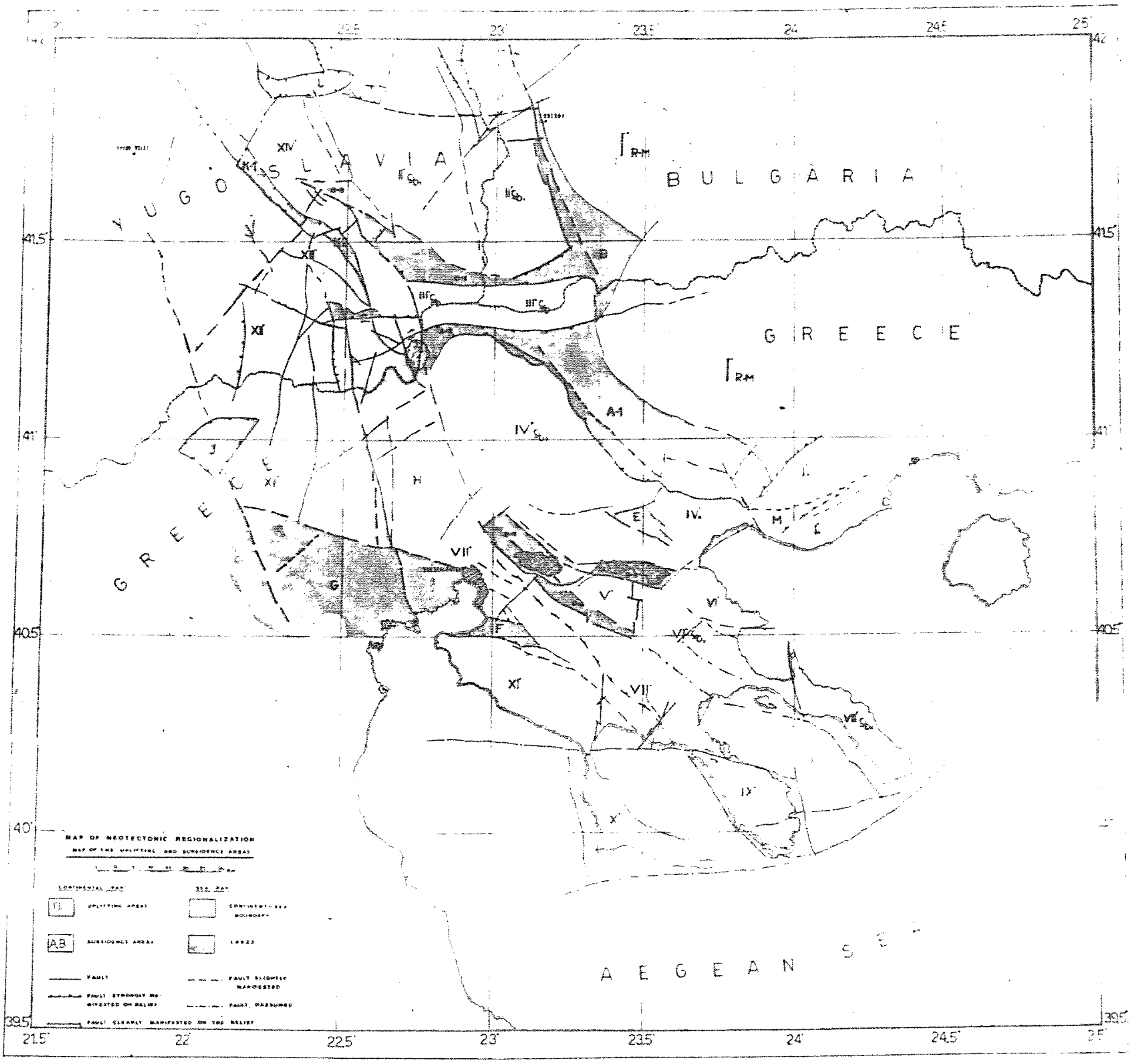


Fig. 2.1 Map of neotectonic regionalization in which the uplifting and subsidence (shadow) areas are shown.

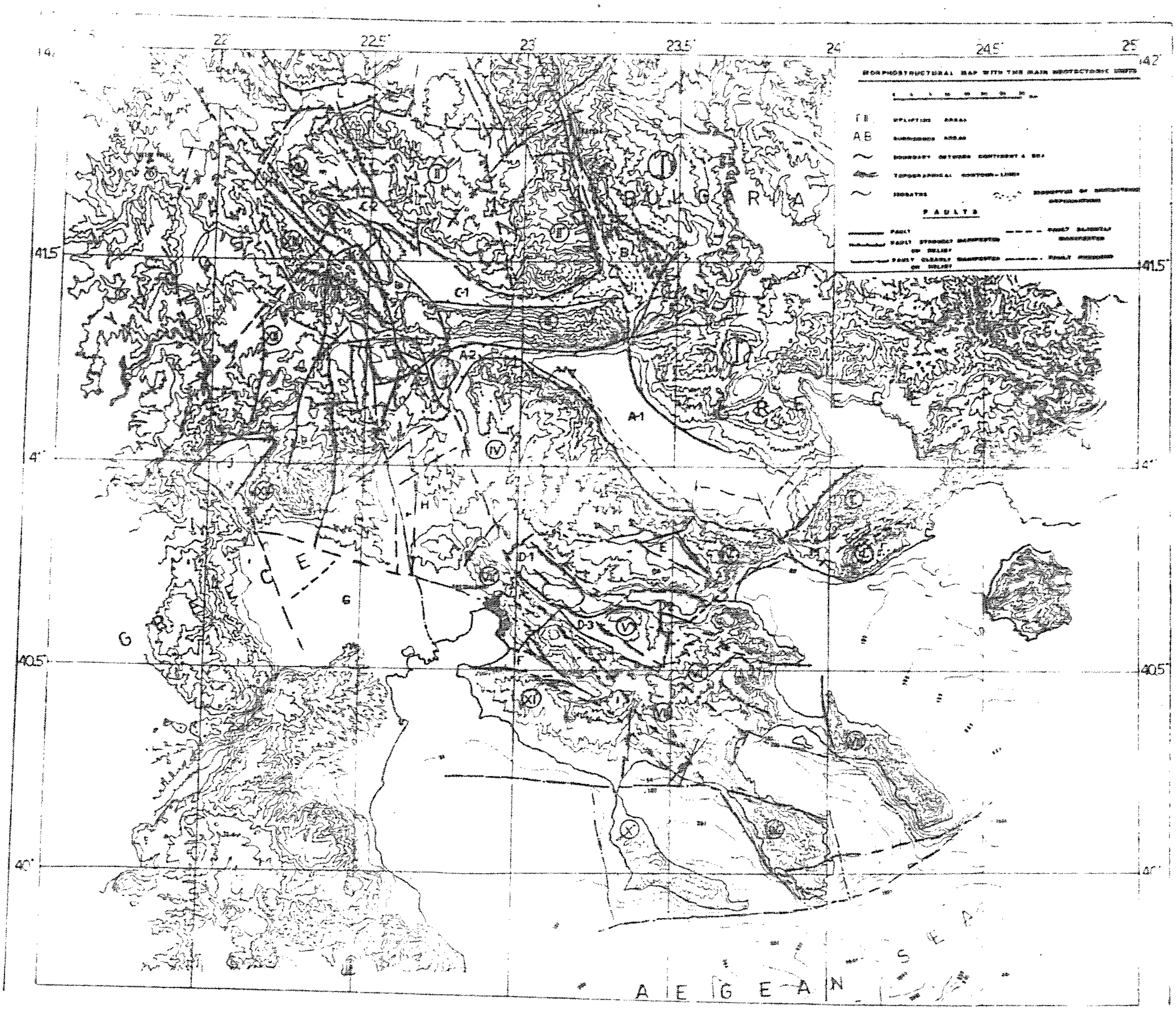


Fig. 2.2 Morphostructural map, representing the relation between neotectonic elements and surface relief.

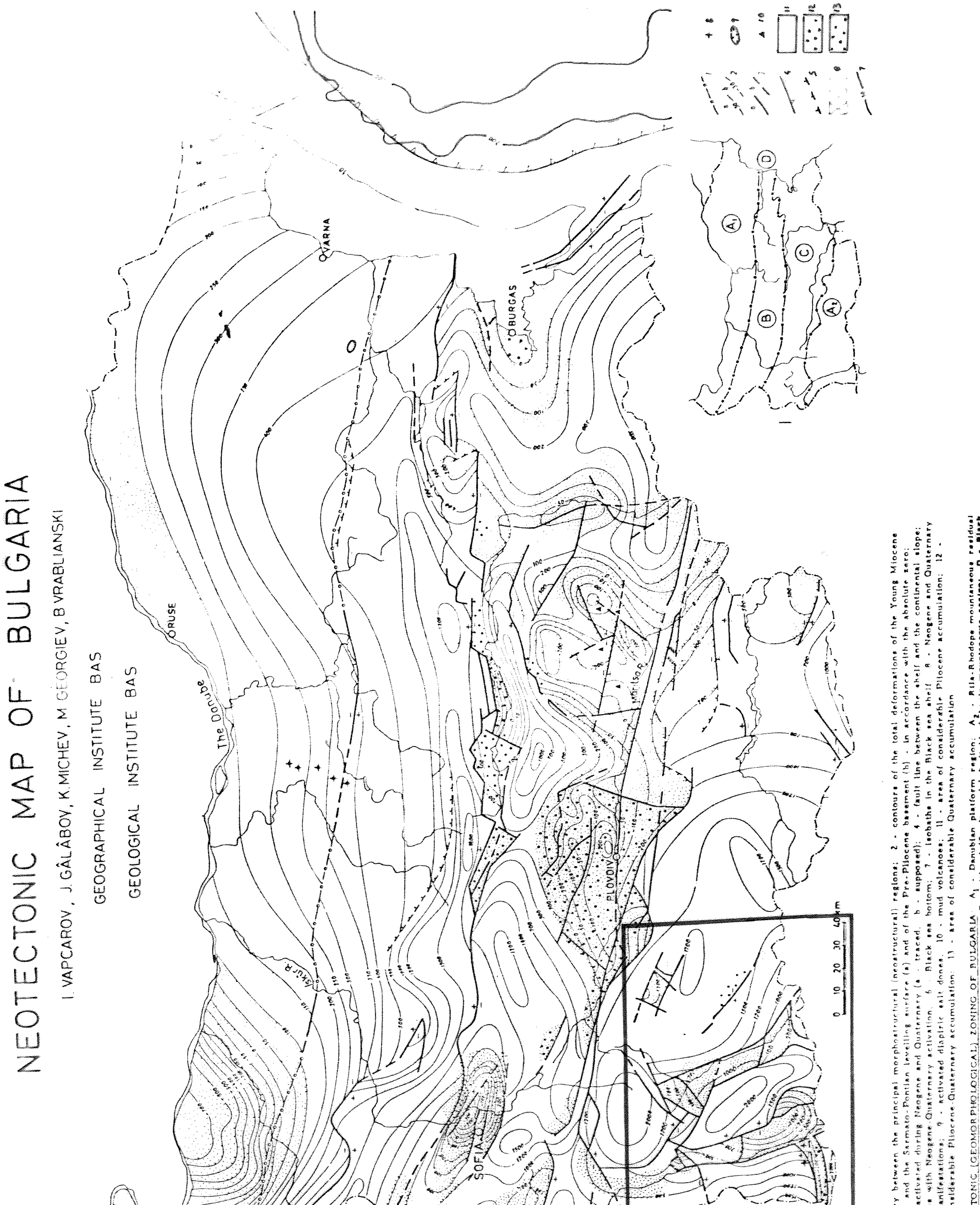


Fig. 2.3 Bulgarian studied area

quaternary sediments of Serres basin, up to the altitude of 500m. Local tectonics and climatic conditions seem to be responsible for this kind of weathering and erosion of the granitic mass of the Vrontou mountains. The Rhodope neotectonic zone is superimposed on the extensive stable fragment of the old Trachian massif and also on the Kraishtides zone subjected to stable uplift a long time before (KARAGJULEVA et al. 1973). Also VRABLIANSKI (1974) by studing the recent vertical movements of the earth´s crust in South-western Bulgaria and especially the Dospat massif in Western Rhodope, worked out a geodetic method by the use of data from the repeated leveling of the state triangulation. In this zone, speeds of 3 to 5,9 mm per year have been found. This is a region of the most intense recent vertical movements (Fig 2.3).

The uplifting region I_a^+ belongs to the main area I^+ . The Pangeon mountain is the main uplifting at the altitude of about 2000 m. The Pieria basin separates the Pangeon mountain from another uplifting area, the Symvolon mountain, at altitude about 700 m. PSILOVIKOS and SYRIDES (1983) studied the stratigraphy, sedimentation and palaeogeography of the eastern side of the Strymon river.

The uplifting region II^+ includes a part of the Bulgarian Serbomacedonian massif, a part of the Yugoslavian Serbomacedonian massif and a part of the Southern Bulgarian Kraishtides zone. The Bulgarian part comprises the Ograzden-Maleshevska area at the altitude of about 1200-1500 m (VRABLIANSKI 1973, VARCAROV 1973). This zone has rather moderate recent vertical movements, expressed in absolute speeds of (+1) to (+3) mm per year (VRABLIANSKI 1973, 1974, CHRISTOV and his colleagues 1973). The Yugoslavian part includes the Malesevska Planina mountain system at an altitude about 1500 m. This region is surrounded by deep and long faults in two different directions. The older ones are oriented north-south, while the newer have east-west directions.

The III^+ area is the mountain range among Yugoslavia, Bulgaria and Greece and belongs to Serbomacedonian massif. This chain of mountain is called Belassitsa in the Northern part and Kerkini mountain in the southern part. The highest altitude is about 2000m and the Belassitsa horst is separated by the Belassitsa fault from the Strumeshnitsa graben. This fault follows the main direction of the Belassitsa mountain, West-east (VRABLIANSKI 1973).

The uplifting area IV^+ includes the mountains Krousia and Vertiskos at the altitude range 1000-1200 m. The same region comprises all the stable horst which is extended from Axios valley to Strymon basin (West-east) and from Kerkini valley to Mygdonia valley (North-south). The area has the orientation of the general direction of the Serbomacedonian lineament. The IV_a^+ region is the same region but is separated by the main area with a small subsidence area E(Fig 2.1).The Kerdilion mountain is the predominant uplifting in this area at the altitude of about 1000m. The region belongs to the Serbomacedonian massif.

In the Mygdonia basin, there is a small uplifting V^+ between the villages Langadikia, Nea Appolonia and Zagliverion. This uplifting area is South of the Lagadas and Volvi lakes and it is surrounded by depressions of the Mygdonian basin. The altitudes of this uplifting is about 600 m. The region is surrounded by faults and is characterized in general by intense activity.

The Stratoniko mountain at the altitude of about 1000 m belongs to the VI^+ uplifting area. This region includes the North-eastern part of Chalkidiki and the Eastern part of Thessaloniki region, and it belongs to the Serbomacedonian massif. It is meaningful to note that the Hierissos high seismicity area is included in this region (MARAVELAKIS 1933 ,PSILOVIKOS 1984).

The uplifting area VII^+ is a parallel "belt" to the main direction of the Serbomacedonian massif and belongs to Circum Rhodope massif and Vardar Axios zone. It is extended in North-western to South-eastern direction.It comprises the Chortiatis-Cholomon mountain chain at the altitude range 1100-1200m. This uplifting area is included in the Thessaloniki territory. From lithological point of view, the ophiolitic sequence is a main characteristic. Many lithological and geophysical studies have been performed by several investigators (MAKRIS 1977,SAPOUNTZIS 1979, KIRIAKIDIS 1984). SAPOUNTZIS (1979) defined four occurrence of gabbroic rocks accompanied by ultramafic members from the Axios-Vardar zone in the area of Thessaloniki and Chalkidiki peninsula and he applied the K-Ar method to conclude that these basic and ultrabasic rocks are Mesozoic in age.

The Athos peninsula is set a $VIII^+$ uplifting area. It belongs to the Serbomacedonian massif and shows the highest altitude about 2000 m in the Northern part of Greece. The predominant mountain is the Athos at altitude 2030m.

The Sithonia peninsula is the IX$^+$ studied uplifting region. It is surrounded by faults without very high mountains .The highest altitude is about 800m .This peninsula belongs to the Circum Rhodope zone, except for its last end which belongs to the Vardar-Axios zone.

The third peninsula of Chalkidiki territory, Kassandra, is also an uplifting region at the low altitude of about 250m. This area belongs to the Vardar-Axios zone and is the X$^+$ uplifting area.

In the same Vardar-Axios zone belongs the uplifting region XI$^+$, which is shown as an area with an uplifting movement up to 100-500 m during Quaternary (BORNOVAS 1973). The geological setting of this region is neogene deposits.

An extensive uplifting region is the XII$^+$ one which includes the Kozuf mountain in the Southern Yugoslavia and Paikon mountain in the Northern Greece. The uplifting belongs to the Vardar-Axios zone with high altitudes. The Paikon mountain has a high altitude up to 1600-1650 m. The Kozuf mountain is higher than 2150-2170 m. There is a high altitude defference between the altitudes of the Paikon and Kozuf mountains and the Aredea basin. This fact is very characteristic of the intense vertical movements in the Vardar-Axios zones. (ARSOVSKI 1973).

The uplifting area XIII$^+$ can be assumed as a continuity of the previous region XII$^+$, but the narrow basin of the Vardar-Axios river separates them into two individual uplifting parts. The region XIII$^+$ mainly includes the Gradeska mountain-range at the altitude of about 1150m.

The Plackovica mountain is the last uplifting region XIV$^+$. This is surrounded by deep valleys, Kocansko Pole, Northwards, Ovce Pole North-westwards and Radovisko Pole, Southwards. The difference between the big altitudes on the Plackovica mountain and the basins presupposes intense vertical movements. This region belongs to the Vardar-Axios zone.

2.1.2 Subsidence Morphostructures

The first area of subsidence, A, can be divided into two subsections, the A-1,which includes the main Greek Strymon valley extended up to the Kerkini-Belassitsa mountain, and the A-2 is a narrow valley surrounded by the Kerkini-Belassitsa and Krousia mountains and the Doirani lake. The A-1 subsidence area is extended all over the Strymon valley from the Kerkini mountain, northwards, to the Strymon gulf, southwards. It has a very low altitude about 0-75 m, and is covered by alluvian deposits. The A-2 triangular area covers a small place Eastwards of the Doiran lake, and it has the altitude about 0-150 m. Similar alluvian deposits cover the region. All the area belongs to the Serbomacedonian massif.

The B subsidence area has a main direction North-South,following the main lines of the tectonic activation of the Earth´s crust (VRABLIANSKI 1974a).This region is known as Struma graben and its altitude is about 75-150 m with considerable accumulation of Pliocene molasses. The Struma graben has a triangular shape with its vertex on the Kresna territory and its base, Southwards, on the Belassitsa-Kerkini mountain .VRABLIANSKI (1973), considering the recent vertical movement in South-western Bulgaria,gave a complex profile of the recent vertical tectonic movements (Fig 2.4).The big difference at altitudes between Struma graben and surrounding mountain (Pirin-Ograzden) implies intense vertical movements.

The graben C can be divided in two sub-grabens, C-1 and C-2 which belong in the Serbomacedonian massif and a part in the Kraishtides zone. The subsidence area C-1 is determined by the parallel orientated narrow zone to the Belassitsa-Kerkini mountain. It is extended from the subsidence area B in Bulgaria territory to the Strumeshnitsa basin in Yugoslavia land. The basin is characterized as Strumeshnitsa graben and it is separated from the surrounded upliftings by two long overthrusted faults. It has the altitude about 150-300 m and it is covered by quaternary deposits. The Radovisko valley is the graben C-2 as a continuity of the previous C-1 . It is covered by quaternary deposits and its altitude of about 150-300 m.This depression presents terrain which is characterized by contemporary geological processes (ARSOVSKI et al. 1975).

The depression D is the well-known basin of the Lagada and Volvi lakes, which is called Mygdonia valley.PSILOVIKOS (1977) studied the paleogeographic evolution of this valley, taking into account many elements. This researcher, considering the morpho - structural features of the area, determined that he Mygdonia valley is the deepest part of a wide basin named "Promygdonian basin" that also comprises the Zagliverion and Marathousa valleys.

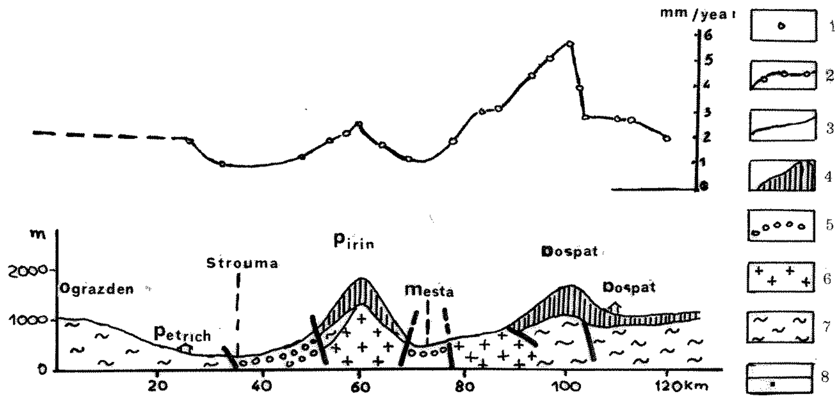


Fig. 2.4 Complex profile of the recent vertical movements in S-W Bulgaria (VRABLIANSKI 1974)

Geodetic data 1 Geodetic signs with repeated measurments in the altitudes for the 1930-1956 period; 2 Curve of the speeds of the levelling verticaltectonic movements in mm per year, according to the data from the repeated alignment of the Central Geodetic Laboratory the Bulgarian Academy of Sciences. Geomorphological data: 3- Profile of the repeated levelling. 4-Profile of the relief along the line of the repeated levelling. Geological data: 5- Neogene-quaternary deposits ; 6- Granitoids; 7- Pre-Cambrian rocks; 8- Fault stuctures. Aligment line Petrich-Gotse Delchev-Dospat.

Geotectonically, the basin belongs to the border of two geological zones, of the Serbomacedonian massif and of Axios-Vardar zone. The main geological characters are gneiss, phyllites and various granitic intrusions. The Mygdonia is a rift valley divided by a ridge of the basement into the smaller rift-valleys . Studing this valley from tectonic viewpoint, the high seismicity and active faults are apparent. The last strong earthquake in this place, occurred in 1978 creating a big fault and a great number of fractures. The hot-mineral springs in the valleys depend on the tectonic activity in the whole Mygdonia valley. The sediments that are deposited in the valley of Mygdonia can be distignuisted in two systems called the Promygdonian and the Mygdonian . A comparative study of the evolution of the Mygdonia valley with other great valleys of Macedonia reveals that from the Middle Paleogene the whole area passed through a series of block-faulting (PSILOVIKOS 1977,PSILOVIKOS and SOTIRIADIS 1982).

This region is divided into three subzones which are called D-1,D-2 and D-3. The above subsidence regions surround the uplifting area V^{+} from three sides. The D-1 area is the valley which surrounds the Lagada lake. Its altitude is about 75-250 m, and its main orientation is NW-SE (N 50° W). The D-2 region is the next valley with direction E-W (long axis) and contains the Volvi lake. Its altitude is about 75-100 m and it is covered by alluvian deposits (Fig 2.5).The D-3 region includes the Zagliveri and Marathousa areas with orientation NW-SE and from the Zagliveri site changes direction in SW-N, surrounding the low uplifting area V^{+} at the altitude of about 300 m.

PSILOVIKOS and SOTIRIADIS (1982) included the Vromolimnes area, the graben E, in the Mygdonian system. We separately considered this subsidence area which is surrounded by small faults. Its altitude is about 300 m and is situated among the Vertiskos(1100m) Kerdilion (1100m) and Besikion (650m) mountains.

The subsidence area F is located southwards of Thessaloniki territory and it is surrounded by the Hortiatis-Cholomon mountain range (1200m) N-SE and the low uplifting (540 m) southwards.Its altitude range is about zero near the sea up to 300m in the inner part of valley. The alluvian deposits are the main geological characters. It is comprised to the Vardar-Axios zone.

The valley G is a very extensive area W-SW of Thessaloniki territory. It is well-known as Thessaloniki-Giannitsa basin and its altitude is about (0-75m). This is extended up to the Vermion, Paikon and Pieria mountains and is included in Vardar-Axios zone.

The subsidence area G is continued Northwards till the Southern part of Yugoslavia , in Gevgelia and Valandovo territory. The Vardar-Axios river passes through this basin which is very narrow in Yugoslavia,and in Valandovo basin and wider in the Greek

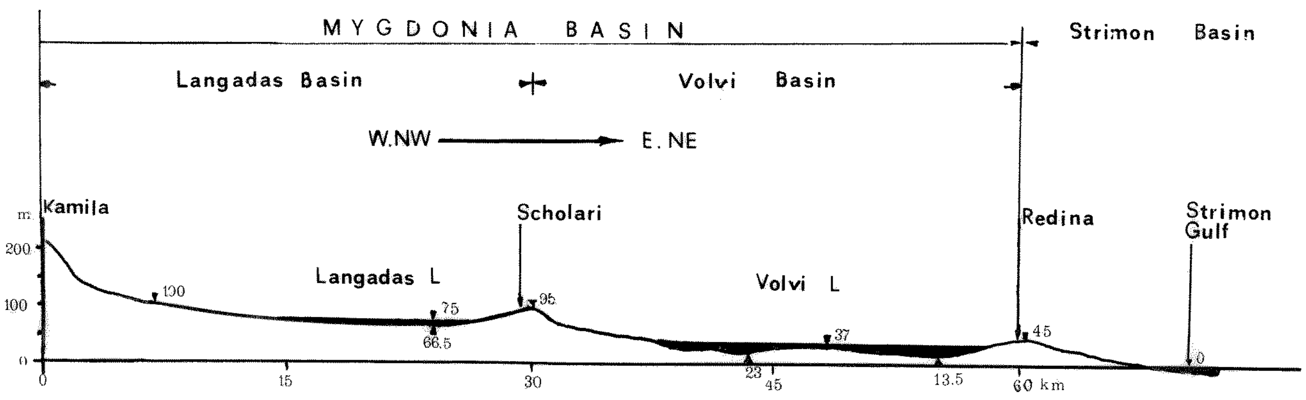


Fig. 2.5 Profile along the big axis of the Mygdonia Basin (PSILOVIKOS 1977)

region. The southern part of this valley has a low altitude, 0-100m, and near the Greek - Yugoslavian border is shown at the altitude 350 m. The valley is covered by alluvian deposits. The northern Yugoslavian part has the same altitude. The Valandovo-Gevgelia depression is separated and represents the youngest structures subjected to subsidence and deposited by Quaternary sediments ARSOVSKI (1975). The Valandovo basin shows high differences with the surrounded upliftings which denotes the intense vertical movements. A result of this condition is the high seismicity.

The subsidence area K is divided into two basins the K-1 and K-2 which are separated by a transverse fault. Pleistocene deposits are the main formations in the area, at the altitude of about 150-300 m.This valley is located between the Gradeska and Plackovica mountains. It belongs to the Vardar-Axios zone and it has the same orientation with the main direction of the zone.

