GEOLOGICKÝ ZBORNÍK — GEOLOGICA CARPATHICA, 40, 3, BRATISLAVA, JUNE 1989,
Pp. 259—280

JAKOB PAMIĆ*

HERCYNIAN AND ALPINE GRANITIC-METAMORPHIC COMPLEXES OF THE ADJOINING AREA OF THE DINARIDES AND PANNONIAN BASIN IN YUGOSLAVIA AS RELATED TO GEODYNAMICS

(5 Figs., 3 Tabs.)

Abstract: Hercynian granitic-metamorphic complexes occur in the Slavonian Mountains located in the southern parts of the Pannonian basin where the Mohorovičić discontinuity at present is at a depth of 22 to 27 km. Two Hercynian granitic-metamorphic complexes can be distinguished: 1 — the Psunj complex is made up of Barrovian-type (?) metamorphic sequence invaded by I-granitoids. 2 — the Papuk complex consists also of Barrovian-type (?) metamorphic sequence which is associated with S-granitoids.

Alpine granitic-metamorphic complexes make up the Prosara—Motajica—Cer—Bukulja zone, which stretches for about 300 km south of the river Sava in the northernmost Dinarides. The zone also includes granitoids and metamorphic rocks of Moslavačka Gora and Požeška Gora Mts. located in the Pannonian basin. Alpine metamorphic rocks consist of greenschist and amphibolite facies rocks of Abukuma (?)-type metamorphic sequence, and in some places with migmatites invaded by S-type granitoids. Alkali-feldspar granites of Požeška Gora Mt. are A-type granites.

The present spatial distribution of the Hercynian and Alpine granitic-metamorphic complexes is related to the evolution of the Pannonian basin, which was created during crustal thinning and uplift of the upper mantle. The Alpine granitic-metamorphic complexes are spatially connected with Upper Cretaceous—Paleogene flysch units. These rocks were metamorphosed along a presumed subduction zone which can be traced for about 500 km to the south to the Vardar zone.

Резюме: Герцинские гранитно-метаморфические комплексы встречаются в Славонских горах, располагающихся в южных частях Паннонского бассейна, где слой Мохоровичича на глубине 22—27 км. Можно различить два гранитно-метаморфических комплекса: 1 — Псуньский комплекс образует метаморфическая последовательность барровского типа (?), интрудирована гранитоидами I-типа; 2 — Папукский комплекс сложен также из метаморфической последовательности барровского типа (?), сопровождаемой гранитоидами S-типа.

Альпийские гранитно-метаморфические комплексы образуют зону Просара — Мотайица — Цер — Букуля, которая простирается около 300 км на юг от реки Сава в самых северных Динаридах. Зона также включает гранитоиды и метаморфические породы Мославачкой горы и Пожешкой горы, находящихся в Паннонском бассейне. Альпийские метаморфические породы состоят из пород зеленоцветносланцевой и амфиболитовой фаций метаморфической последовательности типа Абукумы (?) и местами с мигматитами, интрудированными гранитоидами S-типа. Щелочно-полевошпатовые граниты Пожешкой горы являются гранитами А-типа.

Современное пространственное распределение герцинских и альпийских гранитно-метаморфических комплексов связано с эволюцией Паннонского бассейна, который был образован во время утонения земной коры и поднятия верхней мантии. Альпийские гранитно-метаморфические комплексы пространственно связаны с верхне-меловыми-палеогеновыми флишевыми единицами. Эти породы были метаморфизованы вдоль предполагаемой зоны субдукции, которую можно наблюдать около 500 км на юг от Вардарской зоны.

---

* Dr. J. Pamić, Institute of Geology, Sachsova 2, 410 00 Zagreb.

Introduction

Granitic rocks associated with various metamorphic rocks are very common in the northernmost Dinarides and southern parts of the Pannonian basin. They occur near the Sava river, and to the north in Moslavačka Gora Mt. and Slavonian Mountains (Psunj, Papuk, Krndija and Požeška Gora) and to the south: the Prosara, Motajica, Cer, Bukulja, and Boranja Mountains (Fig. 1). All these granitic-metamorphic complexes appear to have similar lithologies and consist of rocks of granite-granodiorite association, and different metamorphic rocks including phyllite, micaschist, quartz-muscovite schist, greenschist, amphibolite and gneiss that formed under the PT-conditions of greenschist and amphibolite facies. The granite-metamorphic complexes of the Prosara—Motajica—Cer—Bukulja Mts., stretching along and near the southern margin of the Pannonian basin, are included within the Inner Dinaridic Horst zone (Petković, 1958) and the Vardar zone (Dimitrijević, 1982). The granitic-metamorphic complexes of the Moslavačka Gora, Psunj, Papuk, Krndija and Požeška Gora Mts. are located north of the southern margin of the Pannonian basin in the area between the rivers Sava and Drava. To date, this area has been interpreted in several different ways: as a part of the "Oriental Land", Alps, Dinarides etc. All tectonic interpretations so far available on the latter area are compiled in Šparica and Pamić (1986).

Granitic-metamorphic complexes of the northernmost Dinarides and southern parts of the Pannonian basin have not been studied in detail. Petrological papers deal mostly with granitoids; for example, Boranja Mt. (Karamata, 1955), Cer Mt. (Knežević, 1962), Papuk Mt. (Vragović, 1965), Psunj Mt. (Marci, 1973; Pamić et al., 1984); Krndija Mt. (Pamić, 1988), Moslavačka Gora Mt. (Pamić et al., 1984a) and Požeška Gora Mt. (Pamić, 1987). Some papers deal with the associated metamorphic sequences, such as Papuk Mt. (Raffaelli, 1964), Krndija Mt. (Jamičić, 1983; 1988), and Prosara and Motajica Mts. (Varićak, 1957, 1966).

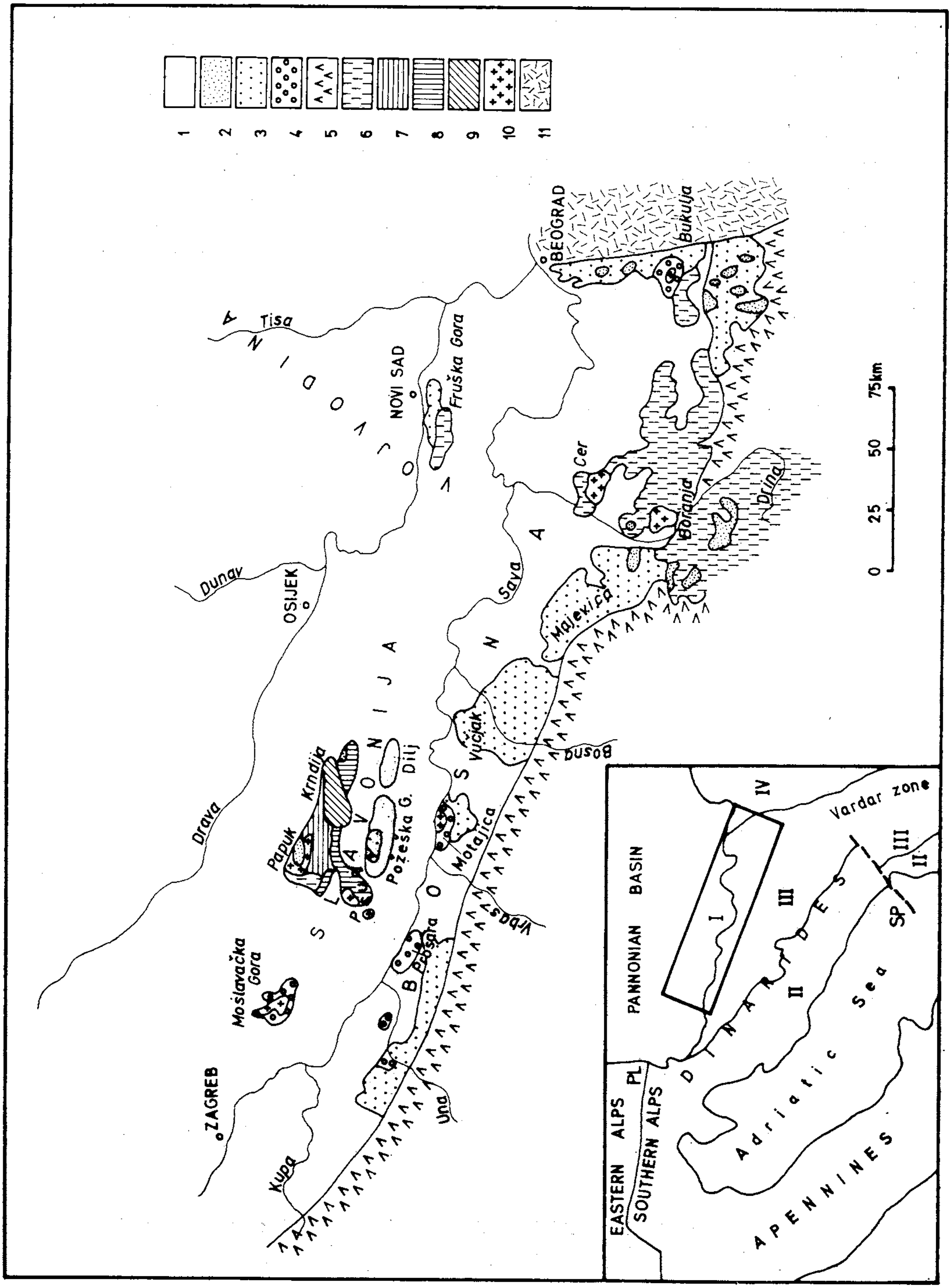
Few geological data are available for these granitic-metamorphic complexes. For this reason their age have frequently been subject to speculation. For nearly a hundred years, these complexes have been considered to be Precambrian or Paleozoic but without any paleontologic or isotopic evidence. Recently, new data have been collected that allow a new approach to the understanding of these granitic-metamorphic complexes.

