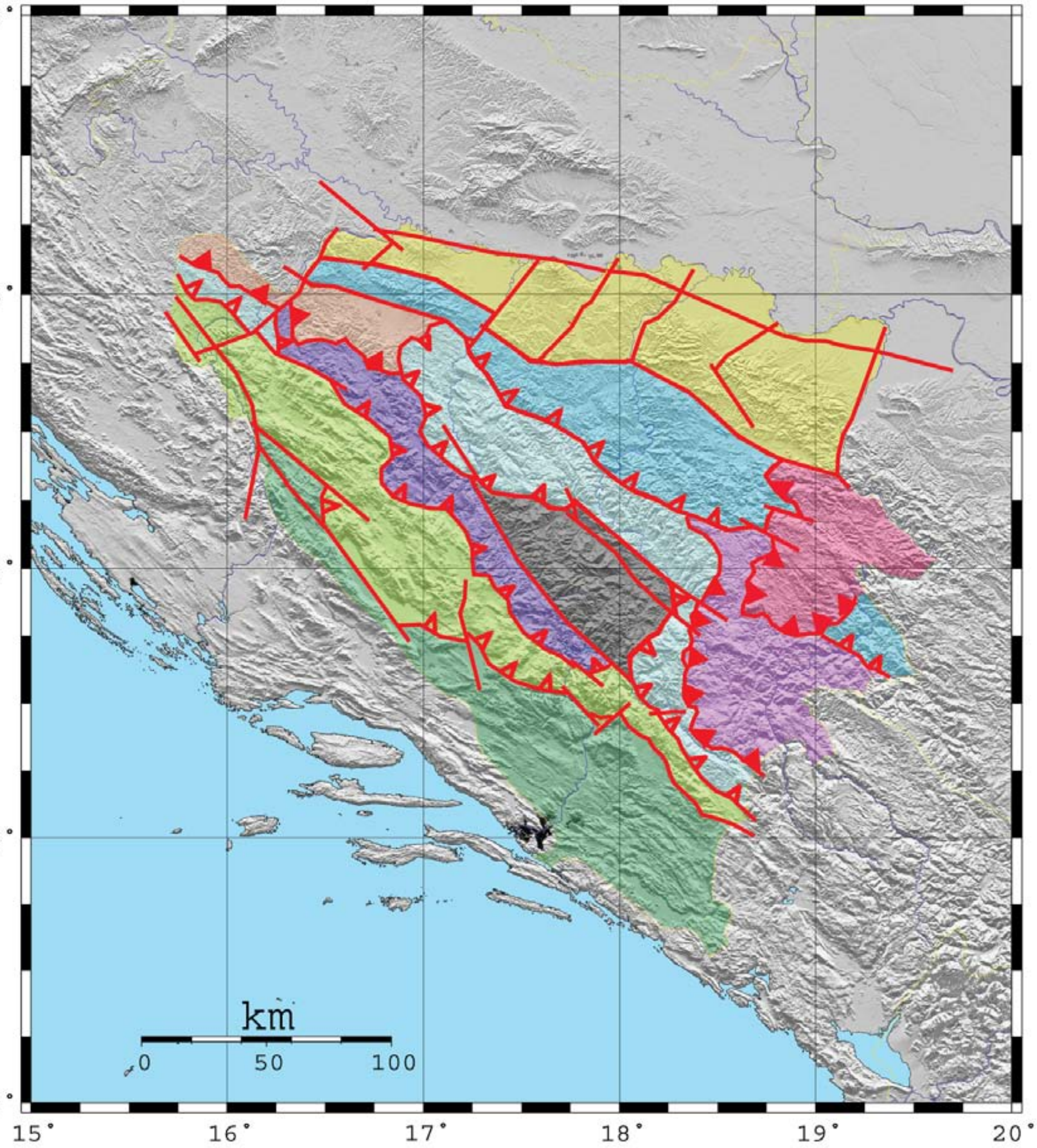
Hazim Hrvatović

GEOLOGICAL GUIDEBOOK THROUGH BOSNIA AND HERZEGOVINA



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Sarajevo, 2006

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PREFACE

Austrian geologist Friedrich Katzer (1903), who was a founder of the geology of Bosnia and Herzegovina, published the first geological quidebook through Bosnia and Herzegovina. The book was prepared for the excursion through Bosnia and Herzegovina organized in the framework of the Ninth World Geological Congress in 1903. in Vienna. This was hard-bound pocket-sized book that contained eight coloured geological maps, cross-section and photographs which were offered to the Congres participations, Katzer (1904) published a report on the realization of the excursion, number of participants (about 30 persons including several Japanese geoscientifics), discussions carried out during the excursion and some new geological observations.

The second geological guidebook was edited by S. Čičić (1978) in the framework of the Ninth Geological Congress of the Jugoslawian geologists which was organized in 1978. in Sarajevo. The book comprises data for three at that time selected routes : 1) Sarajevo – Foča – Trebinje- Mostar; 2) Travnik – Bihać – Banja Luka – Zenica and 3) Vlasenica – Olovo – Vareš – Breza. The book includes 65 pages with topographic sketches of the routes.

During the period of last 30 years numerous papers on the geology of Bosnia and Herzegovina have been published Numerous sheets of the Basic Geological Map 1:100 000 with explanatory notes are of a particular importance.

The Geological Survey of Bosnia and Herzegovina was founded in 1912 by a decree of the “Landregierung” of Bosnia – Herzegovina included at that time in the Austria – Hungarian Empire. In fact, the Geological Survey started with its activity in 1898. when Friedrich Katzer was nominated as a geologist in the administration of the Bosnia – Herzegovina Government. The Geological Surveys both in Sarajevo and Zagreb were canceled by the foundation of the Geological Institute of the Jugoslaw Kingdom and their libraries and archives were transported to Belgrade. The Geological Survey was refounded in 1947. under the name of “ Geological Research Institute of the Ministry of Industry and Mining”. Afterwards the Geological Survey has changed the name and status for several times, nevertheless it prolonged with its development due to the strong economical development.

The Geological Survey has been a center for the organized geological research and exploration activity of the country as a base for the whole economic and humanitarian development of each country. In the framework of the mining activity, the Geological Survey carried out the prospection for new mineral resources and performed exploration works, evaluated the reserves of mineral resources and the exploitation rationality from the point of view of interest for the country as a whole. The scientific research activity was also strongly supported during this period which also resulted in the publishing of this geological Guidebook.

In the first part of the guidebook are presented on the stratigrafy of the country which is divided on its structurale and paleogeographic units including carbonate platform of the External Dinarides, allochthonous Paleozoic – Triassic formations, the passive continental margin formations, ophiolitic and genetically related sedimentary formations and the active continental formations. Finally, Tertiary postorogenic formations, both of the intramontane fresh – water and the Pannonian marine to fresh – water ones are presented at the end of the stratigraphic presentation.

In the second part of the book are presented basic data on tectonic features, and geodinamic evolution of Bosnia and Herzegovina.

The third part of the guidebook represents distribution of the mineral deposites.

In the large shortage of geological literature data in the war devastated country, this guidebook “though probably to voluminous, represents and useful handbook in any manner both for domestic and foreign geologists. In these after war years we had to restrict only to one international field excursion through the areas without mines. However, this is not sufficient and we to continue with the consideration of geological problems on future meetings and field trips which should be for the our everyday praxis. For that reason we invite our geologists to prepare programs for the future excursions according to their own choise and possibility in order that the the acquired experience can be enriched by a new knowledge needed for the life and existance in this part of our planet.

Ivan Soklić

CONTENT

GEOLOGY AND DIVISION OF THE DINARIDES OF BOSNIA AND HREZEGOVINA

REGIONAL SETTING

Position of the Dinarides within the Alpine-Himalaya orogenic belt

The Dinarides as a mountin system have not been as yet clearly spatially defined relative to the surrounding mountain systems. In the framework of classical but abandoned geosynclinal concept, Kober (1911) separated «two branches» within the Alpine-Himalaya belt (index-sketch in Fig. 1) and the Dinarides, together with the Apennines, Southern Alps and Hellenides he included in the «southern branch» and the Eastern Alps and Carpathians into the «northern branch».

Continuation of the Dinarides toward the Alps is not clearly defined. As a matteh of fact, the External Dinarides, e.g. the Adriatic-Dinaridic carbonate platform continue, paleogeographically, in the Southern Alps, although some geologists (Carrulli et al., 1991; Placer, 1998) their structural boundary put along the Southalpine Front, e.g. thrust which is in its eastern prolongation joined with disconnected fragments of the Internal Dinaridic lithologies occur in frontal parts of the Sava-Vardar Nappe that can be traced westwards to the Slovenia-Italy frontier.

Recently, in the Alps/Dinarides adjoining area is separated a transitional zone named Mid-Trans-Danubian Zone (Fulop et al., 1987), Zagorje-Mid-Transdanubian Zone (Pamić & Tomljenović, 1998) or Sava Zone (Haas et al., 2000). The zone is composed of mixed blocks from both the Alps and Dinarides and is the results of Tertiary (Oligocene-Miocene) lateral extension tectonics (Kazmer and Kovacs, 1985; Ratschbacher et al., 1991).

The relationship between the Dinarides and Hellenides is much clearer. This is shown in the fact that all paleogegraphic and structural units of the Internal Dinarides continue southeastward into the Helenides (under different names) suggesting that they must have originated from one and the same oceanic domain, i.e the Dinaridic-Hellenidic Tethys (Pamić 2002) or the vardar Ocean (Dercourt 1972; Stampfli 2000).

The southwestern boundary between the External Dinarides and Adria Microplate is covered by Adriatic Sea. The Adriatic-Ionian Zone is positioned between them as foredeep zone. It does not outcrop along the Adriatic shore but southeastward of the Skadar-Peć fault it represents the most external zone of the Hellenides. (Fig. 1).

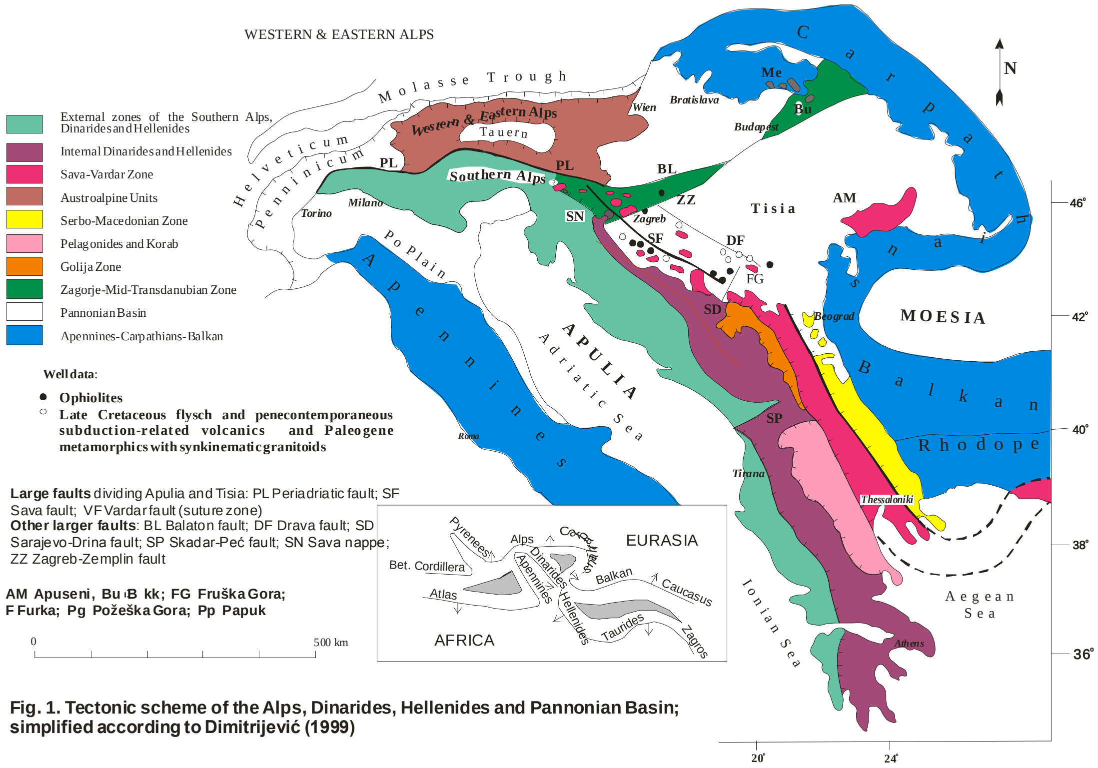


Fig. 1. Tectonic scheme of the Alps, Dinarides, Hellenides and Pannonian Basin; simplified according to Dimitrijević (1999)

The best outcrops of Paleozoic and Mesozoic tectonostratigraphic units of the Dinarides are found on the territory of Bosnia and Herzegovina. In the present structure of the Dinarides the Alpine distinctly predominate tectonostratigraphic units over the Paleozoic ones in an approximate relation 4:1. Both Paleozoic and Alpine tectonostratigraphic units originated in the Tethys as proposed by Suess (1893). According to current of the geodynamic ideas on the evolution of the Alpine-Himalaya belt the Paleozoic formations originated in the Paleotethys, i.e., by the convergnece of the Laurassia in the north and Gondwana in the south (Ziegler, 1990; Matte, 1991; von Raumer&Neubauer, 1993; von Raumer, 1998 and other). On the other hand, the Alpine tectonostratigraphic units of the Alpine-Himalaya belt, including the Dinarides, originated in the Neotethys, or simply Tethys by the convergence of Euroasia in the north and Africa in the south (Dercourt, 1970; Dewey et al., 1973; Dercourt et al., 1993 and other).

At the present erosional level, the Dinarides and Carpathians are not in direct contact; mountains of the northernmost Dinarides are about 400-500 km far from the southernmost Carpathian mountains with the Pannonian Basin in the between. However, its basement is composed broken of from the Carpathians during the Berriasian (Marton, 2001). Virtual boundary between the Dinarides and South Tisia (e.g. Carpathians) coincides approximately with the northern marginal fault of the Sava Depression. Based on field observation and refraction seismic data southern Tisia dips to the southwest beneath the Dinarides at an angle of about 10-15 (Tari and Pamić, 1998).

The area of Bosnia and Herzegovina is included in the middle parts of the Dinaridic Mountain System and it is positioned between Apulia (Adriatic Microplate) in the south and the Panonian and South Tisia, respectively. Evolution of the Dinarides was genetically related to the Tethys which existed during the Mesozoic and Early Palaeogene between two supracontinents – Euroasia or its Moesian fragment in the north and Africa or its Apulian fragment in the south. The Dinarides represent a typical orogenic system included in the Alpine – Himalaya belt. Main large lithofacies associations of the Dinarides originated during the Alpine orogenic cycle. However, there are also large lithological units which originated during the Variscan orogenic cycle (the Paleozoic complex of the Una-Sana area, Mid-Bosnian Schist Mts., Southeast Bosnia and North Bosnia) and the postorogenic ones originated during the Oligocene – Neogene (marine to fresh-water sediments of the South Panonian Basin) and Neogene intramontane fresh-water basins: Sarajevo-Zenica, Tuzla, Ugljevik, Kamengrad, Bugojno, Livno, Duvno, Gacko, Bihać-Cazin, Drvar, Mesići, Miljevina and others.

Numerous papers have been published on geotectonic evolution of the Dinarides and they are summarized alsewhere (Herak, 1991). Based on modern plate tectonics ideas, the Dinarides can be subdivaided into several large structural-paleogeographic units as first proposed by the Frenche geologist (Aubouin et al., 1970) for the whole Dinaride-Hellenide area.

Despite their complex, imbricate thrust structure, in the Dinarides is preserved distinct zoned pattern in the spatial distrubution of large tectonostratigraphic units, reflecting their paleogeographic evolution. From the southwest (Apulia) to the northeast (Moesia), the following tectonostratigraphic (paleogeographic) units can be separated (Pamić, 1993):

1. Dinaric carbonate platform (External Dinarides)
2. The Bosnian Flysch
3. The Dinardie Ophiolite Zone
4. Sava-Vardar Zone

The units 2 to 4 define the Internal Dinarides. This regular pattern in the distribution of tectonostratigraphic units is disturbed by allochtonous

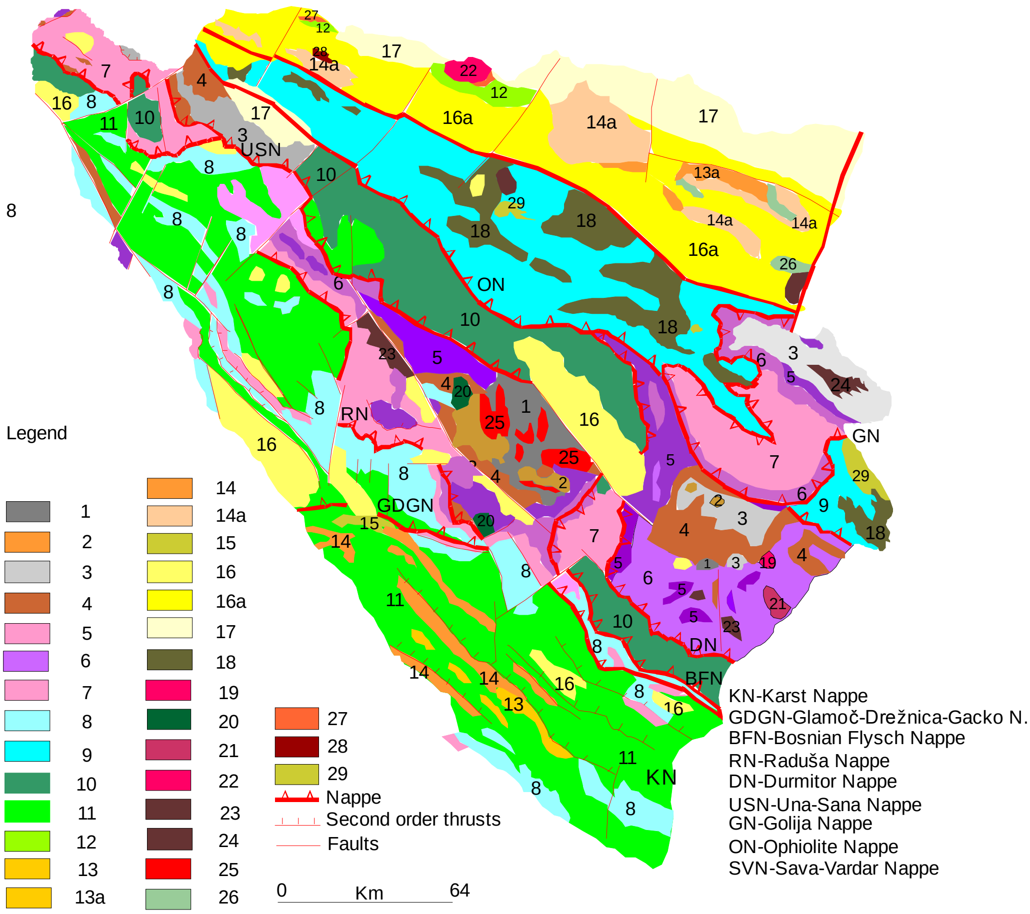
Paleozoic-Triassic masses (5) which are thrust onto the units of the Internal Dinarides and onto the northeastern margin of the External Dinarides (Fig. 2), In many areas, the Dinarides are disconformably overlain by postorogenic Oligocene, Neogene and Quarternary sediments (6).

The Dinarides are characterized by fold, imbricate and thrust structures striking NW-SE with distinct southwestern vergences. Alpine tectonostratigraphic units mentioned above are thrust each to other with the External Dinarides at the base and the Sava-Vardar Zone at the top (Fig. 2). As distinguished from the whole Central Dinarides the northernmost parts of the Sava-Vardar zone are characterized with northern vergences which are recognized in the northern parts of the Mts. Majevica, Motajica and Prosara.

Geological map (fig. 2) show the most recent knowledge and serve as base for geographic information system (GIS) including a geological database. Map show the geology of the pre-Quarternary. This map is compiled on the basis of numeorus sheet Geological Map of Bosnia and Herzegovina, scale 1:100 000. The geological units and tectonic lines as faults and thrust are bounded by red coloured lines. The most important data field is the identification number (IN) was created for each geological unit. This IN provides the link between geological unit on the map and the description in the database table 1. (legend). The description geological unit is provided in database: age, petrography, tectonic environment, regional name, submarine morphology, etc.