The basin L is bounded by a number of transverse faults with the long axis of the basin in the same direction. It is covered by Quaternary deposits, at an altitude of about 300-450 m. The Plackovica mountain and the basin L represent very different altitudes, meaning intensive vertical movements.

The last studied subsidence valley M is between the Pangeon and Symvolon mountains. It has triangular shape with the vertex in inner part and the base near the sea . The alluvian deposits are the main characteristics of the valley. Two faults divide the Pangeon mountain (1950 m) and the Symvolon mountain (700m) with the valley causing very high differences at the altitude . The basin is the connection of the Drama extensive valley and the coastal valley on the Strymon gulf.

2.2 Determination and Classification of the Neotectonic Faults

It is well-known that there is a relation between geological structures and the neotectonic processes which are followed by the recent vertical movements. In the texts 2.1.1 and 2.1.2 we distinguished various morphostructural elements as uplifting and subsiding blocks. Their physical boundaries are the faults along which occur differential movements . Based on the lenght, the direction(longitudinal,transverse), reactivation or not, and the relations to the gradient of vertical movements of the neotectonic processes , the faults are classified into three categories, F_L^1 , F_L^2 , F_L^3 for the first second and third order longitudinal faults and F_T^1 , F_T^2 , F_T^3 for the corresponding transverse faults.

The lenght of faults is very important geological factor in the determination of activity of the neotectonic units. The long active faults are related to very intense vertical movements and with very strong earthquakes. Many researchers showed the correlation between length of fault and Mangitude of the main shock. (TOCHER 1958, UTSU 1961, BEN-MENAHEM and TOKSÖZ 1963, BONILLA and BUCHANAN 1970 and KARAKAISIS 1984). The significance of the fault length is obvious. The orders of fault length are : ⩾60km, 30-60km and ⩽30km.

The longitudinal faults are divided into three categories according to their lengths and to their morphological features. They might be recently reactivated preneotectonic structure, such as those which are shown in Serbomacedonian massif and Vardar zone. The transverse faults are also distinguished, according to their character, that is, faults which cross two or more structural zones of faults manifested within the zone. These features have some relation to the length and neotectonic activity of the transverse faults (SKOKO et al.1975).

The gradient of the vertical movements for the neotectonic stage is used for the determination of the neotectonic activity, and of the fault displacement. In many cases where the gradient has high value, the corresponding deformations are also large and they have a significant influence on the fault activity (SKOKO et al.1975)

In order to classify the faults, all the above factors are teken into account (Fig 2.6).

The fault which is on the eastern part of Struma valley belongs to the main faulting line called Pirin (VRABLIANSKI 1973). It has an orientation N-SE, following the main direction of the geotectonic lineaments (Kraishtides, Serbomacedonian massif etc). VRABLIANSKI (1974 a) studying the main lines of tectonic activation of the earth's crust in Bulgaria during the Anthropogean, defined the Rose diagram, and for the Kraishtides the main direction is 160°, which coincides wiht the orientation of the fault. Also, this fault is the essential boundary between Pirin Planina (I^+) mountain (about 2500-3000 m) and Struma valley (B) (about -1500 m) crossing neotectonic formations.

The fault lenght is about 80 km.The fault is defined as first order fault $-F_L^1$.

On the other side of the Struma graben there is the Struma fault in the boundary of the graben(B) and the uplifting area II^+ of Ograzden-Maleshevska. The Struma fault follows the synonymous river up to the Northern part of the Greek-Bulgarian territory.It crosses the long transversal fault along the Kerkini mountain.The total length of the Struma fault is about 60 km. As the previous one, it is the main boundary between uplifting area(II^+) and Struma graben (B) which have very high altitude differences. This fault belongs to the first order $-F_L^1$. Both of them are longitudinal old-faults which are reactivated during the recent time and are associated with strong Earthquakes of the Kresna territory (M=7.7, 1904). Near the Struma fault, Neogene and Quaternary volcanic manifestations are observed (VAPCAROV et al.1973).

The Ograzden-Maleshevska uplifting area is separated from the Struma graben by a longitudinal fault about 30 km. Intense vertical movements are manifested in the region with very big altitude differences. This fault is connected with the strong earthquake of Kresna area. The fault is defined as second order $-F_L^2$.

A number of transverse faults are observed in the Kresna area. A very long transverse fault about 60 km is extended from Yugoslavia to Bulgaria crossing the previous two longitudinal (Pirin and Struma) faults. This fault crosses two geotectonic zones, the Serbomacedonian and Vardar Axios zones. The fault is determined as F_T^1 .

In the same direction, there are two faults with lengths of about 10-20 km and an E-W orientation . These cross the longitudinal faults in the Kresna territory and are of the F_T^2 order.

The fault with orientation NE-SW which passes through the Kresna region, cross the two geotectonical units, the Serbomacedonian and Vardar-Axios zones. It has a lenght of about 65 km and is determined by F_T^1 order. This neotectonic fault is cleary manifested in the Bulgaria territory, while is slightly manifested in Yugoslavia territory.

The longitudinal fault, along the Yugoslavian-Bulgarian border and with orientation N-SE, has length of about 60 km. It follows the main direction of the geotectonic lineaments (Serbomacedonian massif).It belongs to F_L^2 order.

The subsidence area L is surrounded by two transverse faults

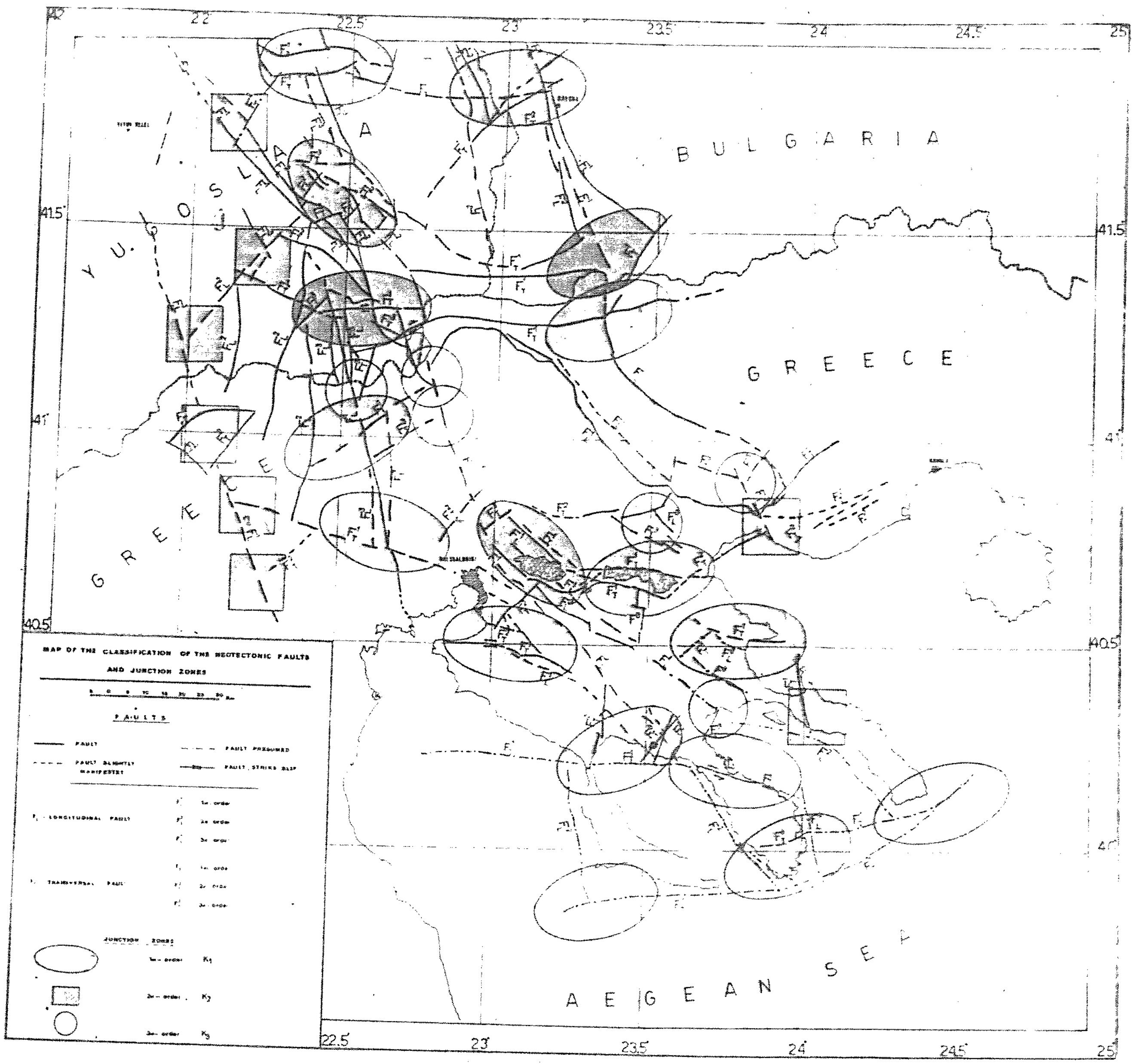


Fig. 2.6 Map of the classified neotectonic faults and of tectonic junction zones.

from North and South. These faults cross the Vardar-Axios zone and Serbomacedonian massif and have length of about 40 km.The adjacent Plackovica mountain has an altitude of about 1750m, which denotes very intense vertical neotectonic movements in the area. They belong to F_T^1 -order.

Southwards of the subsidence area L two old longitudinal faults are shown. Their orientation is NW-SE as the general direction of the lineament. The fault lengths are about 25km and belong to the F_L^3 -order. From the same side of the L area a transverse fault of the orientation NE-SW is observed crossing another system of faults. Its length is about 30 km and it is defined by F_T^2 -order. This fault is crossed by two longitudinal faults, which are at parallel position, creating the subsidense area K . The first one, is an overthrusted fault with orientation NW-SE while the other is one of the longitudinal faults of the Vardar-Axios zone. The overthrhsted fault is extended about 30 km and it belongs to F_L^2 -order. While the second one has a length about 100 km extended till the Yugoslavia-Greek border and is of F_L^1 -order.

The two longitudinal faults are crossed by a small transverse faults, about 15 km, creating two subsidence areas K_1 and K_2 . This transverse fault is determined as F_T^3 -order.

The Strumeshnitsa graben is a very extensive subsidence area from the Radovich of the Yugoslavian territory to the Struma graben in Bulgaria (C-1,C-2-studied areas) The Strumeshnitsa valley is surrounded by the two transverse faults which are overthrusted in the Ograzden-Maleshevska and Belassitsa mountain territories with orientation NW-W-E. They possess a parallel position, showing very big altitude differences with the neighboring mountain ranges. The fault has a length of 70 km and it defines the boundary between Ograzden and the neotectonic Strumeshnitsa graben. It is classified in F_T^1 -order. The Southern part of the Strumeshnitsa valley is bounded by the Strumeshnitsa fault (VRABLIANSKI 1973). This is the neotectonic contact between the Belassitsa mountain and the Strumeshnitsa graben and it has a length of about 80 km from Yugoslavia (Radovich) to the Bulgaria territory in an almost W-E direction. It is classified as fault of F_T^1 -order.

In the Greek-Bulgarian border and at parallel position with the Kerkini-Belassitsa mountain,there is a transverse fault in the W-E direction. Its length is about 85 km crossing two different geotectonic zones, Rhodope and Serbomacedonian massif. This fault possesses the boundary between the uplifted Belassitsa-Kerkini mountain and the subsidence neotectonic graben A-2. The fault along the W-E direction of the Belassitsa Kerkini mountain is an overthrust. This fault is crossed by the old longitudinal Struma fault. Its order is the first, F_T^1 .

A big longitudinal fault following the same direction NW-SE of the geotectonic lineaments (Vardar -Axios zone and Serbomacedonian massif) is observed in the western part of our studied area. The fault length is about 110 km crossing neotectonic structures and simultaneously the Arnea subsidence area. This area is defined by small transverse faults of the F_T^2 order. The longitudinal fault is of F_L^1 order.

At a parallel arrangment with the previous one, there is another longitudinal fault -F_L^1 which is extended from Yugoslavia territory (Valandovo valley) to Greece (Thermaikos gulf). The total fault-lenght is about 100 km. These two faults are extended on the Vardar-Axios zone and are crossed by many transverse faults of various orders.The whole region is covered by alluvian and Neogene-Quaternary deposits.There are no high altitudes, except for the Paikon mountains. It is significant to notice that the second fault is connected with the strong active Valandovo basin. This fault is crossed by a transverse fault of about 35 km with main direction NW-W-E and can be classify as F_T^1 order.

Northwards of the Thessaloniki-Gianitsa valley a transverse fault is shown. The length of the fault is about 75 km and we suppose that has slight manifestation and passes through the Thessaloniki´s city. Seismic activity has been slightly manifested during the recent time.

South-eastwards of the city of Thessaloniki and on the Vardar-Axios zone, a neotectonic transverse fault F_T^2 is shown.This fault crosses some secondary longitudinal faults. It is a very characteristic strike-slipe fault on the neotectonic formations (BORNOVAS 1973,KING 1985 , personal communication).On the whole fault trace some fans are observed, denoting the activity of the fault. Taking into account its short distance from the city of Thessaloniki and the low seismic activity we must pay special attention to this fault.

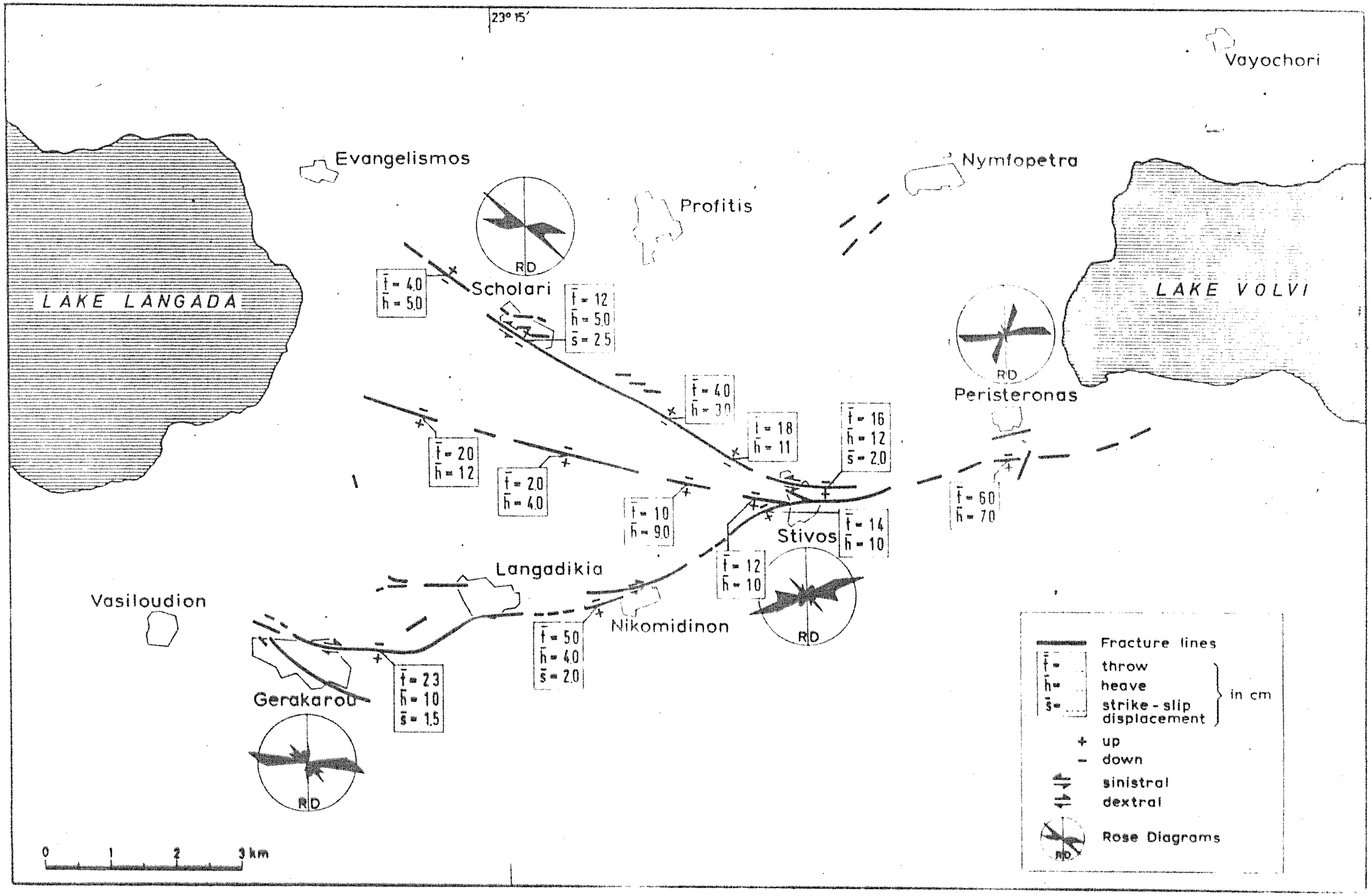


Fig. 2.7 Fracture lines in the epicentral region of the June 20, 1978 earthquake (PAPAZACHOS et al. 1979)

The overthrust between Axios-Vardar zone and Serbomacedonian massif is a very big longitudinal fault with the same direction of the geotectonic lineaments. It is extended from Yugo - slavia to the Chalkidiki region (Kassandra gulf). The total fault length is about 150 km and it shows some secondary longitudinal faults. It is classified as first order F_L^1 because many parts of the fault have been reactivated during strong earthquakes.

The overthrust of the Vardar-Axios to the Serbomacedonian massif is cut by a system of transverse faults which surround the Lagadas and Volvi lake. Many of the faults have been observed during the strong earthquake of the June 20,1978. Surface fractures lines in the epicentral area are observed along the villages Peristeronas and Stivos as well as along Stivos and Scholari (PAPAZACHOS et al.1979) During that earthquake a main fracture trace and two secondary lines were shown (Fig 2.7).A description of these is given. The main fracture with general trend E-W (75°to 100°) had a visible length of 12 km and fracture lines along the Peristeronas-Stivos-Gerakarou villages, cutting alluvian deposits. The second fracture line had a length of 8 km and NW-SE (128°)trend between Stivos and Scholari villages cutting the quaternary deposits.The other fracture line occured between the mentioned two lines on the alluvian deposits, had a NW-SE trend and a length of about 5 km (PAPAZACHOS et al. 1979). Considering the transverse faults from neotectonic point of view, these faults surround the lakes and create basins of a greater valley (Promygdonia).The surrounded upliftings are overthrusted to these valleys, denoting intense vertical movements of the area. The main neotectonic trend of the fault system is NW-W-E continuing to the Strymon gulf. The length of the faults is about 70-80 km and it is classified as F_T^1 -order.

Another transeverse fault with main orientation W-E,North, of the Hierissos gulf, is observed. Its fault length is about 30km but it continues to the sea. It is shown as an overthrust .Another branch of the fault is directed SE to the Hierissos gulf. This fault belongs to the first order F_T^1 faults.

In the Northern part of Athos peninsula a fault with trend N-S is shown. This fault is continued to the sea. The region is characterized by high seismicity. Many strong earthquakes have occurred in this region (1932,1933) and a great mumber of the faults are activated.Its length is about 25km and is clearly manifested on the ground $-F_T^1$.

A longitudinal fault with main direction NW-SE is observed Northwards of the Sithonia gulf. It has a fault-length of about 50 km and on the coast is crossed by a transverse small fault (10 km) of F_T^3 -order.This fault can be classified as F_L^1 -order. In addition, a longitudinal fault (presumed) passing along the Western coast of Athos and having a fault-length of about 55 km can be considered as an extension of the previous one. This fault is F_L^2 -order.

Two long transverse faults North and South of the Kassandra and Sithonia peninsula are shown. The Northen fault passes through the Kassandra channel with main trend W-E and reaches in the Sithonia peninsula. Its total fault-length is about 130 km and cuts two geotectonic zones, the Vardar-Axios and Serbomacedonian. It is classified as F_L^1 -order. The second Southern fault with trend W-E-NE passes along the ends of the peninsulas and crosses the Athos peninsula to the South and another transverse fault which is observed in the Sithonia territory. The first one has length of about 130 km and the other 55 km .Both of them are classified as F_T^1 -order.

The Sithonia peninsula is surrounded West and East by longitudinal faults. The western fault has a length of about 45 km and crosses the three transversal faults which are observed on the Sithonia peninsula. The eastern fault is about 27km crossing the same faults. These faults are manifested on the sea level. The seismic activity is high in the historical and recent time. They are classified as F_L^2 -order.

Finally, we can describe some transverse faults of NE-SW direction. These are overthrusted faults of the Pangeon mountain to the surrounded valleys. The classification of the fault-order is F_T^2 .

2.3 Classification of Junction Zones

Junction zones (tectonic knots) are the zones where the faults cross each other. Classification into three types can be considered. The first type is the simplest form, where two faults cross each other within the geotectonic zone. The second type is where regional faults, manifesting themselves within two or more zones, cross each other in the zones they traverse . The third type is a complex form of faults or faulting zones that cross several structures(SKOKO et al.1975).

Taking into account the fault length, the number of faults, which are crossed in the same position and the neotectonic activity of the faults, an attempt has been made to classify the juction zones. These are classified into three categories:K-1 ,K-2 and K-3 (Fig 2.6) The first category, K-1 , includes the crossings between the first order (F_L^1) longitudinal faults with first order (F_T^1) transverse faults. However, faulting knots between (F_L^2) longitudinal faults with (F_T^1) transverse faults and (F_L^1) longitudinal with (F_T^2) transverse faults are characterized as K-1 junction zones. The crossings between (F_L^2) longitudinal faults with (F_T^2) transverse faults or (F_L^3) longitudinal faults with (F_T^2) transverse faults define the second category K-2 of the junction zones. The last category K-3 are characterized by the crossings between (F_L^3) longitudinal and (F_T^3) transversal faults but there is posibility for existence of K-3 category which is the crossings between (F_L^2) longitudinal fault and (F_T^3) transversal fault.

In any case, the fault-length ,the number of the crossing faults and their neotectonic activity, play a significant role in the classification of the junction zones. Some seismic knots with a great number of very active F_T^3 crossing faults are possibly characterized by K-2 junction zones. The seismic activity of the region is another important factor which will be subsequently considered.

Figure (2.6)shows all the classified junction zones of the studied area.

The Northern part of the Struma valley (B subsidence area) with long faults in various directions (E-W and N-S) of F_L^1 -order and some F_T^2 -order transverse faults, is defined as K-1 junction zone. This region is the well-known Kresna territory with high seismic activity.

Westewards of the previous tectonic knot, there is another K-1 junction zone, combining (F_T^1) transverse faults, crossing two geotectonic zones, and a great number of (F_L^2),(F_L^3) longitudinal neotectonic faults.

In the Southern part of the Struma valley near the Greek-Bylgarian border a K-1 junction zone is created, due to the e-cistence of many (F_L^1) and (F_L^2) longitudinal faults and (F_T^1) transverse overthrusted faults on the two geotectonic zones, on the Serbomacedonian and on the Vardar-Axios.

The Valandovo valley near the Yugoslavia-Greek border with the extensive longitudinal faults of F_L^1 -order, the long tranverse F_T^1 -order faults and a great number of (F_T^2), (F_T^3)-order faults of various directions define a K-1 faulting knot.

Southernwards, in Goumenitsa area, a crossing of two extensive longitudinal faults (F_L^1) with two (F_T^1) and (F_T^3) long transverse faults determine a K-1 junction zone. In the Thessaloniki-Giannitsa valley a crossing of the (F_L^1) longitudinal fault with an extensive (F_T^1) transverse fault, passing through the city of Thessaloniki, creates a K-1 faulting knot. Around the Thessaloniki region, there are three K-1 juction zones. The first, in the Lagadas-Volvi lakes, is determined by an extensive longitudinal fault of F_L^1 -order and some long transverse faults of various orders (F_T^2) and (F_T^3). These junction zones are very active from neotectonic and seismic viewpoint (PSILOVIKOS 1977, PAPAZACHOS 1976). The other is a crossing between the (F_T^1) transverse active neotectonic fault and some longitudinal (F_L^2) and (F_L^3) faults.

The peninsulas of Chalkidiki are surrounded by K-1 junctions. North of the Kassandra and Sithonia peninsula and along the (F_T^1) southern transverse faults, knots of the first category are created.

The K-1 first order junction zone is shown in Arnea valley, including the (F_L^1) longitudinal fault and (F_T^2) transverse fault, and in Hierissos gulf where a complex system of transverse faults (F_T^2) cut a transverse $-F_T^1$ fault. It is important to note that in this region a great number of strong earthquakes occurred during the period 1932-1935.

Some other junction zones of K-2 or K-3 order are shown in the region studied without intense neotectonic or seismic activity.

3. SEISMICITY

3.1 Seismic Characteristics and Seismotectonic Models

The studied in this paper area is located within the Alpine-Mediterranean region. The main morphological feature of tectonic origin of the broader area, from south to north, is the Mediterranean ridge. The Mediterranean ridge is a belt parallel to the Hellenic trench and is due to the compressional stress which is created by the collision of the African and Eurasian slabs,(RABINOWITZ AND RYAN 1970, COMNINAKIS AND PAPAZACHOS 1972, PAPAZACHOS AND COMNINAKIS 1978). The Hellenic arc,which is composed of the outer sedimentary arc and the inner volcanic arc, is separated from the Hellenic trench by the Mediterranean ridge.

The Northern Aegean region is dominated by the characteristic trough of the Northern Aegean sea with maximum water depth of 1500 m. An extension of this trough is probably the Marmara sea. BOCCALETI and his colleagues (1974) based on magmatic evidence,concluded that this trough was active during Jurassic and Cretaseous. Figure (3.1) shows these main morphological features of tectonic origin (PAPAZACHOS 1984). The Hellenic trench,the Alpine folding,the south Aegean trough and the northern Aegean trough are shown. In the same map the isodepth of 150 km of the intermediate focal depth earthquakes which is associated with the southern Aegean volcanic is also shown.

The active tectonics of the region is determined by the direction of the tectonic stress. In order to determine the direction of the geotectonic stress, PAPAZACHOS and his colleagues (1983) estimated the maximum horizontal compression and tension by the earthquake fault plane solutions which occurred in the major Aegean area during the last thirty years. Figure (3.2) shows the horizontal compression by black converged arrows and the horizontal tension by white deverged arrows. The two numbers close to each symbol are the last two digits of the year of the occurrence of the corresponding earthquake. Compressional stress is observed along the Hellenic arc and along the western coasts of Yugoslavia,Albania and Greece (RITSEMA 1974,PAPAZACHOS 1974). The southern and southwestern compressional zones are associated with a well-developed Benioff zone. Another compressional zone is observed on the Benioff zone.

This is the result of the subduction of the African plate under the Eurasiatic plate (COMNINAKIS AND PAPAZACHOS 1976).

