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PETROTECTONIC RELATIONSHIPS IN THE INTERNAL HELLENIC ZONES (NORTH GREECE)

(Figs. 3)

Abstract: Concerning the internal Hellenides, in order to establish geological similarities, the following aspects have been reached: Pelagonian zone, Rhodope and Serbo-Macedonian massifs underwent the Hercynian metamorphism with isoclinal folding. Transgression of marginal sea basin has been observed in all internal Hellenic zones, starting probably at Permian and completing at Lower Jurassic. These sediments have been metamorphosed in Vardar and Pelagonian zones probably in Late Jurassic—Early Cretaceous and in Serbo-Macedonian and Rhodope massifs in Middle Jurassic. The same metamorphism has affected the crystalline basement rocks as retrograde metamorphism. Additionaly, in most parts of internal Hellenic zones numerous acid intrusions of plutonic rocks mainly granodiorite occur.

Резюме: Что касается внутренних гелленид, для того, чтобы установить геологические сходства, были достигнуты следующие факты: Пелагонская зона, Родопский и Сербско-македонский массивы претерпели герцинский метаморфизм с изоклинальной складчатостью. Трансгрессия бассейна берегового моря наблюдалась во всех зонах внутренних гелленид, начиная вероятно с перми и конча нижней юрой. Эти осадки были метаморфизованы в вардарской и пелагонской зонах вероятно в поздней юре — раннем меле и в Сербско-македонском и Родопском массивах в средней юре. Тот же метаморфизм воздействовал на породы кристаллического фундамента как ретроградный метаморфизм. Кроме того, в большей части зон внутренних гелленид встречаются многочисленные кислые интрузии плутонических пород, главным образом гранодиоритовых.

Introduction

In this present, paper we try to examine the geology of the internal Hellenic zones in N. Greece and then, we will attempt to compare this, with the geology of a broader area beyond the Hellenic boundaries and especially with the geology of Alps who's southern extention are the internal Hellenic zones.

It is well accepted that such comparison is really very difficult because similar detailed works are not known, until present, especialy in the classical geological sense. Another important reason is that, the area under study, at present, is observed by a great number of authors under modern plate tectonics theory, which is not our purpose, at the present. In this paper

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we will avoid to envolve the plate tectonic theory because the treated area is very old and it is not simple to make any rough assumptions for it.

Practically is difficult to make geological comparison between members of internal Hellenides their rock units have undergone the same, or variable grades of metamorphosis, the same type of folding and their sediments age. But most important, of all above, is the same grades of metamorphism. All above belong to different geological time intervals.

Various radiometric dating attempts, for the internal Hellenides, do not appear dependable due to the broad geological interval between particular members and especially due to the obscurity caused by metamorphism and rejuvenation.

There are risky theoretical aspects, expressed by British colleagues, according to which a huge piece, which actually belongs to the internal Hellenides has been detached by decollement, from the continental crust of north Africa and has been moved along a strike slip fault of NW-SE direction, during Late Jurassic (Dixon — Robertson, 1985). Many similar problems oblige us to examine the geology of the internal Hellenides from the Pre-Palaeozoic to Middle Mesozoic avoiding the complications of the interpretation, which envolve more recent events.

Geotectonic and geological setting

For the first time Renz (1940) used the term "zone" in the geological study of the Hellenic area. The interpretation of the term according to the geotectonic sense refers to a geological unit, which is defined by specific petrotectonic facies, of a particular geological time. Although in this parer we intend to treat the internal Hellenic zones, we think it is necessary to mention briefly the essential differences between internal and external Hellenic zones. Basically in the internal Hellenic zones we observe high grade metamorphic rocks interrupted by frequent granite-granodiorite intrusions. On the contrary in the external Hellenic zones predominate sedimentary rocks of a younger age.

On the other hand, in the internal Hellenides, deep sea sediments are observed the genesis of which is related to the evolution of marine basins of orthogeosyncline type. Besides the above sediments in the same areas we observe also magmatic members, ophiolites. Extensive folding has been observed. On the contrary in the external Hellenic zones dominate sediments of a miogeosynclinal type (formations of shallow seas).

As we can see at the geotectonic scheme of Alps, according to Chorowicz (1977), it is obvious that the internal Hellenides have been characterized as (SM), Serbo-Macedonian massif including as well the Rhodope massif, while the western part of the under study area is symbolized as (DI), which means internal Dinarides zones. In this case we can observed that the division between Serbo-Macedonian and Rhodopian massifs, is a fact in Greek literature, but without any practical signification, for the geology of a broader area of the Alps.

We dont believe that the differentiation of Vardar and Pelagonian zones, from the other internal Hellenides, serves to solve any geological problems in the Greek area. However, we observe, a possible continuation of the internal Hellenic zones through the internal Dinarides (DI) and the corresponding Carpathians toward Austrian-Alps and particularly to High-Tauern (see H-T_1; Fig. 1).

On the geotectonic map of the (Fig. 2) we can see the implacement of the internal Hellenic zones, just as it is perceived today. From the E to W we distinguish, the Rhodope massif (RM) the Serbo-Macedonian massif (SM) the autochthonous series of Svoula (ASS), the Vardar zone (VZ) and the Pelagonian zone (PZ). Among the old major authors, which have studied the above mentioned zones, are Kossmat (1924), Bontschew (1920), Osswald (1938), Medwenitsch (1956), where among the younger ones we must refer to Dimitrijević (1974), Dimitrijević — Ćirić (1966), Mercier (1966, 1973) and Kockel et al. (1971, 1977). Also we must report here Meyer — Pilger (1963) which contributed positively, in a limited district of Rhodope massif. We owe the subdivision of Vardar zone from the Pelagonian to Kossmat (1924). Thus the same author introduced in the geological bibliography the term "Vardar zone". Bontschew (1920) studied the southern and eastern Rhodope and gave an innitial autlook of the minerology and petrography of Macedonia. Essentially first of all Osswald (1938) puts the principal geological bases for N. Greece.