GEOLOGICAL MAP OF BOSNIA AND HERZEGOVINA

(Hrvatović, 2000)



Dinaridic carbonate platform: 7. Late Triassic dolomites, limestonesand marlstone, 8. Jurassic limestones and dolomites, 11. Cretaceous limestones, 13. Paleocene limestones, 14. Eocene limestones and calcareni te,

Flysch bosniaque:
10. Tithonian to Barriasian siliciclastic flysch (Vranduk group); Late Cretaceous-Lower Paleogene c arbonate flysch(Ugar group)

Dinaridic ophiolite zone: 18. Late Jurassic ophiolitic melange or wildflysch"; 9. Ultramafic massifs;
29. Overstep formations (Pogari formation and platform limestone);

Allochthonous Paleozoic and Triassic formations:Metamorphyc rocks :
1. Silurrian greenchist and epidote-amphibolit e facies ; **Sedimentary rocks:** 2. Devonian limestones and dolomites;
3.Carboniferous siltstones, shales, sandstones, limestones (with turbiditic character);
4. Late Permian siliciclastics, limestones and evaporites; 5. Early Triassic siliciclastics and limestones;
6. Middle Triassic (limestones, chert, tuffite, dolomites); 7. Late Triassic limestones and dolomi tes; **Volcanic rocks** :
25.Paleozoic rhyolite group; 20. Middle Triassic basalt group; **Plutonic rocks** Middle Triassic19. Alkaly-feldspa r syenite,
20. Gabro group, 21. Granodiorite-dior ites group. **Sava-Vardar Zone:** 13a. Paleocene limestones and siliciclastics, 14a. Eocene siliciclastics, 26.Late Cretaceous limestones and siliciklastics; 12. Non-metamorphose d to Greenschist-amphibolite facies Late Cretaceous-Paleogene flysch (Prosara and Motajica),
22. Eocene granite group(Motajica), 24. Andesite i dacite (Srebrenica); 27. Orto and Paragneiss (P rosara and Motajica);
28. Mafic and ultramafic magmatites N-Kozara

Post-orogenic Oligocene, Neogene and Quarternary sediments
15 Oligocene (Promina formation); 16. Miocene intramontain fresh-water sediments, 16a. Miocene South Pannonian Basin
17. Pliocene-Quarternary sediments

Table, 1: Legend

1	2	3	4	5	6
(IN) number	**Age**	**Petrography category and rocks type**	**Orogen**	**Genesis**	**Region**
1	O, S	Metamorphic: Greenschist (shale, quartzite, marbl)	Alpine	Deep sea floor to escarpment	Mid-Bosnian Schist Mountains
2	D	Metamorphic: Limestone, dolomite, marble	Alpine	Marine platform	Mid-Bosnian Schist Mountains and
3	C	Metamorphic: Greenschist: (Siltstone, sandstone, claystone, chert)	Alpine	Turbidite	Una-Sana, Southeast Bosnia and East Bosnia
4	P_3	Sedimentary: gypsum, ahydrite, sandstone, siltstone, limestone	Alpine	Epicontinental marine	Dinarides
5	T_1	Sedimentary: Sandstone, siltstone, claystone, limestone		Epicontinental Marine and fluvial system	Dinarides
6	T_2	Sedimentary: Limestone, marlstone, tuffite chert		Continental rift	Dinarides
7	T_3	Sedimentary: Limestone, dolomite, marlstone		Marine carbonate platform	Dinarides
8	J (Lower to Late)	Sedimentary: Limestone, dolomite, marlstone,		Marine carbonate platform	External Dinarides
9	J_{2-3}	Mixed: Sandstone, siltstone, chert, diabase, gabro,			Dinaride Ophiolite melange
10	J, K_1 K_2	Sedimentary: Sandstone, marlstone, siltstone, conglomerate, chert		Pasive Continental margin	Flisch Bosniaque
11	K_2	Sedimentary: Limestone, marlstone,		Marine carbonate platform	External Dinarides

		dolomite			
12	K_2	Metamorphic: Sandstone, marlstone, siltstone, phylite		Active Continental margin	Sava- Vardar Zone
13	Pc	Sedimentary: Limestone, marlstone,		Marine carbonate platform	External Dinarides
13a	Pc	Sedimentary: Limestone, sandstone		Active Continental margin	Sava-Vardar zone
14	E	Sedimentary: Limestone, marlstone, sandstone, siltstone		Marine carbonate platform	External Dinarides
14a	E	Sedimentary: Sandstone, siltstone		Active continental margin	Sava-Vardar zone
15	E,Ol	Sedimentary: Conglomerate, sandstone, claystone		Marine molasse	External Dinarides (Promina conglomerates)
16	M (Lower to Late)	Sedimentary: Claystone, marlstone, sandstone, limestone		Continental molasse	Neogene intramontain basin Dinarides
16a	M	Sedimentary: Sandstone, siltstone, shale, evaporites, dolomites, limestone		Shallow marine	South Panonian basin (Tuzla basin)
17	Pl	Sedimentary: Claystone, marlstone, sandstone, silt		Continental molasse	Neogene intramontain basin Dinarides
18	J_{2-3}	Mixed: Peridotite, dunite, harzburgite, lherzolite, amphibolite, serpentinite		Mid ocean ridge -Ophiolite complex	Dinaric Ophiolite Zone
19	T_2	Plutonic: Alkaly syenite		Active continental margin	Čajniče area (East Bosnia)
20	T_2	Plutonic: Gabro group,		Active continental	Vrbas fault (Gabro

				margin	Jablanice)
21	T_2	Plutonic: granodiorite group		Active continental margin	East Bosnia (Čelebići)
22	E	Plutonic: Granite group		Magmatic arc	Vardar zone (Motajica and Prosara Mts.)
23	T_2	Volcanic: Basalt group		Magmatic arc	Vrbas fault
24	M	Volcanic: Trachyte group, dacite, andesite		Magmatic arc	Vardar zone (Srebrenica area)
25	S,D	Volcanic: Rhyolite group		Continental rift	Mid-Bosnian Schist Mts.
26	K_2	Limestones and siliciklastics		Active continental margin	Vardar zone
27	E	Orto and Paragneiss		Magmatic arc	Vardar zone
28	$J_{2,3}$	Mafic and ultramafic		Ophiolite zone	N-Kozara (Vardar zone)
29	K_1	Conglomerate, sandstone, siltstone, marly limestone		Fluvial system and shallow marine	Pogari formation (Overstep sequences in Ophiolite zone)

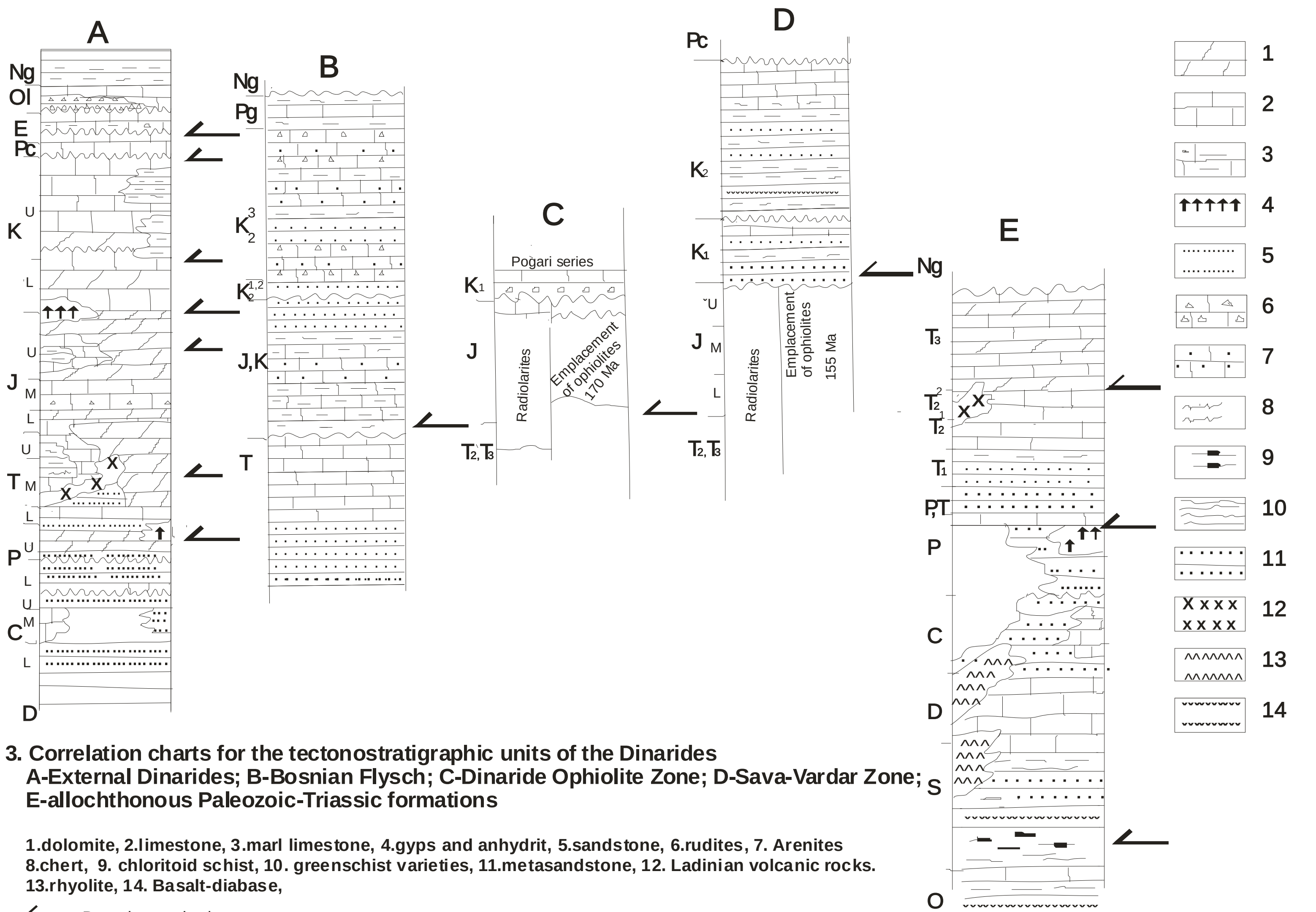


Fig. 3. Correlation charts for the tectonostratigraphic units of the Dinarides
A-External Dinarides; B-Bosnian Flysch; C-Dinaride Ophiolite Zone; D-Sava-Vardar Zone; E-allochthonous Paleozoic-Triassic formations

1.dolomite, 2.limestone, 3.marl limestone, 4.gyps and anhydrit, 5.sandstone, 6.rudites, 7. Arenites 8.chert, 9. chloritoid schist, 10. greenschist varieties, 11.metasandstone, 12. Ladinian volcanic rocks. 13.rhyolite, 14. Basalt-diabase,

Detachment horizonts

DINARIC CARBONATE PLATFORM (External Dinarides)

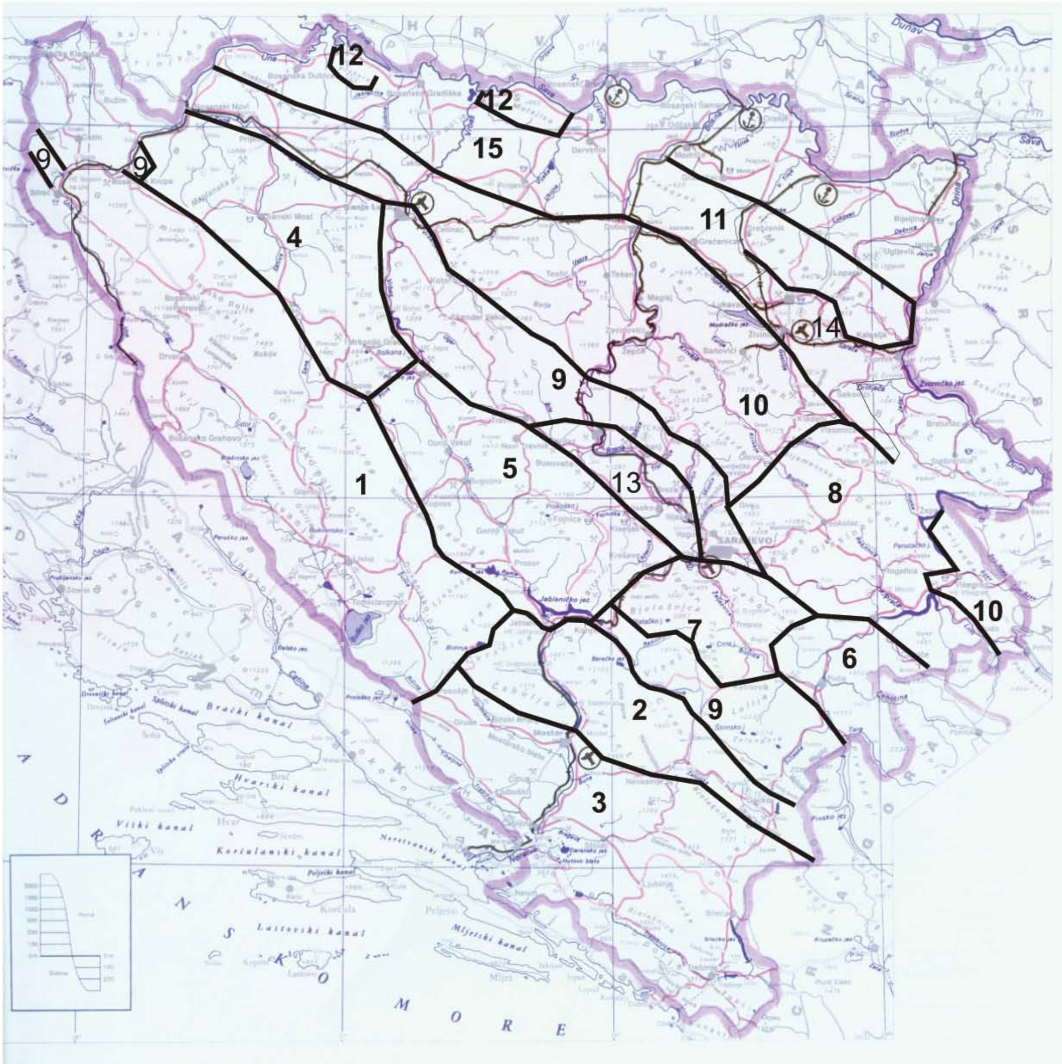
In the present structure of the Dinarides, the Dinaric carbonate platform is included in External Dinarides. Its southwestern marginal parts overlaying the Apulia are covered by the Adriatic Sea, whereas its northeastern margin is thrust by allochthonous Paleozoic-Triassic formations. The Dinaric carbonate platform largely composed of a) an Upper Paleozoic sequences composing Late Carboniferous-Early Permian clastics and carbonates, b) a Late Permian to Norian sequences of clastics and platform carbonates and associated synsedimentary igneous rocks deposited during the initial rifting stage of the Alpine cycle. In some areas the carbonates are interlayered with chert, shale, pyroclatic and volcanic rocks, which accumulated in platform depressions, particularly during the Ladinian. Middle Triassic formations are confromably overlain by Carnian limestone and associated volcanics and by Norian limestone and dolomite. During the Norian conditions for long-lasting carbonate platform sequences were finally established, and c) the Norain-Lutetian carbonate platform, which begins with the Norian-Rhetian «Hauptdolomit», which only in some areas overlies the Carnian Raibls Beds (Pamić et al. 1998). Stable shallow-marine environments prevailed during Jurassic-Cretaceous and lasted until the Lutetian temporairly interrupted by several pelagic incursions (Fig. 3).

Platform carbonate deposits, besides their significant thickness (4000 to 8000 m) they are characterized lateral and vertical alternations of different facies, mostly associated with shallow marine environments. Environments are from peritidal through low-energy shallow subtidal-lagoons, restricted inner platform shallows, high-energy tidal, beach and shoreface.

This presention of the Dinaric carbonate platform is based on published data resultes from the elaboration of the Basic Geological map 1:100 000: Papeš (1975, 1978, 1985), Mojičević (1973), Raić(1977, 1978), Behlilović(1974), Slišković(1962, 1964), Ahac (1968) and others. Data presented in this chapter are mainly taken from the book II: Mesozoic Formations which represents a part of geology of Bosnia and Herzegovina, Explanation books for separate sheests of the Basic Geological map and papers published by Papeš (1985).

Carbonate platform is presented trough description of three (geographic) parts; 1. Mountains and valleys of Southwest Bosnia. 2. Mountains and valleys of North Herzegovina, 3. Mountains and valleys of South Herzegovina (fig. 4)

Fig. 4. Geographical map of Bosnia and Hercegovina



1. Mountains and valleys of southwestern Bosnia,
2. Mountains and valleys of northern Hercegovina
3. Mountains valleys of southern Hercegovina
4. Sana-Una area, 5. Middle Bosnian Schist Mountains
6. Area of southeastern Bosnia,
7. Area of the Mts. Jahorina-Bjelašnica-Trskavica
8. Area of eastern Bosnia, 9. Bosnian flysch; 10. Ophiolite Zone,
11. Majevica and Trebovac, 12. Prosara-Motajica, 13. Sarajevo-Zenica Basin
14. Tuzla Basin, 15. Pannonian Basin sensu lato

Mountains and karst valleys of Southwest Bosnia

Southwest Bosnia includes several high mountains and several karst valleys: Glamoč, Duvno and Livno (Fig. 4). Its southwestern boundary with Dalmacija is defined by the Mts. Dinara (the root name for the Dinarides) and Kamešnica.

In this area, folds, thrust, reverse faults, with horizontal displacement up to 40 km, and intramontane depressions can be separated. However, these thrusts do not represent large nappes correlatable with the ones from the Alps, except the Stožer Nappe in which Permian and Triassic formations are completelly separated from their root.

Papeš (1985) separated nine large tectonic units; the southwestern units are underthrust beneath the northeastern ones.

The Stožer unit comprises the Mts. Veliki and Mali Stožer and Šuljaga. This unit consists of Permian, Scythian and Ladinian formations Permian formations represented by evaporites, breccias and marly shales. Scythian sedimentary rocks near Bosansko Grahovo represent storm-generated deposits in inner (Lower Scythian) and outher (Upper Scythian) shelf settings (Aljinović, 1995). The Lower Scithian is represented by siliciclatic facies which consists of two subfacies components – thin beded shale-siltstone-sandstone alternations attched to the distal part of the inner shelf, and thick-bedded sandstone-oolite subfacies. Repetitive alternation of these two subfacies is interpreted as high frequency sedimentary cycles possible related to high-frequency sea-level changes which in turn induced wave-base oscillations. Upper Scythian sedimentary rocks are lime mudstones with marls in the Mud facies, and with marls and calcarenaceous siltstone in the Siltstone-mudstone facies. Acording to the facies characteristics the Lower Triassic succesion near Bosansko Grahovo is interpreted as a consequence of a low-term, possibly third-order seal level rise compared to the global seal leve rise during the Scithnian (Aljinović, 1995). Conformably overlain by Scythian are brecciated limestones and further upwards by Ladinian spilites, diabases, keratophyres and quartz keratophyres interlayered with marly shales and cherts.

The Cincar tectonic unit includes the Slovinj and Cincar thrusts. Only the oldest formations are composed of Scythian clastic sediments which are conformably overlain by Middle and Upper Triassic carbonates. Jurassic is represented by Lithiotis limestones, Liassic-Doggerian dolomites, Doggerian oolitic coral limestones and Malmian limestones with cladocoropsis and clipeyna.

The Glamoč tectonic thrust unit is positioned between the Staretina and Cincar units and the large Dinara thrust dipping beneath the Livno Valley. Lithostratigraphy of these units is illustrated by geological columns (Fig. 6 and 7.).

In deep Glamoč-1 (fig 7) oil-well, a fossiliferous Scythian clastics with anhydrites and 50 m thick breccias were penetrated which are overlain by fossiliferous Ladinian limestones. In the Glamoč unit, Upper Triassic is represented by fossiliferous Carnian limestones, Norian and Carnian oolithic and dense dolomites, about 900 m thick, which grade into Liassic fossiliferous limestones and dolomites. Middle and Upper Jurassic is represented largely by varieties of fossiliferous limestones, only in some parts interlayered with dolomites. Conformably overlaying Cretaceous formations are represented largely by varieties of fossiliferous limestones with subordinate dolomites. All stages of the Cretaceous are supported by index-fossils.