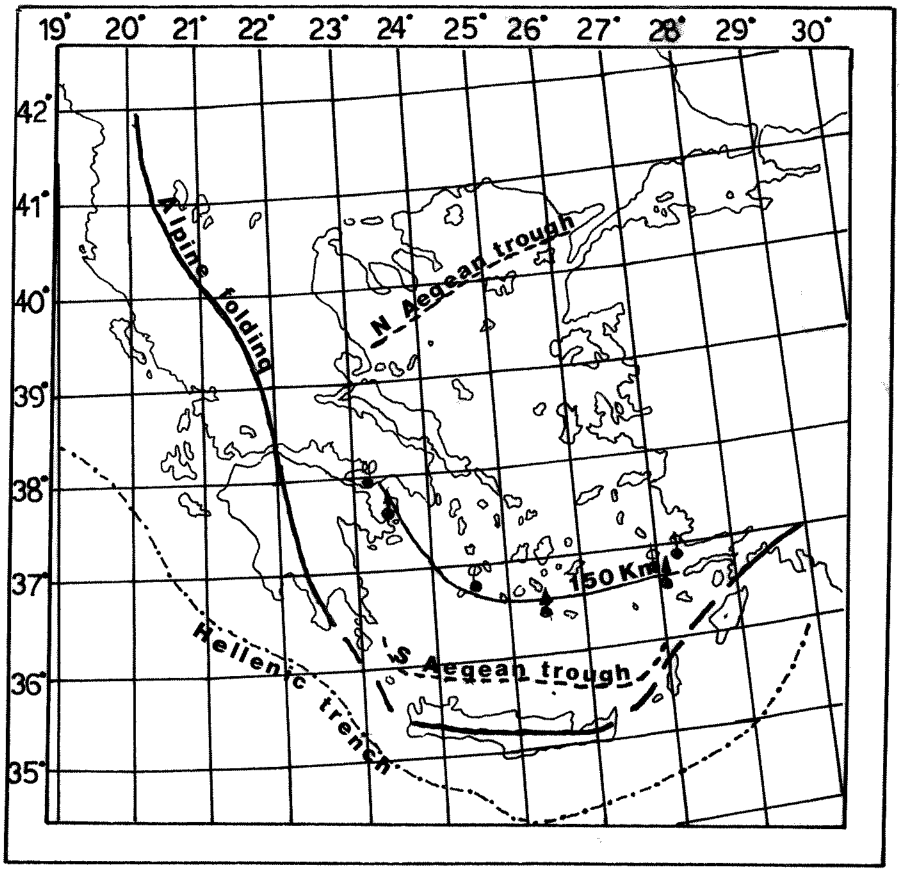


Fig. 3.1 The main features of the Hellenic arc with the isodepth of 150 km. (PAPAZACHOS 1984)

In the inner part of the Hellenic arc horizontal tension stress is mainly observed. Its main direction is N-S and is due to the extension of the Aegean lithosphere along the same orientation. It is significant to note that a second compressional zone is observed in the northern part of Aegean sea. PAPAZACHOS (1974), assumed that this zone is probably the result of interaction between the expanding central Aegean lithosphere to this belt and the Rhodopian block for which evidence exists that moves to this zone too.

An important factor for the seismotectonics and for practical purposes is the knowledge of the main characteristics of the seismic faults (orientation, dip etc) in this area.For the determination of some of these faults, surface fault traces have been considered. The most effective technique for this problem is the determination of the fault plane solutions using records of the first onsets of P waves in various seismological stations (PAPAZACHOS et al. 1984).

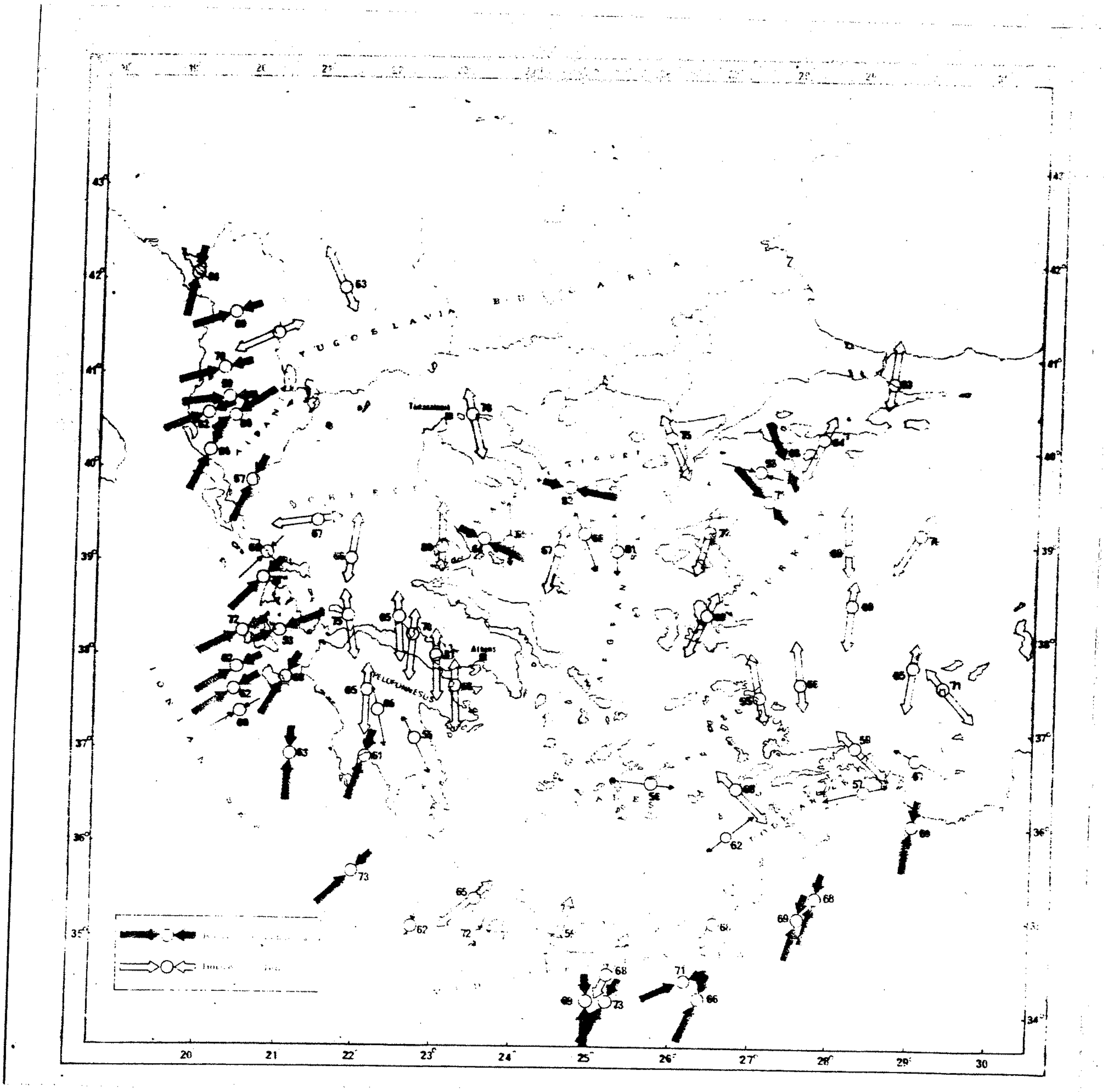


Fig. 3.2 Horizontal compression and tension stress in the Aegean and surrounding area (PAPAZACHOS et al.1983).

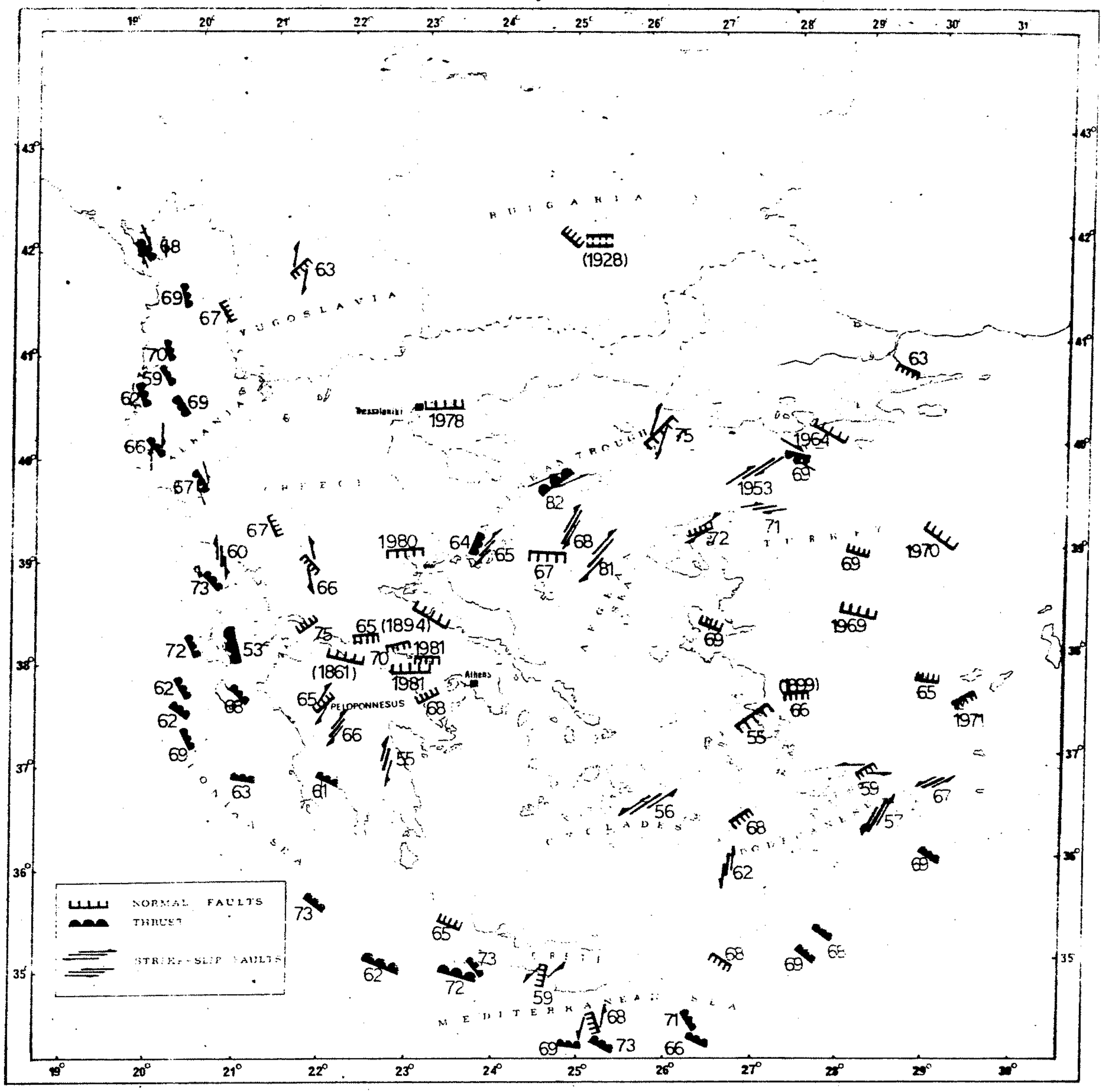


Fig. 3.3 Seismic faults in the Aegean area (PAPAZACHOS et al. 1984)

PAPAZACHOS and his colleagues (1984) considering Mc KENZIE'S (1972,1978) and RITSEMA'S (1974) results for the seismotectonics of the area studied and using the above mentioned method, divided the Aegean and surrounding area in eight sections according to the type of faults and the direction of the slip vector.For the determination of the nodal plane of each fault plane solution, they ..

used many other information relating to surface fault traces, Landsat photos, distribution of aftershock foci,deep tectonics, geological and geomorphological data,etc. Figure (3.3) shows their results.

The main conclusion is that thrust faults follow the outer part of the Hellenic arc. Parallel to this thrust zone,a zone of normal faults is located. In the inner part of the Aegean area, there are strike-slip faults with considerable thrust component.

In this point, it is useful to describe the conditions of the active tectonics of the region studied. It has been mentioned that the active tectonics is due to the convergence of the Lithospheric slabs. The area studied is localized in a region of convergence between the Eurasian and the African plate.Many models about these relative movements have been suggested by a great number of researchers (McKENZIE 1972, RITSEMA 1969,1970, PAPAZACHOS AND COMNINAKIS 1971, ANGELIER 1978, LE PICHON AND ANGELIER 1979).

McKENZIE (1972) suggested a model on the relative movements between several slabs in the Mediterranean sea and the related seismicity in the same area (Fig 3.4) The plates with numbers (5) and (3) show the big Eurasian and African slabs, while the plates (2) and (4) denote small plates called by McKENZIE Aegean plate and Turkish plate, respectively.The plate with number (1) includes the northern and central Greece and the northern part of Aegean sea. These plates are separated by thrust faults and extension zones, which are denoted by thick lines crossed by small normal lines and by double lines, respectively, as well as by transform faults. The fast motion of the (2) and (4) plates is in well accordance for most of the seismic activity in this sea. (McKENZIE 1972).

Considering seismic, geological and geophysical data,RITSEMA (1969,1970) attempted to interpret the active tectonics of this area. He assumed that there are many conditions, apart from the drift of the plates, which contribute to the active tectonics of region. Some of them are the passive gravity sliding and flow of the mantle material in the low velocity layer of the mantle.

PAPAZACHOS (1974) studied the seismicity and tectonic regime of the Eastern Mediterranean area and proposed another model

(Fig 3.5). Based on the distribution of seismic foci in this area, the focal mechanisms of the earthquakes which occured there, the direction of P and T axes of the fault plane solution and the slip direction of the major faults,he interpreted the tectonic character of the region. He divided the region in ten blocks and named them as follows : Adriatic (1), Ionian (2), Valentine (3),Aegean (4), Taurus (5), Wester Turkey (6), Northern Anatolian (7), Saros (8), Olympus (9), and Rhodopean (10). The term "block" is preferred from the term "plate" cause of the limited knowledge about their real motion.

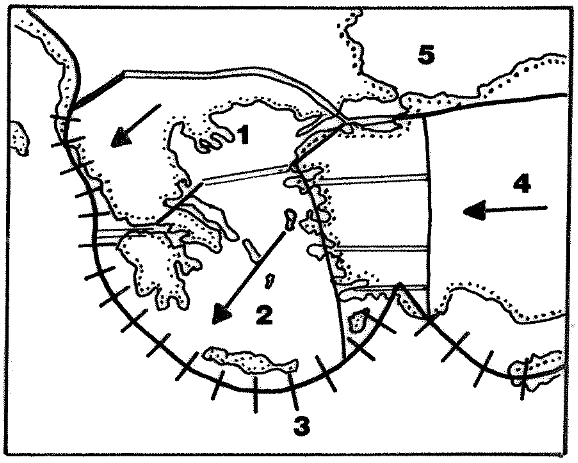


Fig. 3.4 Tectonic boundaries and motions in the Aegean area. (McKENZIE 1972)

Analysing the relative motions of the blocks,PAPAZACHOS (1974) concludes that many of the seismic data cannot be interpreted by these models and that certain geophysical properties of the Hellenic arc do not resemble properties of the Pacific arcs, which means that the tectonics of this region is very complex.

PAPAZACHOS AND COMNINAKIS (1978) tried to interprete the complexity of the geotectonic phenomena of the Aegean and surrounding area and proposed the lithospheric model which is shown in figure (3.6). This figure shows the collision of the Aegean and the Mediterranean lithosphere and the well-known subduction of the Mediterranean under the Aegean lithosphere at a mean angle of about 35° . The main result of the interaction between the two slabs is the creation of the compressional mechanism (thrust faulting) of the shallow earthquakes in the convex side of the Hellenic arc (Fig 3.2).The length of the dipping slab is equal to the respective length of the seismic zone, about 250 km. Taking into consideration that the motion has started 10 million years ago, it is estimated that the mean convergent velocity is 2,5cm/year.

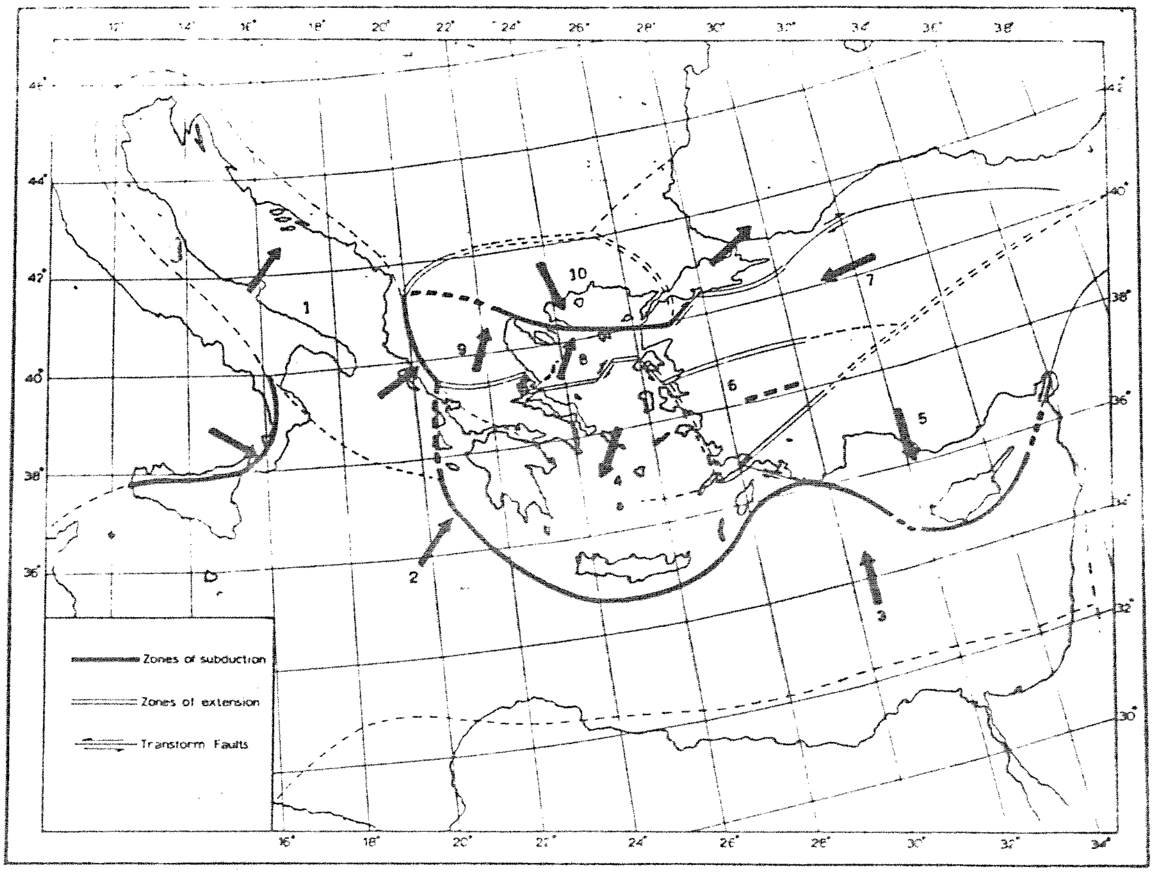


Fig. 3.5 Tectonic features of the Eastern Mediterranean blocks.(PAPAZACHOS 1974)

During the sinking of the Mediterranean slab, in the S-N direction, heat generation along the top surface of the slab and creation of dynamic forces are taking place. For this reason migration of hot material (low Q) in the back-arc southern Aegean asthenosphere occurs. This migration causes currents in the less rigid asthenosphere between the top surface of the Mediterranean slab and the back-arc Aegean lithosphere. The convective cells exert horizontal forces at the bottom of the back - arc southern Aegean lithosphere, breaks it and hot material are intruded into it.The main results are the volcanic activity, high heat flow, magnetic anomalies,modification of the crustal structure, subsidence of the crustal blocks and generation of shallow earthquakes by tensional mechanism. The extensional properties in Northern Aegean sea can be attributed to secondary convection centers such as those expected by the theory suggested by TOKSÖZ (1975).It is important to note that this model interpretes the phenomena of the Southern Aegean in a satisfactory way.

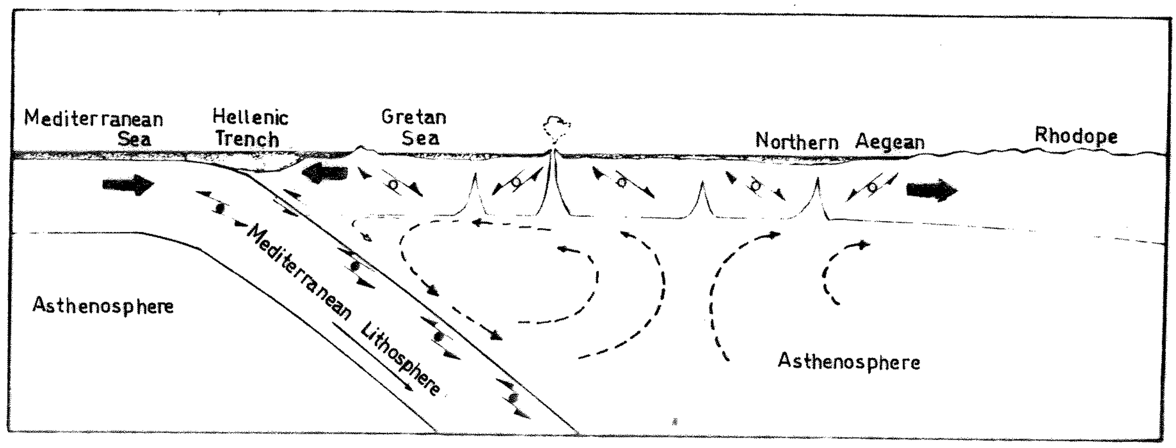


Fig. 3.6 Lithospheric model for the interpretation of the tectonic activity of the Aegean region. (PAPAZACHOS AND COMNINAKIS 1978)

3.2 Distribution of Seismic Foci

COMNINAKIS AND PAPAZACHOS (1982) published a catalogue of earthquakes which occured between 1901 and 1980 in the area limited by the coordinates (31°N-43°N , 18°E - 32°E).

There is also a catalogue of historical earthquakes for the period 479 BC - 1900 AD which was published by the same authors. (PAPAZACHOS AND COMNINAKIS 1982).

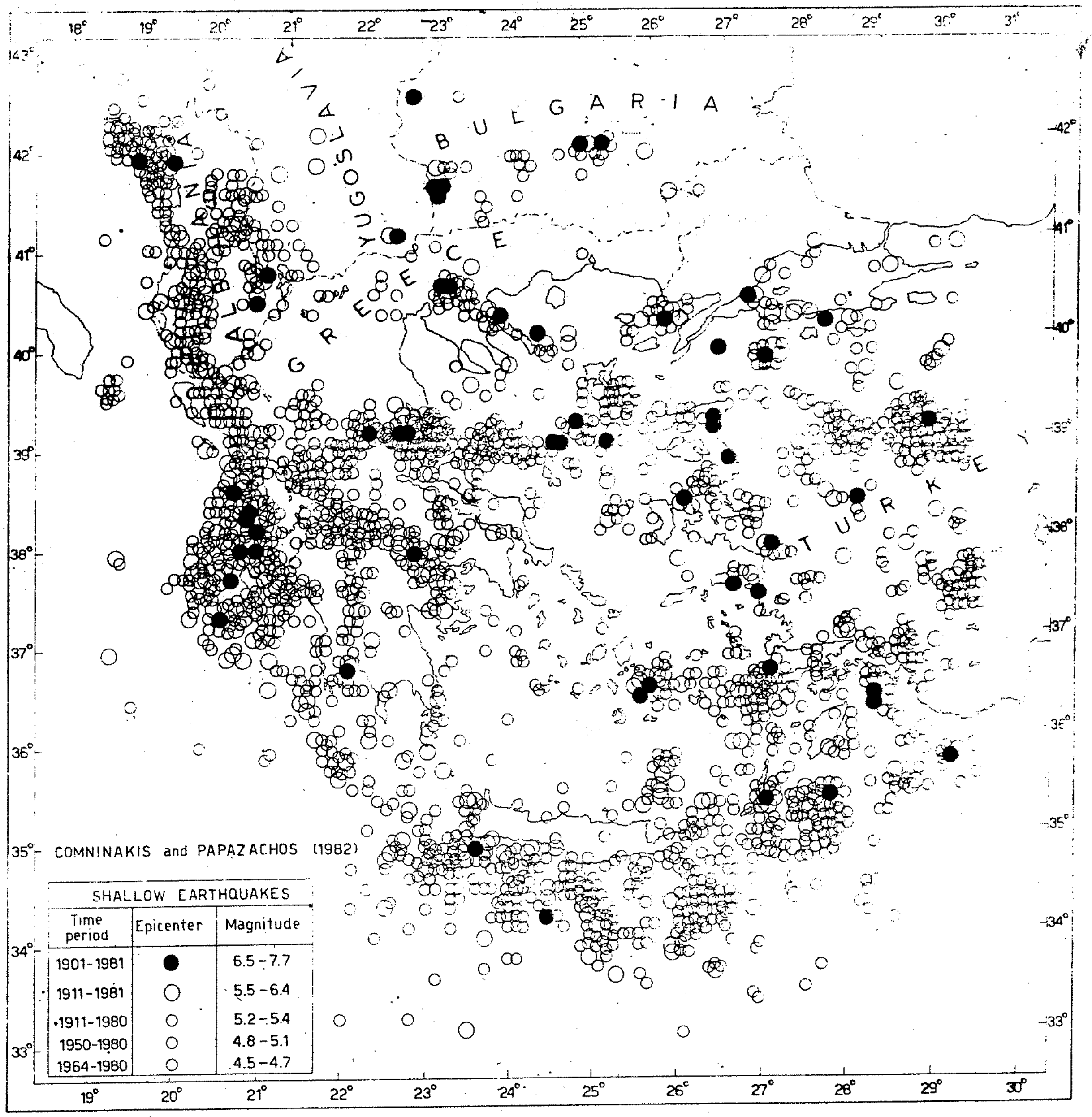


Fig. 3.7 Distribution of the epicenters of the shallow earthquakes in the Aegean and surrounding area (COMNINAKIS AND PAPAZACHOS 1982)

Figure (3.7) shows a map of the epicenters of the shallow shocks in the Aegean sea and surrounding area during the period 1901 - 1980 (COMNINAKIS AND PAPAZACHOS 1982). It is shown

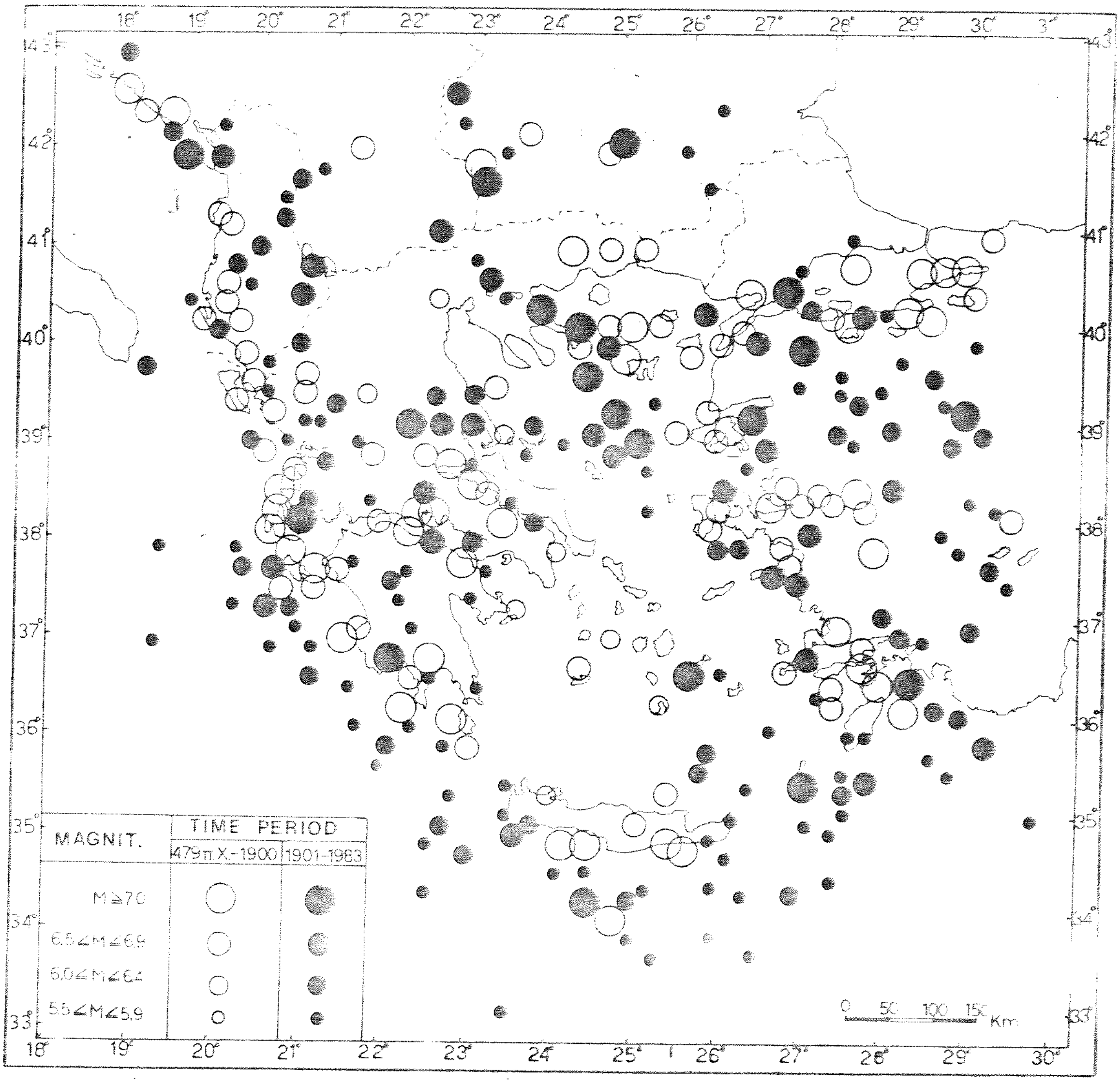


Fig. 3.8 Distribution of observed maximum earthquake magnitudes (h<60 km) for Greece and surrounding area (HATZIDIMITRIOU 1984)

that the epicentral distribution are much scattered, but some concentration of the foci constitute some distinct zones. The maximum concentration is observed along the Hellenic arc up to the SW Turkey. Another important zone is shown in the Northern part of Peloponessus along the Saronikos-Patraikos gulf , while the zone of epicenters which follows the Serbomacedonian massif is very significant for our study. This zone is curved in the Northern Aegean sea and follows the orientation WSW-ENE reaching the northern Anatolian seismic zone.