The subdivision of Vardar zone by Osswald (1938) in to three subzones, partially coincides with a recent subdivision, which have been done by Mercier (1966, 1973) in the same area.

Dimitrijević (1974) has completed the distinction and specialization of Serbo-Macedonian massif, N of the Greek border while Mercier (1966, 1973) and Kockel et al. (1971, 1977) have examined in detail the geology of the Vardar zone and of Serbo-Macedonian massif respectivelly.

Now if we look geologically the internal Hellenides, we find three zones with metamorphic rocks while the forth zone, that of Vardar, is a tectonic trough (graben) which has been filled by the younger geological processes.

There are tectonic contacts between Pelagonian and Vardar zones, the autochthonous series of Svoula and the Serbo-Macedonian massif where each one of them thrust over the other, with a main NW-SE trend (see Fig. 2).

The transition of the Serbo-Macedonian massif to the Rhodope zone is marked along Strimon river where the Serbo-Macedonian massif overlies the adjacent Rhodope massif with an overthrust called "Strimon line" (Kockel — Walther, 1965; Koukousas, 1972).

Chatzidimitriadis — Kelepertzis (1984) disagree with the above overthrust scheme and propose a new one. They accept that the "Strimon line" composes an overthrusting line whereas the Rhodope massif subducts beneath the Serbo-Macedonian massif. Any way these observations are correlate positively by extensional movements observed in north Aegean.

For the same authors the "Strimon line" worked as a rotation axis also, where general tectonic data of the Rhodope massif, with NW-SE trend before the rotation, have been transformed to a NE-SW trend after rotation.

A similar rotational movement has been reported by Kontopoulou (1982) after geomagnetic investigations, in the area of Lesvos island. In this way the petrological features of Skyros and Lesvos islands are similar with those of the autochthonous series of Svoula, while the tectonic features are

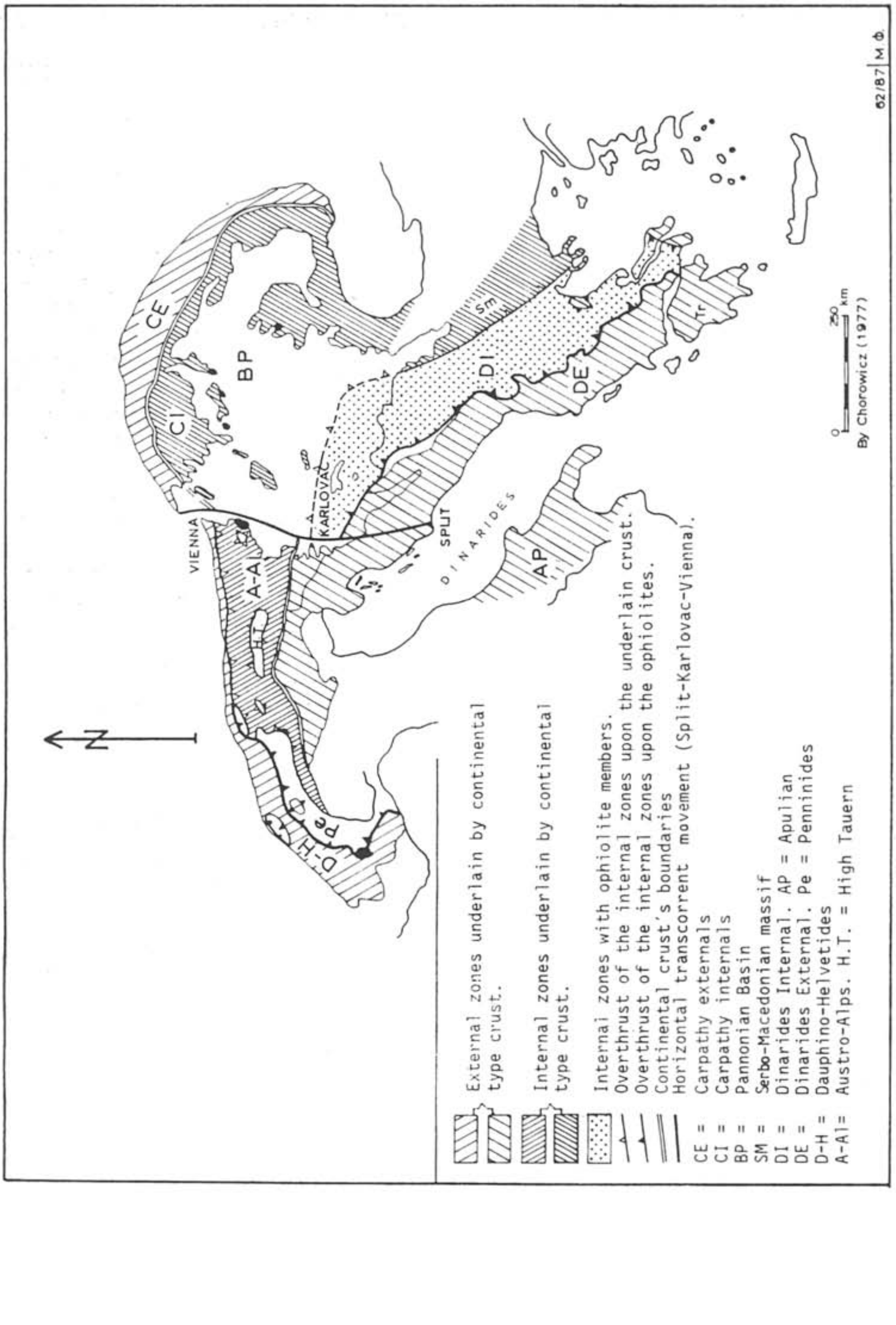
CE
CI
BP
VIENNA
A-Al
KARLOVAC
SPLIT
DINARIDES
AP
Sm
DI
DE
Tr
D-H
Pe
H.T.
0
250 km
By Chorowicz (1977)
62/87 M.Φ.
External zones underlain by continental type crust.
Internal zones underlain by continental type crust.
Internal zones with ophiolite members.
Overthrust of the internal zones upon the underlain crust.
Overthrust of the internal zones upon the ophiolites.
Continental crust's boundaries
Horizontal transcorrent movement (Split-Karlovac-Vienna).
CE = Carpathy externals
CI = Carpathy internals
BP = Pannonian Basin
SM = Serbo-Macedonian massif
DI = Dinarides Internal. AP = Apulian
DE = Dinarides External. Pe = Penninides
D-H = Dauphino-Helvetides
A-Al= Austro-Alps. H.T. = High Tauern