In some parts of the Livno and Dinara areas, complete Late Cretaceous fossiliferous formations are developed: Alb-Cenomanian limestones, Turonian limestones interlayered with subordinate dolomites and Senonian shallow-water rudist limestones and deep-water globotruncana limestones. These are disconformably overlain by marine to brachysh fossiliferous limestones which grade into Paleocene and Middle Eocene fossiliferous limestones (fig. 5).

m	Age	Lithology		Environments	Fossils
900	E_3Ol		Promina sediments -conglomerates, , sandstones	Marine molasse	
				Land (bauxite)	
600	$E_{2,3}$	2 1	**1**.marls, conglomerate, sandstone, clay, **2**.breccia limestone, marl, sandstone	Flysch basin	Lucina saxorum, Cardium dabricense, Cerithium (Campanile) cf. Parisiense, Natica, Galamphylia subtilis, Rotalia, Orbitolites, Alevolina; Cardium, Conus,
				Land (bauxite)	
300	$E_{1,2}$		Miliolid limestone, Alveolinid limestone, Nummulites limestones, Discocyclinid limestone	Restricted shallower and deeper parts open carbonate ramps	Alveolina oblonga, Alveolina minutula, Nummulites perforatus, Nummulites globus; Discociclina discus
				Land(bauxite)	
300	Pc,E		Liburnian deposits: Wackestones/ Packstones, Algal wackestone, microcodium-bearing wackestones/ mudstones and floatstones	Brackish and fresh-water	Characeae, Lagynophora sp., Dasucladaceae, Microcodium sp., Clypeina sp., Alveolina ellipsoidalis, Orbitolites sp., Miliolidae, Orbitolinidae, Stomatopsis
				Land(bauxite)	
>500	K_2		Floatstones, wackestones/ packstones and rudstones	Shallow marine (subtidal, intertidal)	Petkovicia, Katzeria, Gorjanovicia, Pironea, Milovanovicia, Hippurites, Radiolites, Distefanella, Caprina, Neocaprina,

Fig. 5. Paleogen carbonate platform -External Dinarides (after Raić, 1978)

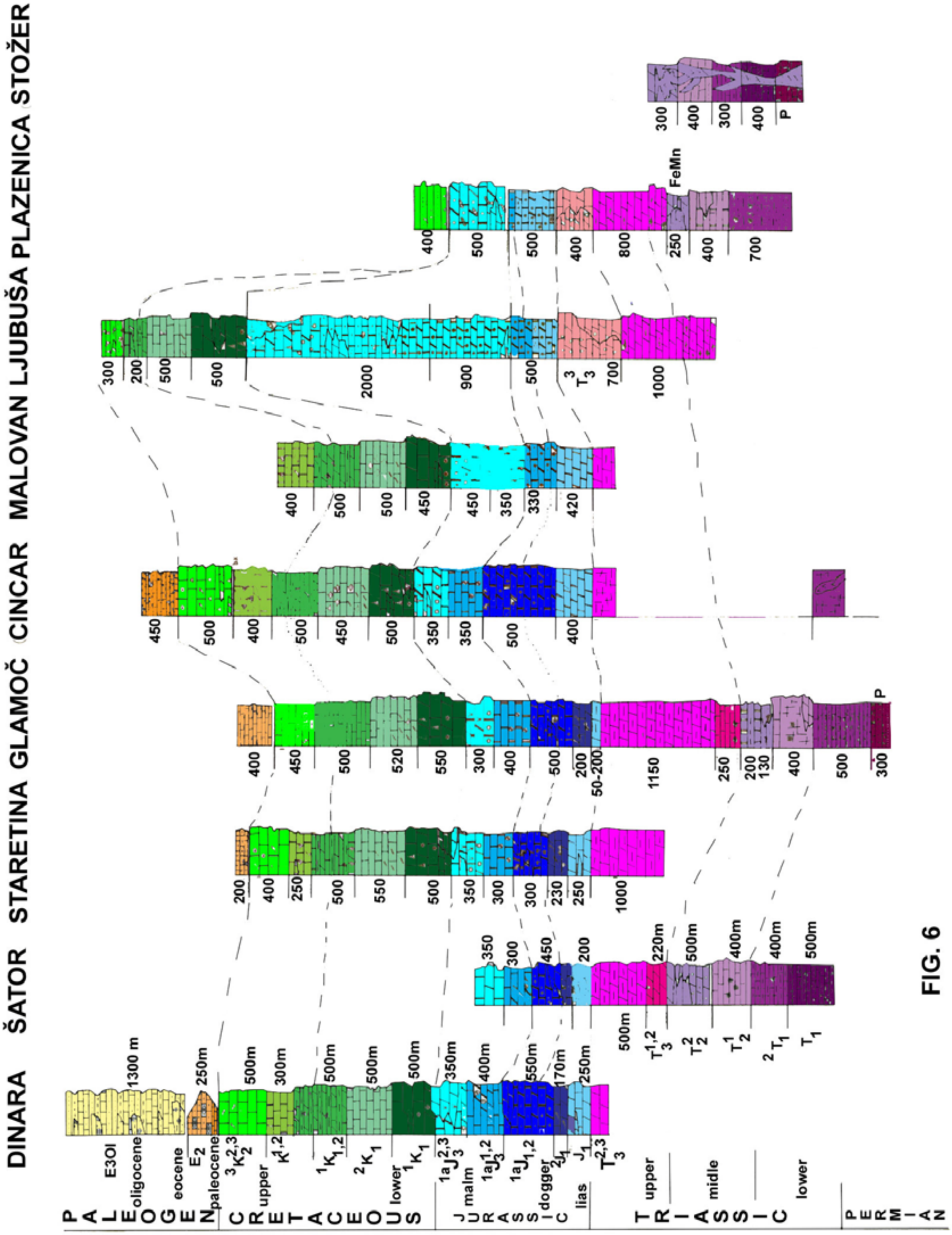


Fig. 6. Geological columns for the carbonate platform of SW Bosnia (simplified, after Papeš, 1985)

Legend for fig. 6:
P-Permian red sandstones, shale, breccia, gypsum and anhydrite; T_1-schistose micacaeous sandstones and shale; $^2T_1$-marly shale and limestone with ammonites; T_2^1-brecciated limestones; T_2^2-dolomites, tuff, spilite, chert marly limestones; $T_3^{1,2}$-dolomite, platy limestones; $T_3^{2,3}$-brecciated and laminated dolomites; T_3^3-megalodone limestones; J_1-dolomites and platy marly limestones with lithiotidae; $^2J_1$-limestones and limestons with lithiotidae and orbitopsellae; $^{1a}J_{1,2}$-oolithic pizolithic and brecciated limestones interlayered with dolomites; $^{1a}J_3^{1,2}$- oolithic pizolithic limestones and dolomites with solenoporellae curnobiae and hydrozoa ; $^{1a}J_3^{2,3}$-brecciated limestones interlayered with dolomites and breccia; $^1K_1$-thick bedded limestones and dolomites; $^2K_1$-bedded limestones with orbitolinaea and salpingoporellae; $^1K_{1,2}$-thin bedded and platy limestones and dolomites interlayered with cher and breccia; $K_2^{1,2}$-bedded limestones with chondrodontae; $^3K_2^{2,3}$-rudist limestones; E_2-limestones with alveolinae and numulites; Ol_3M-Promina beds-conglomerates, calcarenite and marl;

The area of Southwest Bosnia represented the whole Oligocene a land with fairly disected relief, probably due to transpressional processes which gave rise to the origin of large depressions, i.e., the incipient karst valleys. However, not earlier than Early Miocene started deposition od fresh-water coal-bearing clastic and carbonate formations. The coal-seam, 6 m thick, is radioactive (350-1000 gr U per 1 tone). The “older” Miocene formations, which are 1800 to 1200 m thcik, are repsresented by fossiliferous bituminous and marly limestones, marls, limestones, sandstones and tuffs. The “yanger” Miocene complex composed of coal-seams overlain by thick marl and limestones strata interlayered at the top by lignites, is disconformably underlain by the “older” Miocene complex indicating subsidance processes which continued during the Late Quarternary. In the Livno Valley two peat-bogs crop out: Ždralovac and Jagme which cover total area of about 50 km^2, average peat-thickness amounts 1 m.

In the Dinaric carbonate platform of Southwest Bosnia, economically the most interesting mineral resources for explorations and exploitation are coal, peat, technical stone, oil and uranium.

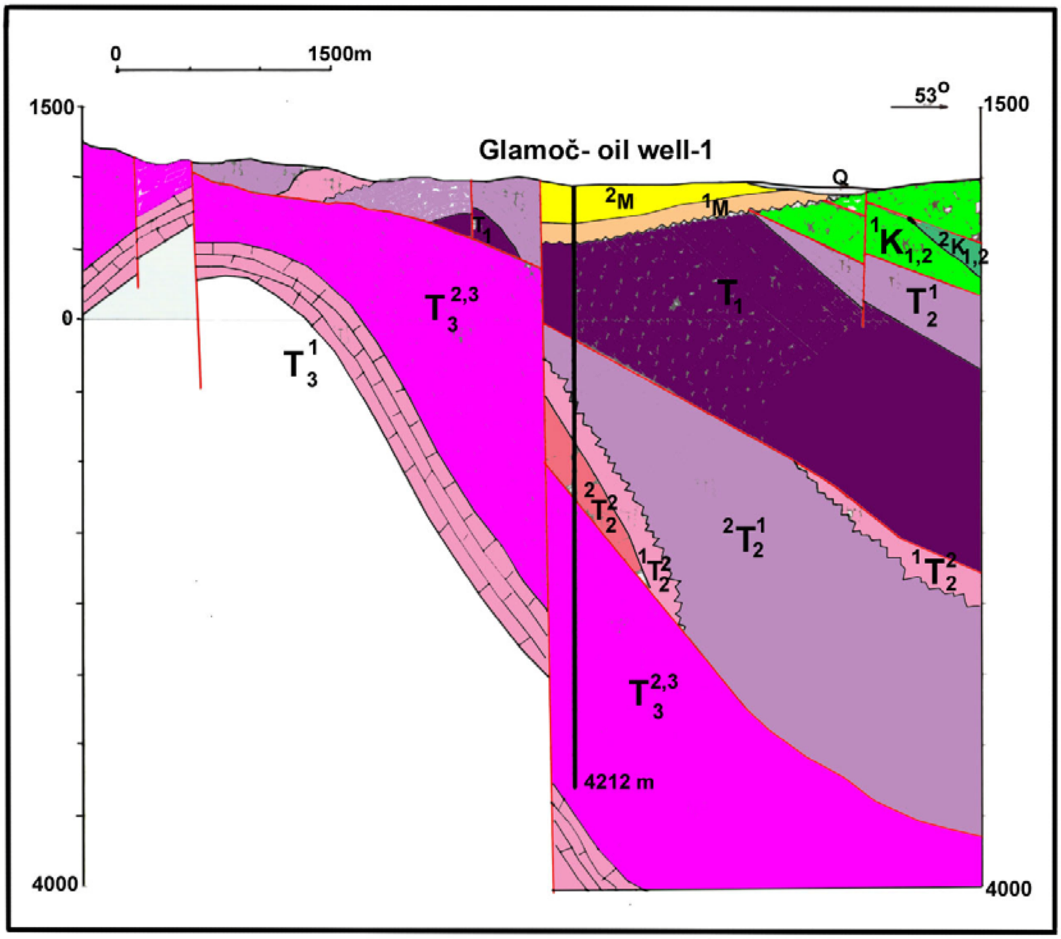


Fig. 7. Cross-section Glamoč – 1, oil-well (Papeš, 1985)

Stratigraphic column of SW Bosnia

PLIOPLEISTOCENE
Dazian, Romanian, Lower and Middle Pleistocene
Duvno Valley: Alluvial sediments of the depression (200 m).

LATE MIOCENE (SARMATIAN, PANNONIAN AND PONTIAN)
Livno and Duvno Valleys: marls and sandstones with several productive lignite seam (200 m).

EARLY MIOCENE (OTNANGIAN, KARPATIAN AND BADENIAN)
Southeastern parts of the Neogene Livno Basin

EARLY PALEOCENE (DANIAN)
Privala above the Buško Blato Valley: algal limestones with foraminifers (Miliolidae) and snails.

LATE UPPER CRETACEOUS
(CONIACIAN, SANTONIAN, CAMPANIAN, MAASTRICHTIAN)
Privala (northward of the Buško Blato Valley): Upper Senonian Rudist limestones (Hippurites, Katzeria, Petkovicia, Buornonia) and Globotruncana limestones, Lower Senonian Rudist limestones (Radiolites).

EARLY UPPER CRETACEOUS (CENOMANIAN AND THURONIAN)
Mts. Tušnica: Thuronian massive limestones interlayered with limy dolomites with rudist (Radiolites, Sauvagesia, Durania), Cenomanian foraminiferal limestones (Orbitolina) with mussels (Chondrodonta, Neocaprina, Ichtiosarcolites, Sauvagesia).

LATE EARLY CRETACEOUS (BARREMIAN, APATIAN, ALBIAN)
Mts. Staretina: algal limestones interayered with dolomites (salpigoporella, Pianella, Munieria) with mussles (Requienia) and foraminifers (Cuneolina, Orbitolina, Coscinolina).

LATE LOWER CRETACEOUS (BARESIAN, VALANGINIAN, HAUTRIVIAN)
Limestones with dolomites and marly limestones interlayers with Tintinidae, foraminifers, mussles, snails (Nerineidae), ostracods, and algal limestones (Pianella, Munieria).

LATE JURASSIC (OXFORDIAN, KIMMERIDGIAN, TITHONIAN)
Tithonian-Vallanginian of Mts. Vran: dolomites only.
Kimmeridgian-Tithonian of Mts. Vran: limestones with Clypeina.

Oxfordian-Kimeridgian of Mts. Vran: limestones with hydrozoa (Cladocoropsis), foraminifers (Kurnubia, Pfenderian), spongs, corals, bryozoa and small gastropods (Nerinea).

MIDDLE JURASSIC (AALENIAN, BAJOCIAN, BATHONIAN, CALLOVIAN)
Mts. Staretian: algal limestones (selliporella), limestones and dolomites, oolithic crinoidal limestones (Pentacrinus).

EARLY JURASSIC
(HETTANGIAN, SINEMURIAN, PLIENSBACHIAN, TOARCIAN)
The Glamoč Valley: foraminiferal limestones (Orbitopsella) and molluscs (Lithiotis)-200 m, limestones and dolomites, and dolomites (250 m).

LATE TRIASSIC (CARNIAN, NORIAN, RHEATIAN)
Norian-Rheatian at Glamoč: dolomites and oolithic limestones (900 m), Late Carnian at Glamoč: limestones with ammonides (Tropites, Paratropites, Sandligites, Glamocites).

MIDDLE TRIASSIC (ANIZIAN, LADINIAN)
Ladinian at Glamoč: limestones with molluscs (Daonella, Posidonia) and ammonids (Protrahyceras)
Anizian-Glamoč – 1 oil-well-continental breccia of pressumed Anizian-Early Ladinian age.

EARLY TRIASSIC (SEISSIAN, CAMPILIAN)
Campilian at Glamoč: limestones with gastropods (Turbo).
Scithian at Grahovo: shale-limestone-sandstone alternations (inner shelf), sandstone oolite subfacies (inner shelf or to the shoreface), lime mudstones with marls.

Mountains and karst valleys of North Herzegovina

are included in the karst area of the Mts. Čabulja, Velež, Vran Čvrsnica and Prenj with the Bijelo Polje Karst Valley in the between (Fig. 4). This is a thick carbonate sheet composed of Triassic carbonates, which is faulted into blocks and longitudinally imbricated. In this area, the Jablanica, Čvrsnica and Crvanj thrusts are separated. Within the Jablanica thrust is included Mt. Prenj to which is in south added the Mt. Crvanj thrust which includes also the area of the Zalomka River. In this area it can be traced at Drežnica, between the Mts. Prenj and Velež and on the slopes of Mt. Crvanj to Gacko Valley.

At the same time, this would be a bordering zone between the carbonate platform and the allochthonous Triassic complex, and the passive continental margin formations including the Jurassic-Cretaceous flysch zone (Pamić&Jurković, 1997).

The Mt. Čabulja thrusts of Triassic formations which are overlain with Jurassic and Early Cretaceous strata, Upper Cretaceous limestones and alveolina-nummulitic limestones of Paleogene age. Further eastward is located the Velež thrust which, further to the east includes Mt. Gacko-Bjelašnica area. Those are fact the Mts. Velež and Bjelašnica anticlines which overlie further southward the Mt. Sniježnica thrust.

In the Bijelo Polje Valley north of Mostar, between villages Humci and Lišani below Mt. Prenj out from depths of 600-1000 m. Early Triassic formations, 200 m thick, which contain fossils Claraia, Miophoria, Turbo and Tirollites. This displacement took place along the Neretva fault. In the mountain area of North Hercegovina, the thickest Early Triassic formations (460 m) are found in the area of Jablanica which is included in the allochotonous Paleozoic-Triassic complex. In the mounting area of River Rama, reddish clastics with Anodontophora and Claraia occur which differ from the Campilian beds represented mainly by grayish-greenish marly shales with fossils Myophoria, Naticia, Tirollites and Dinarites.

In the western part of Mt. Crvanj, these are overlain by reddish Han-Bulog limestones with ammonites. At Tovarnica nearby Jablanica, the Anisian limestones are intruded by gabbro stock with contact metamorphosed zone with magnetite mineralization along its margin. The magmatic activity took place during the Ladinian as indicated K-Ar ages and interlayering of tuffs with surrounding fossiliferous Ladinian sediments.

In the River Drežanka canyon (Fig. 8), Ladinian is represented by shales, cherts and limestones with Avicula (Behlilović, 1964) which are overlain by marly shales and dolomites (60 m) and grayish dolomites (110 m) with spherical collection of algs (Sphaerocodium). These are overlain by Megalodon limestones and thick dolomite strata of Norian and Rhaetian age. These formations occur in the area between Jablanica and Prozor, on the northern slopes of Mt. Čvrsnica from where extend in the Mt. Prenj area to Konjic up to Mt. Crvanj where are represented by thick-bedded limestones with dolomite interlayers and leuses. In the area of Ulog (upper course of Neretva River) Late Triassic formations are thrust by Upper Cretaceous flysh sediments. In the River Zalomka valley, Liassic bedded siliceous dolomites are underlain by Late Triassic formations. Along the Gacko Valley margin, grayish dolomites grading into thick-bedded Megalodon limestones are found.

Upper Triassic carbonates are covered by Liasic formations, about 320 m thick, represented by limestones (Gaković, 1972). They contain Paleodasycladus in lower parts and Lithiotis, Durga and Orbitopsella in middle and upper parts. In Mt. Plasa and Neretva canyon, the Liassic limestones grade into Doggerian oolithic limestones. In the area between the Mts. Vran and Čvrsnica, Upper Liassic is represented by thick-bedded limestones (30 m) which contain Durga, Rinchonella and Orbitopsella.

In the area of the Zalomka River and Gacko, a detailed stratigraphic classification was carried out. In this area, at the beginning of the Jurassic, a depression with specific type of ammonite fauna was formed. Hettangian, Sinemurian and Early Plinsbachian are supported by characteristic foraminiferas and radiolarias, whereas Late Pliensbachian is characteristic foraminiferas and radiolarias, whereas Late Pliensbachian is characterized by a unique ammonite fauna not yet found in any parts of the Dinarides. These are dark gray to black limestones from which about 30 specia of ammonites (hildoceratidae and dactiloceratidae) were determined. In toarcian limestones with ammonites, belemnites and brachyopodes are overlain by Early Doggerian carbonate formations with ammonite species Stephanoceras. In the area of Zalomka, Doggerian is subdivided by microforaminifers and calcareous algs, whereas on slopes of Mt. Velež, Doggerian is characterized by oolithic limestones with crinoid (Pentacrinus).

m	Age	Lithology		Environments	Fossils
	K_2		Reef limestones, bituminous marly limestones and dolomites	Marine platform	Globotruncana
			Bauxite	land	
	K_1		Dolomites with limestones	Marine platform	Salpingoporell a, Cylindroporella Cuneolina, Toucasia, Nerinea
			bauxite	land	
550	**J_3**		Limestone with dolomites	Mrine platform	-Clypeina, Ellipsactinia, Ptygmatis, -Cladocoropsis, Kurnubia, Pfenderina
250	**J_2**		Limestone with dolomites	Marine platform	
300	**J_1**		-bedded limestone, -limestone with lithiotis, -black bituminous limestone, -dolomites	Marine platform: -subtidal, -lagoonal	-Glomospira sp. -Lithiotis problematica, Durga crassa -Orbitopsela praecursor
500	**$T_3^{2,3}$**		-dolomites and limeston-dolomites with megalodon	Marine platform	Megalodon
110	**${}_2T_3^1$**		Dolomites	Marine platform	Sphaerocodiu m
60	**${}_1T_3^1$**		Red and green marls, dolomites	Marine platform	
150	**${}_1T_3^1$**		Gray and black dolomites (bituminous dolomites)	Marine platform	Daonella, Posidonia
250	**${}_2T_2^2$**		-Gray and black cherts and limestone, -Tuffs, volcanic breccia, limestone and marls	Continental reef	Daonella
90	**${}_1T_2^2$**		Red schists and yelow sandstone	Continental reef	Avicula globulosa

Fig. 8. Geological column Mezozoic Drežnica area (Hrvatović 2004, after Behlilović, 1964)

In the northeastern flank of the Gacko-Bjelašnica anticline Late Jurassic formations are about 400 m thick. They are represented by massive and thick-bedded limestones, with plenty of various fossils: Ellipsactinia, Ptygmatis, Diceras and others. In the Mts. Prenj and Čvrsnica, Oxfordian and Kimmeridgian are represented by limestones and dolomites with Cladocoropsis, Curnubia and Pfenderina which are overlain by Late Kimmeridgian and Tithonian bedded limestones with Ptygmates, corals and Clypeina.

In the Mts. Čabulja, Raška Gora and Velež, the Lower Cretaceous is represented by dolomites with nerineids, tintinides, foraminifers (Cuneolina) and algs (Salpingoporella, Munieria), with are overlain by bedded limestones interlayered with dolomites with Nerinea, Requienia, Toucasia and particularly calcareous algs (Cuneolina, Orbitolina, Salpingoporella, Cylindroporela). In some beds occur Characea algs, indicating periodical «sweetening» of sea water. The youngest Lower Cretaceous (Albian) is represented by plate limestones with fish reamins (Mt. Velež) which grade into Cenomanian bedded and platy limestones and dolomites with foraminifers (Cuneolina, Coskinolina).

Upper Cretaceous is mostly represented by rudist limestones originating on reefs grown fond shells and parareefs and by submarine accumulation of shells. In some areas (Trebinje and Bileća), in deeper sea parts remaind fossil fishes and reptiles which are found in dense well-bedded limestones with plenty of foraminifers (globotruncanide). Thicker masses of dolomites are characteristic for Cenomanian and Early Turonian.

In the southwestern parts of Mt. Čabulja, lowermost parts of Paleocene are represented by breccias, bituminous shales and marly shales with brakish gastropods (Melanopsis) and algs (Characea). Only in Mt. Čabulja, higher parts of the profile are represented by Lower Eocene alveoline-nummulite limestones which are overlain by flysch sediments with terrigeneous admixtures. The flysch is composed of conglomerates and breccias which are overlain by sandstones, marly shales, limestones with dark-greenish shales at the top.