HATZIDIMITRIOU (1984) using the catalogues of earthquakes of the present century (1901-1980) of COMNINAKIS AND PAPAZACHOS (1982) and the data of the historical earthquakes (479 B.C - 1900A.D) of PAPAZACHOS AND COMNINAKIS (1982) constructed a map of the distribution of the shallow earthquakes with observed maximum earthquake magnitudes (Fig 3.8). The magnitudes were divided into four groups : $M \geq 7.0$, $6.5 \leq M \leq 6.9$, $6.0 \leq M \leq 6.4$, $5.5 \leq M \leq 5.9$ which are figured by circles of various sizes. The historical earthquakes are denoted by white circles, while the earthquakes of the present century are denoted by the black circles.

The distribution of these observed maximum earthquake magnitudes have the same pattern with this one shown in figure(3.7). It`s noteworthy that such a concentration of the observed maximum earthquake magnitudes is observed along the Serbomacedonian massif and especially in the western border to Axios-Vardar zone.

It is well known that intermediate depth earthquakes (60km<h<200km) occur also in the southern part of this area. The spatial distribution of these intermediate focal earthquakes led to important conclusions about the deep-tectonics of area. (COMNINAKIS AND PAPAZACHOS)(1976,1980) have studied the distribution of the epicenters of the earthquakes of intermediate focal depth and drawn the isodepths of 100 km and 150 km (Fig 3.1).It is found by the same researchers that the epicenters of all these earthquakes are associated with the Hellenic arc. PANAGIOTOPOULOS and his colleagues (1984) considered also the problem of the distribution of the intermediate focal earthquakes and used new data for the time period 1977-1984 to find similar results. They used many data similar to the previous ones and in addition they used the data of the period 1977-1984 to check the previous results and to determine more accurately the dip of the Benioff zone in the southern Aegean. They found that the 100 km and 150 km isodepths determined by them were in good agreement with the two isodepths determined by PAPAZACHOS AND COMNINAKIS (1971).

Figure (3.9) shows the distribution of epicenters of all intermediate earthquakes which occured during the period 1964-1984 in this area. Six symbols have been used to denote two ranges of magnitudes (3.5-4.4 , 4.5-6.3) and three ranges of focal depths (70-100 km, 101-130 km, 131-183 km). Figure (3.10) shows the projections of the seismic hypocenters of the intermediate depth earthquakes onto the sections AA´,DD´ and FE´. Thus, by using accurate and homogeneous data for the intermediate focal depth earthquakes, a well defined Benioff zone is defined, which dips from the convex to the concave part of the Hellenic arc. Its shape is amphitheatrical and its angle varies between 32° and 37°.

SCORDILIS (1985) performed a microseismicity study in Serbomacedonian massif and surrounding area. He used the data of the local telemetered seismological network of Thessaloniki.A sample of 700 earthquakes during the time period 1981-1984 was accurately located. He also determined a crustal model for the area and calibration functions to determine the magnitude of local earthquakes.

He presented the distribution of epicenters of the small earthquakes. Figure (3.11) shows the epicentral distribution of the earthquakes for three magnitude ranges ($M < 2.5$,$2.5 < M < 3.5$ and $M \geqslant 3.5$) and figure (3.12) shows distribution of the epicenters for magnitudes $M \geqq 2.1$. This second distribution is correlated with topographical contour lines.

One map of epicenter distribution has been made for the Macedonia territory (for 1900-1970 and $M \geqq 3.5$) by HADZIEVSKI (1973) and one for the Bulgaria territory (for 50 BC-1980 AD and magnitude range 5.0-7.8) during the UNDP-UNDRO project.High concentration of epicenters is observed in both maps in the Kresna region (SW Bulgaria). Figures (3.13) and (3.14) show these maps.

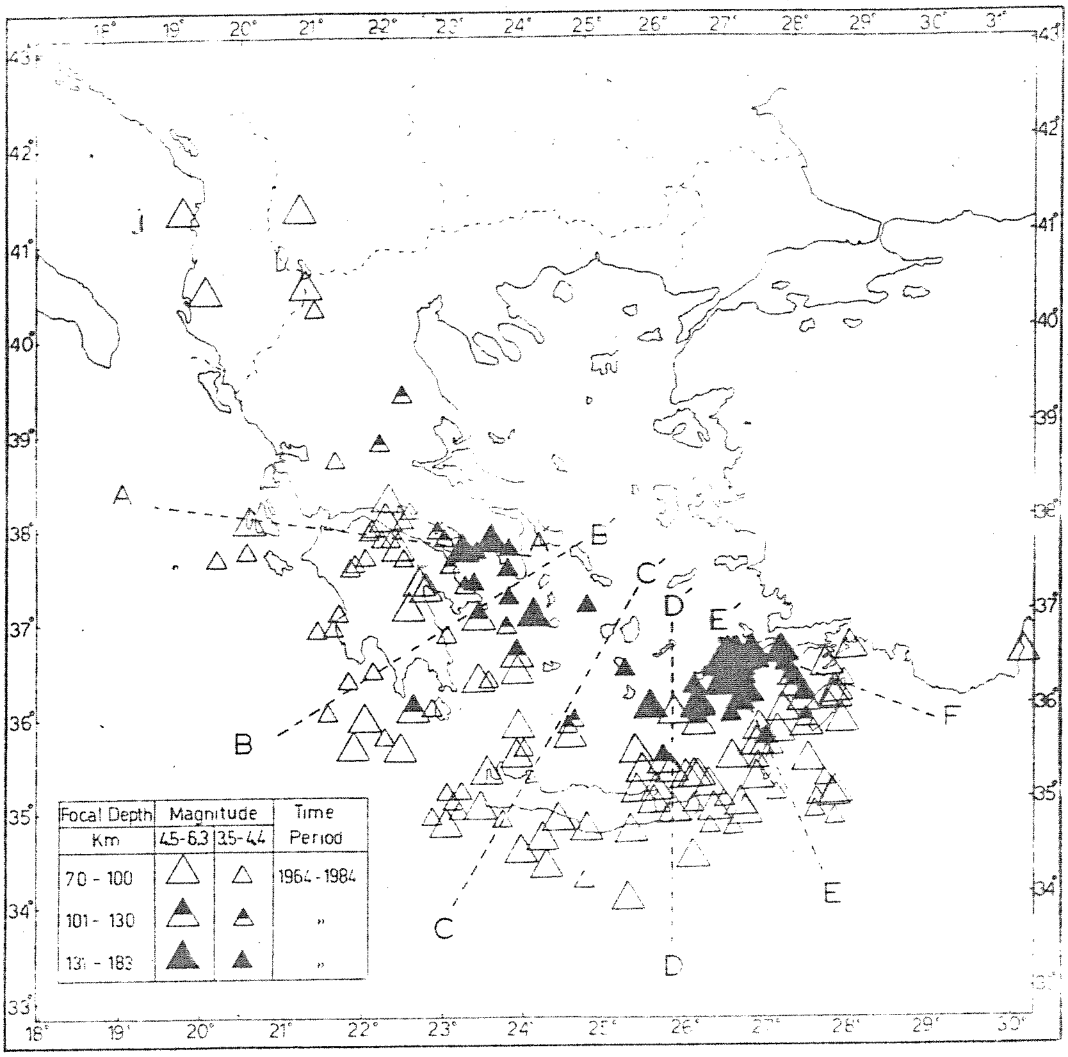


Fig. 3.9 Distribution of the epicenters of intermediate earthquakes (h≧70km) in the Southern Aegean during 1964-1984 (PANAGIOTOPOULOS et al.1984)

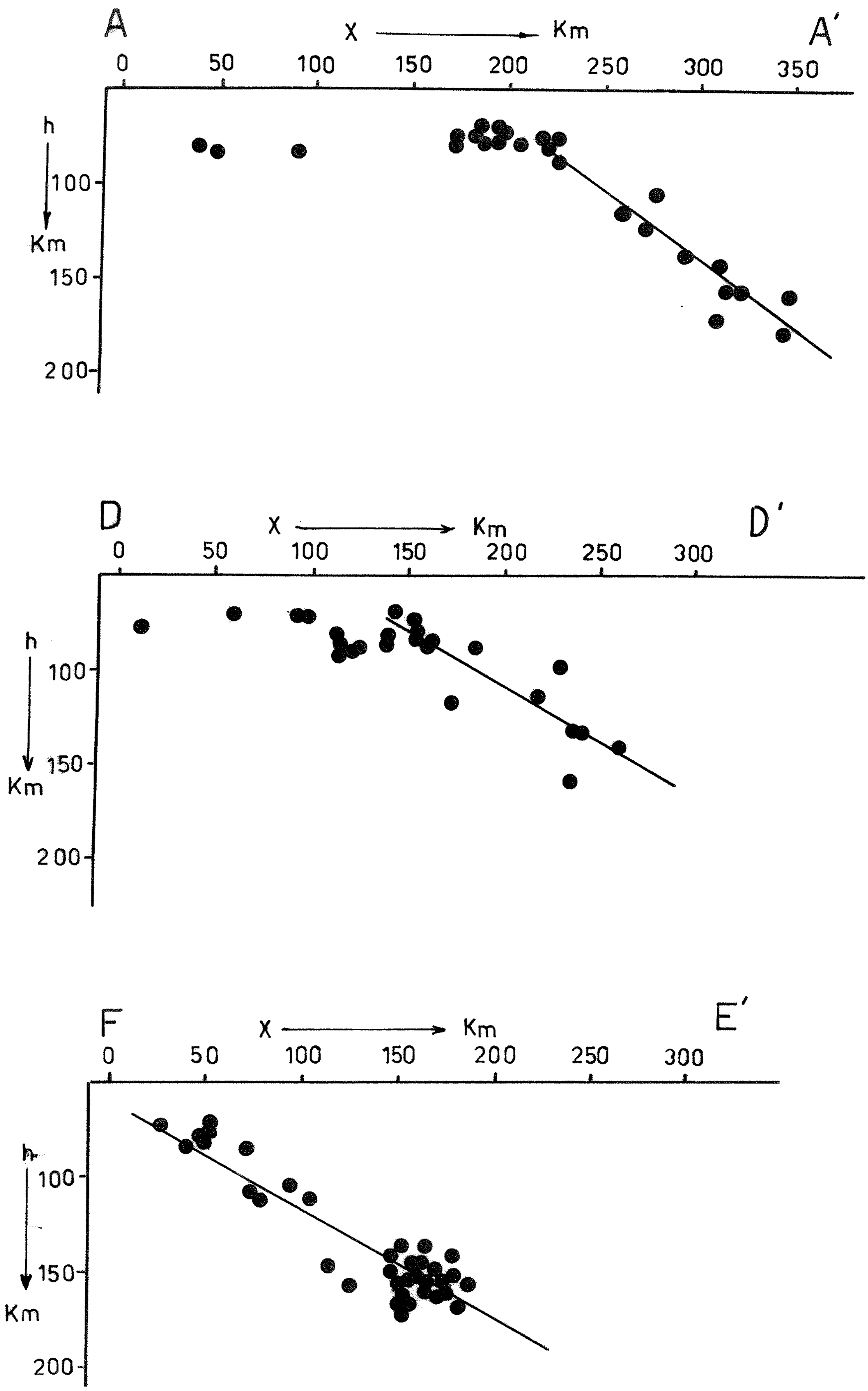


Fig. 3.10 Projection of the hypocenters of the intermediate foci onto the sections AA',DD'and FE'(PANAGIOTOPOULOS et al. 1984)

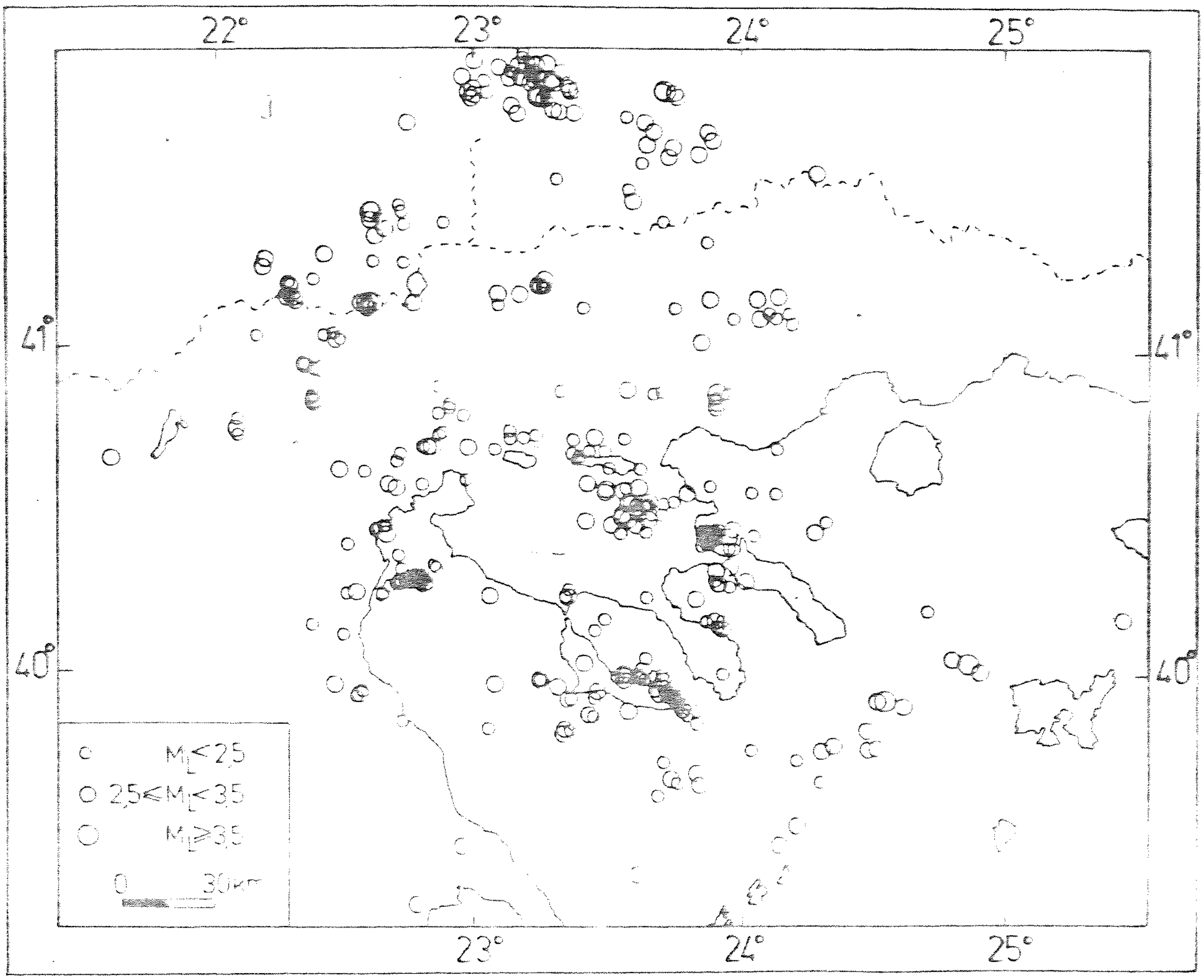


Fig. 3.11 Geographical distribution of epicenters of small shocks in the Serbomacedonian zone (SCORDILIS 1985)

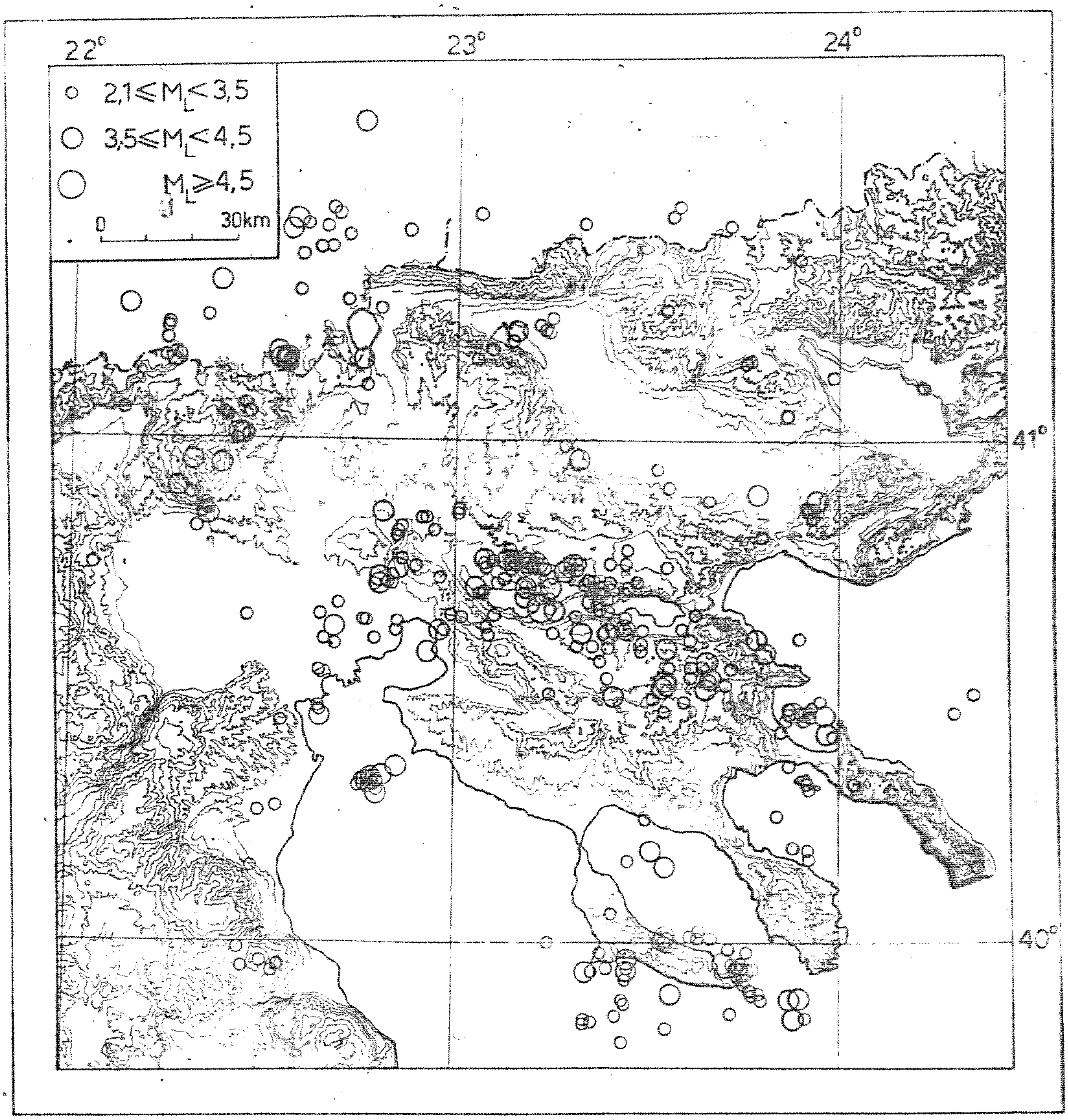


Fig. 3.12 Distribution of epicenters in the Serbo-macedonian zone and topographical contour-lines (SCORDILIS , 1985)

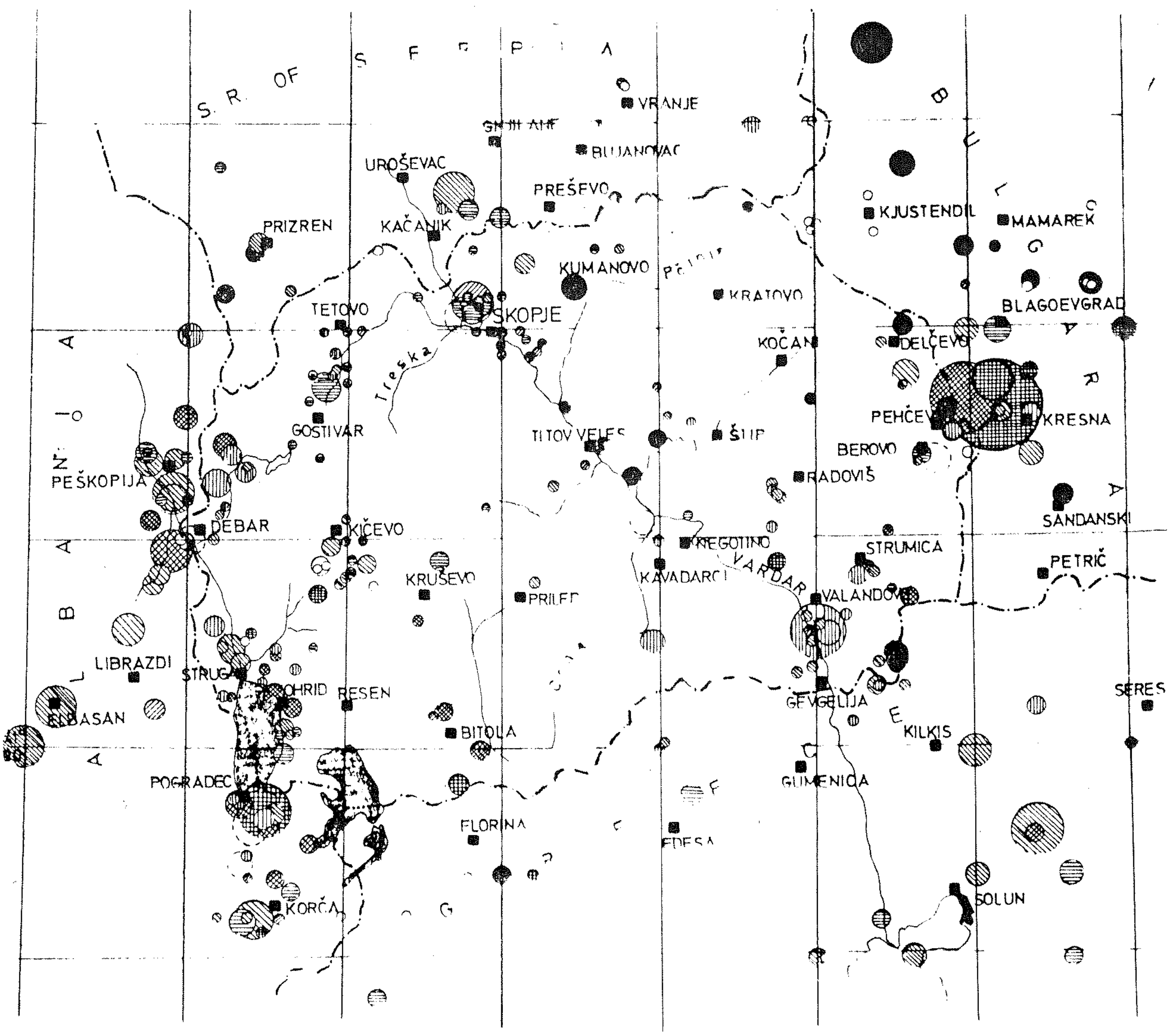


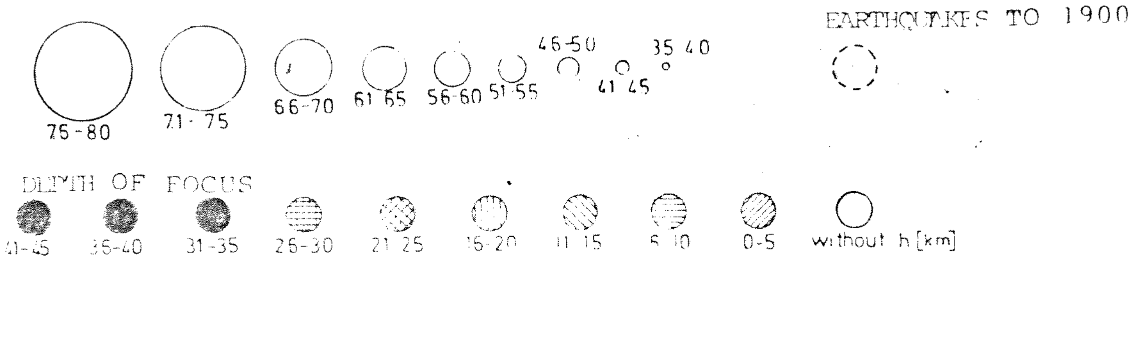
Fig 3.13 —MAP OF EPICENTRES OF MACEDONIA (1900-1970, M ≥ 3.5)