Fig. 1.

similar with those of Rhodope massif. So it seems to be evident that, for the above cited islands, we had a rotational case of N 45° E or NW 90° NE direction. All the internal Hellenic zones are thrusted, over the external zones, by a Ne to SW movement.

Petrotectonic features of the Internal Hellenic zones

From the geotectonic map of the internal Hellenides (Fig. 2) is evident, that in every particular zone, high grade metamorphic Paleozoic rocks and low grade metamorphic Neo-Paleozoic to Middle-Mesozoic sediments are present. The dotted area (Fig. 2) represents formations of Late Jurassic to Quaternary age.

We regard useful to start the description from E by the Rhodope massif and to finish going to the west by the Pelagonian zone. Following extensive field work, combined with detail examination of a large number of thin sections, we have reached the next petrological subdivisions of Rhodope massif. From the E (Fig. 2) are represented migmatite gneisses, augen-gneisses with intercalations of amphibolites and amphibolitic gneisses.

This area with the intense migmatitic phenomena of low and high temperature, like the aplites, pegmatites, quartz veins of milky-white colour, augen--gneisses and various nebulite phenomena, which completely have been lost the proper gneissic texture are shown (Fig. 2) separated, with coarse dotted lines from the remained area of Rhodope massif and then also shown in the Serbo-Macedonic massif.

At the central part of the Rhodope massif, augen-gneisses to gneisses without intense migmatitic phenomena occur while near the Strimon line the gneisses change to green schist-gneisses and marbles of a very-low to low-grade metamorphism than the previously listed rocks of same zone (Figs. 2, 3).

In Fig. 3, lithostratigraphic column (V) by the number (1) repressents the gneisses of the eastern and central part of the Rhodope massif, while by the number (2) gneisses of a very-low to low-grade metamorphism, which cover the western area of the Rhodopian massif.

The rocks of the eastern and central part of the Rhodope contain the following minerals: feldspars, quartz, green hornblend, biotite, less muscovite, kyanite, andalusite, garnet. Accessory minerals are: sericite, less chlorite and epidote. The last minerals maybe derive from biotite or partially from hornblend too. At the same parts of the Rhodopian massif a second paragenesis is observed consisting of large crystals of alkali feldspar, plagioclases less quartz, biotite and others. In the same thin sections myrmekitic phenomena are observed. Among the secondary minerals we distinquished sericite, less chlorite, apatite, zircon e.c.t. According to Turner — Verhoogen (1960) the above parageneses indicate a regional metamorphic grade which reaches the almandine-amphibolite facies. According to Barrow (1893—1912) (Winkler, 1967) classification of the minerals are classified in B.2.2. subfacies, that is in the medium grade of the almandine-amphibolite facies, with typical minerals disthene-almandine-muscovite.

Besides the above high-grade regional metamorphism, has been observed a retrograde metamorphism which reaches the greenschist facies Ivanov —