Fresh-water Miocene formations, significant in thickness, crop out in depressions in the areas of Prozor, Ostrožac, Konjic, Borci, Hotovlje and in the Mostar and Gacko Valleys. Drilling data indicate that the Miocene formations in the Mostar Valley are composed, going upwards, of basal conglomerates overlain by sandstones, marls and clays (150 m), foot coal-seam interlayered by fossiliferous marls (50 m), calcareous marls and sandstones (190 m), main coal-seam interlayered with marls (20 m), marls with Pisidium and, at the top, marls with melanopsides.

High montains of North Hercegovina are characterized by morphological forms and uncosolidated clastics which originated during the Late Pleistocene by glaciation. These are found in the Mts. Čvrsnica, Prenj, Velež and Vran. For example, in Mt. Prenj several glacial cirques occur in the areas of Otiš Peak, Veliko Brdo and Vjetreno Brdo. Based on field data, this Mt. Prenj glaciation was Würmian age during which older fluvial terraceas and younger moraines originated. In the area between the Mts. Vran and Čvrsnica, above the Blidinje Lake (1800 m) frontal parts of moraine are preserved, whereas the stadials in the same area had the snow boundary at 1700 and 1950 m. In the Neretva River canyon, the fluvioglacial terraces have the highest thickness because the river represented the reservoir for waters from larger numbers of moraines. The terraces are composed of conglomerates, with pebbles up to 1 m in diameter, whose composition changes depending on source rocks of the river basin.

Economicaly potential natural mineral resources for the are in question are decorative and building construction rocks, coal, oil and gypsum.

Stratigraphical column of the North Hercegovina

PLEISTOCENE

W ü r m i a n: At Bijela nearby Konjic – older fluvial terrace is overlain by a younger moraine probably originating during last stages of glatiation.
Jablanica – Mostar: fluvioglacial terrace composed of very coarse-grained conglomerates, 60 m thick (pebbles up to 1 m in diameter).

EARLY MIOCENE (OTNANGIAN, KARPATIAN, BADENIAN)

Bijelo Polje nearby Mostar, going downwards: marls with molusk fauna (Melanopssis, Clivunella), 30 m thick; marls with the main coal-seam, 20 m thick, sandstones underlain by marls with mollusk and ostracode fauna, and ostracode fauna, and the foot coal-seam, 50 m thick; sandstones, marls and clays, 150 m thick, and basal conglomerates and breccias.

MIDDLE EOCENE (LUTETIAN, BARTONIAN)

Slopes of the Mts. Čabulja and Velež: dark-greenish clays; greenish sandstones, brownish marls and limestones with mollusk, coraland and foraminifer fauna.

EARLY EOCENE (YPRESIAN)

Mostar: limestones with foraminifers (Nummulites, Alveolina)

EARLY PALEOCENE (DANIAN)

Foot of Mt. Čabulja: algal limestones (characeae); marls with fresh – water gastropods (Stromatopsis); bituminous shales and marly shales; basal breccia.

LATE UPPER CRETACEOUS (CONICIAN, SANTONIAN, CAMPANIAN, MASTRICHTIAN)

Mostar: dense limestones with formainifers (Globotruncana)

EARLY UPPER CRETACEOUS (TURONIAN, CENOMANIAN)

Bileća: dense bituminous limestones with snack-like reptilia remains (Pachyophis) in Late Cenomanian.
Talež nearby Trebinje: bituminous limestones with fish remains.
Large areas are covered by rudist limestones of this age.

LATE EARLY CRETACEOUS (BAREMIAN, APTIAN, ALBIAN)

Mt. Velež: Albian platy limestones with fish remains.
Mts. Čabulja and Velež: limestones with algs (Salpingoporela, Pianella, Cylindroporella), formainifers (Cuneolina, Orbitolina), mollusks (Requienia, Toucasia), gastropods (Nerinea), and brakish algs (Characeae).

EARLY LOWER CRETACEOUS (BERRIASIAN, VALANGINIAN, HAUTERIVIAN)
Mts. Čabulja and Velež: dolomites and limestones with Tintinidae, Cuneolina, Nerinea, Clypeina, Salpingoporella and Munieria.

LATE JURASSIC (OXFORDIAN, KIMMERIDGIAN, TITHONIAN)
K i m m e r i d g i a n – T i t h o n i a n: Mt. Gacko Bjelašnica: algal limestones (Clypeina), hydrozoae (Ellipsactinia): Mts. Čvrsnica and Prenj: limestones and dolomites with algs (Clypeina) and gastropods (Ptygmatis).
O x f o r d i a n – K i m m e r i d g i a n: Mts. Čvrsnica and Prenj: limestones and dolomites, with hydrozoas (Cladocoropsis) and foraminifers (Kurnubia, Pfenderina).

MIDDLE JURASSIC (AALENIAN, BAJOCIAN, CALLOVIAN)
Zalomka River: limestones with ammonites (Stephanoceras).

EARLY JURASSIC (HETTANGIAN, SINEMURIAN, PLIENSBACHIAN, TOARCIAN)
Mts. Plasa with downward profile: oolithic limestones with Entolium and Chlamis; limestones with foraminifers (Orbitopsella, Vidalina) and bivalves (Lithiotis, Durga); algal limestones (Palaeodasycladus).
L a t e T o a r c a i n; Zalomka River: limestones with ammonites (Hildoceras) and belemnites; limestones with siliceous admixtures.
L a t e P l i e n s b a c h i a n (Domerian); Zalomka River: limestones with microforaminifers and cherts with radiolarias.

LATE TRIASSIC (CARNIAN, NORIAN, RHAETIAN)
N o r i a n – R h a e t i a n; Drežanka River: grayish dolomites with mollusks (Megalodon).
C a r n i a n – Drežanka River: marly shales and dolomites with oncoliths (Sphaerocodium).

MIDDLE TRIASSIC (ANISIAN, LADINIAN)
L a d i n i a n; cross-section in Drežanka River: nearly black bituminous dolomites; dark limestones with mollusks (Daonella, Posidonia) – 250 m; marly shales and nodular limestones with andesite tuffs (50 m); reddish shales with mollusks (Avicula) and cherts. Jablanica: gabro stock with contain metamorfphosed magnetite skarns; Jablanica – Prozor: (meta) volcanics and pyroclastics.
A n i s i a n; Jablanica – Prozor: reddish limestones with cephalopods, dolomites and varieties of limestones with brachyopods; black platy limestones (400 m).

LOWER TRIASSIC (SEISIAN, CAMPILIAN)

C a m p i l i a n; Jablanica – Prozor: marly shales and sandy limostonites with mollusks (Myophoria), gastropods (Natiria) and ammonites (Tirollites, Dinarites) – 200 m.

S e i s i a n; Jablanica – Prozor: reddisch marly sandstones with mollusks (Anadontophora, Claraia) – 260 m.

Mountains and karst valleys of South Herzegovina

In this section is included part of Hercegovina northward of the Dalmatian frontier up to Posušje, Čabulja, Velež and Gacko-Bjelašnica. In the west of Neretva River is Mostarsko Blato and south of it is Mt. Trtla, Bekija Plain up to Trebižat, Humina and Čapljina. East of Neretva River, from Mt. Velež in the south to Bregava River is Mt. Dubrava; between the Mts. Velež and Gacko-Bjelašnica is Nevesinje Valley, whereas Dabar-Fatnica Valley is northward of Mt. Baba. Between Dabar and Popovo Valleys are located the Mts. Sitnica, Viduša and Trebinje-Bjelašnica. All the area is included in the External Dinarides and carbonate platform, respectively; according to Anđelković, this area isncluded in the Neretva zone in the north and the Hercegovina zone in the south. The Velež and Čabulja thrusts are included in the Neretva zone, whereas all the other areas are included in the Herzegovina zone.

Going northeastward this area includes the following thrusts: Sniježnica, Fatnica-Grahovo, Ljubuški-Leotar and Trebinje Bjelašnica-Orijen and all of them terminate in adjacent Montenegro. Westward of Neretva River the thrusts reach the Una geofracture, except the Sniježnica thrust which terminate at Mostar. In the Dalmacia zone is included the Bistrina anticline which stretches from the Neretva River moth up to Slano. At Neum two anticlines separated by a syncline can be recognized Liassic-Doggerian limestones are overlain by Upper Jurassic limestones with hydrozoa Cladocoropsis and formainifers (Kurnubia, Pfenderina), grading upward into thick sequence of dolomites and whites microcristalline limestones with calcareous algs (Clypeina, Salpingoporella), tintinides and gastropods (Ptygmatis).

Crestal parts of the Mt. Gacko-Bjelašnica consist of Liasic-Doggerian carbonates grading into Malmian carbonate sequences, which are overlain by early Lower Cretaceous (Neocomian) with tintinides. In the same area early Lower Cretaceous (Barremian, Aptian and Albian) carbonate sequence occur, which contain in some places gastropods (Nerineae) and mollusks (Requienia, Toucasia), but more common are calcareous algs (Salpingoporella, Pianella, Munieria) and foraminifers (Cuneolina, Orbitolina). Most parts of South Hercegovina is covered by rudist limestones (fig. 9). Which, based on pachiodont mollusks, can be subdivided as follows:

C e n o m a n i a n limestones with Carpinulla, Durania, Radiolites, Disthephanella, Hippurite;

T u r o n i a n limestones with Carpinulla, Durania, Radiolites, Disthephanella, Hippurites;

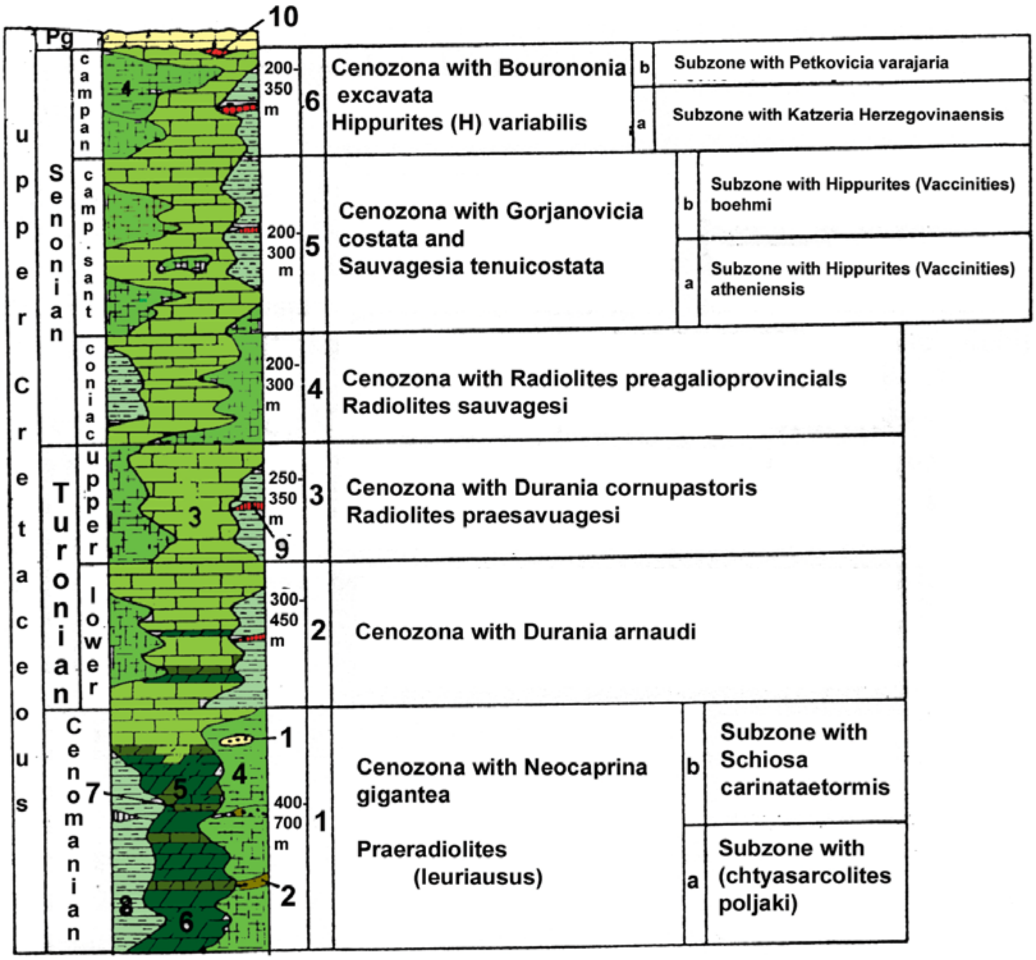
C o n i a c i a n Limestones with Radiolites, Disthephanella, Hippurites;

S a n t o n i a n – early C a m p a n i a n limestones with Radiolites, Durania, Milovanicia, Hippurites,
L a t e C a m p a n i a n - M a s t r i h t i a n limestones with Pironea, Burnonia, Katzeria, Petkovicia, Gorjanovicia.

Paleocene, which is best studied in Podveležje, is represented by Danian strata with Characeas (Lagynophora) which are overlain by foraminiferal limestones with Periloculina, Coscinolina and Glomalveolina. Early Eocene is supported by foraminifers: Operkulina, Numulites, Alveolina.

Data on rich fauna of corals, gastropods and mollusks are known since the beginning of this century. Recently, Eocene clastics at Zagorje, nearby Posušje were paleontologically studied. Here, Santonian – Campanian rudist limestones are overlain by remains of Paleocene limestones with brakish gastropods (Stomatopsis). Those are disconformably overlain by Eocene clastics containing fauna: corals in biogenic clastics and gastropods (Cerithium, Velates) and mollusks (Lucina, Cardium) in marls. Based on these and earlier data, it can be concluded that this fauna is of Lutetian to Bartonian – Priabonian age, i.e., it is younger than in previous localities described at the beginning of this century.

At Bistrina bay east of Neum, Upper Cretaceous limestones are thrust onto Lower Eocene alveoline-nummulite limestones and Middle/Upper Eocene flysch sediments. At Trebinje such a flysch is up to 200 m thick.



1. Conglomerates, 2. Breccia, 3. Bedded limestones, 4. Masive limestones, 5. Dolomitic-limestone, 6. Dolomites, 7. Marl limestone, 8. Pelagical limestone, 9. Bauxite

Fig. 9. Geological column Late Cretaceous sediments Sotuh Herzegovina (Slišković, 1984)

In South Hercegovina, fresh–water Miocene sediments occur in Vir Valley at Vinjani, west of Neretva River, at Posušje, in Imotski Valley, at Rakitno, Kočerin, Široki Brijeg, Donji Gradac, Blatnica and Ljubuški. They are also found east of Neretva River between Rotimlje and Hodovo, at Nevesinje and in Dabar and Gacko Valleys. At Gacko Miocene sequence, about 400 m thick, two coal horizonts are included.

Economically important mineral resources at this area as follows: coal, bauxite, decorative and building rocks, clay, oil and bituminous schists.

Stratigraphic column for South Hercegovina

PLEISTOCENE (EARLY QUARTERNARY)
At Mogorjelo (Čapljina) and Hodbina, loess formations, up to 8 km thick, are underlain by Würmian periglacial material

PLIOPLEISTOCENE
In Imotsko Polje these sediments remains of mollusks, plant products, roots (Rhizosolenia) and charas; ostracodes (Candana nelgeeta, Paralimnocythera sp.) found in marls and clay, indicate cold climate conditions.

EARLY MIOCENE (OTNANGIAN, KARPATIAN, BADENIAN)
At Posušje, limestones and marls, about 400 m thick, contain rich mollusk fauna: Congeria jadrovi, Congeria dalmatica, Melanopsis cf. Lyrata.
The Vir area nearby Posušje, platy porous limestones contain melanopsis, planorbis and fosaruluse (Fossarurlus cf. Bulići) and includ coal-bearing zone, 7 m thick.
At Kočerin, west of Široki Brijeg: fresh-water porous limestones and marls contain Bythinia tentaculata, Planorbis cf. Bulići, Lymnea aquaris.
In Hodovo – Rotimlje Basin: clays and marls with congerias and melanopsises include a lignite seam.
Coal-bearing Gacko Basin: foot, main and roof coal seams with congerias, melanopsises and origocerases.

MIDDLE EOCENE (LUTETIAN, BARTONIAN)
Podveležje: limestones and marly limestones with foraminifers (Nummulites, Opreculina).
Posušje: sandy marls and limestones with corals, molusks (Lucina, Cardium) and gastropods (Cerithium, Velates).
Neum: limestones with foraminifers (Nummulites, Alveolina).
Stolac and Mostarsko Blato: alveoline-nummulite limestones (Alveolina oblonga, Alveolina minutula, Nummulites perforatus, Nummulites globus, Discociclina discus).

LATE PALEOCENE (THANETIAN)
At Ljubinje, Domanovići, Čapljina, Ljubuški, Stolac, Goranci and Podveležje, the Liburnian beds contain fossils as follows: Characeae, Lagynophora sp., Dasicladaceae, Microcordium sp., Clypeina sp., Alveolina ellipsoidalis, Orbtilites sp., Miliolidae and Orbitolinidae.

EARLY PALEOCENE (DANIAN)

Podveležje: algal limestones with foraminifers (Periloculina, Coskinolina, Alveolina).

Zagorje nearby Posušje: limestones with fresh-water gastropods (Stomatopsis).

EARLY UPPER CRETACEOUS (CONIACIAN, SANTONIAN, MAASTRICHTIAN)

Rudist division of Senonian: Late Campanian-Maastrichtian (Petkovicia, Katzeria, Gorjanovicia, Pironeae); Santonian-Campanian (Milovanovicia, Hippurites, Radiolites); Conician (Radiolites, Hippurites, Distefanella).

EARLY UPPER CRETACEOUS (CENOMANIAN, TURONIAN)

T u r o n i a n – rudist limestones (Radiolites, Hippurites).

C e n o m a n i a n – rudist limestones (Caprina, Neocaprina, Ichtyosarcolites).

LATE EARLY CRETACEOUS (BARREMIAN, APTIAN)

Mt. Gacko Bjelašnica: limestones with calcerous algs (Salpingoporella, Pianella, Munieria), foraminifers (Cuneolina, Orbitolina), molusks (Requienia, Toucasia) and gastropods (Nerinea).

EARLY LOWER CRETACEOUS (BARRIASIAN, VALANGINIAN, HAUTARIVIAN)

Mt. Gacko Bjelašnica: limestones with Tintinidae.

LATE JURASSIC (OXFORDIAN, KIMMERIDGIAN, TITHONIAN)

K i m m e r i d g i a n – T i t h o n i a n: Neum, whiteish limestones with Clypeina, tintinides (Campbellia) and gastropods (Ptygmatis).

O x f o r d i a n – K i m m e r i d g i a n: Neum, limestones with hydrozoaes (Cladocoropsis), foraminifers (Kurnubia, Pfenderina) interlayered with dolomites.

MIDDLE JURASSIC (HETTANGIAN, SINEMURIAN, PLIENSBACHIAN, TOARCIAN)

Hutovo and Popovo Valley: Limestones with lithiotises, megaloduses and orbitopsels. North and northeast of Trebinje: limestones and dolomites (400 m) with algs (Palaeodasycladus mediterraneus, Thaumothoporella parvovesiculifera), Protodiceras pumilum, Durga trigonalis and Durga crassa.

LATE TRIASSIC (CARNIAN, NORIAN, RHAETIAN)

In frontal parts of the High Karst Nappe at Neum, Upper Triassic sediments are thurst onto Paleogene and Cretaceous formations. Dolomites contain megalodons. At Rade village northward of Neum, in limestones foraminifers and caclareous algs (Involutina sinuosa sinuosa, Glomospirella friedli, Giropotella vesiculifera.

In the Lastva and Grančarevo area, in crestal parts of the Lastva anticline, Carnian-Norian-Rhaetian formations occur. Carnian: limestones with Cuspidaria gladis, Myophoria heferstein, Pseudosealites and Unio. Norian and Rhaethian are represented by afossiliferous dolomites, 400 m thick.

MIDDLE TRIASSIC (ANISIAN, LADINIAN)

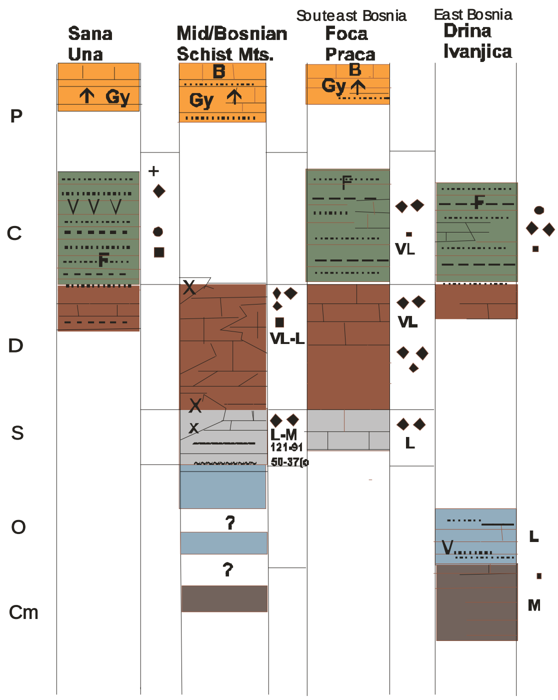
North of Trebinje in River Trebišnjica Valley, in crest of the Lastva anticline occur limestones and marly shales with Posidonia cf. Wengensis.

EARLY TRIASSIC (SEISIAN, CAMPILIAN)

At Sobač nearby Posušje, gypsum strata are included in reddish and brownish sandstones.