Compiled by: D.HADŽIEVSKI,1973

10 0 10 20 30km

L E G E N D

EPICENTRES OF EARTHQUAKES AND MAGNITUDES



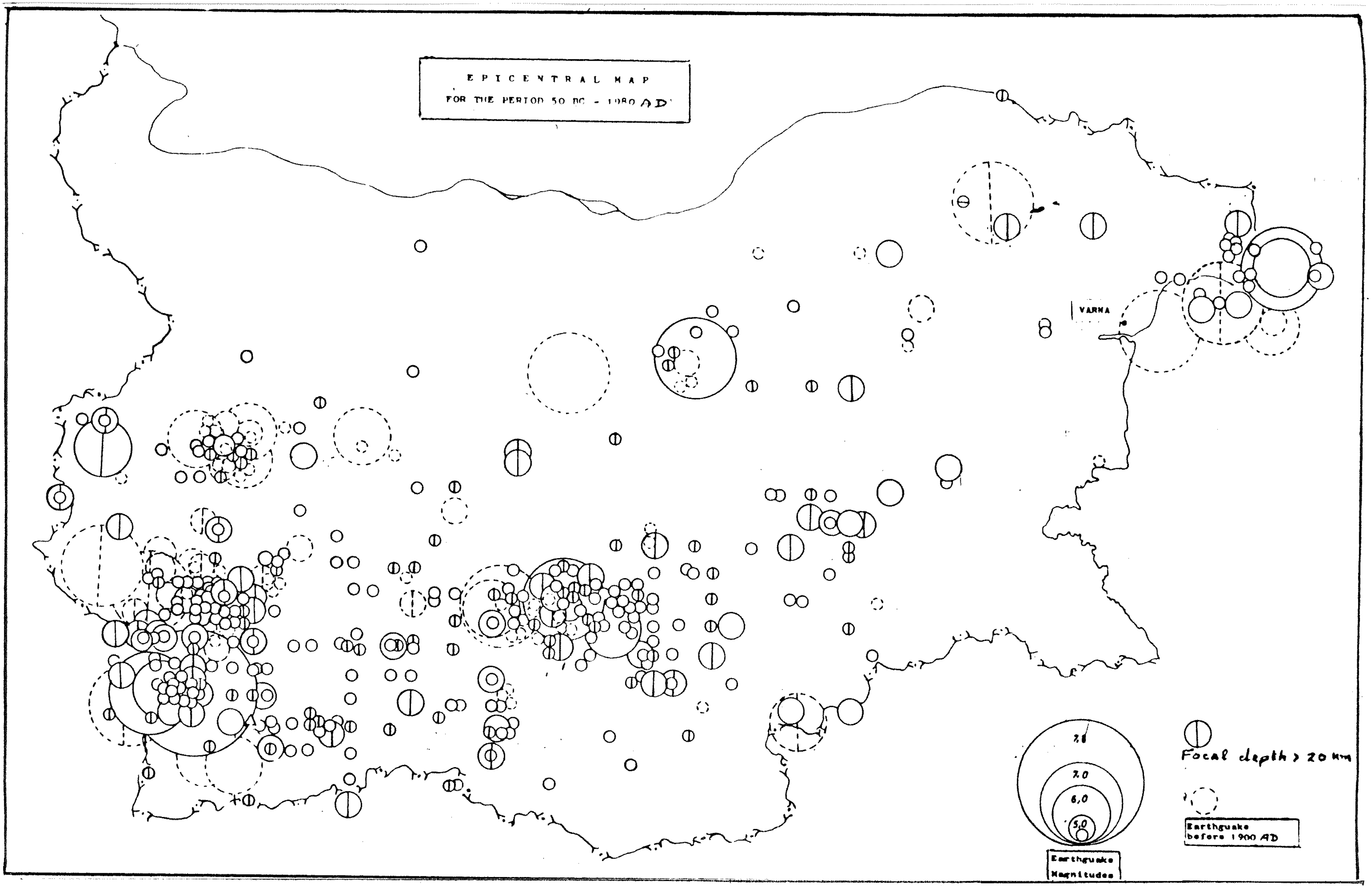


Fig.3.14 Map of earthquake epicenters occured in Bulgaria during the period 50BC-1980 AD (UNDP-UNDRO PROJECT)

3.3 Seismicity of the Region

The exact definition of the seismic activity is no completely determined. Generally, this definition describes the earthquake distribution in space, in time and in magnitude, without considering quantitative determination of the seismic activity. The necessity for a quantitative determination led to the definition of s e i s m i c i t y. This term represents a function of the magnitude and earthquake frequency. Various seismicity measures have been defined ,i.e the energy which is released per time unit and surface unit,etc. It is important to consider the seismicity measures which are related to the parameters a and b of the relation between earthquake frequency and magnitude (GUTENBERG AND RICHTER 1944).

For the present study, the catalogues of the historical data of PAPAZACHOS AND COMNINAKIS (1982) and some information of the catalogue of the UNDP project were used, in addition to the data of the present century given by COMNINAKIS AND PAPAZACHOS (1982).Data from SCORDILIS (1985) were used for the last four years (1981-1984). The epicenters cover the area which is defined by 39,5°N-42.0°N and 21.5°E-25.0°E.From historical data (479 BC-1900 AD), only those of the last century (1801-1900) are complete and only for magnitudes higher than 6.5. The data of present century are complete for the time-period 1901-1945 and for $M \geqq 5.4$, for the period 1950-1963 and for $M \geqq 5.0$,for the period 1964-1980 $M \geqq 4.5$, and for the period 1981-1984 and for $M \geqq 4.0$. The data taken from SCORDILIS´catalogue are represented by M_L magnitude. They were converted to M_S by the use of the KIRATZI AND PAPAZACHOS (1985) relation

$$M_S = M_L + 0.50 \qquad (3.1)$$

where M_S is the surface wave magnitude and M_L is the local magnitude of the earthquake.

The information given in this catalogue have been obtained from the catalogues (historical and present century) which have been published by PAPAZACHOS AND COMNINAKIS(1982). In addition, data which included in the UNDP´s project catalogue (1974) and in SCORDILIS´ PHD thesis catalogue (1985) have been used.

CATALOGUE OF EARTHQUAKES FOR THE REGION DEFINED BY

(39.5 - 42.0 Φ^{o}_{N}, 21.5 - 25.0 λ^{o}_{E})

HISTORICAL EARTHQUAKES

DATE	TIME	Φ	λ	h	M	REGION AND MAX INTEN.
479 B.C		39.7	23.3	n	6.7	Chalkid.(IX Potidaea)
330 B.C		40.0	25.0	n	7.0	Lemnos (XI Chrysi)
52 A.D		41.0	24.3	n	6.5	Kavala (VIII Philip)
518 A.D		42.1	21.4	n	6.9	S.Yugoslavia (X)
896 Mar.		40.6	22.5	n	6.3	Emathia (VIII Verria)
896 Sept.4		41.7	22.9	n	6.5	Bulgaria (IX)
1366 Jun.1		40.2	24.6	n	6.5	Chalkid.(VIII Karyes)
1572 Jun.18		40.2	24.5	n	6.6	Chalkid.(VIII Athos)
1585 Jul.18	02	40.1	24.4	n	6.6	Chalkid.(VIII Athos)
1641 May		42.3	23.7	n	6.9	Bulgaria (IX)
1750 Oct.		42.1	24.8	n	6.7	Bulgaria (IX)
1759 Jun.22		40.7	23.1	n	6.5	Thess (VIII)
1765 Mar.21		40.2	24.7	n	6.6	Chalkid.(VII Athos)
1781 Aug.28		39.6	22.5	n	6.3	Larissa (VIII)
1797 Mar.		40.3	24.8	n	6.6	Chalkid.(VI Athos)
1829 Apr.13		41.1	24.8	n	6.7	Xanthi (X)
1829 May.5	09	41.1	24.3	n	7.3	Drama (XI)
1866 Dec.6	16:25	42.0	23.0	n	7.0	Bulgaria(VII Sofia)
1887 May 14	05:30	40.1	24.9	n	6.7	Lemnos (VII)

1901 - 1949 M≧5.4

DATE	TIME	Φ	λ	h	M	REGION AND MAX INTEN.
1902 Jul.5	14:56:30	40.8	23.1	n	6.6	Thes.(IX Assiros)
1903 Nov.25	23:16:42	42.1	23.2	n	5.6	S Bulgaria (VIII)
1904 Apr.4	10:02:34	41.8	23.0	n	7.1	S Bulgaria (IX)
1904 Apr.4	10:25:55	41.8	23.1	n	7.7	S Bulgaria (X)
1904 Apr.4	10:30:30	42.1	23.4	n	5.5	S Bulgaria (VI)
1904 Apr.4	11:09:30	42.0	23.0	n	5.5	S Bulgaria (VI)
1904 Apr.10	08:52:46	42.7	22.7	n	6.5	Bulgaria (VII)
1904 Apr.13		42.0	23.1		5.5	S Bulgaria *
1904 Apr.13	09:55:30	42.4	22.8	n	5.6	Bulgaria (V)
1904 Apr.19	18:14:30	42.0	23.1	n	5.9	S Bulgaria (VII)

continued)

DATE	TIME	Φ	λ	h	M	REGION AND MAX INTEN.
1904 Apr.25		42.0	23.0		5.5	S Bulgaria *
1905 Jan.20		39.7	22.9		5.6	Larissa *
1905 Oct. 8	07:27:30	41.8	23.1	n	6.5	Bulgaria (VIII)
1905 Oct.23	02:38:48	41.4	24.0	n	5.5	Drama
1905 Nov. 5		40.7	23.0		5.5	Thes . *
1905 Nov. 8	22:06:30	40.3	24.4	n	7.5	Chalkid.(X Athos)
1905 Nov.18	00:19:00	41.0	23.0	n	5.6	Kilkis
1911 Mar.11	20:40:18	42.0	23.0	n	5.5	S Bulgaria (V)
1921 Aug.10	14:10:32	42.3	21.4	n	5.8	S Yug.(VIII Prizren)
1923 Dec. 5	20:56:35	39.8	23.5	n	6.4	Chalkid.(VIII Kasand)
1928 Apr.14	09:00:01	42.2	25.3	n	6.8	S Bulgaria (IX Plov)
1928 Apr.18	19:22:48	42.2	25.0	n	7.0	S Bulgaria(X Plovd.)
1928 Apr.18	19:40:58	42.2	25.0	n	5.4	S Bulgaria
1928 Apr.18	23:14:36	42.2	25.1	n	5.6	S Bulgaria
1928 Apr.28	17:58:50	42.1	25.0	n	5.4	S Bulgaria(VII)
1931 Mar. 7	00:16:52	41.3	22.4	n	6.0	S Yug.(VIII Valand.)
1931 Mar. 8	01:50:28	41.3	22.5	n	6.7	S Yug.(X Valandovo)
1932 Sep.26	19:20:42	40.5	23.9	n	7.0	Chalkid.(X Hierissos)
1932 Sep.26	21:26:56	40.5	23.8	n	6.0	Thes .(V)
1932 Sep.28	16:52:17	40.5	23.8	n	5.7	Thes .(VI Sochos)
1932 Sep.29	03:57:26	40.8	23.3	n	6.2	Thes .(VIII Sochos)
1932 Nov. 1	16:19:34	40.5	23.8	n	5.5	Chalkid.(VII Hieris.)
1933 May 11	19:09:50	40.4	23.7	n	6.3	Chalkid.(VIII Hieris)
1936 Apr. 8	04:17:18	41.0	23.5	n	5.5	Serres (VI)
1941 May 14	08:36:21	39.5	22.6	n	5.5	Larissa
1947 Apr.12	14:05:09	39.7	25.2	n	5.7	Lemnos (VIII)
1947 Jun. 4	00:29:48	40.0	24.0	n	6.1	Chalkidiki
1947 Nov. 6	16:08:00	40.2	24.5	n	5.5	SE of Chalkidiki

1950 - 1963 M≧5.0

1952 Jun.27	13:09:18	40.7	23.5	n	5.0	Thes .(VI Askos)
1954 Aug. 3	18:18:13	40.1	24.5	n	5.9	Lemnos(IV Myrina)
1954 Aug. 5	04:12:51	40.1	24.5	n	5.1	Lemnos(IV Myrina)
1954 Aur. 5	04:37:33	40.1	24.5	n	5.0	Lemnos(IV Myrina)
1954 Aug. 6	16:01:18	39.7	25.0	n	5.0	Lemnos(III Myrina)

(continued)

DATE	TIME	Φ	λ	h	M	REGION AND MAX INTEN
1955 Jul. 9	23:53:42	40.7	22.2	n	5.3	Pella (VIII Kali)
1958 Jul.17	05:37:06	40.7	23.4	n	5.6	Thes. (VII Askos)
1959 May 14	19:22:20	40.0	23.3	n	5.0	Chalkid.(IV Kassandr)
1960 Mar.12	11:54:00	41.9	20.9	n	5.7	S Yugosl.(VIII Tetovo)
1960 Jul.13	13:01:01	40.6	23.4	n	5.4	Chalkid.(VIII Krimni)
1963 Jul.26	04:17:12	42.0	21.4	n	6.1	S Yugosl.(IX Skopje)

1964 - 1980 M≧4.5

1964 Apr.11	16:00:43	40.3	24.8	33	5.5	Lemnos (V Myrina)
1964 Jul.4	11:11:18	42.0	23.4	2	4.9	Bulgaria (VI Razlog)
1965 Jan.28	23:10:47	42.5	23.1	77	4.9	Bulgaria (VII Pernik)
1965 Dec.20	00:08:16	40.2	24.8	33	5.6	Kavala(V Nea Karvali)
1965 Dec.20	00:30:58	40.0	24.8	42	4.6	Thasos(III Limenaria)
1965 Dec.25	12:15:33	39.8	25.0	41	4.5	SW of Lemnos
1966 Sep.22	20:14:39	39.8	23.9	35	4.6	S of Chalkidiki
1966 Oct.22	05:38:24	42.0	23.1	13	4.7	SW Bulgaria (V)
1967 Jul.25	08:37:26	41.9	25.0	53	4.5	S Bulgaria (V)
1970 Mar.17	17:00:57	41.4	21.1	43	4.6	S Yugosl.(VI Kicevo)
1970 Apr.16	22:39:31	40.7	23.4	20	5.2	Thes.(VI N.Apollonia)
1972 May 8	08:58:16	41.5	23.5	51	4.6	Serres (III Vyronia)
1972 May 8	09:20:55	41.7	23.6	12	5.1	S Bulgaria(VI Vranje)
1972 May 23	03:14:30	41.5	23.6	5	4.5	S Bulgaria
1972 Jul. 8	05:46:15	41.6	23.7	38	4.8	S Bulgaria
1972 Aug.12	23:47:58	41.1	22.7	12	4.9	Kilkis(VII Kalindria)
1972 Sep.23	01:53:16	42.2	25.3	25	4.7	S Bulgaria
1972 Dec.13	02:58:53	41.7	24.1	41	4.5	Drama(IV Paranesti)
1973 Jul. 2	12:14:10	39.7	23.7	33	4.5	S of Chalkidiki
1974 Mar.10	21:51:06	40.9	21.1	32	4.5	Yugosl.(VI Bitola)
1974 Jun.22	23:30:12	41.2	23.0	8	5.2	Serres(VI A.Poroia)
1974 Sep. 8	19:09:57	39.7	24.4	0	4.6	SE of Chalkidiki
1974 Sep.13	18:24:57	40.5	23.4	8	4.5	Chalkid.(V Palaeochor)
1974 Oct.15	09:56:49	40.7	23.0	0	4.5	Thes.(V Triandria)
1974 Dec.18	21:30:55	39.9	23.9	33	4.5	S of Chalkidiki
1977 Nov. 3	02:22:56	42.1	24.6	11	5.4	S of Bulgaria(VII)

(continued)

DATE	TIME	Φ	λ	h	M	REGION AND MAX INTEN
1977 Nov. 6	02:48:46	42.1	24.2	23	4.7	S' of Bulgaria
1977 Nov.17	06:28:09	42.1	24.1	10	4.6	S Bulgaria
1978 May 8	14:39:00	40.7	23.4	14	4.7	Thes.(V Peristeronas)
1978 May 10	13:12:52	40.7	23.4	17	4.6	Thes.(V Peristeronas)
1978 May 13	08:35:36	40.7	23.4	11	4.5	Thessaloniki
1978 May 16	08:23:42	41.1	21.0	10	4.5	S Yugoslavia
1978 May 23	23:34:11	40.7	23.2	9	5.8	Thes.(VII Perister.)
1978 May 24	02:12:30	40.7	23.4	14	4.9	Serres(IV H.Pnevma)
1978 May 24	05:57:28	40.7	23.3	13	4.8	Serres(VI H.Pnevma)
1978 Jun. 2	22:31:25	40.8	23.2	19	5.0	Thes.(VI Sochos)
1978 Jun.12	17:44:48	40.7	23.4	19	4.6	Thes.(VII Kavalari)
1978 Jun.12	23:36:42	40.8	23.3	16	4.5	Thessaloniki
1978 Jun.19	03:12:54	40.7	23.3	11	4.5	Thessaloniki
1978 Jun.19	10:31:07	40.7	23.3	12	5.3	Thes.(VI Sochos)
1978 Jun.19	10:48:11	40.7	23.3	11	4.8	Thessaloniki
1978 Jun.20	20:03:21	40.8	23.2	11	6.5	Thes.(VIII Stivos)
1978 Jun.20	20;45:25	40.8	23.2	6	4.5	Thessaloniki
1978 Jun.20	21:51:04	40.7	23.2	11	4.7	Thessaloniki
1978 Jun.21	03:20:26	40.7	23.2	15	4.5	Thessaloniki
1978 Jun.21	06:00:18	40.7	23.3	2	4.6	Thessaloniki
1978 Jun.21	12:29:46	40.7	23.1	1	4.9	Thessaloniki
1978 Jun.21	18:52:06	40.7	23.2	10	4.6	Thessaloniki
1978 Jun.23	01:57:03	40.7	23.1	2	4.5	Thessaloniki
1978 Jul. 4	22:23:28	40.7	23.1	8	5.1	Thes.(VI Langadas)
1978 Jul.13	17:26:57	40.7	23.1	6	4.5	Thessaloniki
1978 Dec.31	15:56:15	42.0	23.2	21	4.7	Drama(IV K.Nevrokopi)
1978 Dec.31	16:26:06	42.0	23.2	9	4.6	S Yugosl.(V Berovo)
1979 May 11	01:46:27	40.7	23.3	5	4.7	Thes.(V Kryoneri)
1979 Jun. 2	03:11:59	40.3	24.1	10	4.6	Chalkid.(IV Krimni)
1979 Aug.31	17:24:10	40.7	23.4	11	4.7	Thes.(V Arethousa)
1979 Sep.13	12:06:43	43.1	25.3	16	4.6	S Bulgaria
1979 Oct.14	15:00:16	40.2	21.5	41	4.5	Kozani

1981 - 1984 $M \geq 4.0$

(continued)

DATE	TIME	Φ	λ	h	M	REGION AND MAX INTEN.
1981 Mar. 2	21:37:47.1	40.66	23.22	9	5.1	Thessaloniki
1981 Mar. 6	01:01:33.6	40.73	22.83	10	4.2	N of Thessaloniki
1981 May 8	19:51:35.9	39.89	23.90	4	4.0	S Chalkidiki (Aegean)
1981 May 10	23:33:01.8	40.62	22.69	6	4.0	W Thessaloniki
1981 Aug. 4	04:30:17.5	40.68	23.39	4	4.2	Volvi Lake
1981 Sep. 7	17:43:10.8	41.43	22.58	2	4.3	S Yugoslavia
1982 Feb.25	11:55:36.6	39.99	23.08	7	4.0	S of Kassandra Gulf
1982 Apr.12	03:39:31.3	40.53	23.60	19	4.1	Arnea
1982 Nov.14	09:09:41.6	40.34	24.39	15	4.0	E of Athos Peninsula
1982 Dec.27	08:14:41.3	40.86	22.80	13	4.3	N of Thessaloniki
1983 Apr. 6	04:55:27.1	40.84	22.91	4	4.2	N of Thessaloniki
1983 Apr.19	02:49:49.5	40.75	23.19	3	4.0	Langadas Lake
1983 Jun.14	04:40:43.2	40.44	23.97	13	4.7	Hierissos
1983 Aug.26	12:52:10.7	40.46	23.89	9	5.2	Hierissos
1983 Aug.26	16:15:31.7	41.01	22.43	9	4.3	N of Thessaloniki
1983 Sep.16	21:15:43.9	39.85	23.88	11	4.2	S of Sithonia Penins.
1984 Feb.19	02:53:01.0	40.62	23.41	6	4.4	Central Chalkidiki
1984 Feb.19	02:54:01.8	40.61	23.40	8	4.4	Central Chalkidiki
1984 Feb.19	03:47:22.1	40.63	23.39	14	5.7	S of Volvi Lake
1984 Feb.19	03:59:57.9	40.62	23.44	10	4.2	S of Volvi Lake
1984 May 4	02:52:32.0	40.73	23.29	5	4.3	W of Volvi Lake
1984 May 8	05:04:04.9	40.35	22.85	15	4.5	Thermaikos Gulf
1984 May 8	08:08:11.0	40.31	22.79	12	4.0	Thermaikos Gulf
1984 May 14	18:18:02.0	40.33	22.81	10	4.3	Thermaikos Gulf
1984 May 15	04:35:46.7	40.32	22.79	10	4.0	Thermaikos Gulf
1984 Jul. 3	08:23:04.1	41.01	22.43	10	4.0	Edessa
1984 Jul. 8	03:31:40.0	41.16	22.55	6	4.6	Kilkis
1984 Jul.16	13:52:45.8	40.02	23.56	1	4.0	Kassandra Peninsula
1984 Sep.25	06:58:14.4	40.69	23.41	10	4.3	Volvi Lake
1984 Oct. 5	14:22:48.6	40.97	23.32	6	4.7	N of Thessaloniki
1984 Nov.14	14:53:50.9	40.69	23.38	1	4.7	Volvi Lake

* UNDP UNESCO Catalogue

Based on this catalogue an attempt is made to estimate the seismicity of this region, by applying the well-known mean value statistic method as it has been proposed by GUTEMBERG and RICHTER (1944)

$$\log N = a_m - bM \qquad (3.2)$$

where N is the number of shocks with magnitude equal to or greater than M which occured in the defined region and a_m and b are parameters. The parameter b depends on the stress and on the mechanical properties of the material in the focus while the parameter a_m depends on the seismicity of the area and on the surface which is covered by the epicenters. The parameter a_m is normalized for one year time period. Thus, the normalized value a is given by the relationship :

$$a = a_m - \log m \qquad (3.3)$$

where m is the time in years.
The relationship (3.2) for one time period becomes

$$\log N = a - bM \qquad (3.4)$$

Based on these parameters a,b the mean reccurrence period T_m for the earthquakes is estimated by the formula

$$T_m = 10^{bM} / 10^{a} \qquad (3.5)$$

We applied these relation to our data. We considered the data for the time period 1800 ÷ 1984 (185 years) and for the time period 1900 - 1984 (85 years). The best results were obtained for the 185 year period and the least squares method for these data led to the relation

$$\log N = 4.16 - 0.82M \qquad (3.6)$$

Therefore a=4.16 and b=0.82. These data were plotted in figure (3.15). Table (4.1) gives the recurrence period T_m(in years) for the corresponding magnitudes. These results are in good agreement with results of HATZIDIMITRIOU and his colleagues (1985). They studied the seismic parameter b of the frequency-magnitude relation and its association with the twenty-one seismic zones in the Greek and surrounding area and found the b-value of the 18-zone (Serbomacedonian massif) for the time period of 180 years equal to 0.84. This seismic zone geologically coincides to our studied area. Thus the estimated b-value is in well-accordance with the value which is estimated by that study.

The same methodology was applied for the determination of magnitude-frequency relation for the 85 years time period. The following relationship was found :

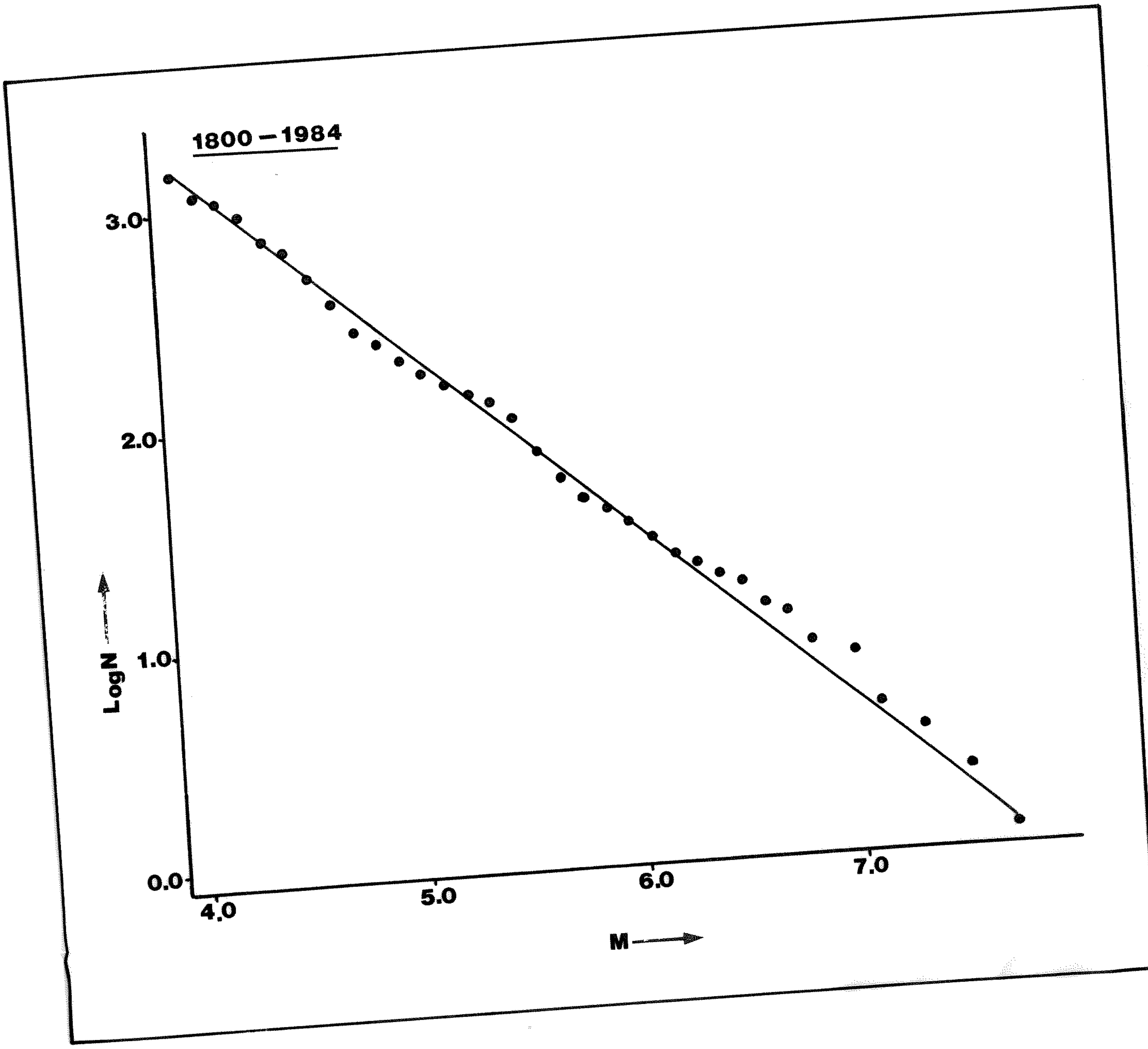


Fig. 3.15 The cumulative frequency-magnitude relation Log N=a-bM for the 185 years time periods (1800 - 1984)

Table-3.1 The relation magnitude-mean recurrence period

M	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
T_m	0.1	0.3	1	2	6	15	38	97	251

$$\log N = 3.76 - 0.73M \qquad (3.7)$$

where a=3.76 and b=0.73. This is in fairly good agreement with a relation determined by MIHAILOV AND PETROVSKI (1975) for the Macedonian territory $\log N = 3.95 - 0.59M$.