The aim of this paper is to combine the petrology and geology of the granitic-metamorphic complexes of the northernmost Dinarides and southwestern

▲

Fig. 1. Schematized geological map of the adjoining area of the northern Dinarides and Pannonian basin with the index-map taken from Parotto—Protuilon (1981).

Legend: 1 — Pannonian basin; 2 — Tertiary volcanics; 3 — Upper Cretaceous-Paleogene flysch; 4 — Alpine metamorphic rocks; 5 — Dinaride Ophiolite zone; 6 — allochthonous Paleozoic nad Triassic masses; 7 — Papuk complex; 8 — Psunj complex; 9 — Radlovac complex; 10 — granitoids; 11 — Carpathians. I — Location of the area investigated; II — external and III — internal units of the Dinarides; IV — Carpathians and Balkans; PR — Periadriatic Lineament; SP — Skadar-Peć transversal fault.


1
2
3
4
5
6
7
8
9
10
11
ZAGREB
Kupa
Una
Moslavačka Gora
Drava
Papuk
Krndija
Psunj
Požeska G.
Dilj
Motajica
Prosara
Vrbas
Vučjak
Bosna
OSIJEK
Dunav
Sava
Majevica
NOVI SAD
Fruška Gora
Tisa
VOJVODINA
SLAVONIJA
BOSNA
Cer
Boranja
Drina
BEOGRAD
Bukulja
0
25
50
75km
EASTERN ALPS
SOUTHERN ALPS
PL
PANNONIAN BASIN
I
II
III
IV
Vardar zone
DINARIDES
SP
Adriatic Sea
APENNINES

Pannonian basin within the framework of modern geodynamic theories. Their present spatial distribution and interrelationships are intimately connected with the evolution of the Pannonian basin. This basin is the result of crustal thinning and uplift of the Mohorovičić discontinuity and upper mantle during Miocene extension. The granitic-metamorphic complexes of the Papuk, Psunj and Krndija Mts. are Hercynian in age, and the complexes of Moslavačka Gora, Požeška Gora, Prosara, Motajica, Cer, Bukulja and Boranja Mts. are mostly Early to Middle Alpine[1] in age. The latter are spatially connected with rocks of Upper Cretaceous—Paleogene flysch that were metamorphosed along a presumed subduction zone by high heat-flow due to intrusion of granites. The presumed subduction zone can be traced for about 500 km to the south to the Vardar zone.

Geological data

The Hercynian granite-metamorphic complexes

Highly metamorphosed rocks which occur in central parts of the Psunj, Papuk and Krndija Mts. have been considered long as Archaean (Gorjanović—Kramberger, 1897; Koch, 1919; Poljak, 1952) and were distinguished from semimetamorphic rocks of presumed Paleozoic (mostly Silurian and Carboniferous) age which occur in their marginal parts. Raffaelli (1964), Vragović (1965) and Tajder (1969) presumed that the Paleozoic semimetamorphic rocks were metamorphosed under PT-conditions of greenschist and amphibolite facies and partly migmatized and partly invaded by granites during the Hercynian orogeny. Jamičić (1983) distinguished in the Slavonian Mountains: 1. — the Psunj complex of presumed Baikalian age; 2. — the Caledonian Papuk complex, and 3. — the Hercynian Radlovac complex. The Carboniferous age of the Radlovac semimetamorphic complex was estimated from palynological data (Brkić et al., 1974), and the age of the first two complexes only on the basis of structural analysis. The Radlovac complex will not be considered in this paper because it does not include granitoids.

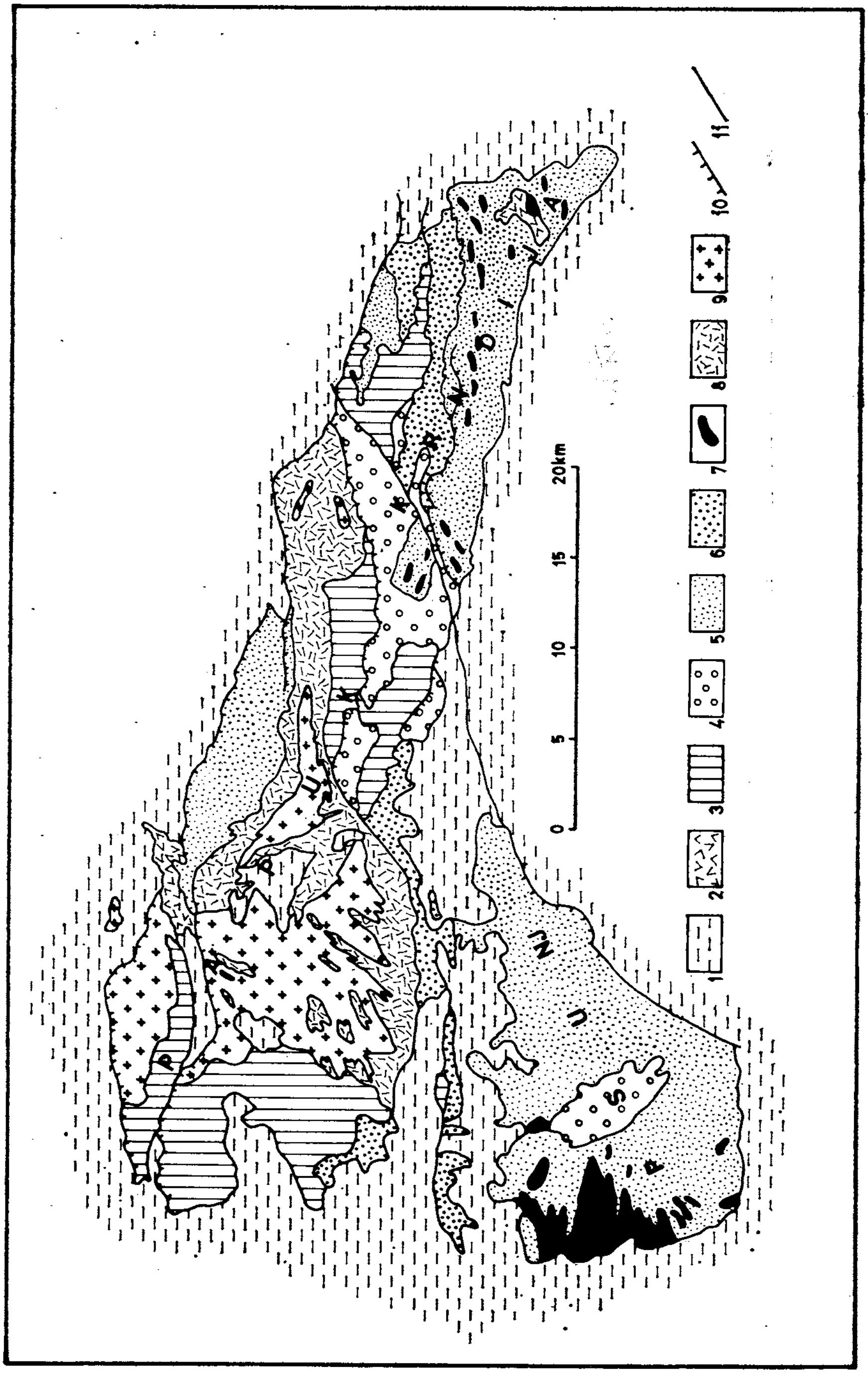
The Psunj granitic-metamorphic complex consists of various metamorphic rocks invaded mostly by small granite bodies commonly up to a hundred metres

Fig. 2. Simplified geological map of granite-metamorphic complexes of the Slavonian Mountains — based on unpublished detailed maps prepared by Jamičić (1988), Šparica, and Korolija.

Legend: 1 — Tertiary and Quaternary cover; 2 — Miocene volcanics; 3 — Mesozoic, mostly Triassic sediments; 4 — Radlovac complex; 5 — Psunj complex (mostly amphibolite facies rocks); 6 — Psunj complex (mostly greenschist facies rocks); 7 — I-granitoids; 8 — Papuk complex; 9 — migmatites and S-granitoids; 10 — reverse faults; 11 — normal faults.

---

[1] The terms Early and Middle Alpine (Van Yesinga, 1975) correspond to Eoalpine and Mesoalpine phases commonly used in the dating of metamorphic and tectonic events of the Alps (Dal Piaz et al., 1972; Trümpy, 1973, and others).


P
A
P
U
K
K
R
N
D
I
J
A
P
S
U
NJ
A
0
5
10
15
20km
1
2
3
4
5
6
7
8
9
10
11

across. They occur on Mt. Psunj and, further to the east on the northern flanks of Mt. Papuk and on most parts of Mt. Krndija (Fig. 2).

This is the only granite-metamorphic complex for which there are neither paleontologic nor radiometric age data.

K/Ar and Rb/Sr determinations are in progress and preliminary data point mostly to a Hercynian age, as presumed by Raffaelli (1964) and Marci (1973).

The Papuk granitic-metamorphic complex, as distinguished from the Psunj complex, has a distinctly migmatitic character. It includes smaller and larger bodies of anatectic granites.

Rb/Sr measurements on micas from rocks of the complex give 279 and 285 Ma (Tab. 1) and indicate Uppermost Carboniferous to Lower Permian age (Deleon, 1969). K/Ar and Rb/Sr determinations on additional samples, now being dated, suggest a larger range in age but still Hercynian.

Consequently, rocks both of the Psunj and Papuk complexes despite their petrological differences, have the same Hercynian age as do the adjacent semimetamorphic rocks (mostly shales and schistose metasandstones) of the Radlovac complex. The latter are most probably the protolith for both of the granitic-metamorphic complexes (Raffaelli, 1964; Vragović, 1965).