PALEOZOIC AND TRIASSIC ALLOCHTHONOUS COMPLEXES

In the geological structures of the Dinarides of Bosnia and Hercegovina are also included Paleozoic complexes which represented basement on which strated Mesozoic-Paleogene evolution of the Dinaridic Tethys. The Paleozoic complexes, together with frequently accompanied Triassic formations are allochthonous and occur in the areas as follows: Sana-Una, Mid-Bosnian Schist Mts., Southeastern Bosnia (Foča-Prača area) and East Bosnia (Drina-Ivanjica area).



Limestone Dolomite ·····Psamite ----Pelite B-Bellerophon limestone Gy-Gypsum F-Flysch GF-Groden Formation x-Rhyolite Vv-Basalt
● Foraminifers ◆ Corals ◆◆Conodonts + Brachiopods ▪ Flora
50-37 (O)-overprint-isotopic age Ma Metamorphism: H-high, M-medium, L-low grade, VL-very low grade

Fig. 10. The graphical presentation of the lithology of Paleozoic in the Internal Dinarides (Hrvatović, 2004)

Sana-Una area

Numerous papers have been published on Paleozoic formations of the Una-Sana area, and the most important are those published by Filipović (1963), Maksimčev&Laušević (1964), Jojić&Kačar (1964), Jurić (1960, 1961, 1963, 1968, 1971), Jurković (1961), Kulenović (1964, 1966), Pantić-Prodanović (1965) and Vrhovčić (1977).

The Una-Sana Paleozoic complex comprises the area of Bosanski Novi, Prijedor, Kozica, Sanski Most, Budimlić Japra, Ključ and Mrkonjić grad (Fig. 11). This allochthonous complex is included in the Pannonian Nappe (Miladinović, 1974) or Pannonian-Golija-Macedonia Nappe (Hrvatović and Pamić, 2005) which stretches here from Mt. Petrova Gora in Banovina up to Broncani Majdan. Paleozoic formations are thrust onto various Triassic formations which occur as milonitic zones, tectonic windows and klippes. Within the same thrust system in also included the Sanski Most thrust composed of Triassic formations, which crops out beneath the Sana-Una Nappe. The Sana-Una Paleozoic area is bounded to the north by the Sava Zone from which is separated by the Kozara-Spreča fault.

The oldest Paleozoic formations of this area are Late Devonian in age. They are represented by marly limestones with tentaculitides and conodonts with predominant Palmatopsis, were found at Bosanski Novi, Blagaj and Stari Majdan (Jurić&Maksimčev, 1964; Kulenović, 1966). Geological position of the Late Devonian formations, which originated in deep water submarine environments, is ambigous. However, Grubić et. al., (2000) said: «The Carboniferous of Blagaj near Novi Grad contains olistoliths of fossiliferous Devonian limestone hosted by a metasiltstone matrix».

From some quartz sandstones, a continental plant Cyclostigma hercynium was found. In sandstones from the same area were found fine-grained sandstones with asterocalamites and siltstones with fern remains (Neuropteris), indicating Moscovian-Casimovian age (Late Carboniferous).

At Razboj Hill east of the Sana River, a primitiv fusulinid (Millerella) was found, which is characteristic for Visean-Serpuhovian (Early Carbonferous) – Kostić- Podgorska (1955).

In the area south of the Ljubija iron mine, dark blue limestones with goniatides (Retikuliceras) and conodonts were found which are of Early Carboniferous in age.

m	Age	Lithology		Environments	Fossils
400	$J_{1,2}$		Thick bedded dolomitic limestone	Marine platform	Orbitopsella praecursos, Lituosepta recoarensis
900	$T_3^{2,3}$		Bedded dolomites with interlayers of marls and sandstones, and limestone	Marine platform	Megalodon
270-400	$T_3^{1,2}$		Limestones with megalodontidae, «rabels beds» black limestones, tuffs, sandstones and marls	Marine platform	
350-500	T_2^2		-Limestones with daonellae, cherts abd sandstones, -cherts, tuffs and sandstones	Continental rifts	Daonella, Posidonia
150-200	T_2^1		-bedded white limestone, -bedded and massiv dolomites	Shallow marine	Meandrospira dinarica, Macroporela cf. alpina
520	P3,T1		Alternation of sandstones reddish limestones, marls and schists, -quartz sandstones and conglomerates; gypsum	Shallow shelf/ramp	Myophoria balatonensis, Anodonthophora canalensis, Natiria costata
	P_3			land	
120	P_2		Greenish siltstones, rare siltstones, breccia	lagoonal and fluvial	
	P_1			land	
	C_2^2		metasiltstone	turbidite olistostrome	moscov
				land	
	C_2^1-C_2^2		Sandstone, limestones	continental slope	Bashkirian-Moscovian Dasycladaseae, Lepidodendrales, and Moscovian-Kasimovian Neuropteris
				land	
	C_1		-bedded limestones -upper flysch, -wild flysch, -siderite, lower flysch	-shallow marine -turbidite (continental slope)	-Serpukhovian Reticuliceras and conodonts, -Visean-Serpukhovian Mierella,
	D_3		Dolomite, limestone, psammite,	Shallow marine	Cyglostigma hercyinium, Asterocalamites,Palmatolepsis, Ozarcodina regularis

Fig. 11. Geological column Una-Sana area (after Jurić, 1964)

In the same area, clastics and limestones contain Bashkirian and Moscovian fauna: corals, bryozoaes, brachyopods, foraminifers, conodonts, algs (dasycladacea), reddish algs and fern spores (Stojanović-Kuzenko, 1966/67).

By the end of the Moscovian prevalied deposition accompanied by basalt submarine volcanism. The metabasalts (spilites) occur as interlayers, a few centimetre to several metre thick, in ankerite graywacky sandstones. In these rocks is included part of the Ljubija siderite deposit, mainly transformed into limonite, whereas the other part of the deposit is included in limestones. All these formations are, as a rule, strongly tectonized and, therefore, normal contacts between clastics, limestones and iron ores can be hardly recognized (Jurić, 1968; Podupsky, 1968; Podupsky&Pamić, 1969).

In this Carboniferous formations, about 1000 m thick, predominate clastics and only in some places subordinate carbonate facies occur (Fig. 16). Those are limestones, dolomites, ankerites and their transitional varieties. The limestones occur as irregular bodies which are in tectonic contact with surrounding clastics. Katzer (1926) was of the opinion that limestones are different in stratigraphy than the clastics. This became evident when Jurić&Maksimčev (1966) found Devonian fauna in the limestones. Crnolatac (1949) and Spasov&Filipović (1966) considered that these mutually isolated limestone masses were broken off by tectonics from an original large carbonate body. The limestone are of organogenic origin; dolomites and ankerites commonly occur in marginal parts of limestones bodies. The ankerite also occur as a secondary product, and the ankeritization is a large-scale proces. Ankerite parts alter by oxydization into limonite.

At Sanica, Ključ and Mrkonjić grad crop out the Werfenian Beds, composed of micaceous reddish and yellowish sandstones and porous brecciated limestones. These formations could not be separated from the Permian one and, therefore, they are marked as Permo-Triassic. The Early Triassic formations, represented by reddish sandstones, also occur as remains onto the Paleozoic formations at Bosanski Novi, Ljubija, Budimlić Japra and Sanski Most. In the wider Banjaluka area, Werfenian sediments crop out at Klašnica and on southeastern slopes of Mt. Kozara.

Middle Triassic formations cover large surface areas from Velika Kladuša in the northwest to Bužim and Bosanska Krupa up to Mrkonjić Grad in the southeast. Anisian is represented by varities of limestones and dolomites; at Vrnograč (Džaferović Hill), Anisian fossils: Meandrospira dinarica, Macroporella cf. Alpina and others were found.

Ladinian is represented by volcanic-sedimentary formations (cherts, sandstones, marly shales, limestones, spilites and tuffs). In the Ladinian formations are included manganese ore deposits (Bužim). Middle Triassic formations also crop out at Ljubija, Sanski Most, Broncani Majdan and Bosanski Novi.

Upper Triassic formations occur in the spring area of Sanica River, at Velika Kladuša, Bužim and Bosanska Krupa. They are largely represented by dolomites. In the area of Budimlić Japra and Stari Majdan, megalodon limestones are found, which are in some areas conformably overlain by afossiliferous dolomites interlayered with cherts.

In the wider area of Sanski Most, in south of Bliha River, Upper Jurassic carbonate sequences with ellipsactinians, corals, sponges and scare belemnites occur.

In the area of Sana-Una, lacustrine neogene formations, represented by terrestrial-limnic coal-bearing basinal sequences are very common. Those formations, which are widespread in the areas of Kamengrad, Bihać and Cazin are mainly Miocene and, to a lesser extent, of Pliocene ages.

In the Kamengrad Basin, the Early Miocene polyfacies complex is represented by reddish, mainly clastic sequence underlying the base of main coal-seam, the sequence is about 200 m thick. Going upward, the sequence is composed by weathered basal conglomerates and gravels which are overlain by sandstones and clays with sand and gravel admixtures, a few metre thick; those are overlain by coal zone, 2-3 m thick, composed of impure coal, coaly clays and coaly marls; the uppermost zone is composed of yellowish limestones and alternating conglomerates, sandstones and marls, more than 100 m thick, characterized by red colour.

The Late Miocene polyfacies complex is developed in the Kamengrad Basin and Bihać Depression. In the Kamengrad Basin, lithostratigraphycally, the Late Miocene sequences are completely developed. Going upwards, those are composed of brown coal strata, coaly schists, coaly clays and coaly marls is in average 11 m thick (maximally 23 m). In the Fajtovci tunnel, in these strata a tooth of mammal Mastodon longirostris was found. The Main coal-seam is conformably overlain by grayish, about 200 m thick, in whose lower parts tuffs, up to 7 m thick, are interlayered. The overlying limestones contain numerous fauna: Congeria sp., C. Cf. Basteroti, gastropods (melanopsides, planorbises and others). The limestone sequence is overlain by roof cola-zone, about 70 m thick, which is composed of banded coaly limestones, marls, colay clays, coaly schists and impure coal strata. The roof coal-zone is overlain by yellowish-grayish congerian limestones and marls, about 500 m thick, interlayered with conglomerates and tuffs. This sequence contains fossils as follows: Congeria dalmatica, C. Zoisi and C. Jadrovi and orygocerasides (Orygoceras dentali, Orygoceras carnucopiae, O. Filicinatum, melanopsides (Melanopsis Kišpatići, M. Pilari), neridontes (Neridonta sinjana, N. Pilari) and fosaurulusi (Fosaurulus bulići).

In the Bihać Depresion, the Early Miocene polyfacies complex is composed of whiteish marls and limestones which is mined as decorative material and known under the comercial name BIHACITE. In the marls the following fauna was found: Congeria cvitanovići, C. Bosniaca, C. Dalmatica, and Melanopsis lyrata and M. Miseri. Uppermost parts of the complex are composed of conglomerates with predominant limestone pebbles.

The Late Miocene polyfacies complex, which is developed in the Cazin-Tržac Basin, can be divided in three zones. The lowermost zones, composed of sandstones and conglomerates, 20 m thick, is covered by the coal-zone, 2-4 m thick, with coaly clays and sandstones. The hanging zone consists of grayish marls and marly clays. In the area of Bosanska Krupa, this complex is composed of limestones and marls.

Paleozoic siderite-ankerite deposits, particularly those of the Tomašica area, were affected during the Tertiary by weatering and altered in limonite which was further eroded and trasported in the north and deposited in Omarska Valley, together with debris composed of fragments of surrounding rocks. This proluvial material was deposited onto Neogene fresh-water sediments over the 10x4 km surface. Nevertheless, this was not the typical proluvial buildup, because waters separated the detrital material according size and gravity. Limonite dust, which experienced the longest transport, represents the most valuable iron reserve of the Sana-Una area. With its red colour this dust reminds to by fire burned clays and siltstones found in some Neogene fresh-water basins in Bosnia, e.g. «brand» in the Kreka area within the Tuzla Basin. The same term brand is in usuge for the limonite dust of the Omarska Valley. Hower, the Ljubija deposits are not only iron-bearing, because the iron ore affected also by subvolcanic mineralization processes. For example, the Brdo siderite deposits are, in some parts, enriched by lead-zinc ores, up to 8 %, and economically significant barite qualities. In the Omarska Valley, the deposition continued during the Quarternary and it gave various clays, including the ceramic ones, peats and sandstones. These sediments are entirely horizontal, whereas the original paleorelief was strongly dissected thus giving rise that in some parts of the Omarska Valley brand formations are up to 200 m thick. The Quarternary to date has not been studied in detail; some clays at depths of 20 m are Riessian-Würmian in age indicated by pollen data.

Economically important mineral resources of this area are as follows: coal, iron, barite, fluorite, clay, tuff, decorative-building rocks, quartz sand, gypsum, bauxite, thermomineral , thermal and mineral waters.

Stratigraphic column for the Sana-Una area

PLEISTOCENE (LATE QUATERNARY)

R i e s s – W ü r m i a n: Omarska Valley – forest trees from interlayered period Pinus Picea, Picea omorika.

PLIO-PLEISTOCENE

Dacian, Romanian, Early and Middle Pleistocene Omarska Valley: clays, sands and dusty limonite (200 m).

LATE MIOCENE (SARMATIAN, PANONIAN, PONTIAN)

P o n t i a n – Prijedor Basin: sands mixed with clays; at Kozarac village: fine.grained sands and sandy clays and fine-grained sands with fauna: Paradacna abichi, Limnocardium ochetophorum.
P a n n o n i a n: at Kozarac (northern Omarska Valley margin): gray marls, sandy marls, marly clays, sandy clays and fine-grained sands with fauna: Congeria partchi, Linocardium schedelianum.
S a r m a t i a n, in the Kozara River Valley is represented by grayish sandy clays and marls with Syndosmya efelxa and Irus gragarius. In conglomeratic limestones are present gastropods of late Sarmatian: Pirenella disjuncata, Calliostoma podolicormis.

EARLY MIOCENE (OTTNANGIAN, KARPATIAN, BADENIAN)

Along the northern Prijedor Basin margin, Badenian is represented by schlieren marls and clays interlayered by sandstones originated from igneous rocks with numerous fossils: Amussium denudalum, Pecten duodecim – lamelatus, Venus multilamella, Corbula gibba, Brissopsis and pteropods. In the Bihać Depression (Bihacite) and the Kamengrad Basin, sediments with congerias.

MIDDLE EOCENE (LUTETIAN, BARTONIAN)

At Baljevac west Bihać, outcrops of foraminiferal limestones.

EARLY EOCENE (YPRESIAN)
Mt. Kozara. Limestones with Lithotamnium torulosum, Discocyclina sp., nummulites sp., Alveolina sp.

LATE JURASSIC (OXFORDIAN, KIMMERIDGIAN, TITHONIAN)
South of Bliha River nearby Sanski Most: limestones with ellypsactinias, corals, spong and belemnites.

LATE TRIASSIC (CARNIAN, NORIAN, THAETIAN)
N o r i a n an R h a e t i a n: Bosanski Novi – Budimlić Japra – Ljubija – megalodon limestones are overlain by grayish dolomites interlayered with yellowish and greenish marly shales and marly limestones.
C a r n i a n: Budimlić Japra – Stari Majdan – megalodon limestone.

MIDDLE TRIASSIC (ANISIAN, LADINIAN)
L a d i n i a n: in the area Ljubija, Sanski Most, Broncani Majdan, Bosanski Novi and Bužim: volcanic-sedimentary formations composed of chert, sandstones, marly shales, limestones, spilites and tuffs.
A n i s i a n: Vrnograč (Džaferović Hill): in carbonate rocks Menadrospira dinarica, Macroporella alpina and others.

EARLY TRIASSIC (SEISIAN, CAMPILIAN)
In the area of Bihać, Sanica, Ključ, Bosanski Novi, Budimlić Japra and Sanski Most crop out the Werfenian Beds composed of micaceous sandstones and porous limestones.

LATE CARBONIFEROUS (BASHKIRIAN, MOSCOVIAN, KASIMOVIAN, GZELIAN)
B a s h k i r i a n – M o s k o v i a n: at Ljubija crop out marly shales, sandstones and limestones with Dasycladaceaes, Lepidodendrales, formainifers, conodonts, corals, bryozoaes and brachyopods.
M o s c o v i a n - K a s i m o v i a n: at Stari Majdan outcrops of siltstones with Neuropteris.

EARLY CARBONIFEROUS (TOURNASIAN, VISEAN, AND EARLY SEPUKHOVIAN)
S e r p u k h o v i a n: at Ljubija South crop out dark blue limestones with goniatitids (Reticuliceras) and conodonts.
V i s e a n – S e r p u k h o v i a n: at Razboj limestones with foraminifers Millerella.

LATE DEVONIAN (FAMENIAN AND FRASNIAN)
Blagaj: blueish marly limestones with tentaculides and conodonts.
Stari Majdan: marine quartz sandstone with Cyclostigma.

Mid – Bosnian Schist Mountains (MBSM)

The Mid-Bosnian Schist Mountains sensu lato include the mountains Middle Bosnian (southwest of Sarajevo) – which stretches from Tarčin in the southeast up to Jajce in the northwest the surface area 80 km long and 30-40 km wide. The highest is Mt. Vranica with the peaks Nadkrstac (2112 m) which, orographically, includes the group of montains: Zec, Pogorelica, Bitovnja, Šćit and Kruščica located between Prozor and rivers Vrbas and Rama in the southwest, Bradina, Konjic and Neretva River in the southeast and Kiseljak and Busovača in the northeast (fig. 4).

The allochthonous Paleozoic complex of the MBSM, which included in the Central Dinarides, is incorporated in the intra-Alpine Noric-Bosnian Zone (Flugel, 1990). It is compsed of Variscan metasediments and metavolcanics and post-Variscan formations which are disconformably overlain by rocks of the Alpine cycle (Hrvatović, 1997).

Ţhe Mid-Bosnian Schist Mountains, E. von Mojsisovics (1880) named as "Bosnisches Erzegebirge", Katzer(1924) as "Mittelbosniches Schetergebbirge" and Hrvatović (1995) as "Natural petrological-mineralogical museum"

Paleozoic metamorphic complex of the MBSM, which covers the surface area of about 3000 km^2, is composed of Variscan metasediments, metavolcanics, limestones and dolomites and Permian post-Variscan formations (Katzer, 1924; Živanović, 1979, Hrvatović, 1997).-Fig.12 .

The geological column in Figure 13 demonstrated the geological evolution of the MBSM Paleozoic complex. The oldest rocks are Ordovician (?) and Silurian (?) composed mainly metamorphic sequences originated under greenschist facies and sporadic metamorphosed carbonates. The metamorphic sequences are composed of quartz-muskovite schists, chlorite schists, chloritoid schists, chlorite-epidotite amphibole schists with subordinate limestones, marbles, metasandstones and quartzites. These metamorphic rocks include smaller and larger mases of rhyolites and subordinate metabasalts transformed into varieties of orthogreenschists (Hrvatović, 1999).