HATZIDIMITRIOU (1984) studied the seismicity of Greece and surrounding area and constructed a map of distribution of the maximum probable magnitude for a time period of 181 years. He used the data from PAPAZACHOS AND COMNINAKIS (1982) catalogues divided into four magnitude groups ($7.5 \leq M \leq 7.9$, $7.0 \leq M \leq 7.4$, $6.5 \leq M \leq 6.9$ and $6.0 \leq M \leq 6.4$) and he drew distribution curves for the studied area (Fig 3.16).

The maximum values (7,5-7,9) are appeared in three regions in Bulgaria (Kresna), in the Volvi-Langada lake region, and near the Athos peninsula.

It is interesting that the Aegean sea is shown as an aseismic plateau while the high seismic activity is concentrated in Northern Greece and Southern part of Yugoslavia and Bulgaria (HATZIDIMITRIOU 1984).

3.4 Distribution of Intensities of the Area

Some of the strongest earthquakes occured in this area (1902 Assiros I_o=IX M=6.6 , 1904 Kresna I_o=X M=7.7, 1931 Valandovo I_o=X M=6.7 , 1932 Hierissos I_o=X M=7.0 , 1978 Stivos I_o=VIII M=6.5) (Fig 3.17).

PAPAIOANNOU (1984) used macroseismic observations for 33 earthquakes of the region to determine a relation between the maximum intensity I_o and the magnitude M_s. This is shown in figure (3.18). A relation of the form

$$I_o = a + bM \qquad (3.8)$$

was found by applying the least square method with a=-0.18 and b=1.50.

Some interesting information about the intensities has been given by PAPAZACHOS and his colleagues (1982) in an Atlas of isoseismal maps for the Greek area during 1902 - 1981, which has been published by the Geophysical Laboratory of the University of Thessaloniki.

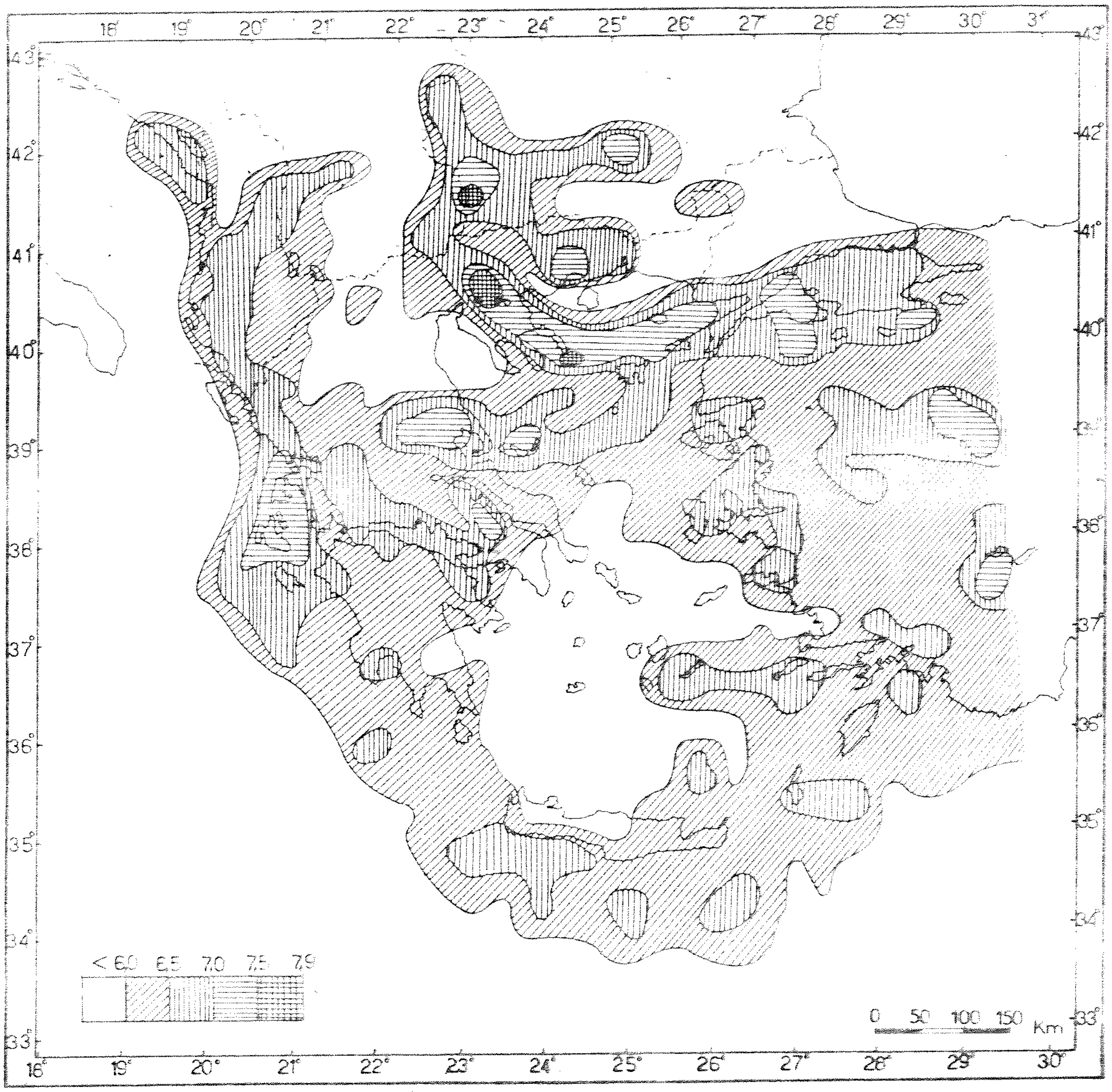


Fig. 3.16 Distribution of the maximum probable earthquake magnitude during the time period of the last 180 years for Greece and surrounding area. (HATZIDIMITRIOU 1984)

Another Atlas of isoseismal maps has been published by SHEBALIN (1974a)during the UNDP-UNESCO project. HADZIEVSKI (1973) presented a map of maximum observed intensities for the Macedonia territory (Fig 3.19), while the same researcher (1974) gave the predominant orientation of isoseismals for Yugoslavia (Fig 3.20). A similar study for Greece and surrounding area was carried out by HATZIDIMITRIOU (1984) and the results are given in figure (3.21).

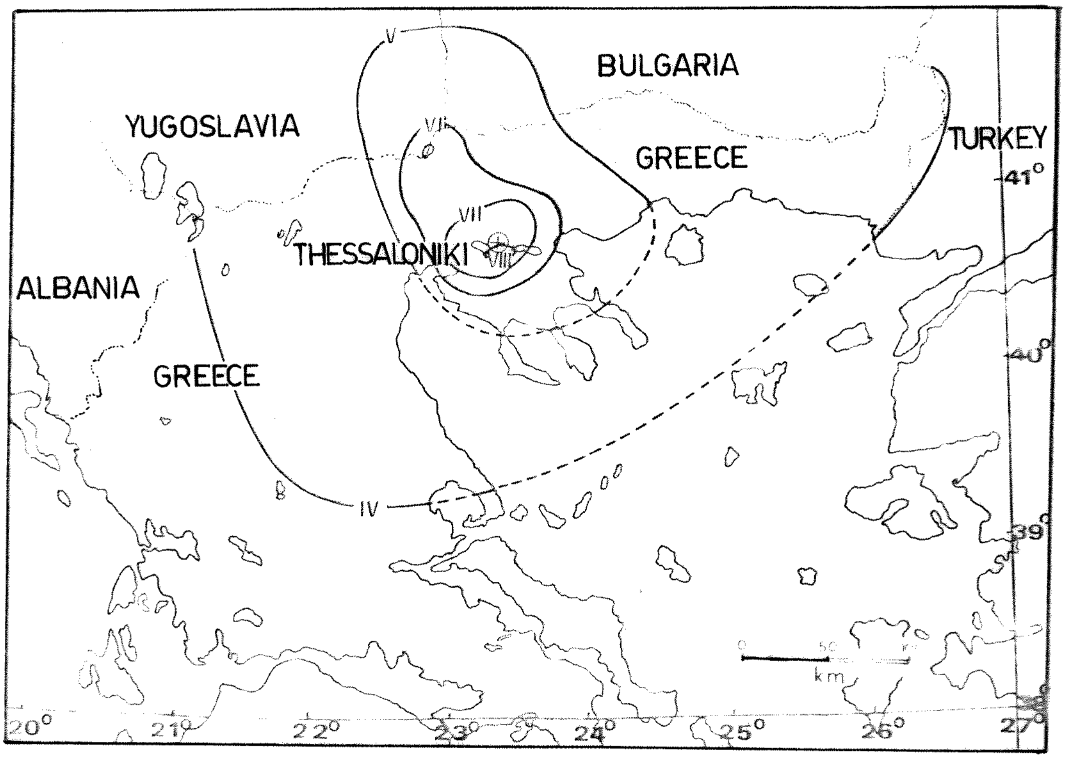


Fig. 3.17 The isoseismals for the strong earthquake ($M = 6.5$ Stivos VIII^{+}) of Thessaloniki . (COMNINAKIS AND PAPAZACHOS 1979).

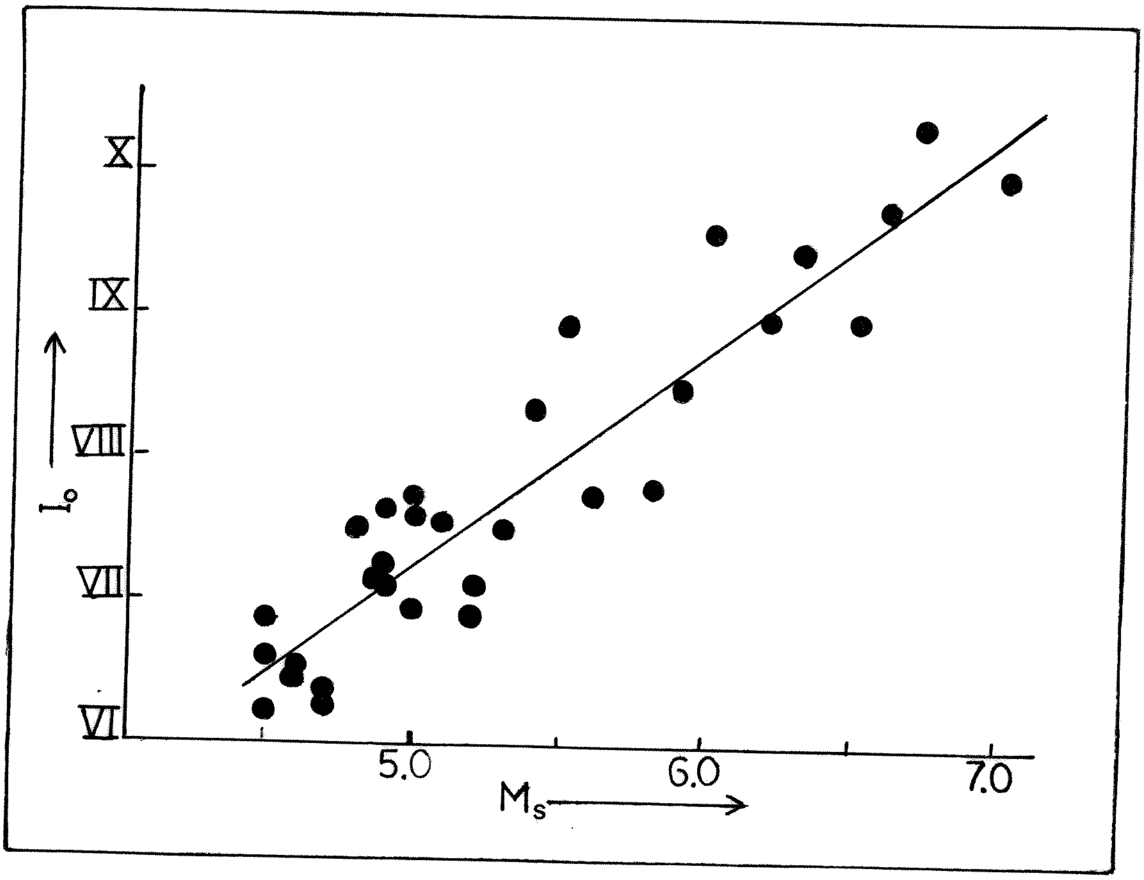


Fig. 3.18 Epicentral intensity versus magnitude for the studied area. (PAPAIOANNOU 1984)

The HADZIEVSKI´s and HATZIDIMITRIOU´s results are in good agreement. A maximum intensity map for the Bulgaria territory is given in the report for UNDP-UNDRO project. High intensities are observed around the Sophia district (IX) and the Kresna region (IX) where the strongest shallow European earthquakes occured in 1904.

The following attenuation relationship of the seismic intensities,defined for shallow shocks in the Balkan region and western Turkey on the basis of Cornell´s modell,was estimated by PAPAIOANNOU (1984) :

$$I_i = 6.59 + 1.18M_s - 4.50\log(\Delta + 17) \qquad (3.9)$$

where I_i is the intensity felt in distance Δ from the epicenter and M_s is the surface wave magnitude.

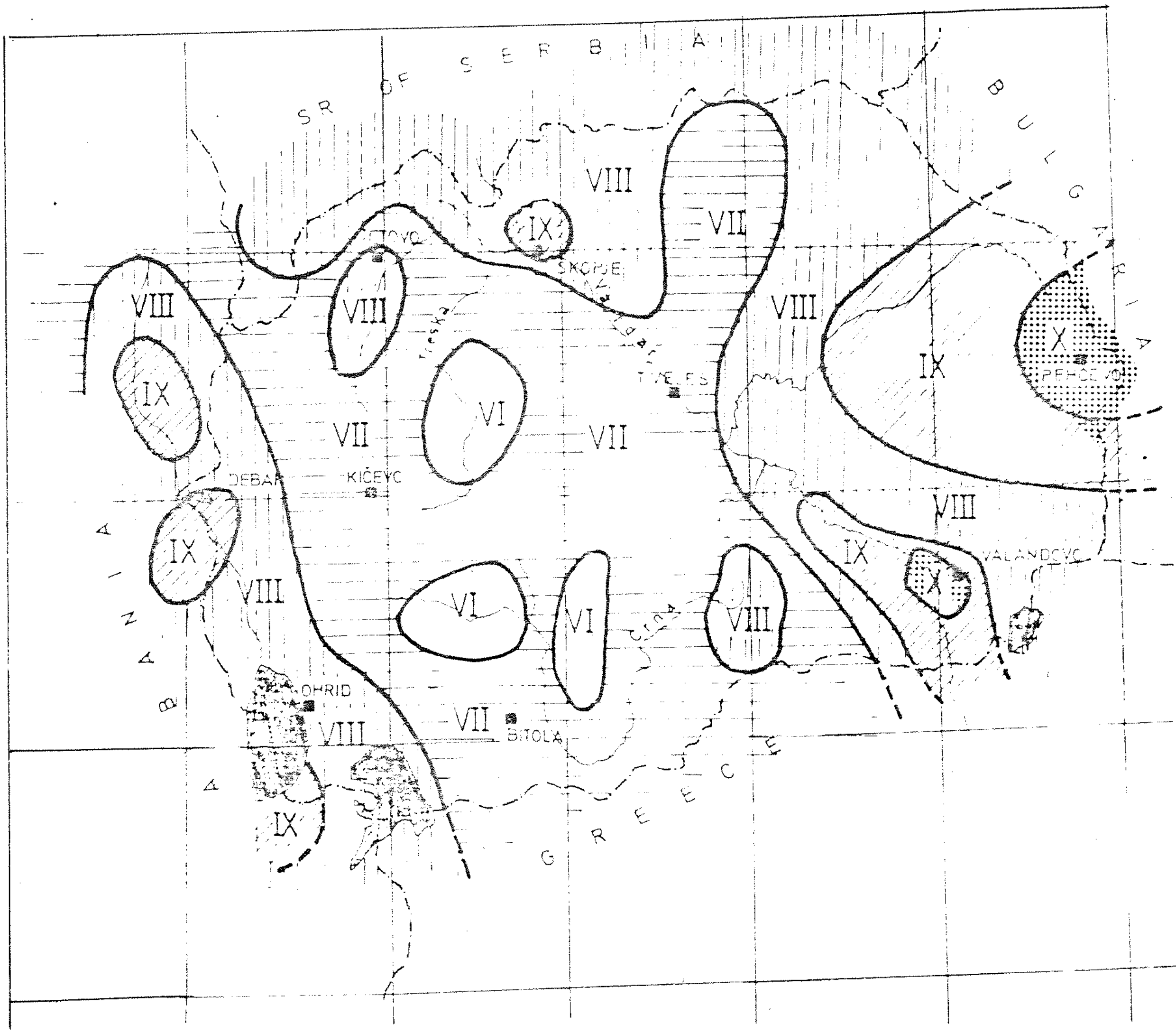
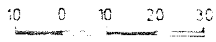


Fig 3.19 - MAP OF MAXIMUM OBSERVED INTENSITY OF MACEDONIA

Compiled by: D.HADŽIEVSKI,1973



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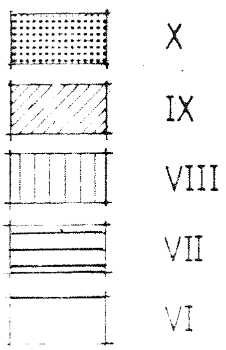

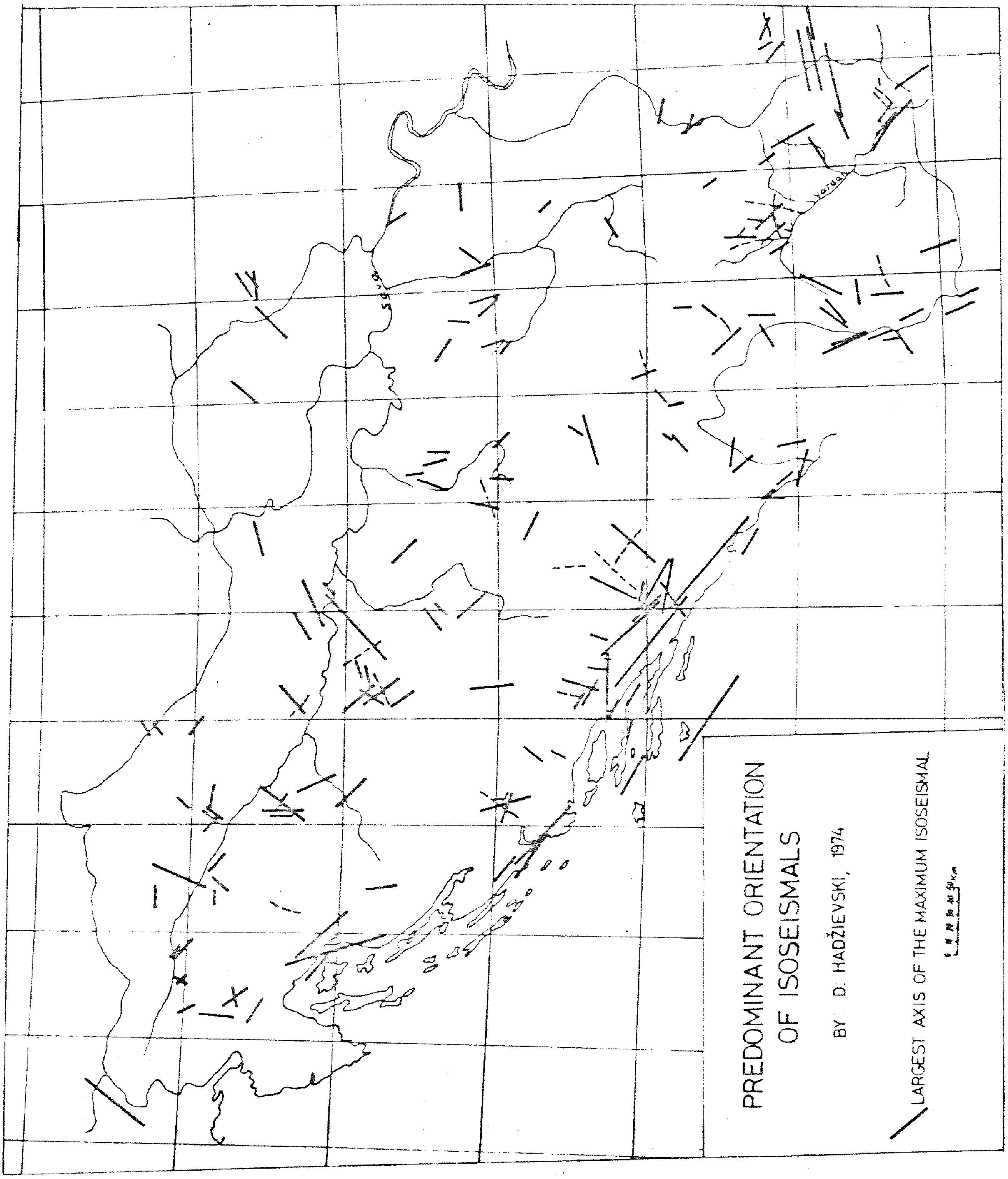

Fig. 3.20 The predominant orientation of isoseismals in Yugoslavia (SKOKO et al,1975)

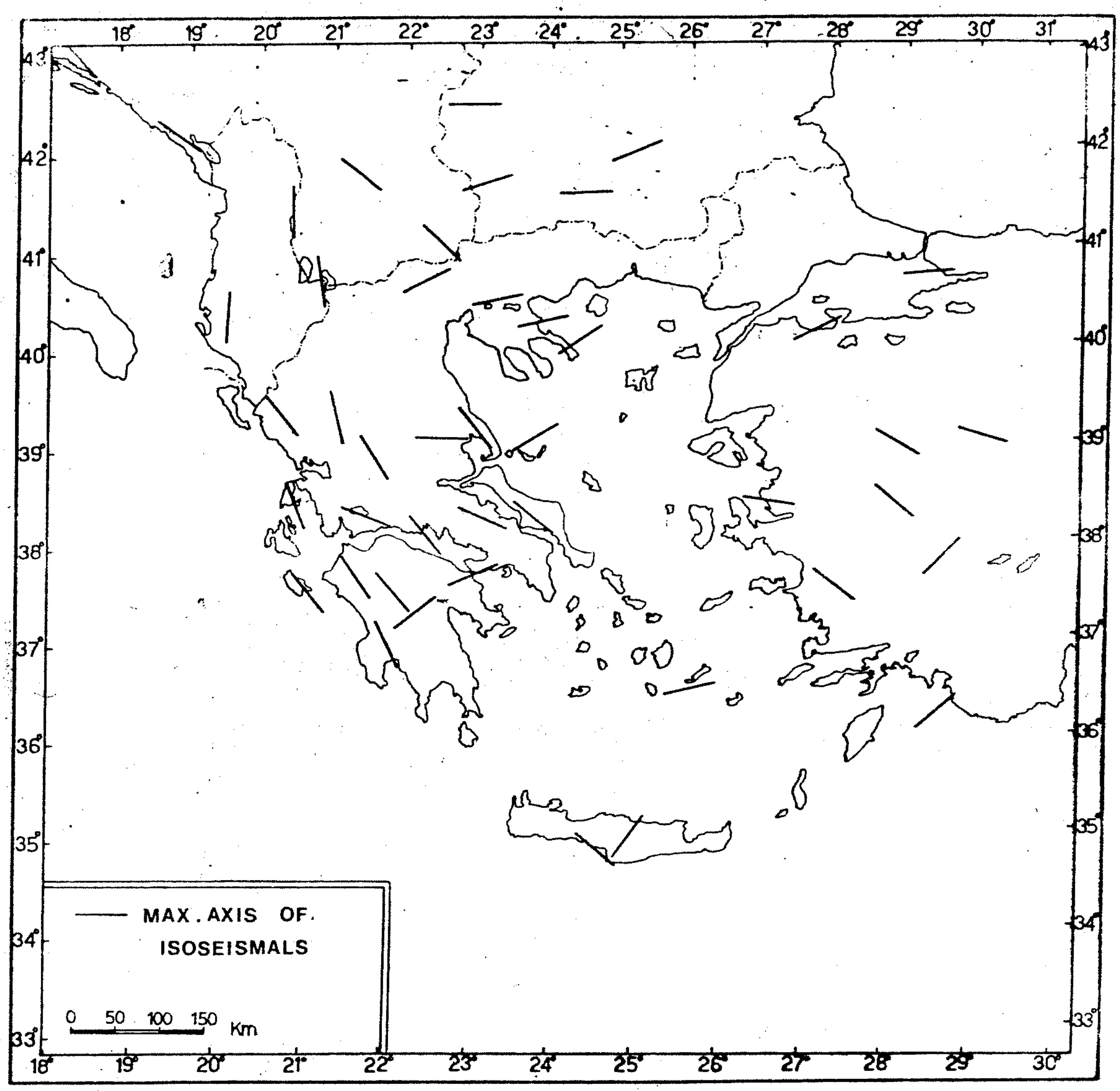

Fig. 3.21 Mean direction of the maximum axis of isoseismals (HATZIDIMITRIOU 1984)

4. SEISMOTECTONICS

4.1 Seismotectonics of the Area

In considering the seismotectonic regime of the Serbomacedonian massif and surrounding area, the seismicity, tectonic and neotectonic data are combined. The synthesis of the geological and seismic data, in relation to some elements of the faulting and seismic foci distribution led to important conclusions concerning the seismicity and the reactivated faults in the area. It is necessary to note some significant previous studies which have been accomplished for the area.