Rocks of the Psunj and Papuk granitic-metamorphic complexes are very common in the Pannonian basement. They have been penetrated in numerous oil wells located north and south of the Slavonian Mountains (Fig. 3) as well as further to the east in the area of Vojvodina (Pamić, 1986; Kemenci—Čanović, 1975).

Rocks of both the Psunj and Papuk granitic-metamorphic complexes can be correlated with similar rocks in Mecsek Mt. and the basement of the Pannonian basin in the adjacent parts of Hungary. The published isotopic ages of the Hungarian rocks are discordant, and show a large range from Precambrian to Permian (Jantsky, 1978). The most recently obtained data using several radiometric dating methods from several laboratories indicate that all of the granitic-metamorphic complexes of Hungary are Hercynian (Balogh et al., 1983).

Jamičić (1983) is of the opinion that the granitic-metamorphic complexes of the Slavonian Mountains are thrust as a whole with north vergence over the surrounding Tertiary sediments of the Pannonian basin. New data on tectonics of the adjacent Mt. Požeška Gora (Šparica — Pamić, 1986) show that the Upper Cretaceous volcanic-sedimentary complex, which is invaded by Alpine granites, is horizontally thrust over young sediments of the Pannonian basin. Šparica (pers. commun.) found young thrust structures but with south vergence in the adjacent Mt. Dilj in eastern parts of Slavonija. Similar reverse and thrust (?) structures have been interpreted in oil wells drilled in the basement of the Pannonian basin in the oil producing area of Molve near the river Drava (Pamić, 1986).

The new tectonic data on reverse and thrust (?) structures in the southern parts of the Pannonian basin have not yet been evaluated, so that it is difficult to give a coherent tectonic interpretation. It is doubtful that such reverse structures can be considered to be thrust faults in terms of the classical Alpine geology! Their origin is connected with young strike-slip faults with large displacements and between which, in some blocks, folding and even

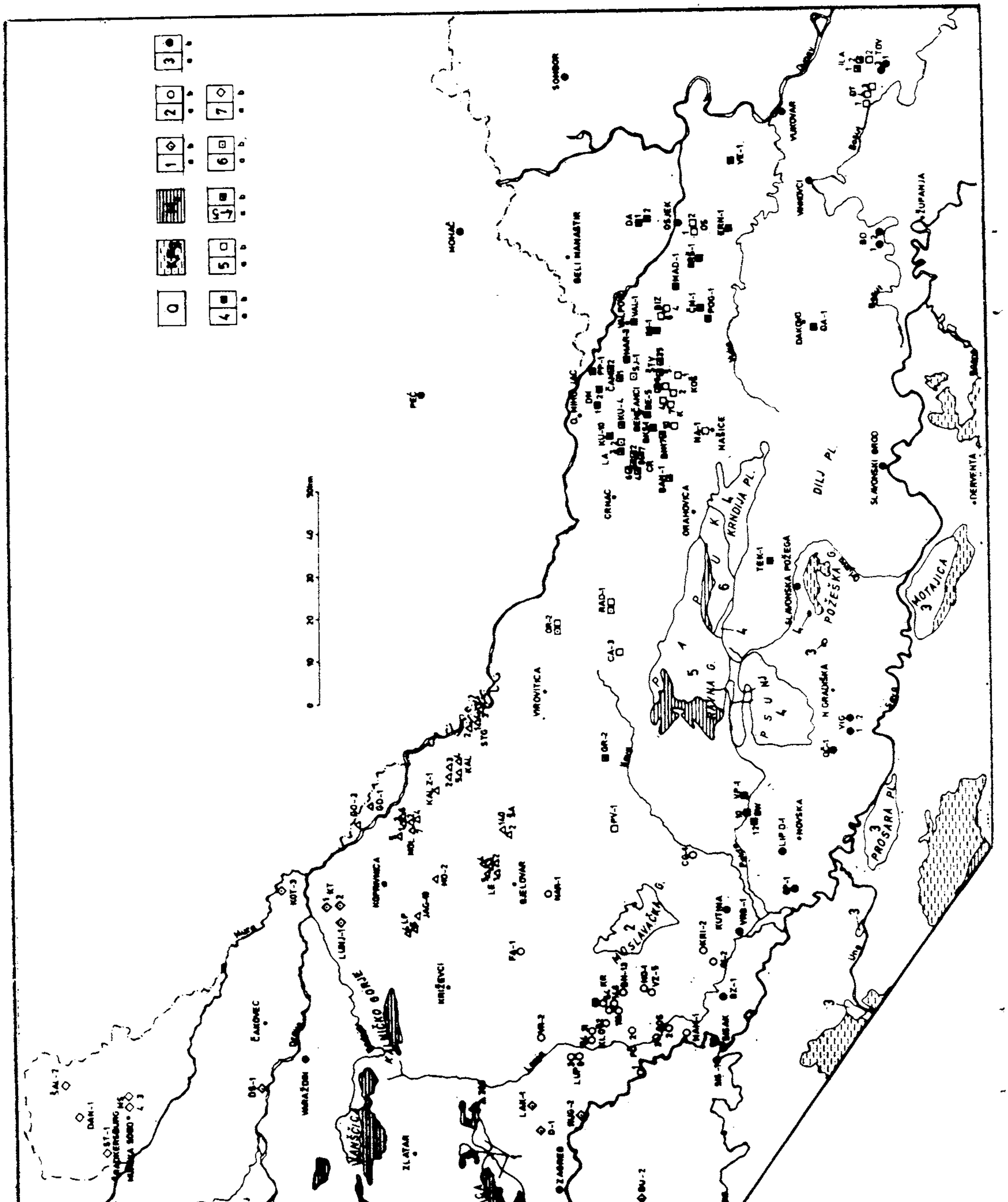
Table 1

Isotope ages for granites and the associated metamorphic rocks of the adjoining area of the northernmost Dinarides and Pannonian Mass

Locality	Rock	Mineral	K/Ar age[1]	Rb/Sr age[2]
Alpine				
CER				
Čakešina	granite	biotite		10.8 Ma
Southern slopes	pegmatite	muscovite		10.7±1
BORANJA				
Boranja	granodiorite	biotite		24
Desivojski potok	granodiorite	biotite		27±2
Boranja	granodiorite	biotite		29±2
MOTAJICA				
Motajica 1	granite	biotite		23±5
Motajica 2	granite	biotite		17±3
Motajica 3	two-micas granite	biotite		72
		muscovite		28
Borehole Visoka Greda, Sample 1	biotite amphibolite	hornblende	48.5 Ma	
		biotite	38.5	
Borehole Visoka Greda, Sample 2	biotite amphibolite	hornblende	43.2	
			27.2	
MOSLAVAČKA GORA				
Moslavačka Gora 1	granite	biotite		90±5
Moslavačka Gora 2	granite	biotite		62
Moslavačka Gora 3	gneiss-granite	biotite		64
Velika Sredska	granite	biotite	70±2	
Kamenica	pegmatite	biotite	57±	
Garić Grad	amphibolite	hornblende	88±3	
Borehole Križ 1	biotite granite	biotite	61±2	
Borehole Križ 2	biotite granite	biotite	64.9	
Borehole Vrbovec 1	biotite granite	biotite	27.2	
Hercynian				
PSUNJ			No published data	
PAPUK				
Papuk 1	gneiss	biotite		283
Papuk 2	two-micas granite	biotite		279
Papuk 3	pegmatite	muscovite		285±10

[1] Data published by Pamić (1985)

[2] Rb/Sr model ages published by Deleon (1969)


SOMBOR
MOHAČ
BELI MANASTIR
OSIJEK
VUKOVAR
VINKOVCI
ŽUPANJA
DAKOVO
NAŠICE
ORAHOVICA
CRNAC
PEČ
VIROVITICA
SLAVONSKA POŽEGA
POŽEŠKA G.
KRNDIJA PL.
PAPUK
PSUNJ
DILJ PL.
MOTAJICA
SLAVONSKI BROD
DERVENTA
N. GRADIŠKA
NOVSKA
PROSARA PL.
KUTINA
MOSLAVAČKA G.
BJELOVAR
KOPRIVNICA
KRIŽEVCI
KALNIČKO GORJE
VARAŽDIN
ČAKOVEC
IVANŠČICA
ZLATAR
MEDVEDNICA
ZAGREB
PTUJ
SISAK
Drava
Sava
Una
0 10 20 30 40 50km

thrusting on a small-scale with different vergences might have taken place (Horvath—Royden, 1981). The horizontal faulting and accompanying folding and thrusting can be probably related to the extensional processes that formed the Pannonian basin.

Alpine granitic-metamorphic complexes

Rocks of the Alpine granitic-metamorphic complexes can be traced discontinuously along strike for about 300 km south of the Sava river (Fig. 1) in the northern Dinarides and the southern margin of the Pannonian basin. The zone starts at Prosara Mt. in the west, and stretches to the east through the Motajica, Cer and Bukulja Mts., further to the south towards the Vardar zone. The zone also includes penecontemporaneous granites and metamorphic rocks of the Moslavačka Gora and Požeška Gora Mts. located north of the Sava river. Alpine granites and metamorphic rocks were encountered during drilling in the Pannonian basement (Fig. 3) in some areas located between the orographic units mentioned above (Pamić, 1986).

Upper Cretaceous—Paleogene flysch sediments, whose basal parts are in some places interlayered with volcanic and pyroclastic rocks, characteristically occur within the zone of Alpine granitoids and metamorphic rocks. These Upper Cretaceous—Paleogene rocks were found on southern slopes of the Prosara, Motajica and Bukulja Mts. and they were penetrated in some oil wells in the basement in the Pannonian basin (Kemenci—Čanović, 1975; Jelaska—Pamić, 1979). Upper Cretaceous sediments, interlayered with coeval volcanics rocks of a bimodal basalt-rhyolite association and invaded by penecontemporaneous granites, were also found in Požeška Gora Mt., north of the Sava river (Pamić—Šparica, 1983; Pamić, 1987).