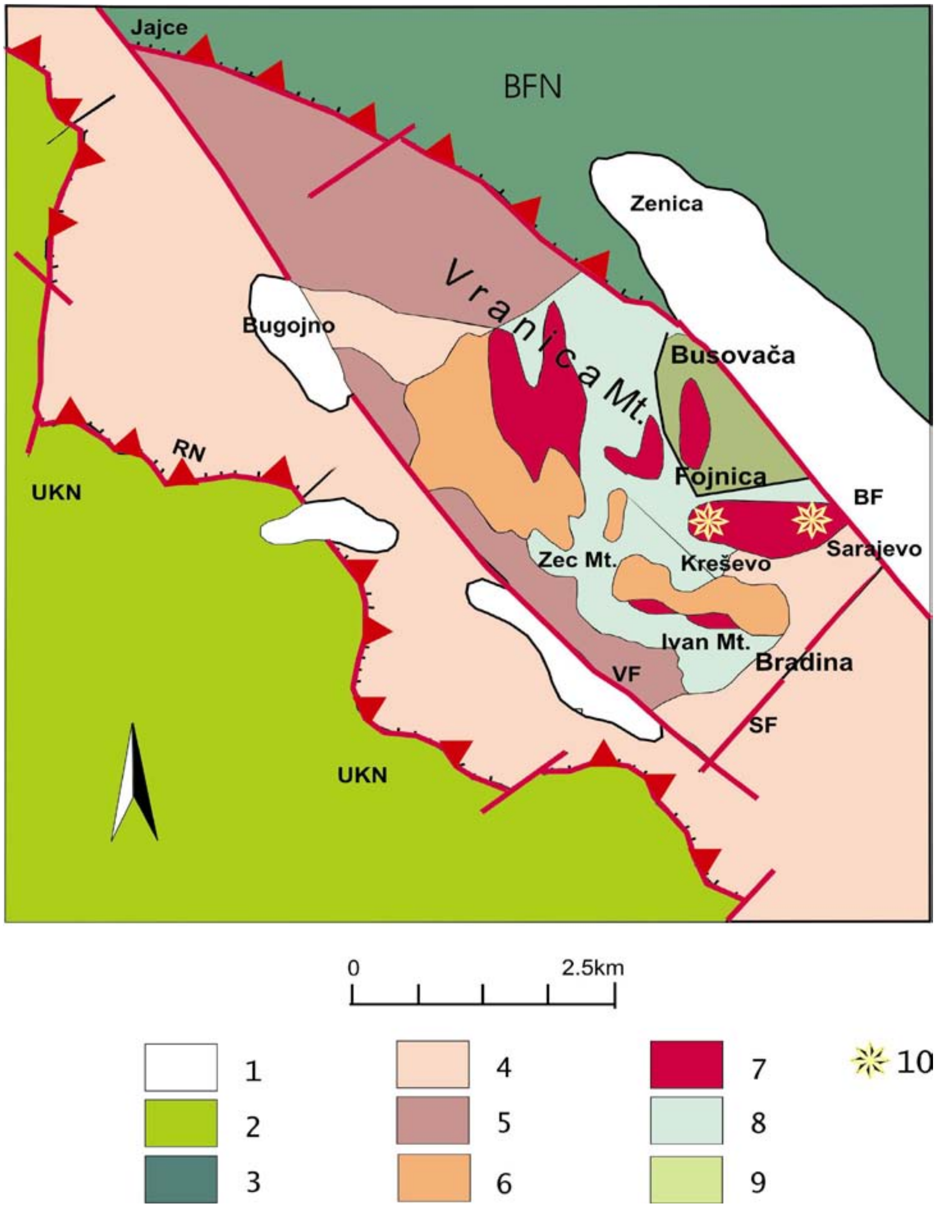


Fig. 12. Simplified geological map of the Mid-Bosnian Schist Mts. (Hrvatović, 1997)

1. Intramontane Neogene basins, 2. External Dinarides (Carbonate plarform), 3. Late Jurassic-Cretaceous and Late Cretaceous Bosnian Flysch; 4. Triassic carbonate, clastic and magmatic formations, 5. Permian and Permo-triasic formations, 6. Devonian carbonates, 7. Silurian-Devonian rhyolites, 8. Silurian-Devonian metaclastics, 9. Ordovicium? metaclastics and metabasalt, 10. Paleovolcanic centre

m	Age	Lithology		Environments	Fossils
450	**P,T**		**Travnik formation** **-alevrite slate** **-mica sandstone** **-metasandstone**		
500	**P_3**		**-Belerophon limestone** **-Evaporites** **-quartz-mica-carbonate slate,** **-Kruščica formations: quartz sandstone and conglomerates, breccia,**	**-Shallow marine** **-Fluvial system**	**Belerophon**
				Land	
<100	D_3		**-black and grey limestone,**	**Marine platform**	**Conodonts:** (Rhomboidea Zone of Sandbewrger, C. A. Ziegler, W. 1973. Following species; Palamatolepsis rhomboidea, Pa. Glabra lepta ZIEGLER&HUDDLE, Pa. Glabra distrota BRANSON&MEHL, Pa. Perlobata schindewolfi MULLER, Pa. Minuta minuta BRANSON&MEHL, Polygnathus glaber ULRICH&BASSLER, Po. Nodocostatus BRANSON&MEHL, Icriodus cornutus SANNEMANN).
200	D_2		**-limestones,** **-dolomites**	**Marine platform**	Amphipore ramose, Favosites vranicae,
300	D_1	**v.v.v.** x x x x x	**-limestones,** **-dolomites.** **-marble** **-rhyolites,** **-piroclastics**	**Marine platform**	Thamnopora brezovicensis Živanović, Cladopora rectilineata Simpson, Hindeodella equidentata Rhodes, Belodella triangularis (Stauffer), Belodus triangularis (Staufer), Nepriniodus bicurvatus (Branson i Mehl), Ozarkodina denckmani Ziegler,
<1000	S,Or	x x x	**Metarhyolites,** **Marble,** **Phylites, amphibolites,** **greenschist,** **metabasalt**		Stromatolites?

Fig. 13. Geological column Paleozoic Mid-Bosnian Schist Mountains (Hrvatović, 1997)

Rhyolites, in many places associated with large masses of pyroclastics are very common within the MBSM; They are either interlayered with metaclastics and then interlayered with pyroclastics, or represent shallow hypabyssal bodies. Petrologically, the rhyolites are allkali-feldspar rocks, which are largely metamorphosed into metarhyolites, schistose metarhyolites and particularly into varieties of schist composed of quartz, “white mica” chlorite, epidote, actinolite and various carbonates.

Rhyolites are products of two stage volcanic activity. Most of them are synsedimentary with presumed Silurian metasediments and thus must be of Silurian age. Some hypabyssal rhyolites intruded into Late Silurian and Early Devonian limestones which also occur as xenoliths within the volcanic body.. (Hrvatović, 1997). However, there are opinions that the rhyolites are Permian in age (Jurković and Majer, 1954).

Metamorphic rocks of the MBSM are frequently cut by Alpine veins, up to a few metre thick, which are mainly composed of quartz and hyalophane, barite, quartz-pirite, quartz-antimonite etc.

The Silurian metamorphic sequences are conformably overlain by fossiliferous Devonian platform limestones, dolomites and marbles (Živanović, 1979; Hrvatović, 1999). The limestones are fossiliferous and contain Geidinnan and Siegenian (Lohkovian and Pragian) corals, conodonts and stromatoporates:
Clatrodictyon sp., Strepteplasma sp., Pseudomicroplasma devonica (Sashkina), Tabularia suhodolensis Živanović, Thamnopora brezovicensis Živanović, Cladopora rectilineata Simpson, Hindeodella equidentata Rhodes, Belodella triangularis (Stauffer), Belodus triangularis (Staufer), Nepriniodus bicurvatus (Branson i Mehl), Ozarkodina denckmani Ziegler, Panderodus unicostatus (Branson i Mehl) Spathognathodus steinhornensis Ziegler (Živanović,1979).

The Middle Devonian represented limestones-dolomites faciec contain. Amphipora ramosa (Philips) and Favozites vranicae Živanović.

The samples, taken from Upper Devonian limestone near Kreševo indicate Famennian age *(Rhomboidea Zone of Sandbewrger, C. A. Ziegler, W. 1973. Following species; Palamatolepsis rhomboidea, Pa. Glabra lepta ZIEGLER&HUDDLE, Pa. Glabra distrota BRANSON&MEHL, Pa. Perlobata schindewolfi MULLER, Pa. Minuta minuta BRANSON&MEHL, Polygnathus glaber ULRICH&BASSLER, Po. Nodocostatus BRANSON&MEHL, Icriodus cornutus SANNEMANN).*

It is surprising that Carboniferous formations, which are predominant within Paleozoic complexes of the Dinarides, have not been yet identified within the MBSM.

Post-Variscan (Permian) formations represented by breccias, conglomerates, quartz-mica-carbonate schist, shales, limestones, dolomites, porous limestones (rauchwackes), sandstones (locally "red beds") and gypsum-anchydrite strata. In some areas the Permian formations grade into Scythian formations (Živanović, 1979; Hrvatović, 1997-fig. 13).

Triassic formations occur along the Vrbas and Busovača faults. Early Triassic fossiliferous kampilian beds occur at Turbe, Tarčin, Hadžići and Bradina. Middle Triassic sediments are accompanied by penecontemporaneous igneous rocks (Radovan pluton). Anisian strata, which are 400 m thick, the area of Jablanica and Prozor, are represented by black platy limestones which are overlain by brachiopodal dolomitic limestones with plenty fossils in the area of Borašnica nearby Konjic. At Rudina nearby Bugojno Ladinian limestones contain mollusk Daonella. It is belived that dolomite formations at Konjic belong to Late Triassic. However, at Kalin and Hum nearby Bugojno, Middle Triassic dolomites are disconformable overlain by basal conglomerates and Liassic-Doggerian fossiliferous limestones. Late jurassic is represented by pisolitic limestones with hydrozoes (Cladocoropsis), clacareous algs (Clypeina) which are unconformably overlain by Tithonian-Valangian limestones with Ellypsactinia.

Within the Mid-Bosnian Schist Mts. various magmatic formations are very common: diabases, gabbros, syenites, spilites and quartz keratophires along the Vrbas fault, gabros and diorites in Mt. Radovan, gabbros at Jablanica, quartz diorites in Mt. Komar and others. The largest Mt. Radovan body, which is bearer of low – manganese iron ores, is composed of various plutonic rocks. Its age is post – Anisian as indicated by contact metamorphic phenomen on fossiliferous Scythian and Anisian sediments and Rb/Sr model ages of 233-223 Ma (Katzer, 1916; Majer&Jurković, 1958; Pamić, 1979; Pamić&Lovrić, 1980).

In marginal parts of the Radovan pluton endometamorphic zone, up to 500 m thick, is developed which is composed of fine-grained, granular to ophitic varieties of albite diabases, albite syenite porphyres and albite granite porphyries. The endometamorphic zone includes numerous xenoliths of schists and carbonates from surrounding country rocks (Šarac&Pamić, 1981).

In the finging country rocks exometamorphic zone is developed and it is composed of various schists, marbles and calc-silicate rocks with magnetite deposits, which developed on account of adjacent Lower and Middle Triassic sediments.

The Jablanica gabbro pluton, with a surface of about 20 km^2, is one of the largest Triassic plutonic body within the Dinarides. It is surrounded by Early Triassic sediments, represented chiefly by marly shales and limestons, and Middle Triassic sediments, represented by limestones and dolomites. Contact between the gabrro body and surrounding rocks is mainly faulted. The geological age of the gabro is Middle Triassic as evidence by contact metamorphic phenomen found in the surrounding rocks: garnet, albite, chlorite, sericite, titanite, epidote and the skarn deposit of Tovarnica with magnetite (Čelebić, 1967). New geochemical investigations (Trubelja at al, 2004) this pluton is explaned as products of subduction-triggered volcanism at an active continental margin.

Rocks of the spilite-keratophyre association found along the Vrbas fault (the area of Gorica – Ljuša – Jajce) partially originated by subaerial volcanic activity. This is indicated by bauxite deposits, originated by lateritization of underlying volcanics (Trubelja, 1989); the bauxite deposits are overlain by Upper Triassic stromatolithic dolomites.

Date on Sr isotope composition (Trubelja et al 2000) indicate strongly Triassic magmatic associations might have originated by fractional crystalization from primary tholeitic basalt magma accompanied by moderate contribution of the continental crust (magmatism correlated of convergent plate margins).

Paleozoic formations are bounded in the southwest and southeast by Triassic formations represented by Scythian shales and sandstones, with subordinate limestones, Middle Triassic dolomites and limestones interlayered with penecontemporaneous volcanics and pyroclastics and intruded by plutonic rocks, and Upper Triassic limestones and dolomites.

Main contact between the Mid-Bosnian Paleozoic complex is mainly defined by the large longitudinal Vrbas fault in the southwest and Busovača fault in the northeast and bay the Sarajevo transversal fault in southeast (Fig. 12).

Mid-Bosnian Paleozoic formations are in the northeast disconformably overlain by the Neogene Sarajevo-Zenica coal-bearing fresh-water basin being the largest Tertiary intramontane basin within the Dinarides. In the northwest, the Paleozoic partly accompained Triassic formations are thrust by Mesozoic Bosnian flysch originated along the passive Tethyan margin (Fig. 12).

Geodinamic evolution of the MBSM Paleozoic complex have been genetically related to the Paleotethys. The rifting processes which initiated the evolution of the Paleotethys started along the North Gondvana margin during the Ordovician/Early Silurian on a not yet identified pre-Variscan basement. The rifting is indicated by the occurrence of basalts and rhyolites which are accompanied by Silurian metamorphic sequences.

Opening of the Paleotethys probably started in the Late Silurian/Early Devonian times giving rise to its differentiation. Shelf areas (carbonate platform) originated along the North Gondwana margin whereas clastics, micrites and lydites were deposited in basinal environments. Occurrences of orthoamphibolites of tholeiitic affinity within metasedimentary sequences suggest open ocean environments.

In the MBSM, Katzer (1924) has already recognized cross-folding suggesting a two-stage deformation. Most recently, Hrvatović (1997) recognized four genetically different types of folds. First B_1 pre-metamorphic deformation gave isoclinal folds. Second generation B_2 of axes are related to quartz-ptygme folds. Axes of the third B_3 generation reflect slight folding which deform all existing s-surface. Axes of the fourt youngest folds are related to faults.

Variscan and post-Variscan formations of the MBSM Paleozoic complex were incorporated in Pangea which was disrupted by Mesozoic rifting processes and the opening of the Mesozoic Tethys.

K-Ar ages of metaclastics and metarhyolites

Metamorphic rocks of the MBSM are frequently cut by Alpine veins, up to a few metre thick, which are mainly composed of quartz and hyalophane, barite, quartz-pirite-gold, quartz-antimonite etc.

First K/Ar measurement on fresh biotite gave on overprint age of 35 Ma (Hrvatović, 1987). K/Ar measurements on sampled in the area of Fojnica, Busovača and Bradina (Pamić, Balogh, Hrvatović, Balen, Jurković, Palinkaš, 2004) produced the following results:

1) 343 Ma on “white mica” from a metapelite probably related to the main Variscan deformational event during the Early Carboniferous. It also indicates a pre-Carboniferous age protolithic formations which originated mainly during the Ordovician (?), Silurian and Devonian.

2) Post-Variscan K/Ar ages of 288-238 Ma, obtained on metadiabases and orthogreenschists, are the result of Gzhelian and Permian tectonomagmatic activity. Namely, the ages may be partly result of tectonism related to Permian generation of Pangea.

3) Whole-rocks ages ranging from 121-92 Ma obtained on metarhyolites from the area of Busovača, which were related to Early Cretaceous overprint, and

4) Eocene (45-35 Ma) ages, obtained on "white micas" from the Alpine veins, which were probably related to the main Alpine collisional event (Hrvatović, 1987, 1997; Palinkaš et al., 1996; Pamić and Jurković, 2001).

Structural data

The paleozoic metamorphic complex of the Mid-Bosnian Schist Mountains to date has been studied to a less extent. By the elaboration of the new geological map, carried out during the period 1987-1997, data as follows were obtained: mapping of metamorphic rocks, determination of their age and metamorphic degree, geometry and classification of their fabric and succession of occurrence in the fabric-all of them as very significant are-controlling factors. Based on all these data, Hrvatović and Dimitrijević (1991) are proposed a probable model of the genetic evolution for the Mid-Bosninan Schist Mountains as a contribution to the explaination of the "Bosnian transversal strike" proposed by Katzer (1925).

Basic fabric elements are bedding, foliation, cleavage, fissure and lineation. Mainly NW dip of bedding with low inclination is brought about by isoclinal folding and the transposition of s-surfaces. Foliation is developed along axial-plane cleavage and bedding surfaces. First pre-metamorphic deformation gave isoclinal folds. Second generation of axes are related to quartz-ptygme folds. Axes of the third generation reflect slight folding which deform all existing s-surfaces. Axes of the fourth youngest folds are related to faults. Most common shearing fissures are NW-SE directed.

Genetical model of structural formation is as follows: the oldest stage gave rise to folding whish, by the increasing intensity, graded into isoclinal folding accompanied by the generation of axial – plane cleavage and further by sliding along it into the complete transposition of s- surfaces. Concering the products of this structuration two main structural levels can be distinguished:

-The lower one is characterized by isoclinal folding, complete transposition and foliation developing along the axial-plane cleavage and bedding with excelletly pronounced lineation.

-The upper level is characterized by less pronounced folding without the complete transposition of s-surfaces and with less developed foliation and lineation.

Vertical relation between these two levels of different fabrics (complete transposition – isoclinal folding-folding lower index) and degree of metamorphism (greenschist with foliation cleavage and beds- gradational weak metamorphism with weak foliation) suggest a possible genesis of the fabric by sliding of the whole block of the Mid-Bosnian Schist Mountanis, together with its southwestern Mesozoic envelope along the zone of lower level brought about by NE-directed under thrusting ot the southern Gondwana margin (F_1 and F_2). The isoclinal folding, transposition and metamorfism commenced probably in Triassic as inicated by the fact that the younger formations display less pronounced fabric but of the same quality as the underlying Paleozoic formation. The underthrusting from the southwest continues during the whole Mesozoic.

The northeastern part of the Paleozoic complex close to the Busovaca fault was uplifted before the Late Jurassic giving rise to large fold forms with slight secondary fine-scale folding (F_3). In the frameund of this model very significant are tectonic structurtes located southeastward from the Paleozoic complex which have the direction perpendicular to strike of the Dinarides suggesting to one component of the SE-NW direction. Such a mechanism can be the explaination of Katzer's “Bosnian transversal strike” Northeastward underthrusting of the Adriatic microplate and its Late Cretaceous-Paleogene convergence with the Eurasia gave rise to strong SW-NE reduction and thus to changes of mutually perpendicular predominant stress and compression.

The Mid-Bosnina Schist Mountains include numerous and differend mineral deposits and ore occurences of quartz, barite, iron, gold, antimonite, pyrophyllite, fluorite and others. Structural data indicate that at least three generations of quartz vein exist. The first one corresponds to quartz-ptygmes of decimetre size, the second quartz generation which originated along the foliation surfaces (after F_1 and F_2), is up to 1 m thick and can be traced along strike for 50 m. The third generation quartz, which is 1 to 6 m thick and can be traced along strike for 20-30 m, cut the second generation quartz.

Fig. 14. Lineation in rhyolite (photo. Hrvatović, 1987)

<u>Stratigraphic column for the Mid-Bosnian Schist Mts.</u>

LATE JURASSIC (OXFORDIAN, KIMMERIDGIAN, TITHONIAN)
K i m m e r i d g I a n - T i t h o n i a n; at Kalin nearby Bugojno: pisolithic limestones with algs (Clypeina) and hydrozoaes (Cladocoropsis).

EARLY JURASSIC (HATTANGIAN, SINEMURIAN, PLIENSBACHIAN, TOARCIAN)
Kailn nerby Bugojno: conglomerates, oolithic and other limestones with formainifers.

LATE TRIASSIC (CARNIAN, NORIAN, RHAETIAN)
At Jajce (bazxite deposit: stromatolithic dolomites)

MIDDLE TRIASSIC (ANISIAN, LADINIAN)
Gorica – Ljuša – Bugojno: spilite-keratophyres

EARLY TRIASSIC (SEISIAN, KAMPILIAN)
Kampilian at Hadžići; Tarčin and Turbe: sandstones, siltstone, porous limestones,

LATE PERMIAN (KAZANIAN, TATARIAN)
Bojska and Opare: breccias, conglomerates, sandstones, quartz-carbonate schists.
At Kiseljak: Bellerophon limestones.

LATE DEVONIAN (FAMENNIAN, FRASNIAN)
At Gornji Vakuf: Frasnian limestones with conodonts.

MIDDLE DEVONIAN (GIVATIAN, TATARIAN)
At Gornji Vakuf: Givatian limestones with corals (Favosites) and stromatoporates (Amphipora).

EARLY DEVONIAN (LOHKOVIAN, PRAGIAN, EMSIAN)
At Gornji Vakuf: gray-blueish limestones with conodonts, corals and bryozoaes.

SILURIAN (LLANDOVARY, WANLOCK, LADLOW, PRIDON)
At Busovača and Fojnica: parametamorpfics, probably also pre-Silurian.

ORDOVICUM ?
At Busovača (metabasalt)

Southeast Bosnia area

Southeast Bosnia comprises the areas of Foča, Goražde and Prača; its westernmost boundary is located on southeastern slopes of Mt. Jahorina (Fig. 4).

In the between Foča and Goražde crop out the oldest Paleozoic formations in which are preserved Variscan structures. At Ustikolina occur thick-bedded limestones with Late Silurian conodonts (Ozarkodina, Panderodus). – Fig.15.

Lower Devonian is represented by dark gray platy limestones with conodonts (Neoproniodus, Plectospatodus) and in Upper Devonian limestones occur conodonts (Palmatolepsis), bryozoaes and crinoids.

In the area of Klek on easternmost slopes of Mt. Jahorina, with the Prača thrust below Triassic formations are found «orthoceras limestones» with Early and Late Silurian conodonts and tentaculides (Kostić-Podgorska, 1958). Here, in Lower and Middle Devonian limestones is found rich fauna of corals, stromatoporates, hydrozoaes, bryozoaes, brachypods and crinoids (Kostić-Podgorska, 1958, 1961; Živanović, 1963, 1970; Pantić, 1963). Some Paleozoic formations of the Foča area are of a presumed Devonian age. In the area Paleozoic formations are up to 800 m thick (Buzaljko, 1971).

Devonian formations are overlain by Early Carboniferous flysch, up to 1000 m thick. The flysch sediments contain ammonites (goniatites, orthoceratides), mollusks, gastropods, brachyopods and corals. At Podkoran Knežiček and Grimmer (1898) found Early Carboniferous goniatites subsequently studied in detail by Kittl (1904). Based on the goniatite data, Frech (1906) and Schmidt (1926) supported Visean age of some Paleozoic formations. Podgorska (1939) publiched data on fauna from crinoidal limestones from the area of Prača.

Early Carboniferous flysch was first studied in the Prača area (Dimitrijević&Dimitrijević, 1970; Kulenović, 1971) and afterwards in the Foča-Goražde-Rudo area (Buzaljko, 1971). The flysch is disconformably overlain by Late Carboniferous formations.

A break in sedimentation took place in Late Carboniferous and Early Permian. Late Permian is represented by reddish clastics which are overlain by gastropods (Bellerophon) and calcareous algas (gimnocodium). The Bellerophon limestones were first recorded by Bittner (1880) and afterwards by Kittl (1904) at Han Orahovica, Katzer (1926) at Zbišće and Musići and Kostić-Podgorska (1958) at Vihor, Lunji and Razbojište. In the area of Tjentište, Cadet (1966) found dark gray thick bedded limestones with brachyopods, mollusks and gastropods from Latest Permian. In the area of

Kolina Valley, Fočanska Jabuka and further towards Prača were discovered sideritic-ankeritic limestones with sulphides: pyrite, chalcopyrite, aresenopyrite, galena and antimonite. Buzaljko (1971) did a detailed stratigraphic division of Permian formations of Southeast Bosnia area.