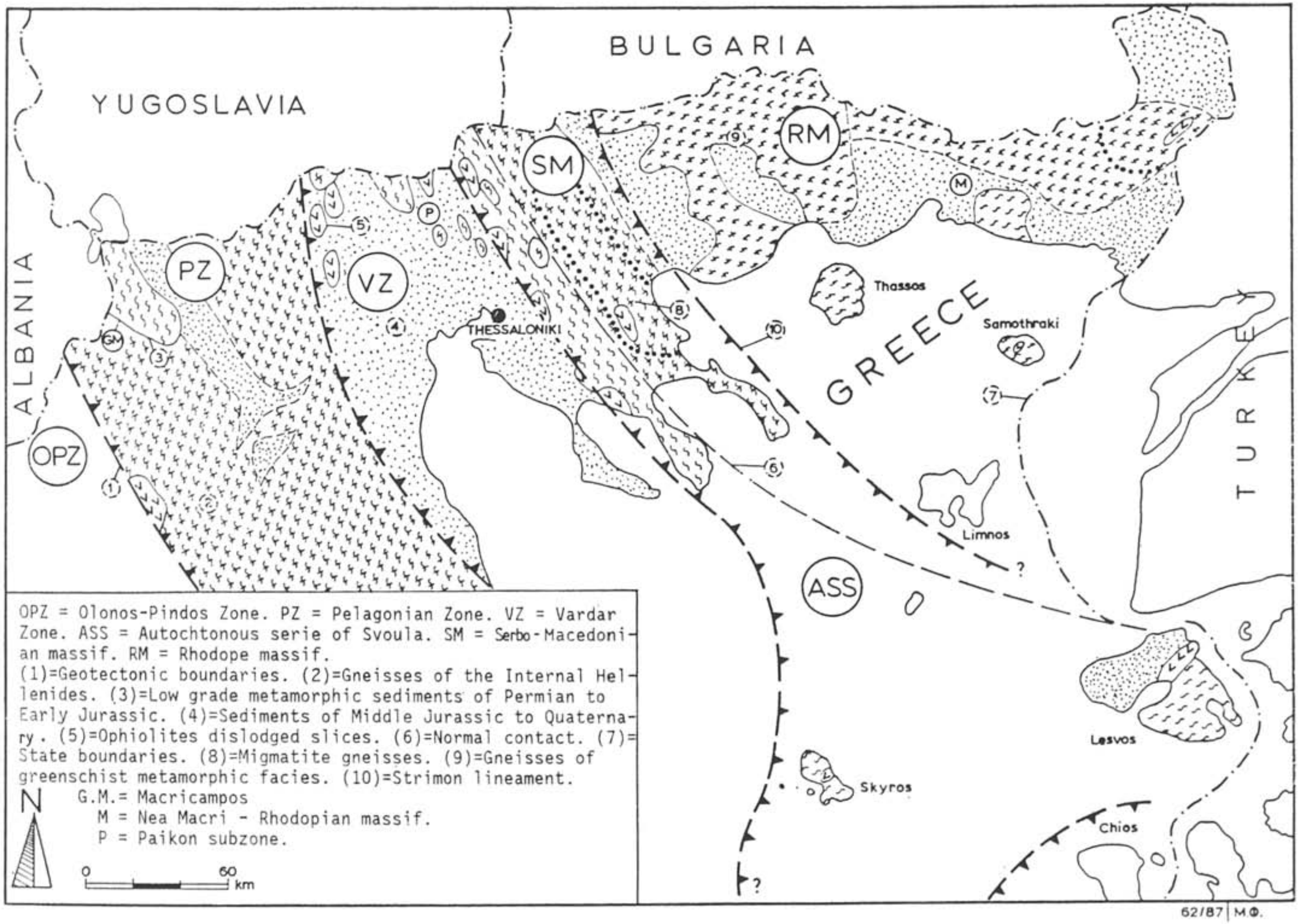
BULGARIA
YUGOSLAVIA
ALBANIA
GREECE
TURKEY
OPZ
PZ
VZ
SM
RM
ASS
GM
P
M
THESSALONIKI
Thassos
Samothraki
Limnos
Skyros
Lesvos
Chios
OPZ = Olonos-Pindos Zone. PZ = Pelagonian Zone. VZ = Vardar Zone. ASS = Autochtonous serie of Svoula. SM = Serbo-Macedonian massif. RM = Rhodope massif.
(1)=Geotectonic boundaries. (2)=Gneisses of the Internal Hellenides. (3)=Low grade metamorphic sediments of Permian to Early Jurassic. (4)=Sediments of Middle Jurassic to Quaternary. (5)=Ophiolites dislodged slices. (6)=Normal contact. (7)=State boundaries. (8)=Migmatite gneisses. (9)=Gneisses of greenschist metamorphic facies. (10)=Strimon lineament.
G.M.= Macricampos
M = Nea Macri - Rhodopian massif.
P = Paikon subzone.
N
0
60
km
62/87 | M.Φ.

Fig. 2.

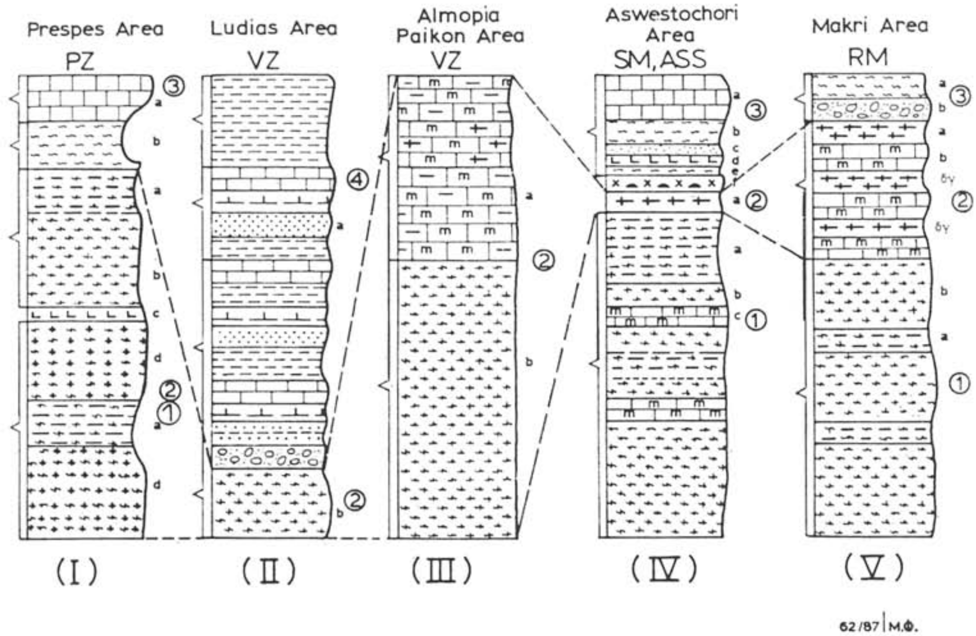

Fig. 3.