For nearly one hundred years, granitoids and the associated metamorphic rocks of Moslavačka Gora, Prosara, Motajica, Cer and Bukulja Mts. have been considered, without any evidence, to be Precambrian or Paleozoic in age (Koch, 1899; Katzer, 1924/25; Simić, 1953; Jurković, 1962; Varićak, 1966 and others). Deleon (1969) was the first to present radiometric data pointing to the Late Cretaceous—Tertiary age of these granitoids. More recently, additional isotopic data show Late Cretaceous—Tertiary age (Pamić, 1985), not only for the granitoids but also for some of the associated metamorphic rocks of the Moslavačka Gora and Motajica Mountains (Tab. 1).

The Tab. 1 indicates that three groups of radiometric ages can be distinguished: 1 — Early Alpine (mostly Late Cretaceous) with approximate span

▲

Fig. 3. Geological sketch-map of the basement rocks of the southern parts of the Pannonian basin between rivers Sava and Drava with the location of oil wells. For the abravations of separate oil wells look in Pamić (1986).

Legend: Q — Quaternary; K, Pg — Upper Cretaceous—Paleogene volcanic-sedimentary and flysch complex; Mz — Mesozoic sediments. 1 — metamorphic rocks of Medvednica Mt.; 2 — granitic-metamorphic complex of Moslavačka Gora Mt.; 3 — granitoids and metamorphic rocks of Prosara and Motajica Mts.; 4 — Psunj granitic-metamorphic complex; 5 — Papuk granitic-metamorphic complex; 6 — Radlovac semimetamorphic complex; 7 — Pohorje granitic-metamorphic complex.

between 90 and 60 Ma; 2 — Middle Alpine (Paleogene) with approximate span between 45 and 30 Ma; and 3 — Late Alpine (mostly Miocene) with approximate span between 10 and 25 Ma. The evaluation of these radiometric data has been presented in a separate paper (Pamić, 1985).

Pantić and his coworkers have made a breakthrough in stratigraphic treatment of metamorphic rocks associated with Early to Middle Alpine granitoids. In many places within this zone they have found Late Cretaceous and Paleogene pollen in slates and phyllites previously thought to have been Archaean or Paleozoic (Pantić — Jovanović, 1970; Pantić et al., 1972; Aleksić — Pantić, 1972).

Consequently, the zone of Moslavačka Gora—Prosara—Motajica—Cer—Bukulja Mts. includes Early to Late Alpine granitoids and penecontemporaneous metamorphic rocks. The age of the granitoids is constrained by radiometric data, and the age of the associated metamorphic rocks by both radiometric and paleontological data.

As distinguished from the Pannonian region, the area of the northern Dinarides is characterized by a distinct zonal distribution of large lithofacies units; this is an ordinary feature of all orogenic belts. The generally prevailing opinion is that the Dinarides are multiply folded and that they display typical thrust and imbricate structures with southwestern vergence developed primarily during A-subduction (Herak, 1986). However, this generally accepted opinion must be questioned for the northernmost Dinarides. For example, Varićak (1966) located a thrust fault with north vergence along the northern margin of Motajica Mt.; the axial planes of folds in the metamorphic rocks which make up its southern parts also show characteristic north vergence. Laskarev (1930) is of the opinion that thrust faults with north vergence are also typical of Bukulja Mt.

There are no reliable data on the tectonics of the northernmost Dinarides. Thus the northern boundary of the area characterized by southern, i.e. Dinaridic vergence cannot yet be fixed. Despite this, the generally accepted opinion is that the main phases of folding, thrusting and uplift of the Dinarides finished by the end of the Pyrenean phase.

Petrology

Basic data on the petrology of Alpine and Hercynian granitoids and associated metamorphic rocks of the northern Dinarides and southern parts of the Pannonian basin are summarized in Tab. 2. Chemical composition of rocks of the granite-granodiorite association from separate areas is illustrated by the major element averages (Tab. 3) and by the $Na_2O + K_2O$ — CaO — $FeO + MgO$ triangle (Fig. 4).

Hercynian granites and metamorphic rocks

Granites and the associated metamorphic rocks of both the Papuk and Psunj complexes are penecontemporaneous and Hercynian.

The Psunj complex consists of gneiss, micaschist, amphibolite, greenschist, phyllite and quartzite with subordinate marble. In tectonically undisturbed areas

Table 2

Basic petrologic data for granites and the associated metamorphic rocks[1]

Hercynian		Alpine			
Papuk	Psunj	Moslavačka Gora	Motajica	Cer	Boranja
Granodiorites with quartz diorites and granites	Granites and granodiorites, mostly cataclastic with subordinate diorites and gabbro-diabases	Granites with subordinate diorites and gabbros	Granites with aplitoide granites and granite-porphyres	Quartz monzonites, aplitoide granites, granodiorites and graniteporphyres	Granodiorites, quartz monzonites and granodioriteporphyrites
Average contents: $Na_2O = 4.10$ and $K_2O = 2.79$ percentage	Average contents: $Na_2O = 4.62$ and $K_2O = 4.55$ percentage	Average contents: $Na_2O = 2.88$ and $K_2O \pm 4.75$ percentage	Average contents: $Na_2O = 2.75$ and $K_2O = 3.74$ percentage	Average contents: $Na_2O = 3.17$ and $K_2O = 4.31$ percentage	Average contents: $Na_2O = 3.40$ and $K_2O = 3.61$ percentage
Average Fe_2O_3:FeO ratio is 0.46; titanite and pyrite	Average Fe_2O_3:FeO ratio is 1.20; magnetite	Average F_2O_3:FeO ratio is 0.85; titanite	Average Fe_2O_3:FeO ratio is 0.85; magnetite (?), ilmenite	Average Fe_2O_3FeO ratio is 1.04; titanite-magnetite (?)	Average Fe_2O_3:FeO ratio is 0.89; titanite-magnetite (?)
Biotite with muscovite, very scarce hornblende; garnet	Biotite with scarce hornblende	Biotite with scarce muscovite pseudomorphs; andalusite and cordierite	Very common muscovite pseudomorphs after biotite; tourmalinization	Frequent muscovite pseudomorphs after biotite, tourmalinization	Amphibolization of biotite
Migmatites with preserved Barrovian-type sequences: phyllites, micaschists, gneisses with subordinate amphibolites	Gneisses, micaschists, amphibolites, greenschists, phyllites with marbles and quarzites. Preserved Barrovian-type sequences	Gneisses, micaschists and amphibolites, in boreholes with greenschists, marbles and phyllites. Contact-metamorphosed hornfeleses and skarns	Gneisses, micaschists, amphibolites, greenschists, phyllites, marbles and quartzites. Contact-metamorphosed hornfelses	Gneisses and micaschists. Contact-metamorphosed hornfelses and skarns	Contact-metamorphosed hornfelses ans skarns
Muscovite, chlorite, biotite, garnet, staurolite, sillimanite and kyanite	Muscovite, chlorite, biotite, garnet, staurolite, sillimanite and kyanite	Muscovite, biotite, cordierite, andalusite and sillimanite	Muscovite, chlorite, biotite and garnet; cordierite and andalusite	Muscovite, biotite and garnet; andalusite and sillimanite	Andalusite and cordierite

---

[1] Based on papers published by: Karamata (1955); Knežević (1962); Marci (1973); Pamić (1986); Pamić et al. (1984 and 1984a); Raffaelli (1964); Varićak (1966); Vragović (1965); Vragović & Majer (1980), Barić (1974).

Table 3

Major element averages of Hercynian and Alpine granitoids

	1(23)	2(17)	3(12)	4(15)	5(10)	6(10)	7(10)	8(13)	9(7)	10(10)
SiO_2	72.89	72.16	67.05	66.71	73.45	70.96	67.82	64.99	71.58	69.87
TiO_2	0.25	0.15	0.55	0.50	0.32	0.18	0.21	0.28	0.20	0.37
Al_2O_3	13.41	13.97	16.94	14.99	13.38	15.97	16.75	16.56	14.95	15.73
Fe_2O_3	0.99	2.25	0.91	1.11	0.89	1.64	1.60	1.81	0.76	2.43
FeO	0.89	0.84	1.97	2.52	1.06	0.82	1.80	2.09	2.07	0.24
MnO	0.02	0.07	0.04	0.11	0.05	0.04	0.07	0.10	0.04	—
MgO	0.78	0.66	1.37	1.86	0.60	1.01	1.01	2.00	0.57	0.27
CaO	0.81	3.33	2.91	2.26	1.22	1.61	2.66	3.75	1.45	0.51
Na_2O	4.62	4.23	4.11	3.48	2.86	2.75	3.19	3.40	3.20	5.70
K_2O	4.55	1.00	3.12	4.10	4.77	3.74	4.05	3.63	4.57	3.64
P_2O_5	0.12	0.01	0.16	0.19	0.17	0.14	0.21	0.22	0.12	—
H_2O	0.88	1.20	1.16	1.59	1.10	0.88	0.73	1.25	0.62	1.61
Total	100.21	99.87	100.29	99.42	99.87	99.74	100.10	100.08	100.13	100.37

Hercynian:
1 — I-granitoids of Psunj Mt.; (Marci, 1973) 2 — I-granitoids of Krndija Mt. (Pamić, 1988); 3 — S-granitoids of Papuk Mt. (Vragović, 1965); 4 — S-granitoids of Mecsek Mt. (Jantsky, 1978);
Alpine:
5 — S-granitoids of Moslavačka Gora Mt. (Pamić et al., 1984); 6 S-(?)-granitoids of Motajica Mt. (Varićak, 1966); 7 — S-granitoids of Cer Mt. (Knežević, 1962); 8 — S-granitoids of Boranja Mt. (Karamata, 1955); 9 — S-granitoids of Bukulja Mt. (unpublished data); 10 — A-granites of Požeška Gora Mt.
(Number of available analyses are between brackets).

metamorphosed sequences show a distinct zonation: chlorite→biotite→garnet→→staurolite→sillimanite, in places with kyanite, which originated under PT-conditions of greenschist and amphibolite facies (Raffaelli, 1964; Jamičić, 1983). Most recently Pamić (1987b) found andalusite in amphibolite facies paragneisses from the zoned sequence of Psunj Mt. More commonly, only some parts of this prograde sequence are preserved depending on the folding index and the kind of faulting.