PAPAZACHOS (1976) studied the seismotectonics of the northern Aegean area. He correlated the focal mechanisms and the distribution of seismic epicenters which were used to investigate the active tectonics of the area. The researcher observed a thrust region which is surrounded by an area of normal faulting, while an eastwards progression of the seismic activity in this normal faulting region has been observed during 1954-1971. The correlation between the seismic events in the thrust and normal faulting regions is, that, each large shock produced by tensional mechanism in the region of normal faulting is preceded or followed by one or more shocks of compressional mechanism in the thrust region.

The same researcher ,considering the distribution of the intermediate foci (h>60 km) between 1962 and 1975, depicted all the epicenters by triangles (Fig 4.1) The white triangles denote earthquakes with focal depths between 60 km and 100 km and black triangles show seismic events deeper than 100km. There is a tendency for the focal depths to increase from the zone of normal faulting in the south to the zone of thrust faulting in the north. Therefore a plot of the epicenters versus the focal depth presents a Benioff seismic zone dipping approximately to the north at an angle about 30° (Fig 4.2). It is more correct to plot the distances x of the epicenters from a curve related to this amphitheatrical surface, versus the focal depths h. As such a curve, the isodepth of 120 km has been chosen (PAPAZACHOS 1975,1976).

As it has been stated the seismic parameter b of the frequency-magnitude relation is of high significance for seismicity problems. Considering the area,which is bounded by latitudes 34°N and

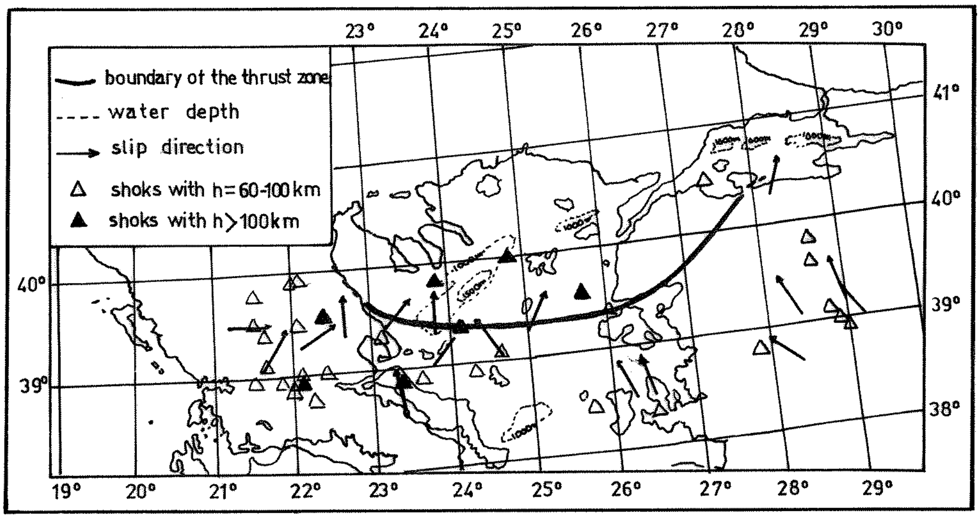

Fig. 4.1 Compressional and tensional zones, isobaths and epicenters of intermediate seismic foci (PAPAZACHOS 1976)

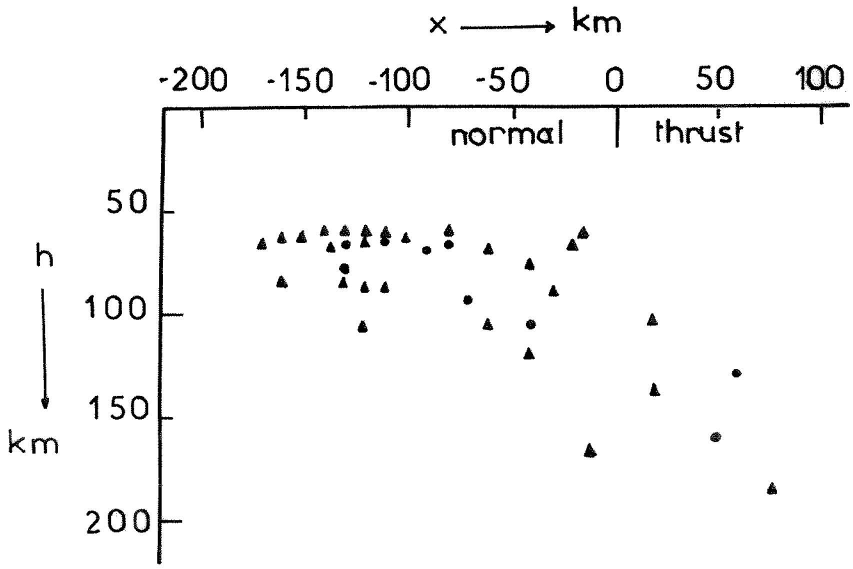

Fig. 4.2 The northern Aegean Benioff zone (PAPAZACHOS 1976)

43°and longitudes 18°E and 30°E, and based on the division of the Aegean and surrounding area (34°N-42°N , 19°E-29°E) in nineteen seismic zones by PAPAZACHOS (1980), an attempt was made by HATZIDIMITRIOU and his colleagues to divide this area in twenty-one seismic zones. He also studied the relations of this zonation with the seismic parameter b of the frequency-magnitude relationship and its association with the geological zones in the area (Fig. 4.3)

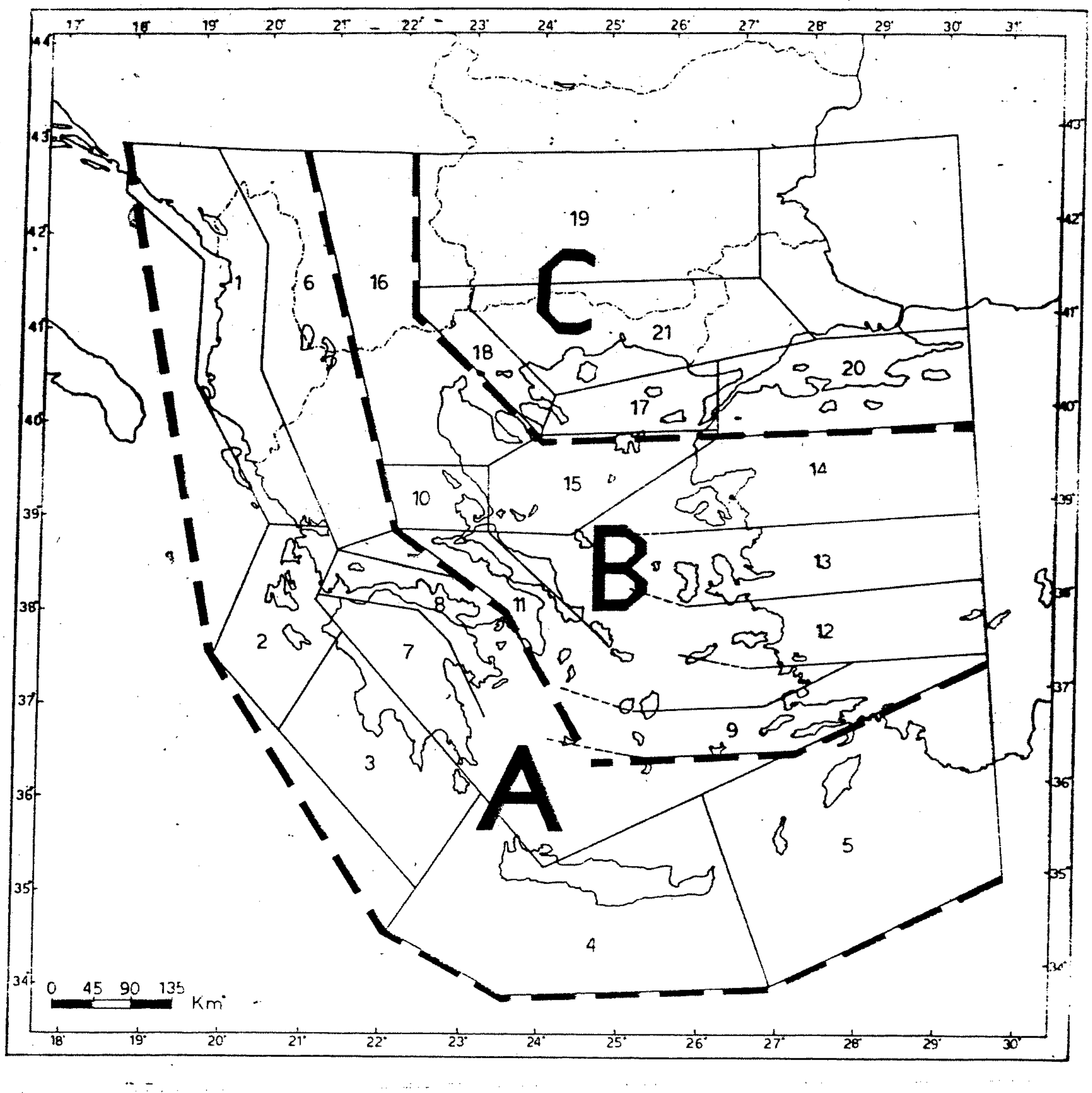

Fig. 4.3 The twenty one seismic zones of Greece and surrounding area and the separation of this area in three seismic regions of various b-values (A,B,C) (HATZIDIMITRIOU et al. 1985)

The zonation is based on some criteria, as the distribution of the seismic epicenters of shallow earthquakes ($h<70$ km) the direction of the seismic faults derived by fault plane solution (PAPAZACHOS et al.1983), the direction of P (max.compression) and T(max.tension) axes derived from fault plane solutions (PAPAZACHOS et al. 1982), the type of seismic faults (normal,thrust, strike-slip) (PAPAZACHOS et al. 1984) and the values of the seismicity rates and the value of the parameter b, (HATZIDIMITRIOU et al.1985).

Considering the geographical distribution of the value b in relation to the seismic zoning (Fig 4.3) the external zones (1,2,3,4,5,6,7,8) constitute the A group with a range of b-values between 0.88 and 1.23 . The zones (9,10,11,12,13,14,15,16) are the B-group with the range of b-values 0,79 and 0,92 while the innermost zones (17,18,19,20,21) are the C-group with the range of b-values between 0,49 and 0,71. The average values of b, as they have been determined by HATZIDIMITRIOU and his colleagues (1985), for each of these groups, are :

A : b= 1.03+0.11

B : b= 0.84+0.05

C : b= 0.60+0.08

The area of Greece has been divided into several geological zones (Chapter 1). By comparing the twenty-one seismic zones of the area (Fig 4.3) and the geological zones (Fig 4.4) some similarities can be seen in their trends (HATZIDIMITRIOU et al.1985). Figure (4.4) shows the geological regime of Greece on which the boundaries of the three seismic regions (A,B,C) of equal b-values are depicted. The seismic region A includes the external geological zones of Greece (External Hellenides), seismic region B comprises the internal geological zones (Internal Hellenides) while it is important to notice that the boundary line between seismic regions A and B coincides clearly with the contact of the External and Internal Hellenides. This contact, in continental Greece, is represented by the neogene Messohellenic trough (molassic basin). The seismic region C is shown in Greece, as well as in South Yugoslavia and Bulgaria including the Serbomacedonian and Rhodope massif and extends eastewards upto the western Pondides on Turkey (HATZIDIMITRIOU et al.1985).KARNIK (1969) has quoted from a world-wide survey by Miyamura (1962) that b=0,4-1,8 and

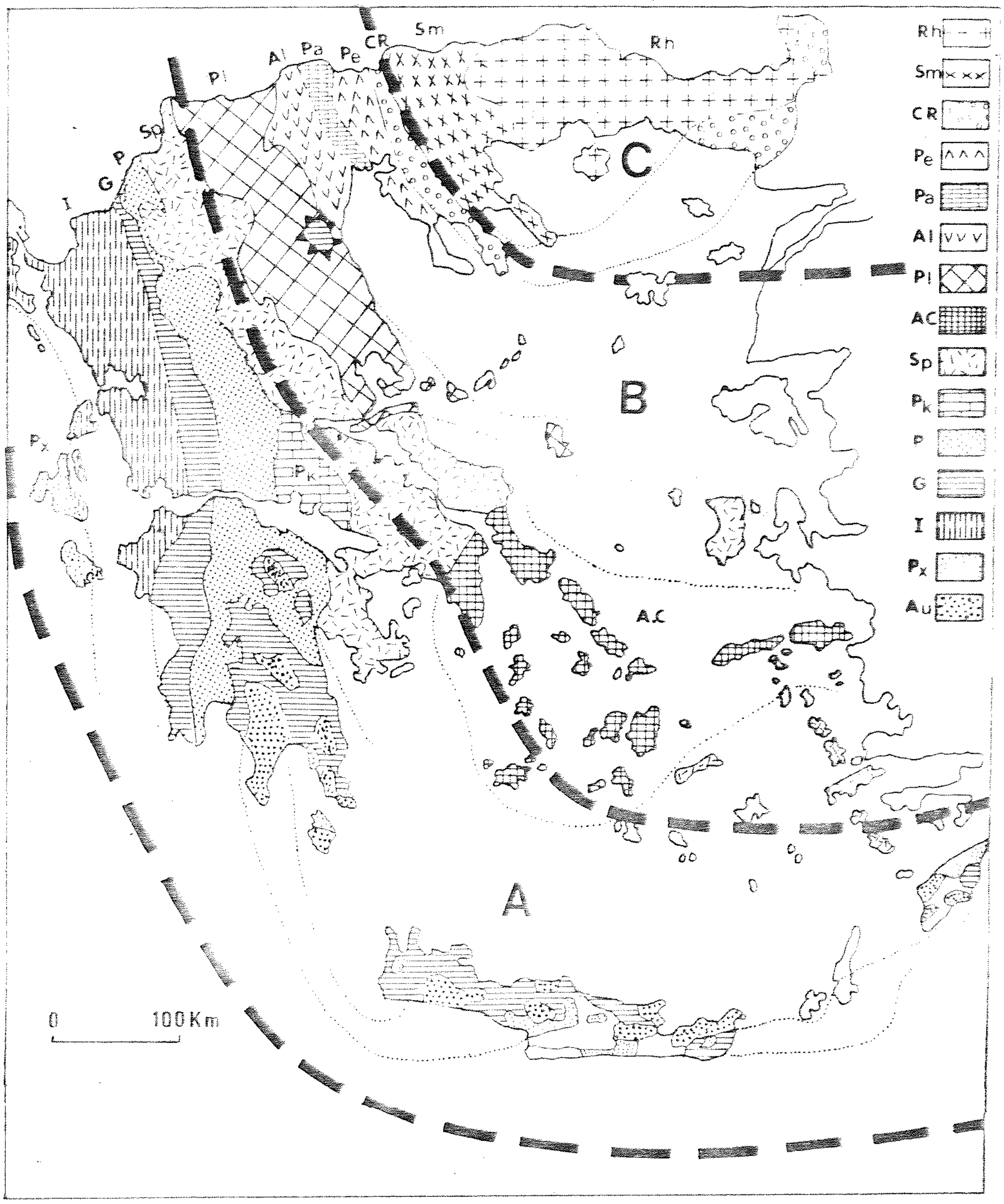

Fig. 4.4 The geological zones in Greece (AUBOUIN et al. 1963, JACOBSHAGEN et al.1978, MOUNTRAKIS et al. 1983). The thick dashed lines show the boundaries of the three seismic regions (A,B,C)(HATZIDIMITRIOU et al. 1985).

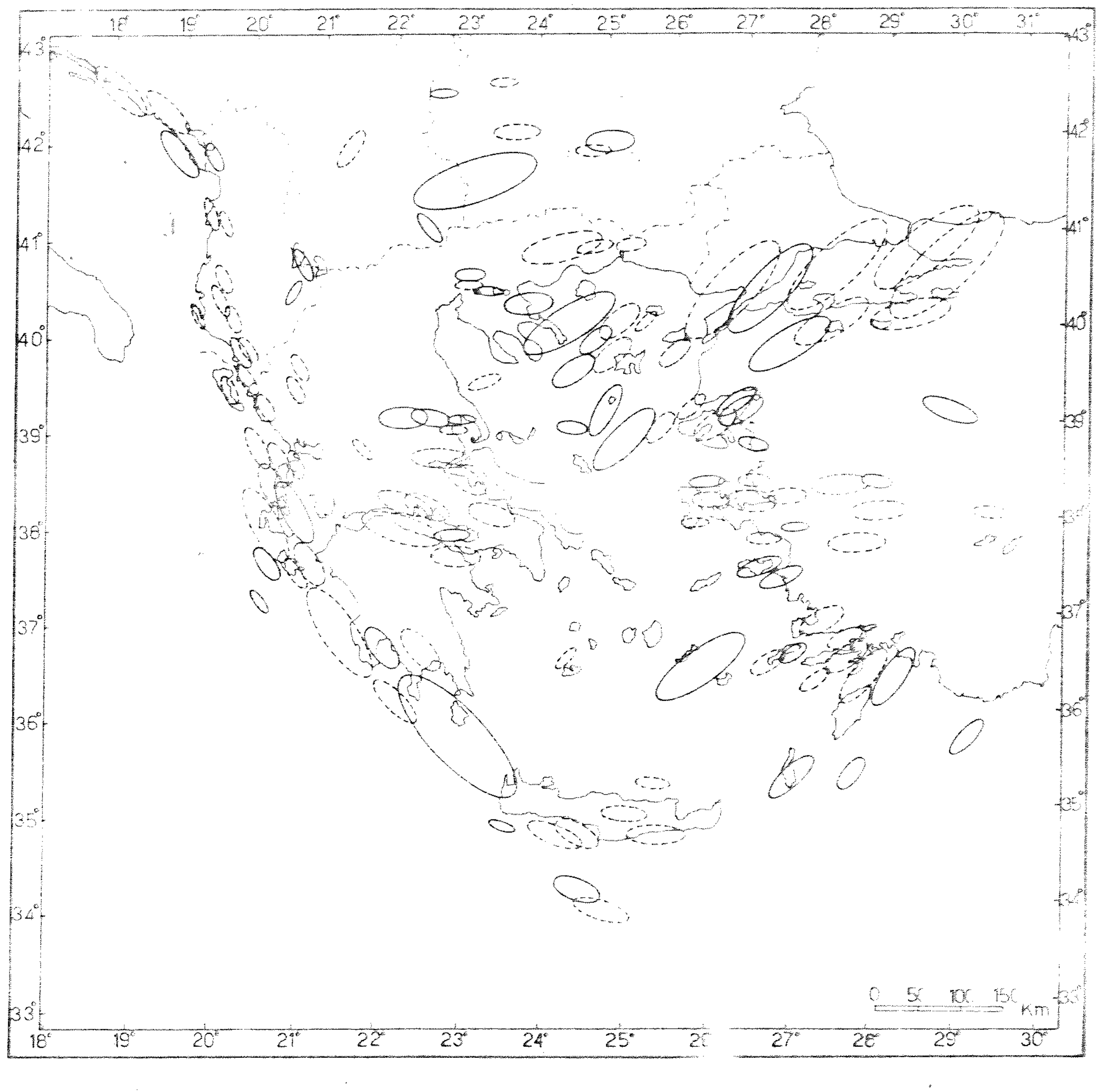

Fig. 4.5 The map of the seismogenic volumes of the Aegean and surrounding area (HATZIDIMITRIOU 1984)

that b changes according to the geological age of the seismotectonic zone. High b values of 1.0-1.8 have been found in the circum-Pasific and Alpine orogenic zones while medium b values of 0.6-0.7 correspond to continental rift zones. Low b values are typical for old shield regions.

Using the relationship

$$\log L = -2.22 + 0.57 M_s \quad (4.1)$$

where L is the faulting length in km and M_s the magnitude of the earthquake (KARAKAISIS 1984), HATZIDIMITRIOU (1984) determined the size of the seismogenic volumes of the Aegean and surrounding area. Using various criteria for the orientation of the seismogenic volumes, i.e. orientation of the seismic faults by fault plane solutions, orientation of the high intensity isoseismal lines, the direction of the aftershock seismic region and the general tendencies of the great seismotectonic units of the area, he compiled the map which is shown fig. (4.5). On this map, the seismogenic volumes of shallow earthquakes with magnitudes $M \geq 6.5$ in period 479 B.C - 1983 A.D of the Aegean and surrounding area is shown. Solid lines represent earthquakes of the present century, while dashed lines represent earthquakes of the period 479 B.C - 1900 A.D.

Considering the distribution of the major shocks ($M \geq 5.4$) as well as the surface fault traces and fault plane solutions of the May-June 1978 major shocks in Thessaloniki area, PAPAZACHOS and his colleagues (1979) investigated seismotectonic features of this area. They associated the distribution of epicenters with the Serbomacedonian massif and especially with the western border of Axios-Vardar zone (Fig 4.6). Many observations were carried out during the fieldwork and three main lines of fracture were observed. The first one is a towards SE extension of a geologic fault located north of Lagadas valley . The second line coincides with the geological fault which is observed at the boundary of the recent deposits with the crystalline bedrock south of Lagadas valley. The third line is located between the other two lines. On account of the fact that the first two lines concide with two geologic faults of the valley, the fractures observed are due to a reactivation of the old faults (Fig 4.7). Macroseismic obserbations as well as fault plane solutions for the main shock and for the largest foreshock show that both are due to a normal fault striking in an about east-west direction (PAPAZACHOS et al.1980).

The microseismicity study of the Serbomacedonian massif and the surrounding area, and fault plane solutions of eight local earthquakes showed normal faulting (SCORDILIS 1985). Thus tensional stress seem to dominate in the area. In addition, the

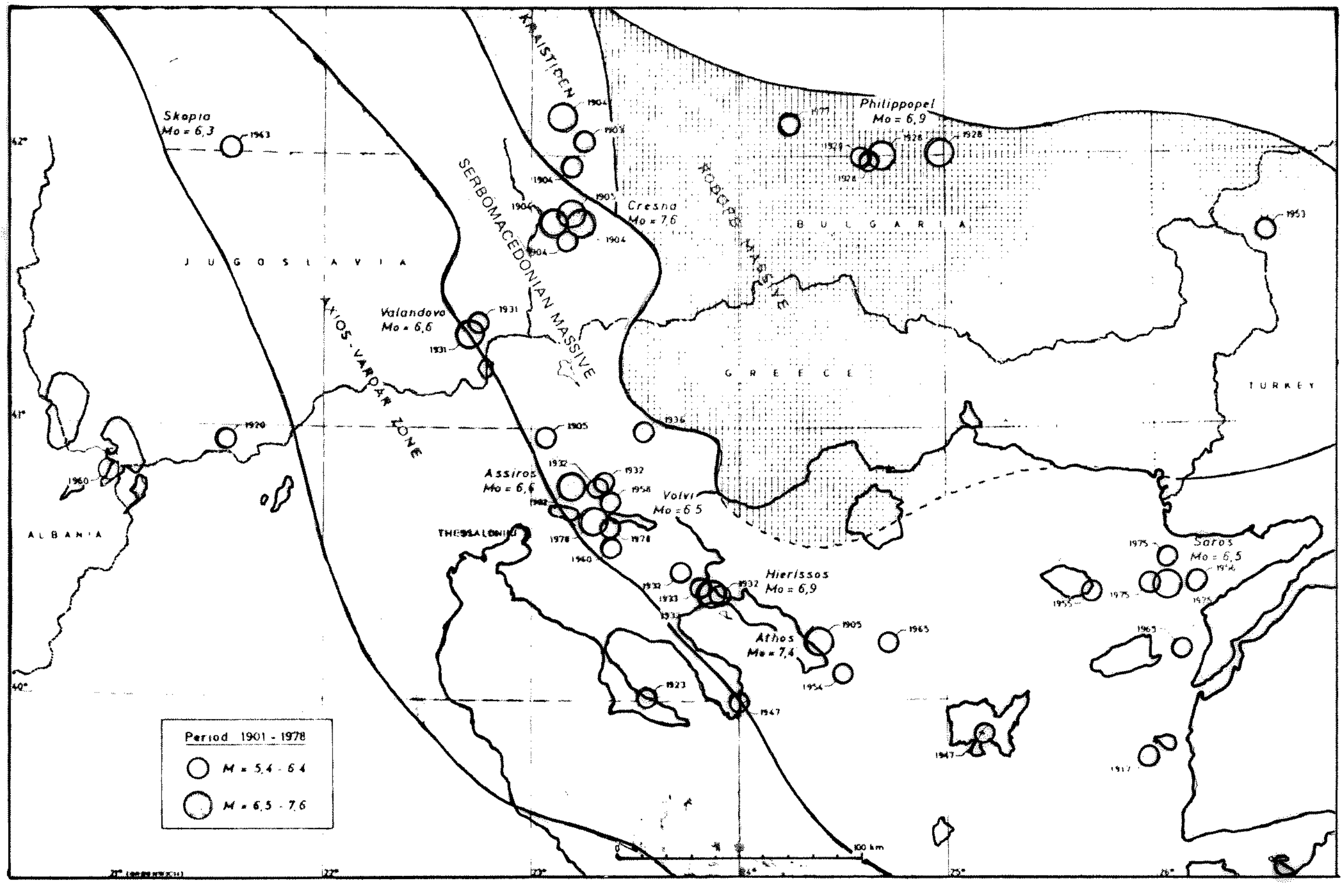

Fig. 4.6 The epicenters of the earthquakes with M≥5.4 in northern Greece and the surrounding area during the present century (PAPAZACHOS et al. 1980)

strike of the fault planes of the small active faults follows fairly well the direction of the surface expression of the faults in the epicentral area (Fig. 4.8).