In the area of Kolina Basin and Mt. Jabuka, Permo-Triassic gypsum strata from a diapiric fold. Analogous gypsum formations were discovered during the building of Prača tunnel. Overlying Early Triassic formations are

m	Age	Lithology		Environments	Fossils
<100	**P_3**		Belerophon limestone, -sandstone. -gypsum, -redisch schists, -siltstone	Shallow marine-lagoonal	Belerophon sp.Archaeocidaris ladina
				Land?	
850	**$P_{1,2}$**		-redisch conglomerate, and quartz sandstone, -gray schist, marble bedded limestone, -breccia	Shallow marine to fluvial	Naneionella, Mizzia cornuta, Globivalvulina, Tubertina sp.
100	**C_3**		Sandstone, claystones, conglomerates, schists		Lepidodendron weltheimianum
	C_2		**Flysch:**	trench	Verneulites librovithi
700	**C_1**		**Flysch:** Subgraywacke, sandstones, claystones, clayey-quartz-sericite schists, microconglomerates, massive limestones	trench	Lepidodenron lasseni, Glyphyoceras sphaericum, Aviculopecten pračaensis, Cyathocarinia rasliana, Chonetes,Nercites
200	**D_3**		Bedded limestone,	Marine platform	Hindeodella sp. Palmatolepsis glabra pectinata, Pa. Rhomboidea, Belodella triangularis
450	**D_2**		Massive reef limestone	Marine platform	Favosites sp. Polygnathus linguformis
200	**D_1**		Bedded limestone layered schist	Marine platform	Neopriniodus bieurvatus, Plectospadus, Panderodus unicostatus
100	**S_3**		Massive limestones	Marine platform	Ozarcodina, Panderodus

Fig. 15. Geological column Paleozoic of SE Bosnia (after Buzaljko 1971 and Kulenović, 1985)

represented by clastics grading into limestones with calcareous algs. Anisian is represented by platy limestones with are conformably overlain by brachyopod limestones and Han Bulog limestones with ammonites. Ladinian is represented by limestones and «pietra verde». In the central and southwestern parts of this area occur igneous rocks (area of Okosovići, Zavajt, Čelebić and Čajniče). The main rocks are andesite (mostly keratophyres) and dacites (commonly quartz keratophyres). Andesite of the Čajniče area are composed: albite, sugite, quartz, chlorite, calcite, epidote, magnetite, pyrite and kaolinite. Dacite comprise albite, augite, chlorite, pyrite, magnetite, apatite, sericite and kaolinite (Trubelja, 1961). New geochemical data (Trubelja, Burgath and Marchig, 2004) support the opinion that subduction was main process which triggered the Triassic magmatic activity in the Central Dinarides (thoelitic basalt-spilite Tjentište; olivine-bearing tholeitic basalt Kalinovik and tholeitic basalt-dijabase Dobro Polje).

In the area between Drina and Čehotina Rivers crop out Liassic marly limestones with Aptychus and belemnites, Doggerian limestones with Posidonia and early Neocomian formations. In the area west of Foča in the lower course of Bistrica River occur Miocene fresh-water formations with coal with which also porous limestones are under exploitation. These formations are Early Miocene in age.

Economically important mineral resources of this area are as foolows: coal, gypsum, amonite, barite, Zn and Pb ores and mineral waters.

Stratigraphic column for Southeast Bosnia.

LATE MIOCENE (SARMATIAN, PANNONIAN AND PONTIAN)

In the Miljevina Basin, equivalents of the Pannonian and Pontian are represented by brecciated conglomerates, sandstones and clays interlayered with coal (200 m).

EARLY MIOCENE (OTTNANGIAN, KARPATIEN, BADENIAN)

Miljevina Basen: light gray porous limestones interlayered with clastics and coal (150 m); marls with flora (Glyptostrobus, Laurus, and Carpolithes), 160 m; coaly marls with the main coal-seam (20 m); clays, sandstones and basal conglomerates.

MIDDLE JURASSIC (AALANIAN, BAJOCIAN, BATHONIAN, CALLOVIAN)

The area between the rivers Drina and Čehotina: limestones with mollusks (Posidonia).

EARLY JURASSIC (HETTANGIAN, SINEMURIAN, PLIENSBACHIAN, TOARCIAN)

The area between the rivers Drina and Čehotina: marly limestones with Aptychus and belemnitides.

LATE TRIASSIC (CARNIAN, NORIAN, RHAETIAN)

In Mt. Kovač: limestones with conodonts and mollusks (Megalodon).

MIDDLE TRIASSIC (ANISIAN, LADINIAN)

In Mt. Kovač L a d i n i a n is represented by platy limestones, calcareous shales, cherts and weathered diabases. Granosyenites at Luka and Okosovići and spilites at Zavajt and Čelebići.

A n i s i a n is represented in Mt. Kovač by limestones with Han Bulog Fauna, Trebević brachyopod limestones and platy limestones.

LATE PERMIAN (KAZANIAN, TATARIAN)

Ustikolina - Mt. Kovač: limestones with algas (Gymnocodium) and gastropods (Bellerophon); coloured clastics.

LATE CARBONIFEROUS (SERPUKHOVIAN, BASHKIRIAN, MOSCOVIAN, KASIMOVIAN, GZELIAN)

B a s h k i r i a n: sanstones and black limestones with goniatides (Verneulites).

EARLY CARBONIFEROUS (TOURNASIAN, VISEAN, NAMURIAN)

Ustikolina – Mt. Kovač: the Prača flysch.

Prača: flysch with fossiliferous limestone interlayers with fauna of foraminifers, corals, brachyopods, gastropods, mollusks and Orthoceratides and Goniatides. Also interlayers of spilites – 1000 m.

LATE DEVONIAN (FRASNIAN, FANIENNIAN)

Ustikolina: darks gray platy limestones with conodonts (Palmatolepsis), bryuzoaes and crinoids

MIDDLE DEVONIAN (EIFENAN, GIVATIAN)

Mt. Klek at Prača: reefal limestones

Ustikolina: limestones with conodonts (Polygnathus, Spathognathodus), corals (Favosites) and, bryozoaes.

EARLY DEVONIAN (LOHKHOVIAN, PRAGIAN, EMSIAN)

Mt. Klek at Prača: reefal limestones with corals, hydrozoaes, bryozoaes, brachyopods. Stromatoporides and crinoids grading in Middle Devonian – 700 m.

Ustikolina: darky gray platy limestones with conodonts (Neoprionodus, Plectospathodus, Spathognathodus).

SILURIAN (LLANDOVARY, WANLOCK, LADLOW, PRIDOLL)
Prača: Lower and Upper Silurian are represented by limestones with saorhoceras, tentaculides and conodonts.
Ustikolina: thick-bedded limestones with conodonts (Ozarcodina, Panderodus) – Late Silurian.

Area of the Mts. Jahorina, Bjelašnica and Treskavica

These mountains, together with the Mts. Trebević and Igman, located south and southeast of Sarajevo are the «olympic mountains» (Fig. 4). In structure of the Internal Dinarides, the Mts. Jahorina and Treskavica from a thick sheet, composed mainly of Triassic formations, which is faulted and imbricated (Durmitor thrust).
The Mts. Bjelašnica and Igman are included in another tectonic unit (Bosnian flysch thrust); forming together a large tectonic klipe between the Busovača and Konjic-Prozor faults, and the Rakitnica fault in the southeast. The structure is broken in blocks below which crop out Mesozoic flysch formation in form of tectonic windows. Mt. Bjelašnica is middly folded and its main ridge represents the northeastern flank of the fold. Mt. Igman forms a syncline with southwest vergency whose northeastern flank passes in anticline composed of Early Triassic formations (in the Sarajevo Valley).

The most characteristic formations of this area are Lower Permian reddish clastics overlain by Bellerophon limestones with brachyopods, echinides and red algas (Gymnocodium). These formations are unconformably underlain by Early Carboniferous flysch.

Fig. 16. Ladinian limestone with chert (Hreša-Sarajevo area), photo. Hrvatović, 2003

Scythian is represented by sandstones and limestones (600 m) which are intruded by diabase sills and dykes. The Early Triassic sequence is largely composed of arenites (subgraywackes, graywackes and subordinate feldspar graywackes), metaarenites, slates and subordinate fine-grained conglomerates. Very characteristic facies are «Sarajevo sandstones» as proposed by Kittl (1906). In the Sarajevo sandstones, major mineral is quartz with muscovite and feldspar admixtures, quartz and chert fragments grading into feldspar graywackes; heir haevy fraction is composed of zircon, tourmaline and hematite.

Anisian is completely developed, at the base with crinoid limestones which are overlain by limestones with well known brachyopod (Trebević limestones) and, finally Han Bulog limestones with «locus typicus» fauna (orthoceratides, nautilides and older ceratithides). The Anisian limestones are conformably overlain by Ladinian limestones with stromatoporides and calcareous algas (Teutloporella) and chert which are interlayered (Involutina) limestones grading into Lias.

Late Triassic is represented by limestones (fig. 17), dolomites and breccia.

Fig. 17. Megalodon limestone- Bjelašnica Mountain (photo. Hrvatović, 2003)

m	Age	Lithology		Environments	Fossils
400	**T_3**		Limestones with megalodon, breccia and dolomites	Shallow marine	Megalodon triqueter, Megalodon sp.,
250	**$T_{2,3}$**		Bedded limestones and dolomite	Shallow marine	Orthoceras dubium,
400	**$T_{2,3}$**		Black and gray limestones breccia and limestones	Shallow marine	
200	**$T_{2,3}$**		Dolomites and limestones	Shallow to deep marine	
250	**T_2^2**		Limestones, chert, tuff, sandstones, splite		Daonella, Posidonia
350	**T_2^1**		Massive and bedded limestones, breccia limestones,		Zones: -Dadocrinus gracilis, -Rhynchonella decurtata, -Ceratites trinodosus
	T_1		Quartz sandstones, shale, alevrolite, marl limestones,	Epicontinental marine	Myophoria costata, Naticella costata Munst, Tirolites cassianus Quent

Fig. 18. Geological column of Bjelašnica-Igman area (Hrvatović, 2003)

East Bosnia area

East Bosnia includes rich ore-bearing areas of Srebrenica and Vlasenica (Fig. 4) This is the Drina Zone composed of Paleozoic formations which are unconformably covered by Mezozoic formations. The zone stretches from Mt. Javornik in the north to the area south of Spreča River up to Kosovo in the southeast.

East Bosnian Paleozoic formations represented the northwesternmost parts of the large Drinja – Ivanjica Paleozoic complex, also reffered to as the Golija Zone (Aubouin et al., 1974) which is thrust onto the Dinaride Ophiolite Zone. The Paleozoic formations are accompanied by Triassic formations which form the large Ravna Romanija thrust stretching southeastward up to Sokolac and Višegrad. Below this thrust crop out tectonic windows composed of rocks of the underlying Dinaride Ophiolite Zone (area of Rogatica).

Triassic formations are conformably overlain by Liassic-Doggerian limestones and Jurassic radiolarites that are unconformably overlain by Lower Upper Cretaceous sediments. In the area Kladanj-Vlasenica-Višegrad, the Ravna Romanija thrust is broken in separate klippes and imbrications which build up parts of the Mts. Javor and Devetak and the peaks Stoborane and Krivača at Žepa.

The Drina Paleozoic complex is best studied in the Drina Valley from Zvornik to Skelane. It stretches up to Tišća and at Bajna Bašta continues into Serbia. Unlike the surrounding Jadar Paleozoic, the Drina Paleozoic is characterized by break in sedimentation during the Late Carboniferous (Kasimovian and Gzelian) during the whole Permian.

The oldest Paleozoic formations represented phylites and metasandstones in the area of Bratunac and along Drina River east of Srebrenica (Ramović, 1963; Podupsky, 1968; Kostić-Podgorska, 1961; Kubat, 1964-1972).

Black limestones from Dragosavac Creek contain Bashkirian to Moscovian foraminifers. Close is also the «Hodžin Gaj» locality from which Katzer (1926) described flora of lepidonderas, calamitas, cycadophylicals and cordiatalas. Nearby at Kuline, «black limestones» contain conodonts. Katzer found flora in «upper sandstones» overlying the «black limestones» and for that reason the flora must be yonger than Moscovian and belongs to the Upper Carboniferous as stated Katzer himself. Carnobiferous sequences, about 700 m thick, consist at the base of Lower/Middle Carboniferous

m	Age	Lithology		Environments	Fossils
	$K_2^{1,2}$		Marly limestones, marls		
				land	
	T_2^2		Limestones, cherts, sandstones, diabase and tuffs.	Shallow marine	Daonella, Teutloporella, Diplopora
	T_2^1		Bedded limestone, massive limestones	Shallow subtidal	Ceratites, Ptychites. Orthoceras, Meandrospira, Crinoidea
	T_1		Arenites, claystones, siltstones, conglomerates	Shallow marine	
				land	
350-700	**$C_{2,3}$**		Birač formation: arenites, siltstones, claystones, limestones (Kulm flysch)	trench	Cordaites goldenbargianus, C. Peincipalis, Odontapteris, Calamites major, Laphophyloides carnicum
50	**$C_{2,3}$**		Schistone conglomerates		
500-600	**$C_{1,2}$**		«middle series» metasandstones, phylites, siltstones, sericite and clayey schists, sericite quartzite, actinolite-epidot schists (Golija formation)		
1500	**$C_{1,2}$**		«Lower series» clayey schists, phylites, siltstones, arenites, conglomerates, limestones, spilites, tuffs (Drina formation)		
				land	
	D			land	
	S			land	
	Cm,O		Terrigenous sediments, mafic volcanic rock		Polen

Fig.19. Geological column East Bosnia -Drina paleozoic (after Đoković 1980)

phyllites, sillstones, slates with subordinate metasandstones and carbonates (Fig. 19). Those are overlain by «middle series» composed of slates which are capped by conglomerates, a few to 50 m thick, which are know in geological literature as quartzitic-lyditic formations.

In East Bosnia, the most widespread Paleozoic rocks are included into the Birač Formation (Djoković, 1980), about 700 m thick, whith turbidite signatures, i.e., the flysch formation. Lower parts of the Birač Formation are composed of arenites, siltstones and shales, at the top interlayered by limestones, 40 m thick. Upper parts of the turbiditic sequence mainly consist of arenites and argillites interalyered with limestones up to 30 m thick. Some arenite intervals, up to 10 m thick, have poorly preserved fluxoturbiditic signatures. Uppermost parts of the sequence are composed of shales with subordinate marly shales.

The Paleozoic formations are disconformably overlain Scythian clastics, about 200-300 m thick, represented in lower parts by conglomerates and fossiliferous quartz sandstones with shales at top, which are overlain by dark gray fossiliferous limestone.

Lower Triassic sediments are conformably overlain by Middle Triassic formations represented in their lower parts by dark gray crinoidal limestones. The limestones are covered by light dolomites and limestones with ammonites, about 300 m thick. Ladinian is represented by nodular limestones interlayered with cherts and tuffites, and thin-bedded limestones with mollusks (Daonella; Halobia), spongs, foraminifers and calcareous algs (Teutloporella, Diplopora). In the Gostilja canyon, between Đurđevik and Stupari, this profile terminates with thick-bedded and massive reefal limestones and dolomites of inferred Late Triassic age. Total thickness of this Triassic south plunging sheet might be about 1300 m (Fig. 19).

On small surfaces of Mt. Romanija, small patches of Liassic-Doggerian limestones disconformably overlie Upper Triassic megalodon limestones. The Lower Jurassic limestones are reddish, oolithic, platy to thick-bedded and contain ammonites (Hildoceras), foraminifers (Spirilina), crinoids and corals. These formations do not crop out in the area between Srebrenica and Vlasenica where they were eroded and redeposited in lower terranes. For that reason, here Middle Triassic sediments repsresented the foot for bauxite deposits which are disconformably overlain by Upper Triassic marine sediments. At the base of this disconformably sheet occur sandy and marly limestones with gastropods (Natica) which are overlain by thick-bedded and masive Turonian limestones and Senonian rudist limestones.

In the area of Srebrenica, Miocene fresh-water sediments crop out. At the base, basal conglomerates ore overlain by redeposited pyroclastics, clayish sands and gravels. In the Srebrenica tuffs, logs of mineralized forestry trees were found.

In the Srebrenica area, centres of the volcanic activity are distinctly visible on the satellite scanograms having ring-like morphostructures. The structures are metallogenetically important because Pb, Zn, Sn and Ag deposits are related to them. Based on modern geodynamic interpretations, the volcanic rocks of this part of the Dinarides originated along an ancient magmatic arc existing in final phases of the Alpine cycle along the active margin of the Dinaridic Tethys.

Economically important mineral resources of this area are as follows: Pb, Zn, Sb, bauxite, decorative rocks, kaolinite, roofing slates and others.

Stratigraphic column for East Bosnia

EARLY MIOCENE (OTTNANGIAN, KARPATIAN, BADENIAN)
Equivalents of Karpatien, Srebrenica: clayish sand and gravel; pyroclatics with fossils with tree logs.

LATE UPPER CRETACEOUS (CONIACIAN SANTONIAN CAMPANIAN, MASTRICHTIAN)
Vlasenica bauxite deposits: thick-nedded and massive limestones; sandy and marly limestones with gastropod Natica; bauxite.

LATE JURASSIC (HETTANGIAN, SINEMURIAN, PLIENSBACHIAN, TOARCIAN)
Mt. Ravna Romania: reddish limestones with formainifers (Spirilina) and ammonites (Hildoceras) grading in Middle jurassic.

LATE TRIASSIC (CARNIAN, NORIAN RHAETIAN)
Limestones with mollusks (Megalodon)

MIDDLE TRIASSIC (ANISIAN, LADINIAN)
L a d i n i a n: Gostilja-limestones with mollusks (Daonella) and algas (Tetloporella, Diplopora) and nodular limestones and cherts with tuffs.
A n i s i a n: Han-Bulog limestones with ammonites (Ceratites, Ptychites) and orthoceratides (Orthocerac), limestones with foraminifers (Meandrospira) and algas (Macrolporella); dark grayish limestones with crinoids (Crinoidea).

CARBONIFEROUS (LATE SERPUKHOVIAN, BASHKIRIAN, MOSCOVIAN, KASIMOVIAN, GZELIAN)
Zvornik – Skelani: orthometamorphics with tuffs; Fe-Mn sandstones and shales; conglomerates; upper metasandstones with flora (Lepidodendrales, Calamitaceas) i sericite slates, black limestones with Late Bashkirian and Early Moscovian formainifers and conodonts; lower metasandstones; phylites.

LATE DEVONIAN (FRASNIAN, FAMENNIAN)
Zvornik – Skelani: phyllites and metasandstones.

ORDOVICIUM
Ultramafic rocks, terigenous sediments

FORMATIONS OF THE PASSIVE CONTINENTAL MARGIN (Bosnian flysch)

The Bosnian Flysch (Blanchet et al. 1969), was deposited on the slope (margin) of the Adriatic-Dinaridic carbonate platform and on its foot (Pamić et al. 1998). These formations are most widespread in the area between the Mid-Bosnian Schist Mts in the south and the Dinaride Ophiolite Zone in the north and northeast. In the geological literature these formations were included in the geotectonic and paleogeographic zones by different names by diferent authors: Durmitor flysch (Bešić, 1952), Flysch bosniaque and zone prekarstique (Aubouin et al., 1974), Sarajevo-Banja flysch zone (Mojičević, 1975), Flexure zone (Grandić, 1974) and Sarajevo sigmoid (Dimitrijević, 1982).

The Zone passive continental margin formations includes Mesozoic (Jurassic-Cretaceous and Late Cretaceous) clastic-carbonate formations, commonly of flysch and paraflysch signatures. These Jurassic-Cretaceous “sandy-clayish” formations Olujić (1978) marked as the Vranduk subgroup and the younger “carbonate flysch” as the Ugar subgroup. Unit of the lower rank in both subgroups have the singature of formations which can be distinguished in lithofacies.

Formations of the passive continental margin form a continuous zone from Banja Luka to Sarajevo, and in the area of the Mt. Igman and Bjelašnica they crop oul as tectonic windows beneath Triassic nappes. Further southestward, from Bjelašnica to Gacko and northern Montenegro, they again form a continuous zone, i.e., the Durmitor flysch. In the northwestern Dinarides, the passive continetal formations occur at Topusko, south of Zagreb and further northwestward in Slovenija where they build up tectonic windows beneath the Sava nappe (Mioč, 1984) composed of Paleozoic-Triassic formations, this is “Slovenian trough” of Cousin (1972).