These metamorphic rocks are commonly invaded by small masses of granitoids. These masses in Psunj Mt. are made up mostly of granite with subordinate granodiorite (Marci, 1973) and, in Krndija Mt. mostly of tonalite with subordinate granodiorite (Pamić, 1988). This difference in rock types is brought about by changes in the mineral paragenesis which consists of quartz, oligoclase, biotite with subordinate muscovite and amphibole. Potassium feldspar, represented mostly by postkinematic microcline, is in some granitoids (for example, Psunj Mt.) a major mineral, and in some of them (for example, Krndija Mt.) nearly absent. The granitoids are characteristically cataclastic and they are associated with subordinate quartz monzodiorite and diorite, and gabbro (Pamić, 1988; Pamić et al., 1984).

Some of the features of granitoids from the Psunj and Krndija Mts. such as high Na_2O content (4.62 and 4.23 per cent), high Fe_2O_3 : FeO ratio (1.2 and 2.7) and the presence of quartz diorite, monzodiorite, and gabbro suggest that they might be I-granitoids (Chappell — White, 1974). However, the content of K_2O varies; it is about 1 per cent in microcline-free granitoids from Krndija Mt. and up to 4 per cent in the microclinized ones from Psunj Mt. (Tabs. 2 and 3).

The Papuk complex consists mostly of gneiss, micaschist, greenschist and phyllite with subordinate amphibolite. Within tectonically undisturbed parts of the Papuk complex, regionally metamorphosed prograde sequences are also preserved, and they show the same zonation: chlorite→biotite→garnet→staurolite→sillimanite, which were formed under PT-conditions of greenschist and amphibolite facies. The sequence has been observed for the first time in southwestern parts of Mt. Papuk where its highest parts grade into migmatites (Raffaelli, 1964). Such prograde sequences occur both in the Papuk and Psunj complexes. In fact, both of them are related to a single metamorphic event and thus they represent one single Hercynian prograde metamorphic sequence regardless if being migmatitized (the Papuk complex), invaded by I-granitoids (most of the Psunj complex) or even without granitoids (parts of the Psunj complex).

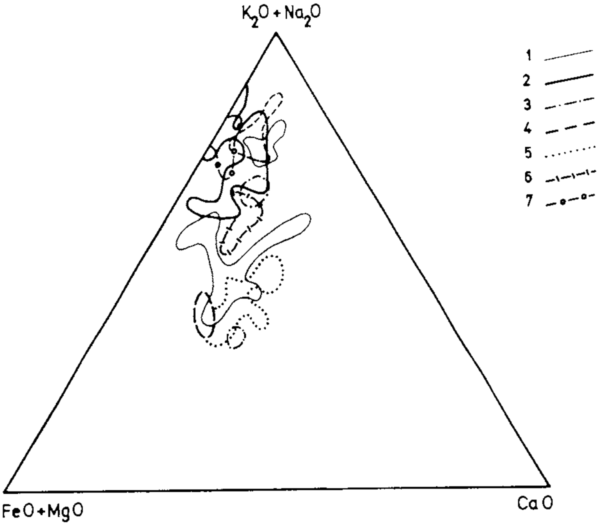


Fig. 4. $K_2O + Na_2O$ — $FeO + MgO$ — CaO triangle for rocks of Hercynian and Alpine granite-granodiorite associations of the adjoining area of the northern Dinarides and Pannonian basin.

Notes: Hercynian: 1 — Papuk and Mecsek Mts.; 2 — Psunj Mt.
Alpine: 3 — Motajica Mt.; 4 — Cer Mt.; 5 — Boranja Mt.; 6 — Bukulja Mt.; 7 — Požeška Gora Mt.

The most striking characteristic of the Papuk complex is the presence of different varieties of migmatites and anatectic granites (Vragović, 1965). The anatectic bodies generally consist of granodiorite and quartz diorite containing quartz, oligoclase and andesine, orthoclase, postkinematic microcline-microperthite, muscovite and biotite with scarce amphibole; garnet is a very common assessory mineral. Anatectic granitoids occur as veins a few centimetres to several tens of metres thick, and also as large bodies which cover a surface area more than 50 km^2.

It is obvious that anatectites from the Papuk complex belong to the family of S-granitoids with very low $Fe_2O_3 : FeO$ ratio (the average is 0.46). The low content of K_2O (the average is 2.71) and the higher content of Na_2O (the average is 4.10 per cent) probably are not representative because the averages were calculated on the basis of a small number of the available chemical analyses.

Alpine granites and metamorphic rocks

Alpine granite-metamorphic complexes have some peculiar characteristics which are different from those of the Hercynian complexes. All of them are characterized by the presence of comparatively small granite bodies surrounded by regionally metamorphosed sequences, but commonly with hornfelses and calc-silicate rocks (skarns) along their contacts (Tab. 2). The granites occur as veins a few metres thick up to bodies commonly not larger than 50 km^2. In some areas, for example in Motajica Mt., metamorphic rocks cover larger surface areas than the granite bodies. But several smaller granite bodies have been geophysically detected in the deep subsurface of the area (Labaš, 1975). By contrast, in the surrounding Prosara Mt., the regionally metamorphosed sequence is cut only by vein bodies a few metres thick of graniteporphyry.

Metamorphic rocks of the Moslavačka Gora—Prosara—Motajica—Cer—Bukulja zone have not been evenly studied in detail. They are best exposed in the Motajica and Prosara Mts., where they have been studied by Varićak (1957, 1966). He had the opinion that they belong to the Hercynian orogeny. Based on Deleon's (1969) radiometric data and pollen determinations by Pantić — Jovanović (1970) it was thought that greenschist and amphibolite facies metamorphic rocks of Motajica Mt. might have been produced by metamorphism of the adjacent Upper Cretaceous flysch sediments due to high heat flow related to the granite intrusions (Pamić, 1977). Most recently, Pamić (1985) gave petrographic evidence for gradational changes from Upper Cretaceous sediments to prograde metamorphic sequence as follows: 1. shale→→slate→phyllite→biotite phyllite→micaschist→gneiss; 2. sandstone→schistose metasandstone→quartz-muscovite schist→micaschist→gneiss; 3 limestone→crystalline limestone→marble. In the adjacent Prosara Mt., the lowermost parts of the metamorphic sequence are mostly covered by Neogene sediments and the highest grade is greenschist facies due to lower thermal input provided by the presence of much smaller granite bodies than in Motajica Mt.

In the northwestern parts of the zone, in Moslavačka Gora Mt., only higher grade parts of the metamorphic sequence are exposed. This is represented mostly by gneiss and micaschist with subordinate amphibolite (Vragović — Majer, 1980; Pamić, 1985). These rocks are, in some places, extensively migmatitized. Some oil wells in the neighbourhood of Moslavačka Gora Mt. penetrated the lower grade metamorphosed parts of the sequence represented by phyllite, greenschist and marble (Pamić, 1986).

The data for metamorphic rocks from Mts. Moslavačka Gora, Prosara and Motajica indicate that they originated under PT-conditions of greenschist and amphibolite facies. Higher-grade parts of the sequence in Moslavačka Gora Mt. characteristically contain andalusite and cordierite (Vragović — Majer, 1980; Pamić, 1985) and the same minerals have been found in some amphibolite facies rocks of Motajica Mt. (Varičak, 1966). Accordingly, these metamorphic rocks from western parts of the zone of Alpine granitoids can be considered as an Abukuma-type metamorphic sequence (Miyashiro, 1961).

By contrast, there are not adequate petrologic and geologic data on metamorphic rocks from eastern parts of the zone in the Cer, Bukulja and Boranja Mts. Based on data from the literature, metamorphic rocks around granite bodies of the Cer and Boranja Mts. are Late Paleozoic, but there are also some metamorphosed Upper Cretaceous sediments (Karamata, 1955; Knežević, 1962). A continuous zone of metamorphic rocks around the Bukulja granite body, consisting of varieties of gneiss, micaschist and marble, has been assigned to the Paleozoic in its western parts (Filipović, pers. commun.) and to the Upper Cretaceous in its eastern parts (Radovanović, pers. commun.). Unfortunately, both interpretations are based only on correlation and speculation; no paleontologic or isotopic evidence has been presented.

Consequently, metamorphic rocks in the eastern part of the zone of Alpine granitoids and metamorphic rocks cannot be yet positively correlated with the corresponding ones in its western part. However, their geotectonic setting, isotopic ages of granitoids, common lithologies and the mode of occurrence of metamorphic rocks suggest that the metamorphic rocks from the Cer and Bukulja Mts. belong, at least partly, to a single geotectonic zone. Future research should pay particular attention to the distinction between regionally metamorphosed sequences and hornfelses, the latter being common in contact areas surrounding granite bodies in nearly all mountains of the zone.

It should be noted that low-grade metamorphic rocks originating from Upper Cretaceous sediments were encountered in deep oil wells in the basement of the Pannonian basin (Fig. 3) in the flat area between the Cer and Motajica Mts. (Jelaska — Pamić, 1979; Pamić, 1986).