Some important studies were accomplished by ARSOVSKI and his colleagues (1975) during the seminar on seismic zoning maps UNDP/UNESCO project. Considering the seismotectonic features of the Vardar zone, they correlated neotectonic morphostructural elements and seismic properties for this geological zone. A seismotectonic map of the region was presented. The main conclusion was, that, the relation of the fault system and the depicted epicenters of earthquakes, follows seismically active zones which

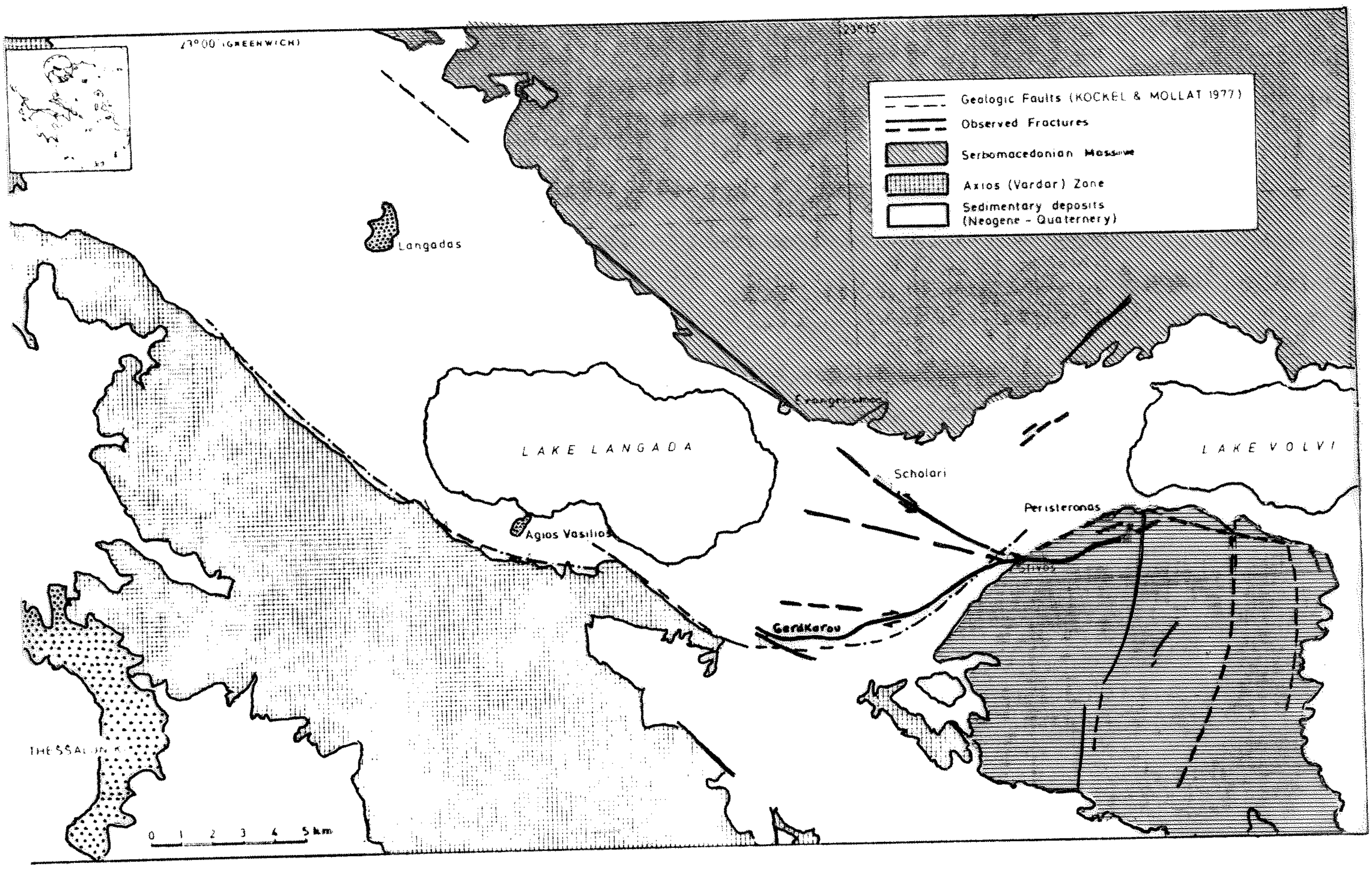

Fig. 4.7 Relation of the Geology with the fracture lines of the earthquake of June 20,1978 (PAPA - ZACHOS et al. 1980)

can be distinguished :Valandovo,Strumica, Titov Veles,Skopje,Kumanovo, etc. These regions are related by tectonic junction zones of reactivated faults of the Vardar-river trend with the newly-formed neotectonic faults in E-W direction.

A map of seismic areas based on the seismological and geological data was prepared by HADZIEVSKI AND ARSOVSKI (1973)(Fig 4.9). This map includes the Macedonia territory and shows seismotectonic features of the region. The first one is the areas with epicenters and maximum observed magnitude and faults, the second is the areas without epicenters (in the period of observation) and faults and the last one is the areas without epicen-

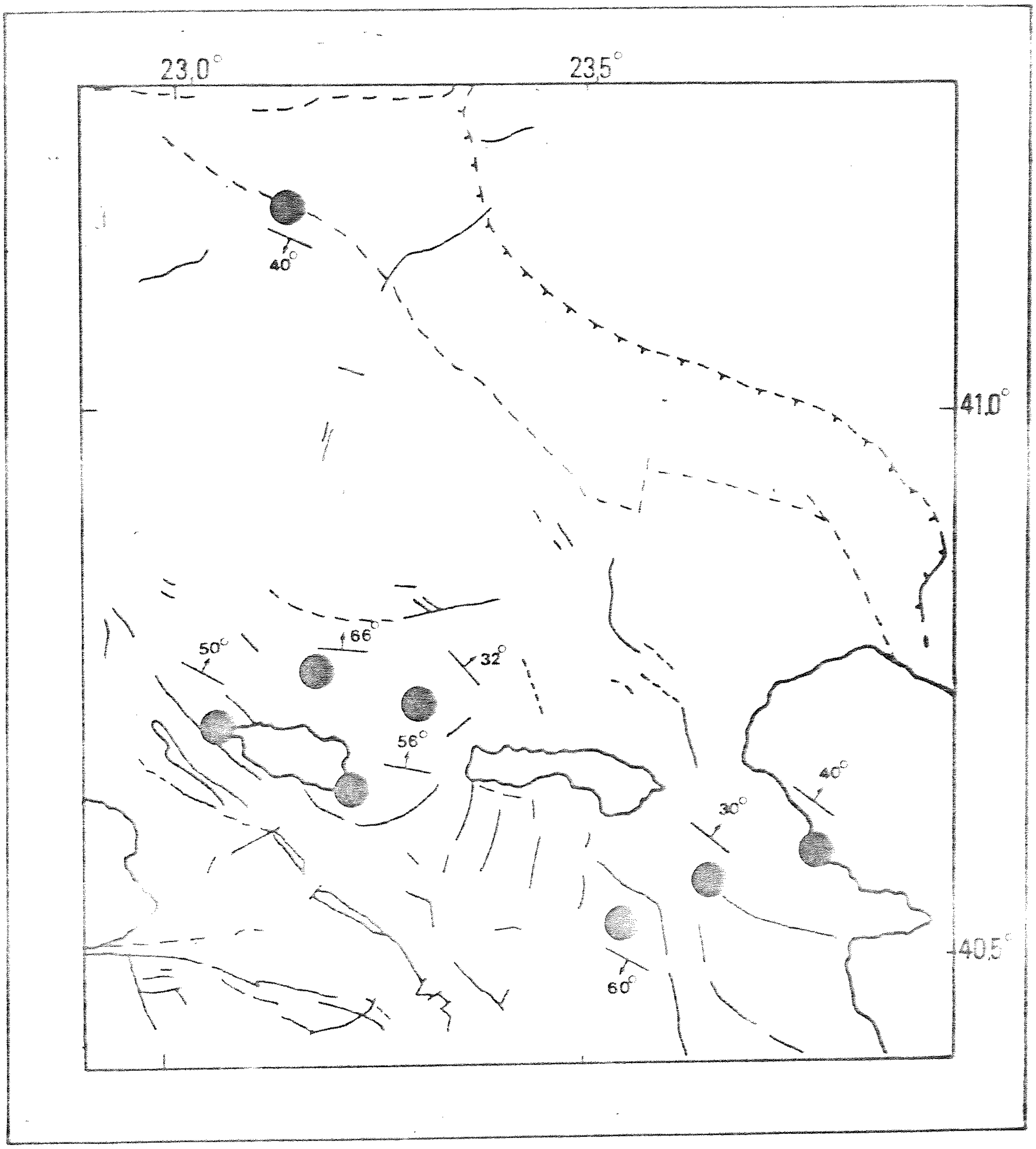

Fig. 4.8 Geological faulting map (IGME) including the epicenters of eight earthquakes with strike and dip symbols of the seismic faults (SCORDILIS 1985)

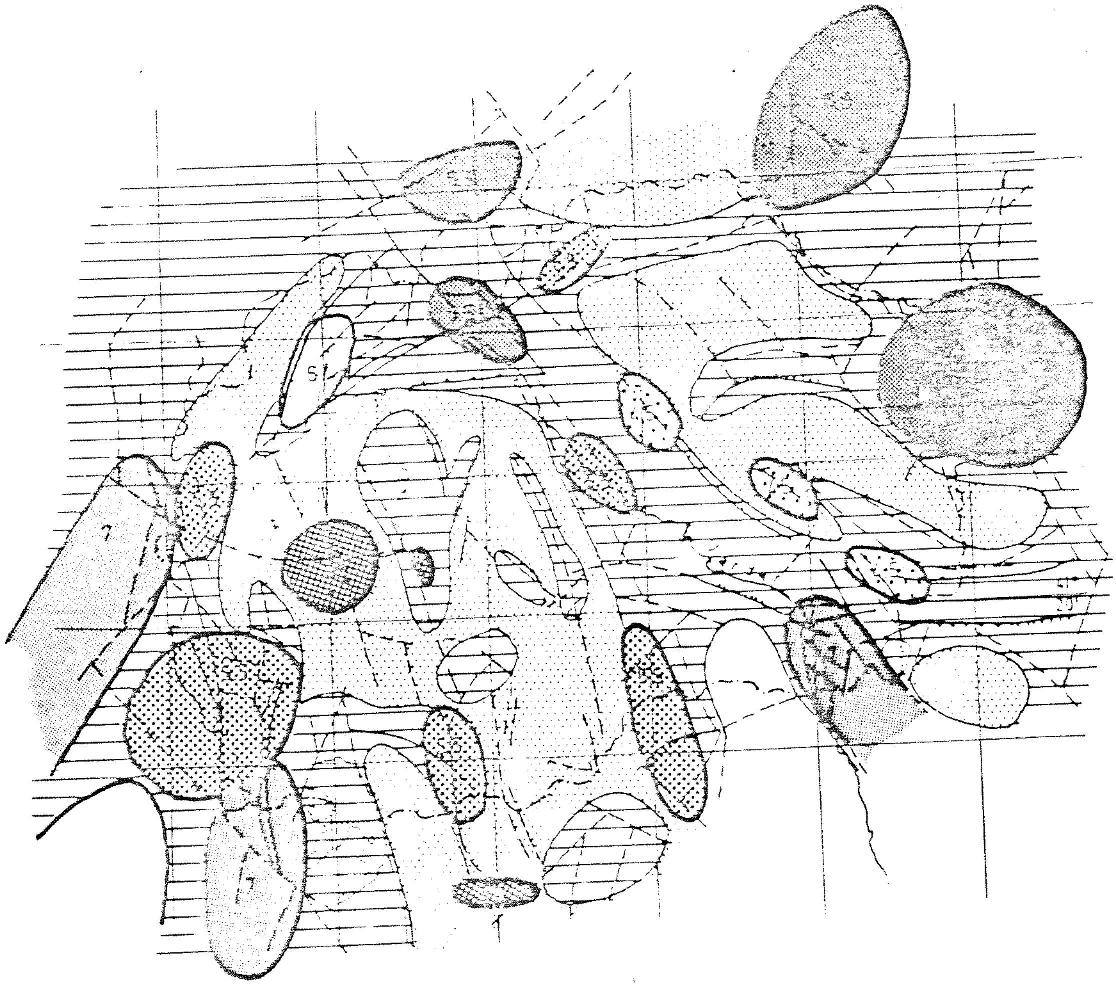

FIG.4.9 - MAP OF SEISMIC AREAS BASED ON SEISMOLOGICAL AND GEOLOGICAL DATA.

Compiled by: D.HADŽIEVSKI,
M.ARSOVSKI,1973

10 0 10 20 30km

L E G E N D

55 — EPICENTRE AREAS WITH MAXIMUM OBSERVED MAGNITUDES AND FAULTS

AREAS WITHOUT EPICENTRES (IN THE PERIOD OF OBSERVATION) AND WITH FAULTS

AREAS WITHOUT EPICENTRES (IN THE PERIOD OF OBSERVATION) WITHOUT FAULTS

MAGNITUDE

45	5	55	6	65	7	8

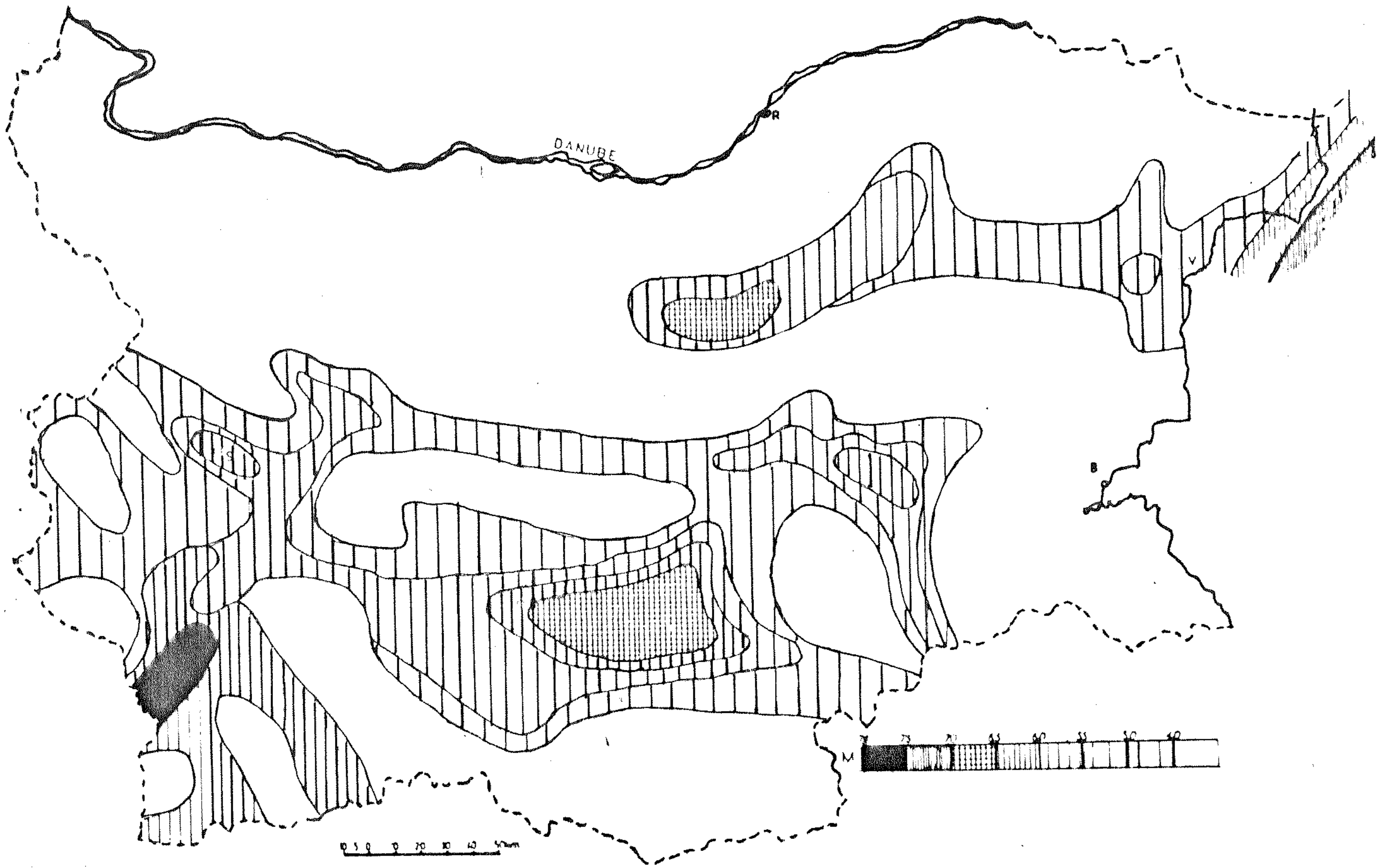

Fig. 4.10 Preliminary map of the expected earthquake origin zones in Bulgaria according to geological and seismological data. (KARAGJULEVA AND GRIGOROVA 1975)

ters and faults .Seven magnitude ranges (4.5,5,5.5,6,6.5,7.8) are shown (Fig.4.9).

A determination of the expected earthquake origin zones by the use of seismological and geological data for the Bulgaria territory was attempted by KARAGJULEVA AND GRIGOROVA (1975). The study comprises an analysis of all existing geological and geophysical data and seismological elements. Thus, considering the geotectonic data and seismic regime of the area, as well as geological and seismological data a map of expected origin zones in Bulgaria was made. (Fig 4.10). Several zones have been outlined-namely, the Struma,Shabla, Maritsa,North-Fore-Balkan,Tundzha and Sub-Balkan zones. The most interesting zone for our study is the Struma zone, in which intense recent vertical movements and very high seismic activity are observed.

4.2 Seismic Activity and Recent Tectonics of the Area

Based on the information on the faults, and on the geotectonic elements, as well as on seismological data,an effort is made to determine some dangerous areas . These risky areas combine long neotectonic faults and high concentration of earthquake epicenters. Long first order transversal faults with complete lack of earthquake epicenters,are considered of interest for further studies.

ARSOVSKI (1979), studing the seismotectonic regime of the Balkan region,used the correlation of the tectonic elements and seismological data to determine the seismogene sources in the Balkan region. He distinguished six types of sources with the following features.

a) Linear seismogene sources which are related to linear geotectonic units and longitudinal reactivated faults.

b) Seismogene sources associated with precambrian crystalline masses (Rhodope,etc.)

c) Sources which are related to the tectonic junction zones with various crossing faults.

d) Seismogene sources associated with the activity of the southern Aegean sea.

e) Local seismogene sources which are related to younger local depressions and faults of smaller order.

f) At the end, stable areas with uniform uplifting or subsidence can be another type of seismogene sources.

HADZIEVSKI (1973), taking into account earthquakes with $M \geq 5.1$ of the period 1901-1970 published a map of earthquake zones. In focusing our interest to the area studied, Kresna territory, in the Bulgarian-Yugoslavian border, is shown as a very active earthquake zone with magnitude range 7.1-8.0. The Valandovo-Gevgelia area, in the Greek-Yugoslavian border, is another active earthquake zone with magnitude range 6.1-7.0. The above mentioned areas are characterized by long transversal faults crossing the longitudinal faults.

In our study, a correlation of the seismic data with the defined faults is attempted. We mapped all the faults and then a geographical distribution of the epicenters was added. The main purpose of this correlation is the simultaneous consideration of all data and the definition of the active junction zones. On the map, the epicenters are symbolized by various side circles, denoting the corresponding magnitudes of the earthquakes. The largest circles show the epicenters with the corresponding magnitude range between 7.0 and 7.7. Different symbols are used for historical and present century data.

In depicting the epicenter on the same map with the faults, it is important to describe, the areas with high concentration of epicenters and faults (Fig 4.11).

In the Kresna first order junction zone, a dense concentration of epicenters are observed. The strongest known shallow earthquakes (M=7.7) in Europe has occured in this area. Also, this region shows a high activity for historical earthquakes. Considering the distribution of epicenters (SCORDILIS 1985)(Fig 3.11 and 3.12) a concentration of earthquakes of low magnitude earthquakes is observed in this area. These earthquakes are well-distributed along the faults. Thus, the first order junction zone and the high seismic activity denote intense tectonic movements manifested by the strong earthquakes.

Another active junction which is correlated with high seismic activity is that of Valandovo-Gevgelia territory. Many earthquakes have occured in this area, with a recent strong seismic event, which was occured on March 8 ,1931 M=6.7.Microseismicity study (SCORDILIS, 1985) and maps of fig.(3.11,3.12) show an epicentral concentration of low magnitude earthquakes in the same area. Some very long transversal faults of neotectonic character and a great number of longitudinal faults are manifested.The tectonic knot with high seismic activity shows another correlation between junction zone and earthquakes in the Serbomacedonian massif.

In the eastern part of Struma valley, (Bulgarian territory), a concentration of epicenters of low magnitude is observed . Recent seismic activity was presented by SCORDILIS (1985) for the last four years (1981-1984). An old longitudinal fault which is crossed by a small transversal fault explain well these low magnitude earthquakes.

Intense seismic activity with strong earthquakes (M=6-6.5) is shown around the Volvi-Lagada lakes. Our map (Fig.4.11) and the microseismicity data (SCORDILIS 1985) show a high earthquake activity. These seismological data and the intense neotectonic deformation in the Mygdonian valley explains the occurrence of strong earthquakes in this area. The neotectonic movements are manifested by the crossing of very active longitudinal faults and by a great number of transversal faults.

The Hierissos area is another junction zone with high earthquake activity. Two very intense neotectonic faults are crossed in the Hierissos gulf. These are associated with the strong earthquake of Sept.26,1932, M=7.0. SCORDILIS (1985)located many small earthquakes in the same region, which are associated with the two faults.

In the southern part of Athos peninsula,in the sea, some historical and present century earthquakes occurredi.e Jun.18, 1572 M=6.6 , Nov.8,1905 M=7.5. These earthquakes are related with the presumed fault (Fig. 4.11), south of the Chalkidiki peninsula. This fault is a long very active transversal fault. It is rather strange that no microseismic activity is observed during the last four years (1980-1984) (SCORDILIS 1985) (Fig 3.11 and 3.12) in this region.

Some junction zones not related to very strong earthquakes are shown around the Sithonia peninsula and the surrounding

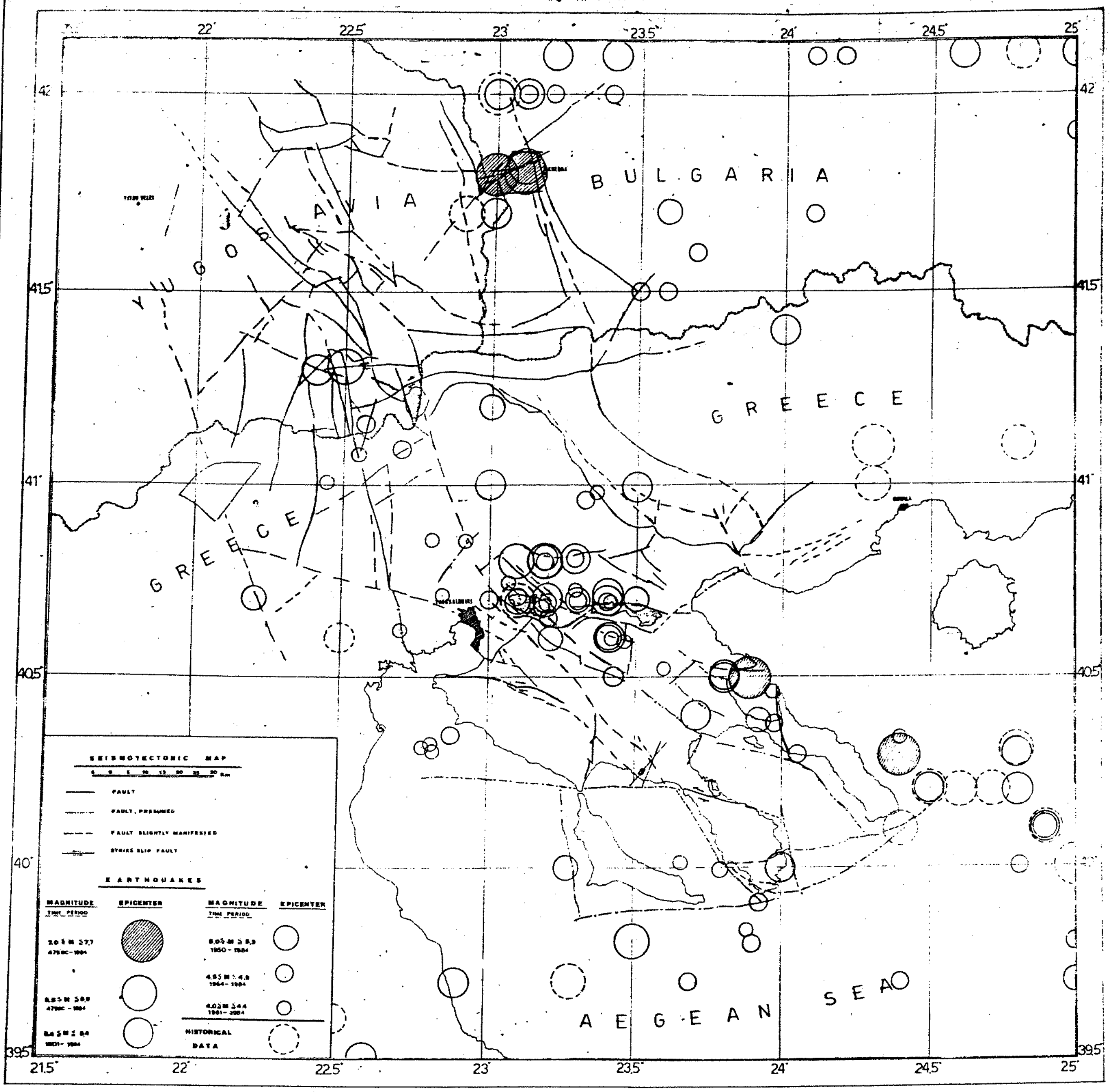

Fig. 4.11 Seismotectonic map of the studied area.

area. These tectonic knots is the result from the crossing of the two long transversal faults of W-E orientation with a great number of longitudinal ones. It is interesting to observe the microseismic data (SCORDILIS 1985) which show a concentration of epicenters around the Kassandra and Sithonia peninsula.

Around the Thessaloniki area and in the Vardar-Axios zone some secondary junction zones with epicenters of low magnitude are shown. These earthquakes are related with small no very active faults (Fig 4.11).

It is important to observe a very active junction zone south of Thessaloniki in Anthemouda area. It includes a very characteristic transversal neotectonic fault which is crossed by a number of small longitudinal faults. Geophysical studies which have been carried out by the Geophysical Laboratory of the University of Thessaloniki ,have shown an intense neotectonic activity. However, no earthquakes have been recorded from this area. The microearthquake activity is also low in this area (SCORDILIS 1985). Thus, this junction zone is a special case for futher investigation.

CONCLUSIONS

The main object of this thesis was to study the correlation between tectonic-neotectonic evolution with the seismicity of the Serbomacedonian massif and surrounding area.

According to the compiled map of the neotectonic regionalization, two main directions are dominant. The longitudinal direction is consisted of old tectonic faults which have N-S orientation,following the main geotectonic zones. The transverse direction includes faults which have E-W orientation,crossing the previous faults. These transverse faults are newer than the longitudinal and more active. The crossing area of the longitudinal and transverse faults is called junction zone. Classifing the two types of faults in three categories,we can recognize three kinds of junction zones. Depicting the first kind of the junction zone as an ellipse,we conclude an accumulation of these,along the geological contact of the Serbomacedonian and Vardar-Axios zone. The last fact is important,because,it have been observed high seismicity in the western boundary of Serbomacedonian and Vardar-Axios zone. While a concentration of second and third order zones are observed eastermost in Vardar-Axios zone and in the geological contact of the Serbomacedonian and Rhodope massif.

On the seismotectonic map,concentrations of large earthquakes are observed in places where first order junction zones are occurred. The existence of longitudinal faults crossed by long transverse ones show high seismicity and large earthquakes. The Kresna territory ,Valandovo, Lagadas-Volvi lakes and Hierissos territory are some characteristic regions.

Considering the seismicity of the area, we determine to the"a"and"b"values of the GUTEMBERG-RICHTER mangitude-frequency relation. The values of"a"and"b"are estimated for two time periods,(1800-1985)and (1900-1985).The results are in good agreement with the estimated values from previous researchers for the Yugoslavia and Greek territory.

The present study attempts to recognize some very risky regions correlating tectonic-neotectonic observations and seismic data. Using those data some further investigations can be accomplished. Some more elaborated seismotectonic investigations for each one of the junction zones and correlations with the seismicity will derive important conclusions about the regional seismicity. Applying seismic hazard assessments, exact data will be obtained about the seismic risk of the area. The regions which show intense neotectonic activity without seismicity must be carefully studied in future.

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