K o p p (1969) report similar rocks for the region of Strangia Dag (Turkey) and D i m i t r i j e v i ć (1974) in Yugoslavia and Bulgaria.

At the western part of the Rhodope massif marbles, greenschists to green gneisses of a low grade metamorphism, occur. Thus J o r d a n (1969), at the western part of the Rhodopian massif, determines the following group of minerals: green hornblend, plagioclase, quartz, epidote, chlorite and biotite while the marbles contain recrystallized minerals, calcite and dolomite. Generally the metamorphism of the above rocks reaches the grade of green schist to amphibolite facies E s k o l a (1939). Typically these rocks can be characterized as para due to the frequent alternations with marbles.

Effusive magmas with a basic chemical composition can not be related to sediments of a shallow sea. Until now we described the first (1) and the second (2) sequences which belong to the lithostratigraphic column (V) of the Fig. 3. The rocks, where are refered, at the sequence number (3) of the same column (V), Fig. 3 compose sediments, of a low grade metamorphism (green schist facies or even less), such as greenstones with quartz sericite, chlorite e.c.t., limestones with an insignificant number of conglomerates, then follow conglomerates consisting of gneiss and ophiolite pebbles, which derive from the eastern part of the Rhodopian massif. On the overlying parts we have carbonaceous shales, greenstones of the upper series e.c.t.

Tubiphites that have been found by M a r a t o s — A n d r o n o p o u l o s (1965) lead us to accept Triassic age for the lower members. At the eastern and partially at the central part, of the Rhodope massif isoclinal folds occur, which display the following tectonic parameters. The interlimb angle ranges

$2\hat{a} = 20—30$ with an axis trend of N-S to NNE-SSW and a plunge of 35° to N-NE. In the same rocks are also observed sub-isoclinal folds, with the interlimb angle that ranges ($2\hat{a} = 40°—60°$) and axis of a N-NE 14° S-SW direction, plunging 20 to N-NE. The sub-isoclinal folds have influence the isoclinal ones sufficiently. Finally we have open folds with an interlimb angle $2\hat{a} > 120°$. The fold axis has a ESE-WNW trend and a plunge of 7° to E-SE

It becomes clear, that the isoclinal fold F1 is older, than the F2 (sub-isoclinal), and the F2 older than F3 (open folds). In the Triassic sediments of Nea Macri (M — Fig. 2, No. 3 Fig. 3), lithostratigraphic column (V) are shown the folds F2, F3. The F2 fold has a N-S trend, its plunging is 20° to the N, and the interlimb angle is analogous, of the one found, in the metamorphic rocks. At the western part of the Rhodope massif two types of folding, of synchronous age, are distinguished. The first of them, we call "Flexion folds" having a micro-isoclinal shape, and the second one we call "Flexion and shearing folds". According to Kronberg et al. (1970) there exist, also synchronous, folding phenomena at the same area found in two different styles of folding?

According to comparative studies we consider the isoclinal folds synchronous to metamorphism, at the eastern and central parts of the Rhodopian massif, which we study. It is very probable that the sub-isoclinal folds are related to the metamorphism of the Nea Macri sediments, as described before. The open folds are younger, and they do not relate to the metamorphic processes.

The western part of the Rhodope massif have a low-grade metamorphism, and contains isoclinal — sub-isoclinal folds. Radiometric dating estimates about 26 m.y. of age of the metamorphism, in this area (compare Kronberg et al., 1970). For the central and eastern part of Rhodope massif in the conglomerate sediments of Nea Macri, gneiss conglomerates indicate, that we can accept, that during the Triassic age, which is the age of the conglomerate deposition, a gneiss-basement of high-grade metamorphism existed. The transgression took place during the Triassic at the eastern part of the Rhodope massif. Therefore the metamorphic age is pre-Triassic, for the gneiss-basement is at least Palaeozoic.

There are not any evidences, for the metamorphic age of the Nea Macri sediments, exept that as assumed by Maratos — Andronopoulos (1965) of a Middle Cretaceuos age. Moreover, it is difficult to understand the age problem of the rocks, at the western Rhodopian massif.

According to radiometric dating here the processes of metamorphism and folding occured during the Tertiary. Nevertheless, in this case, the radiometric datings remains always questionable. Also unknown is the age of deposition of the sediments.

In the lithostratigraphic column (IV) of the Fig. 3 is given the lithostratigraphy of the Serbo-Macedonian massif. In number (1) of the same column as well as at the Fig. 2 (SM) we have rocks of high grade metamorphism which are composed of migmatitic gneisses, schists, amphibolites e.c.t. Chatzidimitriadis—Kilias—Staikopoulos (1985). The minerals that have been distinguished are the following: basic plagioclase, green hornblende, minor biotite and quartz, garnet and others. Among the accesory minerals are: sericite, epidote and minor zircon. The grade of metamorphism according to Winkler (1967) has been risen to (B 2.3) subfacies of the almandine amphibolite facies.