Rocks of the granite-granodiorite association characteristically occur within metamorphic rocks as small intrusive bodies. Granites intrude into surrounding metamorphic rocks as shown by the structural relations, by frequent occurrences of calc-silicate rocks (skarns) and hornfelses in the exometamorphic ones and by extensive tourmalinization (Tab. 2).

Normal granites, and leucocratic and aplitic granites are the most common rock types, and they have been found in varying quantity in all granite bodies except the one in Boranja (Tab. 2). Quartz monzonite and granodiorite make up part of Mt. Cer and all of Mt. Boranja. Small masses of quartz diorite, diorite and gabbro have been discovered only in Mt. Moslavačka Gora (Pamić, 1987a).

Such a large range in differentiation trend suggests that Alpine granitoids of the zone are I-type granites. However, they have some striking characteristics of S-granites as shown by their comparatively low content of Na_2O and low $Fe_2O_3 : FeO$ ratio (Tabs. 2 and 3). In addition, the granitoids from many places contain accessory garnet and in some places cordierite and andalusite. Despite the lack of complete documentation, it can be presumed that the granitoids from the zone of Alpine granites and metamorphic rocks are S-type granites (Chappell — White, 1974). Karamata and Djordjević

(1980) studied the evolution of Late Cretaceous—Tertiary igneous complexes in eastern Yugoslavia, including rocks of the granite-granodiorite association from the Cer, Bukulja, and Boranja Mts. They concluded that the granites belong to a potassium-rich province and that they are of crustal (continental) origin and thus can be implicitly classified as S-granites.

Most recently, Eearly Alpine granites have been found north of the granite-metamorphic zone of the northernmost Dinarides in Mt. Požeška Gora (Fig. 1). The granites occur as small bodies invading Upper Cretaceous cogenetic silicic rhyolites and consist mostly of alkali-feldspar granites (alaskites) with subordinate alkali-feldspar quartz syenites. Based on some of their geochemical features, these granites could be A-type granites (Pamić, 1987; Collins et al., 1982).

Discussion

On the basis of data presented above, it can be seen that, despite their spatial proximity and apparent similarity in lithology, the granite-metamorphic complexes of the northernmost Dinarides and southwestern parts of the Pannonian basin display distinct differences in geotectonic setting, age and detailed petrographic features of both igneous and associated metamorphic members. Although the granite-metamorphic complexes were included by some authors (Kober, 1952; Petković, 1958) in one single geotectonic unit within the Dinarides, it is evident that a distinct difference in geotectonic setting between the Hercynian granite-metamorphic complexes of the Slavonian Mountains and the Alpine ones of the Moslavačka Gora—Prosara—Motajica—Cer—Bukulja zone exists. The complexes occur in two essentially different structural and geotectonic settings. The Hercynian granite-metamorphic complexes of the Slavonian Mountains are located north of the Sava river, where the Mohorovičić discontinuity is at depth of about 22 to 27 km. The Alpine complexes are located south of the Sava river where the Mohorovičić discontinuity gradually increases to a depth of about 40 km below the Dinarides (Roksandić, 1969). This difference in deep structure is also reflected in the surficial structures — the Dinarides represent a typical compressional area and the Pannonian basin a typical tensional area. The zone of Alpine granitoids and metamorphic rocks of the Prosara—Motajica—Cer—Bukulja trend can be taken as a boundary between these two tectonically contrasting areas (Pamić, 1985).

In such a geodynamic interpretation the zone of Alpine granitoids and metamorphic rocks occupies an important tectonic position within the Alpine chain. The exposures of Alpine granitoids and associated penecontemporaneous metamorphic rocks are accompanied in many places by Tertiary andesites that are superficial parts of a relict magmatic arc (Pamić, 1977). The Upper Cretaceous—Paleogene flysch sediments may thus have been derived from the magmatic arc and been deposited in the adjacent fore-arc and trench (Jelaska, 1978); axial parts of the latter probably mark an ancient subduction zone along which Mesozoic oceanic crust was consumed.

Consequently, Alpine granitoids and metamorphic rocks of the Prosara—Motajica—Cer—Bukulja zone might have originated along a magmatic arc that

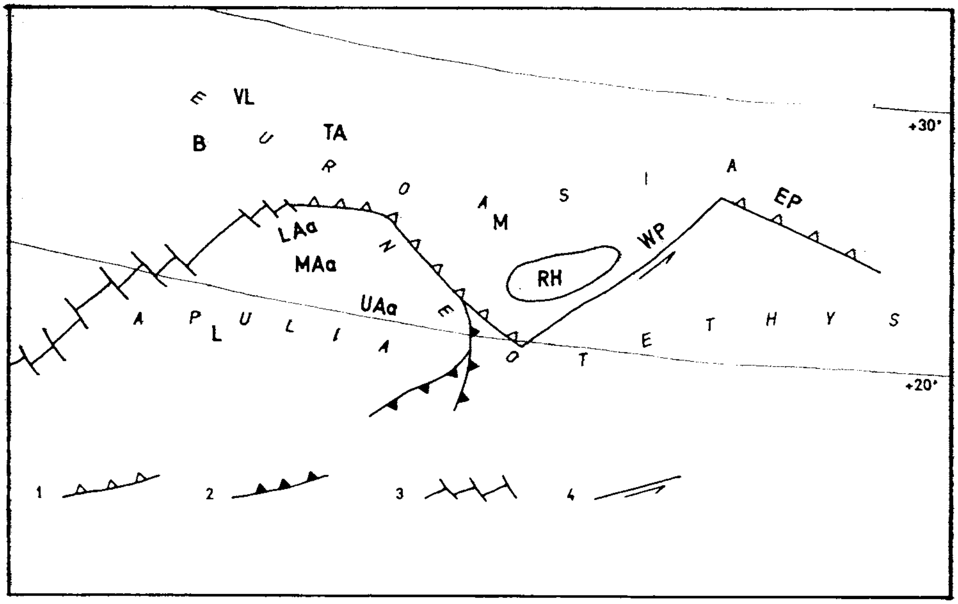


Fig. 5. Palinspastic map for Jurassic—Cretaceous boundary (Aubouin et al., 1986) with the proposed correcture for the extension of subduction zone in front of Moesian block.

Notes: 1 — oceanic subduction; 2 — thrust; 3 — spreading ridge; 4 — horizontal fault. B — Briançonnais; EP — Eastern Pontides; L — Lombard; LAa — Lower Austro-Alpine; M — Moesia; MAa — Middle Austro-Alpine; RH — Rhodopes; TA — Tatras; UAa — Upper Austro-Alpine; VL — Lalais; WP — Western Pontides.

formed above a subduction zone during the final stages of closure of the Dinaridic parts of the Tethys ocean (Dewey et al., 1973).

Detailed evolution of the inferred magmatic arc cannot be reconstructed on the basis of available data. Most of the isotopic ages on Alpine granites and metamorphic rocks are Upper Cretaceous to Early Tertiary, indicating that the magmatic arc was already in existence. Some of isotopic ages indicate that granite intrusion took place at the Turonian—Senonian boundary. In any event, the data available to date do not allow reconstruction of the initial stages of the magmatic arc. If the magmatism can be genetically related to subduction of Mesozoic oceanic crust, which began in the Dinarides in the Late Jurassic (Lanphere et al., 1975), it might be presumed that initial stages of the existence of the magmatic arc were coeval with the beginning of subduction itself. Preliminary radiometric data indicate the presence of Jurassic granites within the zone, thus that the magmatic arc might have started by the end of the Jurassic.

This idea fits quite well with the most recently proposed subduction zone in front of the Moesian block, i.e. Vardar zone (Aubouin et al., 1986). In fact, the subduction zone proposed in this paper represents a continuous north-western extension of the long one proposed by Dercourt et al., (1986) which stretches from the area of the present Vardar zone further to the east to the Zagros Range (Fig. 5). Alternatively, counterclockwise rotation of Apulia with respect to Africa for about 30° during the Cretaceous, as proposed by the same authors, might have displaced the remnants of the subduction zone in front of the Moesian block further to the northwest.

The high heat-flow connected with granitic plutonism along the presumed magmatic arc metamorphosed the surrounding Upper Cretaceous—Paleogene flysch sediments into an Abukuma (?) type sequence under PT-conditions of greenschist and amphibolite facies. This metamorphic phase, which is not at present sufficiantly bracketed by radiometric data, can be chronologically correlated with Eoalpine and Mesoalpine metamorphic events of the Central and Eeastern Alps (Frey et al., 1974, and others).

Final stages of magmatic arc and the initial stages of its destruction may be connected with the beginning of the evolution of the Pannonian basin. After the main thrust and imbricate structures were formed during the Pyrenean phase in the adjacent Dinarides, small basins originated along large strike-slip faults in the area of the present Pannonian basin (Royden et al., 1983; Horvath, 1984 and others). According to this idea, systems of conjugate transcurrent faults with movements directed towards the northeast and northwest can account for the east-west extension of the huge area located between the present Carpathian Mts. and the Dinarides. The extensional process gave rise to a mosaic-block structure of the basement of the Pannonian basin, with great differences in geology from one block to another. The proposed mechanism implies that in some blocks, transform faults can be locally converted into reverse faults. Along these faults, the Hercynian granite-metamorphic complexes from the basement were thrust over younger Tertiary sediments (Horvath — Royden, 1981).

At the end of the Alpine orogeny, the processes of extension and attenuation of continental crust began in the area of the present Pannonian basin and were related to uplift of the upper mantle. These geodynamic processes must have given rise to at least partial destruction of the magmatic arc, which became gradually masked by sediments of the Pannonian basin. At that time, strong volcanic activity took place and during Early Miocene produced andesites and dacites, frequently with tuffs, in the area of already destroyed and modified magmatic arc along the present northern Dinarides. It also produced andesite-basalts, also with tuffs, in southern parts of the Pannonian basin, behind the arc. High heat-flow connected with the magmatic activity gave rise to the next metamorphic event, which can be correlated with the Neo-Alpine phase of the Central and Eastern Alps (Frey et al., 1974 and others). The end of the volcanic activity probably marked the end of subduction.

It the evolution of the present Pannonian basin was really due to extensional processes brought about during attenuation of the crust and by uplift of the upper mantle, than one may ask what existed in this area before the formation of the Pannonian basin? Based on our present knowledge, the Pannonian basin is bordered by two subduction zones: the first one stretches along the Carpathians (Stegena et al., 1975; Szadeczky-Kardoss, 1975 and others) in the north, and the second one along the northern Dinarides in the south, as discussed in this paper. But, that should imply that the Neotethys was characterized by two active continental margins! Jelaska (1978) emphasized that Upper Cretaceous—Paleogene flysch of the northern Dinarides shows a positive correlation with the stratigraphically same flysch of the Carpathians, and Balla (1986) presented an idea that flysch basins of the both mountain systems represented one single paleogeographic unit during the Late Cretaceous and Paleogene. Thus the present Dinarides and Carpathians represented a single paleogeographic unit before the beginning of the evolution of the Pannonian basin, which commence to pull-apart by extensional processes in post-Paleogene time. If so, then two proposed subduction zones of the Carpathians and Dinarides should be complementary to each other, i.e. they might represent a complementary pair originated from a previously existing single magmatic arc of Neotethys. This idea is strongly supported by the fact that paleotransport direction and accessory minerals in flysch sedimentes of the northern Dinarides indicate that the source area was generally located northern of the present Dinarides (Jelaska, 1978; Soklić, personal commun.).

In such a geodynamic consideration, it is interesting to ask whether the zone of Alpine granitoids and penecontemporaneous metamorphic rocks in the Prosara—Motajica—Cer—Bukulja area shows any correlation with similar complexes in the adjacent Alps and Hellenides. The correlation in the southern direction towards the Hellenides is obvious and comparatively simple. The presumed subduction zone with Alpine granitoids as described in this paper extends continuously to the south along the adjoining area of the easternmost Dinarides and Serbo—Macedonian Massif to southern parts of the Vardar zone in Yugoslavia and Greece (Dimitrijević, 1974; Pamić, 1977). Here, the zone also includes rocks of Alpine granite-granodiorite association, Cretaceous flysch and "paraflysch" sediments, ophiolites and "Mesozoic metamorphic rocks". Preliminary isotopic data for granitoids from some localities indicate Late Jurassic (the Furka granites) and Tertiary ages (Deleon, 1969). Dimitrijević (1974) presumed the existence of Mesozoic metamorphic rocks in the area of presumed magmatic arc, i.e. subduction zone. But Marcier (1966) presented evidence for two Mesozoic phases of metamorphism in the southern parts of the Vardar zone in Greece which took place during the Late Jurassic—Lower Cretaceous and the Senonian—Paleogene.

The correlation is much more difficult in the northwestern direction towards the Alps. It is well known that the Dinarides continue without interruption towards the northwest into the Southern Alps whose northern boundary with the Eastern Alps is defined by the Periadriatic Lineament. Numerous papers have been published on the main characteristics of the Periadriatic Lineament; these have been summerized by Boegel (1975) and Exner (1975), and for its easternmost part in Yugoslavia by Mioč (1984). Exner (1976) emphasized that granitoid masses with isotopic ages from 45 to 24 Ma are very common along the Periadriatic Lineament. As far as metamorphic rocks are concerned, if the definition proposed by Boegel (1975, p. 165) is accepted, "Die Periadriatische Naht, bzw. das Periadriatische Lineament ist eine Stoerungszone, die alpin-metamorphen oder wenigstens teilwise alpin-metamorph beenflussten Gebiete der Ost — und Westalpen von den Suedalpen, denen eine solche Beeinflussung fehlt, abtrennt", then a correlation between the area of the Periadriatic Lineament and the adjoining area of the Dinarides and Pannonian basin is obvious. The Dinarides represent continuous southeastern extension of the southern Alps, hence it is reasonable that the Prosara—Motajica—Cer—Bukulja zone has some basic characteristics which are in common with the ones of the area of the Periadriatic Lineament.

Acknowledgment: The author is indebted to Z. Balla and G. Buda (Eötvös Lorand University and Geofizikai Intézet, Budapest), J. Desmons (Universite'de Nancy), M. Herak (Zagreb University), I. Gušić and V. Jelaska (Geological Institute, Zagreb), S. Karamata and N. Pantić (Belgrade University), and L. Royden (Messachusetts Institute of Technology) for discussions and critical reading of the manuscript.

REFERENCES

ALEKSIĆ, V. — PANTIĆ, N., 1972: Mezozojski i paleogeni metamorfiti i dalja istraživanja u južnoj grani alpske geosinklinalne oblasti. Zap. Srp. geol. druš. za 1968—1970 (Beograd), pp. 221—233.

AUBOUIN, J. — Le PICHON, X. — MONIN, A. S., 1986: Evolution of the Tethys. Part II: Maps, Tectonophysics (Amsterdam), 123 (1—4).

BALLA, Z., 1986: Paleotectonic reconstruction of the central Alpine-Mediterranean belt for the Neogene. Tectonophysics (Amsterdam), 127, pp. 213—243.

BALOGH, K. — ARVA-SOS, E. — BUDA, G., 1983: Chronology of granitoid and metamorphic rocks of Transdanubia (Hungary). An. Inst. Geol. Geofiz. (Bucureşti), 61, 1—6.

BARIĆ, Lj., 1972: Kontaktnometamorfni mramori iz okolice Podgarića u Moslavačkoj gori (Hrvatska). VII. Kong. geol. SFRJ, Zagreb, 2, pp. 1—28.

BOEGEL, H., 1975: Zur Literatur ueber die „Periadriatische Naht". Verh. Geol. Bundesan. (Wien), 2/3, pp. 163—199.

BRKIĆ, M. — JAMIČIĆ, D. — PANTIĆ, N., 1974: Karbonske naslage u Papuku (sjeveroistočna Hrvatska). Geol. Vjesn. (Zagreb), 27, pp. 53—58.

CHAPPELL, B. W. — WHITE, A. J. R., 1974: Two contrasting granite types. Pacif. Geol. (Tokyo), 8, pp. 173—174.

COLLINS, W. J. — BEAMS, S. D. — WHITE, A. J. — CHAPPELL, B. W., 1982: Nature and origin of A-granites with particular reference to Southeastern Australia. Contr. Mineral. Petrology (Berlin—New York), 80, pp. 189—200.

DAL PIAZ, G. V. — HUNZIKER, J. C. — MARTINOTTI, G., 1972: Le zone Sesia, Lanzo e l'evoluzione tettonico-metamorfica delle Alpi nordoccidentalli. Mem. Soc. Geol. Ital., 11, pp. 433—460.

DELEON, G., 1969: Pregled rezultata odredjivanja apsolutne starosti granitoidnih stena u Jugoslaviji. Rad. Inst. rud.-geol. istr. isp. nukl. sir. (Beograd), 6, pp. 165—182.

DERCOURT, J. — ZONENSHAIN, L. P. — RICOU, E. L. — KAZMIN, V. G. — LePICHON, X. — KNIPPER, A. L. — GRANDJACQUET, C. — SBORTSCHIKOV, I. M. — GEYSSANT, J. — LEPVRIER, C. — PERCHERSKY, D. H. — BOULIN, J. — SIBUET, J. C. — SAVOSTIN, L. A. — SOROKHTIN, O. — WESTPHAL, W. — BAZHENOV, M. L. — LAUER, J. P. — BIJU-DUVAL, B., 1986: Geological evolution of the Tethys belt from the Atlantic to the Pamirs since the Lias. Tectonophysics (Amsterdam), 123, pp. 241—315.

DEWEY, J. F. — PITMAN, W. C. — RYAN, W. B. F. — BONNIN, J., 1973: Plate tectonics and the evolution of the Alpine system. Geol. Soc. Amer. Bull. (New York), 84, pp. 3137—3170.

DIMITRIJEVIĆ, M., 1974: Dinaridi: jedan model na osnovama nove globalne tektonike. In: Janković, S. (Ed.) „Metalogenija i koncepcije geotektonskog razvoja Jugoslavije". Beograd, pp. 141—178.

DIMITRIJEVIĆ, M., 1982: Dinaridi-jedan pogled na tektoniku. Geol. ves. Zav. geol. geofiz. istr. (Beograd), 11, pp. 113—147.

EXNER, C., 1976: Die geologische Position der Magmatite des periadriatische Lineaments. Verh. Geol. Bundesanst. (Wien), 2. pp. 3—64.

FREY, M. — HUNZIKER, J. C. — FRANK, W. — BOCQUET, J. — DAL PIAZ, G. V. — JAEGGER, E. — NIGGLI, E., 1974: Alpine metamorphism of the Alps: a review. Schweiz. mineral. petrogr. Mitt. (Zürich), 54, pp. 247—290.

GORJANOVIĆ-KRAMBERGER, D., 1897: Geologija okolice Kutjeva. Rad JAZU (Zagreb), 131, pp. 10—29.

HERAK, M., 1986: A new concept of geotectonics of the Dinarides. Acta Geol. (Zagreb), 16, pp. 1—42.

HORVATH, F., 1984: Neotectonics of the Pannonian basin and the surrounding mountain belts: Alps, Carpathians and Dinarides. Ann. Géophys. (Paris), 2(2), pp. 147—154.

HORVATH, F., — ROYDEN, L., 1981: Mechanism for the formation of intra-Carpathian basins: a review. Earth Evol. Sci. (Braunschweig), 3/4, pp. 307—316.

JAMIČIĆ, D., 1983: Strukturni sklop metamorfnih stijena Krndije i južnih padina Papuka. Geol. Vjesn. (Zagreb), 36, pp. 51—72.