In these rocks prevails intensive phenomena of migmatization, as well, as of retrograde metamorphism. At the western part of the Serbo-Macedonian massif there are located the green-gneisses, which are metamorphosed in the greenschist facies (No. 2, Fig. 3, column IV). Overlain the green-gneisses, exist the Svoula formations displaying a low grade metamorphism (No. 3, Fig. 3, column IV). These formations were deposited transgressively during the first stage on the crystalline basement and they are syn-folded with the rocks of the crystalline basement, during Middle Jurassic (Kockel et al., 1971; Chatzidimitriadis et al., 1985). In this manner they appear like a consequence, of the tectonic activity phenomena, of thrust slices in the autochthonous series of Svoula.

The isoclinal folds which are synchronous to the metamorphism of the gneisses have an interlimb angle of $2\hat{a} = 10°$. The fold axis has a NNE-SSW trend and plunge of 20° to the N-NE. The age of the folds and the age of high grade metamorphism of the Serbo-Macedonian massif have been estimated with K/Ar dating and is given by 300 m.y. That is of Hercynian period (Borsi et al., 1964).

Then follow the sub-isoclinal folds, of the Middle Jurassic, which are synchronous to the metamorphism of the Svoula sediments. Their interlimb angle is $2\hat{a} = 40°$, the fold axis has a NW-SE trend plunging 15° to the NW. The open folds of the Late Cretaceous are constant in all the formations with the same parameters of the ones throughout the internal Hellenic zones (Chatzidimitriadis, 1987).

In the Fig. 3 we can see the Vardar zone (Kossmat, 1924), with the two basic lithostratigraphic columns. The column (III) is refered to the Almopian subzone, while the column II, of the same figure, is related to the area of Loudia river where the Public Greek Oil Company had practiced one core drilling.

The Vardar zone has been divided by the Mercier (1966—1973) into three subzones, from the E to the W, the subzone of Peonia (graben), the subzone of Paiko (horst), and the subzone of Almopia (graben). From the lithostratigraphic column (II) of the Fig. 3, is revealed that the Vardar zone, as a unit, forms a graben and in this basement appear gneisses and schists (N2, Fig. 3).

The postmetamorphic system according the descriptions of the Public Greek Oil Company is consisted by sediments of the Eocene, Oligocene, Miocene and Plio—Pleistocene.

From Eocene to Plio—Pleistocene the total depth is estimated apx. 3000 meters. The above sediments have been illustrated by the number 4 in the column (II) of the Fig. 3.

Thus, become comprehensible that the graben of the Vardar generally does not seems to be filled up with disturbed rocks. Nevertheless the difference between the subsided basement for the geological periods (Palaeozoic—Middle Mesozoic) is obvious, by the comparison of the lithostratigraphic columns (II) and (III) of the Fig. 3. Mercier (1966—1973) is refered to the regional metamorphism of the entire area in the Vardar zone and characterises it as a geosynclinic. The metamorphism of the Vardar zone is considered Alpine.

One of the metamorphic stages took place during the Late Jurassic and a second one is placed between Late Maastrichtian and Early Oligocene.

Thus is also demonstrated, by other authors, that the gneiss-basement of the Vardar zone is, of same nature, with the basement of the Pelagonian zone which is metamorphosed during Alpine orogenesis.

The upper horizons are composed of marbles with green stones and cipolins while the lower horizons are constituted of gneisses, schists, amphibolites e.c.t.

It can not be controverted that in the Alpine metamorphosed gneiss-basement of Vardar zone may be found gneiss relicts of Pre-Alpine metamorphism (Hercynian). Four phases of folding are refered by Mercier (1966/1973) for the Vardar zone.

The earliest phase beggins during the Middle Portlandian and the latest is due in the Middle Oligocene. Thus the meaning of the sequence number (2) in the lithostratigraphic columns (V), (IV), (III), (II) and (I) of the Fig. 3. is in relation to the Alpine metamorphism, without any restriction of the above age of the metamorphism is constant or variable in time interval.

The metamorphic grade of the rocks, which belong to the lower members of the Vardar zone, reaches the greenschist facies while is relatively lower for the upper members. There is a peculiarity of the Pelagonian zone, which is composed by gneisses, schists, amphibolites and various granitic intrusions. According to Kilias (1983) who studied the Pelagonian zone, the metamorphic grade of the rocks ranges between the higher grade of the greenschist facies and the lower grade of the amphibolite facies.

Four phases of folding have been recognised by Kilias (1983) for a restricted area of the Pelagonian crystalline basement. An early (π_1) of Late Jurassic, the (π_2) of Lower Cretaceous, the (π_3) of Late Cretaceous—Early Palaeogene and the (π_4) of Priabonian—Oligocene age. The premetamorphic age of the crystalline rocks of the Pelagonian zone is Palaeozoic.

As shown in the lithostratigraphic column (I) of the Fig. (3), above the sequence of the metamorphic rocks (No. 2) overlain the Permo—Triassic sediments (No. 3), which have undergone different metamorphic grades.

If this is a subject of different metamorphic ages, or still, the sediments remain, at all times, on the upper horizons from the basement, and thus they preserved low metamorphism, during the Alpine cycle of the metamorphisms, remain a question.

The Permo—Triassic sediments with crystalline limestones and the phyllites are set over the rocks of high grade metamorphism, in a tectonic contact. Here it could be done detailed petrotectonic observations, of both formations, because it is possible that the sediments were originally in a transgressive relation to the crystalline rocks of the Pelagonian zone.

Correlation of metamorphic and tectonic data in the internal Hellenic zones — conclusions

After the petrotectonic descriptions of the internal Hellenic zones which have been reported on the previous chapter, we have the opinion, that we can proceed in some considerations, regarding the subject of the common events (metamorphism, folding) in these zones or revail the differences that exist. Indeed, if the differences are substantial then the division of internal Hellenides must remain as it is.

From the Figs. 2 and 3 (geotectonic map - lithostratigraphic collumns) it becomes clear that the eastern area of the Rhodope massif has been detached from the remaining part (coarse dots) as well as the corresponding one in Serbo-Macedonian massif (also coarse dots) as illustrated in Fig. 2 with No. (8). They consist by migmatitic gneisses, migmatites of low and high temperature, and prove almost the same grade of metamorphism, with a small difference. That is in the Rhodopian massif, and especially for the eastern and central part where we have a grade of metamorphism which reaches the medium stage of the almandine-amphibolite facies while in the Serbo--Macedonian massif we have the low grade metamorphism of the above same cases.

In the less migmatitic parts of the same zones we have again see similar manifestations of metamorphic grades, naturally exept the area of the western part of the Rhodope massif where the metamorphism reaches the grade of the greenschists facies. In both tectonic units, which we refered, have been recognised similar folds, that is typical isoclinal folds, who's ages very likely, are synchronous with the metamorphism, and for both the cases the metamorphism seems to be quite certain Palaeozoic.

The small differences in the grade of metamorphism perhaps must be attribute to the existing orogenic conditions, at that time, that is a great part of the Rhodopian massif has been found under higher P-T conditions of metamorphism. Yarwood—Aftalion (1976) and Mountrakis (1983) reports a great part of the north Pelagonian zone to have similar conditions of metamorphism, that is high grade of the greenschists facies to the almandine-amphibolite facies, with synchronous isoclinal folds of the Palaeozoic.

The above authors refer to an Hercynian age of (302 ± 4.5 m.y.) which have been resulted by a U/Pb dating. The petrotectonic differences between the Rhodopian and the Serbo-Macedonian massif, at the Bulgarian and Yugoslavian, as reported by Dimitrijević (1974) have not been observed in the Greek teritory. Thus the areas of the three massifs which have been labeled by the number (1) in the lithostratigraphic columns (V), (IV) and (I) of the Fig. 3, compose possible Palaeozoic shields.

Whatever has been illustrated, at the lithostratigraphic columns of the Fig. 3, by the numbers (2) and (3) signify metamorphic rocks of Alpine orogenesis. In this manner, number (2) in the column (V) which compose the western part of the Rhodopian massif, shows a metamorphism in the greenschists facies and corresponding tectonics, the age of which is determined as Eocene—Oligocene. The corresponding number of the column (V) is reported almost in the same metamorphism, with estimated age of Early Cretaceous (Sapountsis, 1969), of Middle Jurassic to Early Cretaceous (Jacobshagen et al., 1976).

The number (2) sequences in the stratigraphic columns (III), (II) and (I) of the Fig. 3, represents metamorphic rocks of which the grade of metamorphism partially overcomes the stage of the greenschists facies, and is the same with that, reported by number (2) of the lithostratigraphic columns

(IV) and (V). Anyway in this present case exists a Late Jurassic metamorphism and tectonic activity.

Here we must clear up the concept that the rocks before metamorphism belonged to Palaeozoic age in all the cases, exept that which is reported in the lithostratigraphic column (III) of the sequence by number 2, case (a). Here we refere to marbles, cipolins and greenstones very likely of Triassic Jacobshagen (1987). An additional younger, metamorphic event, as reported by various authors, in numbers (2) of the columns (I), (II), and (III). Because this event was not accompanied by any deformation fabrics we shall not deal with it. Becomes evident that all the internal Hellenic zones have undergone more or less an Alpine metamorphism, with slight differences reaching the grade of the greenschists facies.

For the overlain stratigraphic members, which have been illustrated at the number (3), in the same columns, we find out almost the same or maybe a little lower metamorphism, from that, of the greenschist facies. Nevertheless at all cases we are refered to Permo—Triassic to Middle Jurassic sediments or maybe even younger. Their metamorphism is justified to be low, in relation to that of the formation number (2), because they have been exposed at lowest conditions of P,T whereas stratigrafically they are overlied by those which they are presented by number (2).

There are tectonic elements such as sub-isoclinal folds, which are observed in all internal Hellenic zones, they are related to the Alpine metamorphism, but they differ partially in age. A Jurassic—Early Cretaceous age is considered for the sub-isoclinal folds of the Pelagonian and Vardar zones, while for the Rhodopian and Serbo-Macedonian massifs as well as for the autochthonous series of Svoula they are proved to be events of Middle Jurassic age.

The metamorphism of the formations by numbers (2) and (3) in the Fig. 3 begin by the greenschist facies and gradually decreases towards the overlain series. It exhibits features of a retrograde metamorphism in the two immense massifs (Rhodopian and Serbo-Macedonian) as well as in a large part of the Pelagonian zone. The same retrograde metamorphism is manifested by the synchronous presence of sub-isoclinal folds in the two massifs, while in the Vardar and Pelagonian zones the same style of folds are considered of Late Jurassic to Early Cretaceous. Unknown remains the Pelagonian part of Hercynian metamorphism.

There are evidences that the sub-isoclinal folds which exist in the autochthonous series of Svoula, the Serbo-Macedonian and the Rhodopian massifs are basically very old tectonic events.