JAMIČIĆ, D., 1988: Strukturni sklop slavonskih planina. Ph. D. thesis, Univ. Zagreb, 152 pp.

JANTSKY, B., 1978: A Mecseki granitosödott kristalios alaphegység földtana. Magy. áll. földt. Intéz. évi Jelent. (Budapest), 60, pp. 1—385.

JELASKA, V., 1978: Stratigrafski i sedimentološki odnosi senonsko-paleogenog fliša šireg područja Trebovca (sjeverna Bosna). Geol. Vjesn. (Zagreb), 30, pp. 95—118.

JELASKA, V. — PAMIĆ, J., 1979: Sedimentacijski i magmatski procesi mladjeg mezozoika na području sjeverne Bosne. IV. Znan. skup JAZU, Zagreb, pp. 85—100.

JURKOVIĆ, I., 1962: Rezultati naučnih istraživanja rudnih ležišta Hrvatske. Geol. Vjesn. (Zagreb), 15(1), pp. 249—294.

KARAMATA, S., 1955: Petrološka studija magmatskih i kontaktnometamorfnih stena Boranje. Glas. Prir. muz. srp. zem. (Beograd), 6(1), pp. 1—130.

KARAMATA, S. — DJORDJEVIĆ, P., 1980: Origin of the Upper Cretaceous and Tertiary magmas in the eastern parts of Yugoslavia. Bull. Acad. serbe scie. arts (Beograd), 72, pp. 99—108.

KATZER, F., 1924/25: Geologie Bosniens und der Hercegovina. Sarajevo, 480 pp.

KEMENCI, R. — ČANOVIĆ, M., 1975: Preneogena podloga vojvodjanskog dela Panonskog bazena. II. Znan. skup JAZU, Zagreb, pp. 248—256.

KNEŽEVIĆ, V., 1962: Postanak i petrohemijski karakter magmatskih i kontaktnometamorfnih stena Cera. Zbor. Rud. geol. fak. (Beograd), 7, pp. 191—201.

KOBER, L., 1952: Leitlinien der Tektonik Jugoslawiens. Pos. izd. Srp. akad. nauka i umet. (Beograd), 189(3): 1—64.

KOCH, F.: 1899: Prilog geološkom poznavanju Moslavačke gore. Rad JAZU (Zagreb), 139, pp. 1—28.

KOCH, F., 1919: Grundlinien der Geologie von West-Slavonien. Glas. Hrv. prir. druš. (Zagreb), 31(1/4), pp. 217—237.

LABAŠ, V., 1975: Gradja Motajice prema rezultatima gravimetrijskih ispitivanja. Panel disk. JAZU (Zagreb), pp. 45—91.

LANPHERE, M. — COLEMAN, R. — KARAMATA, S. — PAMIĆ, J., 1975: Age of amphibolites associated with Alpine peridotites in the Dinaride Ophiolite zone, Yugoslavia. Earth Planet. Sci. Lett. (Amsterdam), 26, pp. 271—276.

LASKAREV, V., 1930: Prilozi za tektoniku Bukulje, Crnog vrha i Fruške gore. Geol. an. Balk. poluos. (Beograd), 1(10), pp. 1—9.

MARCI, V., 1973: Geneza granitnih stijena Psunja. Acta Geol. (Zagreb), 7, pp. 195—231.

MERCIER, J., 1966: Sur l'existence et l'age de deux phases regionales de metamorphisme Alpin dans le zones internes des Hellenides en Macedonie centrale (Greece). Bull. Soc. géol. France (Parise), 8, pp. 1014—1019.

MIOČ, P., 1984: Geologija prehodnega območja med južnim in vzhodnimi Alpami v Sloveniji. Disertacija, Univerzitet u Zagrebu, 273 pp.

MIYASHIRO, A., 1961: Evolution of metamorphic belts. J. Petrology (Oxford), 2, pp. 277—311.

PAMIĆ, J., 1977: Alpski magmatsko-metamorfni procesi i njihovi produkti kao indikatori geološke evolucije terena sjeverne Bosne. Geol. glas. (Sarajevo), 22, pp. 257—291.

PAMIĆ, J., 1985: Kredno-tercijarne granitne i metamorfne stijene u dodirnom području sjevernih Dinarida i Panonskog bazena. Geologija (Ljubljana), 28/29, pp. 219—237.

PAMIĆ, J., 1986: Metamorfiti temeljnog gorja Panonskog bazena u savsko-dravskom medjurječju na osnovi naftnih bušotina. XI. Kong. geol. Jugosl., Tara, 2, pp. 259—272.

PAMIĆ, J., 1987: Mladoalpinski alkalijsko-feldspatski graniti (aljaskiti) Požeške gore u Slavoniji. Geologija (Ljubljana), 30, pp. 183—205.
PAMIĆ, J., 1987a: Granites and associated monzodiorites and gabbros from Kamenac Creek on Mt. Moslavačka gora (northern Croatia, Yugoslavia). Rad JAZU (Zagreb), 431(22), pp. 179—199.
PAMIĆ, J., 1987b: Pojave kordijerita, andaluzita i margarita u metamorfnim stijenama Psunja u Slavoniji. Geol. Vjesn. (Zagreb), 40, pp. 139—147.
PAMIĆ, J., 1988: Stijene granit-granodioritne, associjacije Krndije u Slavoniji. Rad JAZU (Zagreb), in press.
PAMIĆ, J. — ŠPARICA, M., 1983: Starost vulkanita Požeške gore. Rad JAZU (Zagreb), 404, pp. 183—198.
PAMIĆ, J. — JAMIČIĆ, D. — CRNKO, J.: 1984: Bazične i intermedijarne magmatske stijene iz metamorfita središnjih dijelova Psunja u Slavoniji. Geol. Vjesn. (Zagreb), 37, pp. 127—144.
PAMIĆ, J. — KRKALO, E. — PROHIĆ, E., 1984a: Granitne stijene sjeverozapadnog dijela Moslavačke gore u sjevernoj Hrvatskoj. Geologija (Ljubljana), 27, pp. 201—212.
PANTIĆ, N. — JOVANOVIĆ, O., 1970: O starosti „azoika“ ili „paleozojskih škriljaca“ na Motajici na osnovu mikroflorističkih podataka. Geol. Glasn. (Sarajevo), 14, pp. 190—214.
PANTIĆ, N. — ERCEGOVAC, M. — ALEKSIĆ, V., 1972: O starosti metamorfnih stena u okolini Kragujevca. Zap. Srp. geol. druš. 1965—1970 (Beograd), pp. 217—219.
PAROTTO, M. — PROTURLON, A., 1981: Schema structurale dell'area Mediteranea centrale e orientale. Roma.
PETKOVIĆ, K., 1958: Neue Erkentnisse ueber den Bau der Dinariden. J. Geol. Bundesanst. (Wien), 101, pp. 1—24.
POLJAK, J., 1952: Predpaleozojske i paleozojske naslage Papuka i Krndije. Geol. Vjesn. (Zagreb), 2/4, pp. 63—82.
RAFFAELLI, P., 1964: Metamorfizam paleozojskih škriljaca u području Ravne gore (Papučko gorje-Slavonija). Geol. Vjesn. (Zagreb), 18(1), pp. 61—111.
ROKSANDIĆ, M., 1969: O granici Dinarida i Panonske medjuvenačne mase. Zapis. Srp. geol. druš. 1964—1967 (Beograd), pp. 495—501.
ROYDEN, L. — HORVATH, F. — RUMPLER, J., 1983: Evolution of the Pannonian basin system. 1. Tectonics. Tectonics, 2(1), pp. 63—90.
SIMIĆ, V., 1953: Magmatizam i metalogenija naših granitoidnih stena u vezi s volframovim orudnjenjem. Ves. Zav. geol. geofiz. istr. (Beograd), 10, pp. 191—253.
STEGENA, L. — GECZY, B. — HORVATH, F., 1975: Late Cenozoic evolution of the Pannonian basin. Tectonophysics (Amsterdam), 26(1/2), pp. 71—90.
SZADECZKY-KARDOSS, E., 1975: Jungalpine Subduktionslinien im KBD-Gebiet. Proceed. 10th Congr. Carp. Balk. Geol. Assoc., Bratislava, 3, pp. 268—276.
ŠPARICA, M. — PAMIĆ, J., 1986: Prilog poznavanju tektonike Požeške gore. Rad JAZU (Zagreb), 424(21), pp. 85—96.
TAJDER, M., 1969. Magmatizam i metamorfizam planinskog područja Papuk-Psunj. Geol. Vjesn. (Zagreb), 22, pp. 469—476.
TRUEMPY, R., 1973: The timing of orogenic events in the Central Alps. In: K. A. de Jong R. — Scholten eds.) "Gravity and Tectonics". John Willey and Sons, New York, pp. 229—251.
VAN EYSINGA, F. W. B., 1975: Geological time table. Elsevier, Sci. Publ. Comp., Amsterdam.
VARIĆAK, D., 1957: Metamorfne stene Prosare i njihova pripadnost facijama metamorfita. Zapis. Srp. geol. druš. (Beograd) za 1956, pp. 31—38.
VARIĆAK, D., 1966: Petrološka studija motajičkog granitskog masiva. Pos. izd. Geol. glas. (Sarajevo), 9, pp. 1—170.
VRAGOVIĆ, M., 1965: Graniti i gnajsi Papuka. Disertacija, Sveučilište u Zagrebu, 232 pp.
VRAGOVIĆ, M. — MAJER, V., 1980: Prilozi za poznavanje metamorfnih stijena Zagrebačke gore. Moslavačke gore i Papuka (Hrvatska, Jugoslavija). Geol. Vjesn. (Zagreb), 31, pp. 295—308.

Manuscript received September 8, 1988.