The modern concept of "Circum Rhodope Belt" applied at present for the sediments of the western Serbo-Macedonian border has been introduced in Greek bibliography by Kauffmann et al. (1976) after previous Bulgarian authors which characterize by that the Late Jurassic sediments of the Bulgarian Rhodope around the crystalline rocks of the same massif. Nevertheless similar conditions do not exist in the N. Greece as in Bulgaria because on the one hand, the sediments are dated as Late Permian to Early—Middle Jurassic and on the other hand the Greek Rhodopian and Serbo-Macedonian massifs are not exactly the same due to different grade of metamorphism. We believe that during the Permian—Triassic to Middle Jurassic in the Greek internal Hellenic zones have been, interrupted by the formation of narrow marginal basins. Considering the above the sediments formed at the western margins of the Serbo-Macedonian massif are interpreted as autochthonous formations of Svoula series Chatzidimitriadis — Kilias — Staikopoulos (1985). Chatzidimitriadis (1976/1977). A more extensive sedimentation is observed mainly on the Vardar zone while in the Pelagonian the Serbo-Macedonian and Rhodope massifs synchronous transgressions occur during the Permian—Triassic, which continue until Jurassic and part of Cretaceous. All the above mentioned differences in Greek-internal Hellenides are due to tectonic events.

The Vardar zone is Cenozoic great graben (compare lithostratigraphic column II), (Fig. 3). The Pelagonian and Vardar zones as well as the Serbo-Macedonian and Rhodopian massifs they all have as a basic common feature a pre-Mesozoic basement and a prominent Hercynian metamorphism effecting all zones, except the Vardar one which has reached, generally the almandine-amphibolite facies. Although a systematic description of the ophiolite slices are deep sea formations consisting of graphitic shales, the dark coloured cherts etc. observed within the Permo—Triassic sediments of "Svoula" series and to a less extend in the Rhodope massif (area of Nea Macri).

Actually only the plutonic members of the ophiolites are present, while the effusive rocks, most likelly, have been eroded. A Permo—Triassic age of the ophiolites is accepted because the related cherts are observed within the Permo—Triassic sediments. These ophiolitic dislodged slices are believed to be of younger age by other authors, which have studied the area. After an attempt to correlate the geologic, petrographic and tectonic data available for the internal Hellenides zones and their marginal sediments we may outline the following.

a) In the three main internal Hellenic zones, which we can characterize as massifs, that is, the Pelagonian, Serbo-Macedonian and the Rhodopian consist of crystalline rocks, metamorphosed generally in the almandine amphibolite facies Winkler (1967).

b) The age of these geotectonic units is pre-Paleozoic while the metamorphism is younger Neo-Palaeozoic.

c) Isoclinal and recumbent isoclinal folds are observed in the three massifs synchronous to metamorphism, that is syn-metamorphic folds.

d) Migmatitic phenomena of a low and high temperature as well as aplites, pegmatites, nebulites and augen-gneisses are observed clearly in the three zones.

e) Small differences at the metamorphic grade among the three massifs are due to the initial composition and their location before metamorphism. From E to W a decrease of metamorphic grade has been observed. Thus the Rhodope massif has relatively higher metamorphism than the Serbo-Macedonian decreasing evermore in the Pelagonian massif.

f) We assume that metamorphism is related to the Alpine orogenesis consists of greenschist facies that occured for variable time intervals, in all the gneiss basement rocks of the internal zones, exept that of the Serbo-Macedonian massif. In every case this metamorphism is combined by synchronous formation of folds of isoclinal type or bending and shearing.

g) In the crystalline basement of the internal Hellenic zones, during the Permo—Triassic, transgressions took place, followed by sedimentation continuing until Cretaceous while in the Serbo-Macedonian massif ceased during the Lower Jurassic. We have here a metamorphism, which begins from the Middle Jurassic, and continues until the Lower Cretaceous, with presence of synchronous sub-isoclinal folds. The metamorphism in this case reaches the grade of the greenschist facies or perhaps a little less of it. The same metamorphism is manifested also as a retrograde metamorphism in the crystalline massifs, of the internal Hellenic zones, with corresponding manifestation of sub-isoclinal folds.

h) Finally in all the spectrum of the internal Hellenides is manifested a typical open folding probably of the Late Cretaceous followed by granite to granodiorite intrusions of a younger age, without excluding the presence of granitic old bodies within the internal Hellenic zones. Summarizing the comparison of the petrotectonic events in the internal Hellenic zones are established basic similarities, in these zones, but also some small differences.

Thus becomes comprehensible that a pre-Palaeozoic to Palaeozoic without metamorphism basement exist in the internal Hellenic zones in N. Greece, which it continues to exist after the Hercynian metamorphism, as it is observed, until the Cretaceous with various depositions. In this manner the consept of "allochthonous" of the same internal Hellenides it does not seems to have any support as expressed by Dixon — Robertson (1985). From comparisons resulting from the work of Kober (1955) and Chorowicz (1977) is reported that in the mountain ranges of the Alps are envolved the Caledonian, Uralian and Variscan orogenic processes. These processes continue to the east towards the Carpathians and Caucasous, while in the western they continue towards the Pyrenees mountains. The Apennines and the Dinarides continue as a unit with the Hellenides zones and their continuation we find at the Atlas mountains in NW Africa. For the part of the internal Hellenic zones, we may accept that it forms a unique relict bassement, of the pre-Alpine part, of south Europe, which has been modified by the Alpine and post-Alpine tectonic diastrophic movements.

Thus the continuation of the internal Hellenic zones througt the Carpathians (CI, Fig. 1) and Dinarides (DI, Fig. 1) to the area of the High Tauern in Austria (H-T, Fig. 1) it can not be debated. Also the discrimination of the crystalline basement in zones or massifs it does not seems to have a geological practical character after the above ascertainments as expressed in this papper.

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