In the present structure of the Dinarides, the Zone passive continental margin formations is thrust by the Dinaride Ophiolite Zone. To the southeast, the zone of passive continental formations is thrust onto the External Dinarides (carbonate platform), including the Mid-Bosnian Schist Mts.

m	Age	Lithology		Environments	Fossils
200	$^{5}K_2^{2+3}$		Bedded marly micrites, marls and some arenites	Slope	
500	$^{4}K_2^{2+3}$		Massive biocalcrudites, biointramicrites, marly biomicrites	Slope	
1200	$^{3}K_2^{2+3}$		Sandy intramicrites, marly micrites and marls	Slope	Globotruncanids
500	$^{2}K_2^{2+3}$		Massive intramicrites and massive marly micrites	Slope	
100	$1K_2^{2+3}$		Arenites, rudites and marls	Slope	
				Land	
250	$^{4}J,K$		Thick bedded and bedded arenites and marly micrites	Slope	
350	$^{3}J,K$		Bedded and thick bedded arenites, sandy intramicrites, marls, marly micrites	Slope	
300	$^{2}J,K$		Thick bedded and massiv marly micrites, marls and arenites	Slope	
300	$^{1}J,K$		Massive, thick bedded, marly micrites and arenites	Slope	
800	J,K		Marly micrites, marls coarse-grained arenites	Slope	

Fig. 20. Geological column Čemernica-Vlašić-Visočica area (after Olujić, 1980)

m	Age	Lithology	Environments	
200	Paleogen	Marly, intramicrites (arenites, intramicrudites)	Slope	UGAR GROUP
300-400	TURONIAN-SENONIAN	Intramicrudite, intramicrites (marly micrites, olistostromes)	Slope	
700-1000		Intramicrites, marly micrites subordinated and or rarely intramicrudites, marls arenites, olistostromes	Slope	
400		Intramicrites, intramicrudites(marly micrites, olistostromes)	Slope	
80		Micrites (marly micrites, microsparites	Slope	
100		Arenites, rudites, marly micrites, marls, olistostromes	Slope	
			Land	
<250	TITHONIAN-BERRISIAN	Arenite, marls, marly micrites, claystones, siltstones	Slope basin	VRANDUK GROUP
<350		Arenites, marls, marly micrites, sandy intrasparites	Slope basin	
<300		Marly micrites, arenites, marls (intramicrites)	Slope basin	
400		Marly micrites, marls, arenites, sandy intramicrites, micrudites and cherts	Slope basin	
			Land	
	T_3	Cherts, limestones		

Fig. 21. Geological column for the passive continental margin formations (Bosnian flysch; from Hrvatović 1999; after Olujić, 1980)

Within the Zone of passive contineta l margin formations, two subgroups can be distinguished which display differences in stratigraphy and lithology. The older Vranduk subgroup is represented by sadny-clayish carbonate sediments, wheares they younger Ugar subgroup is largley of carbonate-marly composition. The older subgroup is Tithonian-Berriasian in age (calpionelles, tintinopsels) and it grades into mainly arenitic unit of Cenomanian-Turonian age (orbitolines, kuneolines, globigerines). This unit overlain by younger carbonate-marly subgroup which is generally included in Turonian-Senonian (kuneolines, pitonelles, globtruncanas). It is very probable that this subgroup terminates in Early Paleogene.

It is obvious that this group of different formations originated in one single basin which existed from the Tthonian to the Paleogene with a distinct shift of the basen towards the southwest. It is probable that the basin axis sinhed to the southeast and thus its southeastern parts are younger than those in the northwest.

Formations of the Vranduk subgroup, about 1300 m thick, are characterized by general increase of the sandy component going from the NE to the SZ and from older to younger formations, respectively. In the some direction are also manifested turbidite signatures – in some places from non-flysch through paraflysch to proper flysch units and from largely micritic to largely arenitic formations, respectively. The Vranduk subgroup can be divided into four formations characterized by mutually diffuse boundaries between predominant lithological members: 1) marly micrites; 2) marly micrites, arenites and calcareous shales; 3) arenites, marly shales and marly micrites, and 4) arenites.

The marly micrites formation is largely composed of three members: a) thick-bedded to massive marly micrites, frequently grading into calcareous shales, which make up to 80 % of the formation; b) platy bedded calcareous shales, arenites, sandy intramicrites, shales and cherts, and c) quite subordinate coarse-grained arenites. The arenites or sandy intramicrites have gradation intervals and lower parallel laminations. The marly micrite formation, in the area where is widespread, is characterized by dm-hm normal folds and m-dm inverse folds with SE or NW-striking axes and southwestern vergences.

This formation grades into the formation of marly micrites, arenites and calcareous shales. The formation as a whole is bedded to thick-bedded and very similar in composition to the preceding formation, but with increased quantity of arenites, up to 30 %. In the arenites and intramicrites are developed Ta, b, c sequences in which the interval of parallel lamination is always best marked. Paleotransport data point to SSE direction. The formation is about 200-300 m thick.

The formation of arenites, caclareous shales and marly micrites is characterized by increased quantity of arenites (about 50 %) and the decreased quantity of marly micrites. Its thickness amounts up to 350 m. In this formation are significantly developed signatures of turbidite sedimentation. Predominant sequences are of T-b,c type; in both cases, the thickest is the interval of lower parallel lamination, whereas the intervals of convolution is more common than in preceding parts of the formation.

Paleotransport data are scattered but with clearly prominant SE and SW maxima.

In the arenitic formation, with about 80 % arenites with subordinate marly shales, marly micrites, shales and siltstones, generally, two members can be separated: a) bedded, largely turbiditic one with dm – thickness, and b) non – turbiditic thick – bedded one. In the first member complete Bouma sequences are developed, beside the sequences without gradation intervals and also the sequences with only c – intervals. The second member consists of fine – grained to medium – grained arenites massive in structure. Paleotransport directions display SE – SW range but with distinct S – maximum.

Sedimentologically, it is hard to give a precize definition of the Vranduk subgroup formations. Generally, first two formations have paraflysch signatures wherea last two are flysch formations.

The Ugar subgroup, which is 220 m thick, is distinctly sedimentologically and lithologically differentiated from its base to top. This subgroup includes six formations: 1) arenites, 2) micrites, 3) intramicrites and intramicrudites, 4) intramicrites and marly micrites, 5) intramicrudites and intramicrites and 6) marly shales and intramicrites.

The arenite formations has signatures from non-turbiditic to prominant turbiditic elements. From place to place, this formations displays different lithological and sedimentological habitus. In some places, it is represented by dm-packets composed largely or bedded arenites with suboridnate marly micrites and marly shales, whereas in other places (Stavnja River) by thicker packets (70-150 m) consisting largely of arenites or shales or intramicrites.

The micrite formation represents the lowermost carbonate formation within the Late Cretaceous flysch zone. Based on fossils content: kuneolinas, pitonelles and globotruncana, it was classified into Turonian-Senonian. This formations largely consists of micrites with subordinate marly shales, microsparites and quite sparse intramicrites. This is a hemopelagic unit with thickness less than 100 m.

Intramicrites and intramicrudites with subordinate marly mictrites and olistostromes are characterized with significant spans in the seguneces ranging between 0,4 and 5 m. In some places, this formation includes complete Bouma sequences. This fact, occurences of olistostromes and some non – turbiditic members indicate depositional environments within an internal fan.

Intramicrites and marly micrites, with thicknesses up to 1000 m and their turbiditic features represents the most prominant formation within the

Late Cretaceous flysch zone. It is characterized by heterogenous lithology in which distinctly predominate intramicrites and marly micrites over marly shales, intramicrudites, olistostromes and arenites. Tae and Tb sequences, dm-m thick, with commonly well pronounced b or b+c intervals are very common. Paleotransport data display large seattering but with one ESE-directed maximum. This formations represents an example of prominant proximal flysch facies as is anyway the largest part of the Late Cretaceous flysch sequence.

The intramicrudite and intramicrite formation, about 300-400 m thick, is characterized by metre-sized blocks of marly shales within intramicrudite horizon and m-intervals of lower parallel lamination and cross-bedding within intramicrudites.

Marly shales and intramicrites are about 200 m thick. Intramicrite horizon is characterized by easily recognazable four bedding intervals, whereas marly shales probably represent (d) + e intervals.

The sedimentary formations of the passive continental margin originated by the shift of bottom of the flysch basin towards the northwest and sedimentation terminated not earlier than in the Paleocene. In the area between Sarajevo and Banja Luka, strike of these sediments within the zone is perpendicular to the NW-SE directed, whereas in the area of Sarajevo the strike of the zone is perpendicular to the NW-SE directed Dinaridic structures due to the «Sarajevo sigmoid» (Dimitrijević, 1982), i.e., the Sarajevo fault (Katzer, 1904). Further southeastward, wthin the Durmitor nappe, sedimentary formations of the passive continental margin again have the NW-SE strike Dinaridic.

Within the depositional system, defined by the carbonate platform slope and its foot originated two units different in lithology and stratigraphy. The older unit, which originated during the Jurassic and early Cretaceous, is characterized by sandy-clayish (carbonate) sediments with paraflysch signatures, whereas the older, Late Cretaceous flysch unit is characterized by marly-carbonate sediments. It is still questionable if these two units are results of continuous sedimentation. French geologists are of the opinion that these two units represent a depositional whole as result of continuous sedimentation which was taking place from the Late Jurassic to the end of the Late Cretaceous (Aubouin et al., 1970).

Fig. 22. Bedding-cleavage indicating overturned strata in flysch bosniaque –Vranduk group (photo, Hrvatović, 2004)

DINARIDE OPHIOLITE ZONE

The Dinaride Ophiolite Zone, which is the most important geotectonic unit of the Internal Dinarides, can be traced along stike from the area south of Zagreb in the northwest through Borje, Ozren, Konjuh up to the Višegrad area in the southeast. The zone continues without a break through southwest Serbia and Kosovo, and further southward as the Mirdita Zone in Albania (Fig. 1).

Numerous papers have been published on the Dinaride Ophiolite Zone in Bosnia and the most important of them are those published by Kišpatić (1897), Trubelja (1960, 1995), Pamić (1964, 1982, 1996) and Pamić&Majer (1977). Geological and petrological data from the Bosnia part of the Dinaridic Ophiolite zone are also included in large-scale regional interpretations for the Dinarides as a whole (Ćirić, 1954; Dimitrijević&Dimitrijević, 1973; Karamata et al., 1980; Pamić&Tomljenović, 2000 and others). In the mentioned papers is summarized and evaluated all references on the Bosnian ophiolites.

In the Dinaride Ophiolite Zone, ophiloites with genetically related sedimentary formations rerpesent the most widespread rocks of the Internal Dinarides. However, the ophiolites also occur in the Vardar zone. In the Dinaride Ophiolite Zone, ophiolites are largely represented by ultramafics (peridotite, dunite, serpentinite) with subordinate gabbros, diabases, basalts and spilites. The ophiolites are associated with clastic formations, represented mainly by graywackes and shales, and radiolarites.

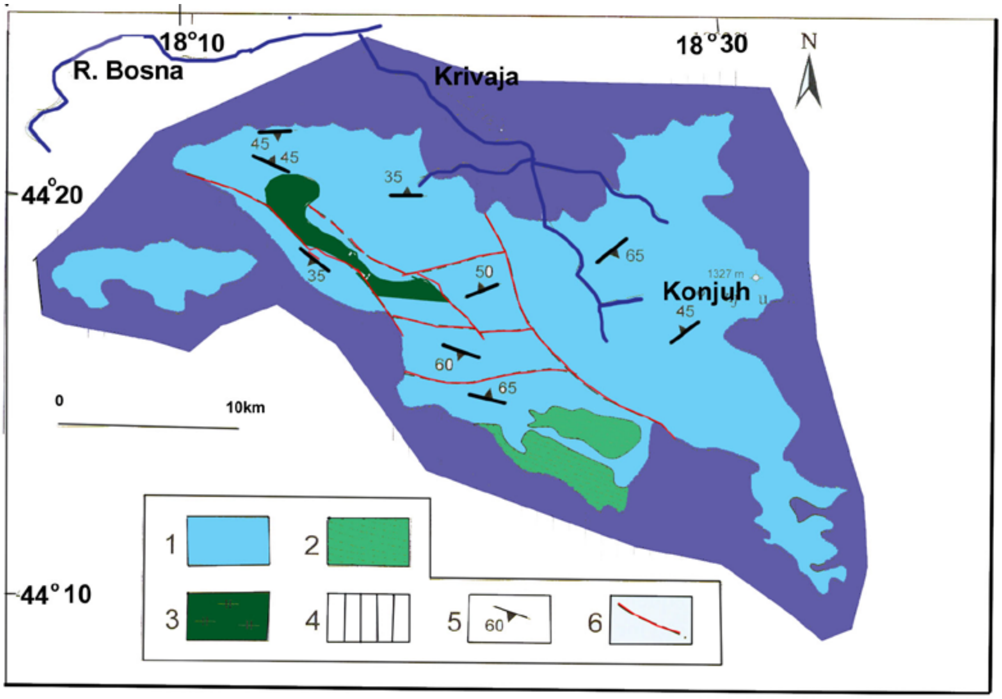
Basic geologic signatures

The Dinaride Ophiolite Zone consist of 3 members that are, from base to top: 1)Late Jurassic wildflysch or «ophiolitic mélange» or «Diabas-Hornstein-Formation» (olistostrome and/or tectonic mélange, «Wildflysch»), 2)Ultramafic massifs and 3)Overstep formations.

1) The mélange composed of shale-silty matrix embedding the fragments of graywacke, ultramafics, gabbro, diabase, basalt, tuff, amphibolite, chert, schist, and exotic blocks of limestone of different ages originating in different environments. The youngest limestone fragment is Tithonian age. In some areas (e.g. Borovica Creeek nearby Vareš), the original interlayering of shales and graywackes with occassional slumps and basalt flows are preserved. However, in some other areas (River Bosna valley south Žepče), most of the mélange is composed of massive

graywackes. In some areas where limestone exotic predominate, the mélange has signatures of olistostrome.

Predominant ultramafic rocks occur in the mélange as small cm- to dcm-sized fragments or hkm- to km-sized bodies, and as large massifs (100 - 500 km^2) that are thrust sheets (e.g. Krivaja-Konjuh massif-fig. 23) overlying the mélange. Thickness of the ultramafic sheets varies from a few hundred meters up to 2000 m as indicated by geophysical prospecting data. Larger ultramafic bodies have their internal structure as illustrated by at Krivaja-Konjuh massif (Fig. 23) which represents a concave sheet, 2000 m thick, separated in several blocks. Each block is characterized by a structural homogeneity; the largest by a metamorphic sole composed of varieties of amphibolites. Some smaller ultramafic massif (e.g. Ozren) display more complex internal structure (Pamić, 1964).



Legend: 1.ultramacis; 2.amphibolites; 3.gabbro; 4.melange; 5.strike and dip of foliation; 6.major faults;

Fig. 23 Simplified map of the Krivaja-Konjuh ultramafic massif (Pamić, et. al, 1977)

Gabbros and diabase-dolerite build up small bodies up to 20 km^2, that in some places intrude peridotites (e.g. Gostovića River, nearby Zavidovići). The diabase-dolerites occur mainly as massive bodies (e.g. southern margin of the Ozren massif), some of them are sheeted (e.g. River Rzav Valley, nearby Višegrad). On tectonicaly undisturbed ophiolite sections, thickness of both diabase-dolerite and gabbro masses is estimated to be about 500-1000 each. Basalt also cover small surface area and they occur rither at top of preserved ophiolite sequences (e.g. northern margin of the Krivaja-Konjuh massif) or interlayered with graywacke and shales (western part of Mt. Mahnjača).

In graywackes and shales of the mélange, no index-fossils to date were not found. In sparse limestones interlayered with graywackes and shales, Jurassic noncharacteristic microfossils were found. The yongest limestone exotic of Tithonian age document the upper age boundary of the mélange. K-Ar measurements on sheeted diabases yielded isotopic ages of 185-180 Ma and 170-160 Ma on amphibolites interlayered with peridotites (Pamić, 1982; Lauphere et al. 1975).

Ophiolite melange of the Dinaride Ophiolite Zone, including large thrust sheest of ultramafic roks, is disconformably overlain by bed-to bed Late Triassic to Late Cretaceous Urgon-type sequnces, about 1000-2000 m thick. These sequences are contained in kilometre to tens of kilometre long synclines, mainly compsed of unsorted shallow-marine conglomerate and breccias that grade into lithic sandstones with surrounding ophiolites as wellas abundant coarse-grained and reddish enigmatic granitoids of inferred Variscian age not yet found anywhere within the Dinarides. The best outcrops of these rocks occur in the Bosna River Valley between Zavidovići and Maglaj.

In this unit included are rocks of the Radiolarite Formation which build into structure of the Internal Dinarides as the southwestern unit of the Dinaride Ophiolite Zone adjoingin the Zone of the passive continental margin format. This is a bed-to-bed sequence in which radiolarites predominate over shales and micrites, interlayered with baslat flows. The best outcrops of these rocks are found in the River Bosna Valley (at Nemila – fig 24, and Bistričak) and in the marginal parts of the Mts. Borje and Skatavica. In the eastern part of the Dinaride Ophiolite Zone (e.g. Glasinac Polje and at Han Pijesak), rocks of the Radiolarite Formation occur in tectonic windows belows the Triassic nappes. The radiolite sequence, which is up to 800 m thick, covers a large stratigraphic interval.

Fig. 24. Radiolarite formation River Bosna Valley at Nemila (photo. Hrvatović, 2004)

Ultramafic formations

Ophiolites of the Internal Dinarides can be divided in the following four basic formations: 1). tectonic peridotites, 2). cumulate gabbros and peridotites; 3) diabases and dolerites, and 4) basalts.

<u>1) Tectonic peridotites</u> are the most widespread ophiolitic rocks; the largest is the Krivaja-Konjuh massif (500 km^2) and a little bit smaller are the Mts. Ozren and Borje ultramafic massifs (300-100 km^2). However, the most common are smaller, tectonically broken ultramafic bodies with hm-dkm surfaces. The ultramafic massifs are in tectonic contact with sedimentary rocks of the surrounding ophiolite melange. Along the contact, ultramafics are strongly cataclazed, mylonitized and serpentinized; the higher degree of tectonization the higher degree of serpentinization.

Ultramafic bodes, particularly the larger ones are associated with narrow zones of amphibolites which from their metamorphic soles. The largest amphibolite zone occur along the Krivaja-Konjuh massifs at Vijaka, north of Vareš.

The tectonic peridotites of the Dinaride Ophiolite Zone in Bosnia have typical metamorphic fabrics which has been alredy recognized by Kišpatić (1897). This is most commonly shown in foliation and lineation; pyroxen prophyroblastes are planparallely embedded in the matrix composed of unevenly serpentinized olivine. In some places, peridotites are bedded and characterized by alternating p<roxenite (+- olivine) and dunite (+- pyroxenite) ribbons, millimetre to centimetre thick. This metamorphiy fabric makes possible the structural stdy of ultramafic massifs.

Primary rocks-forming minerals of tectonic peridotites are olivine, orthopyroxene and clinopyroxene, all of them with high contentc of MgO, accesory spinel and largely edenitic-pargasitic amphibole. For that reason the tectonic peridotites are largely represented by lherzolites. The primary rock-forming minerals are comonly transformed to various degrees: olivine in serpentine group minerals (lizardite, clinochrysotile and antigorite), enstatite in bastite and talc, clinopyroxene in uralite and chlorite, and spinel in magnetite. These secondary minerals are in some places accompanied by chalcedon, quartz, oal, magnesite and other carbonates, forming quartz-carbonate rocks (listvenites) which occur along marginal parts of Mt. Ozren massif and in the Teslić area (Pamić&Olujić, 1974).

Chemical composition of the most common tectonic lherzolites is fairly uniform and this is shown in high content of MgO (up to 40 %) and low CaO content (cca 3 %); they have high MgO:FeO ratio which of MgO is 5 or higher. They also contain higher H_2O contents as result of higher degree of serpentinization.

All Bosnian ultramafic massif, from Mt. Kozara in the northwest to Mt. Varda in the southeast consist of tectonic lherzolites, unuvenly serpentinized. Further southeastward in Serbia, Kosmet and Albania, the ultramafic massif ore composed largely of tectonic harzburgites. This petrological difference is of a regional importance because to the lherzolite subprovince belong ultramafics of the Alps and Apennines, whereas the harzburgite subprovince southeastward through Srebia, Hellenides, Taurides to Zagreb and Himalaya. It is very probable that lherzolites from the lerzoilte subprovince come from the subcontinental upper mantle and harzburginte from the harzburgite subformation from the oceanic upper mantle (Pamić, 1983).

There are different opinions on the origin and emplacement of tectonic peridotites of the Dinaride Ophiolite Zone. Some French and Russian geologists (Ricou et al., 1984) consider that these ophiolite complex were emplacemed during the Late Jurassic along the passive continnetal margin of the Dinaridic Tethys. Pamić et al. (1998) are of the opinion that the Dinaridic ocenaic crust was during the Late Triassic and Jurassic and that its obduction, accompanied by penecontemporaneous north-dipping subduction, took place in Late Jurassic time. This gave rise to the shortening of the Dinaridic Tethys and generation of the oceanic crust continued during the Cretaceous and Early Paleogene in back-arc environments. Afterwards, second stage Cretaceous-Early Paleogene ophiolites was related to final collisionall processes which took place by the and of the Eocene (Pamić&Tomljenović, 2000). These second stage Cretaceous – Early Paleogene ophiolites are included in the Vardar Zone which is in present structure graded in epidermal parts in thrusting, which increased degree of dismembering, and the horizontal transport can be estimated to 100 km. Anyhow by this transport larger ultramaficbodies did not reach formationf ot the passive continental margin.

<u>2) Cumulate gabbros and peridotites</u> occur most commonly as fragments, a few kilometre thick into ophiolite mélange. In some areas (e.g. southern margin of the Krivaja-Konjuh ultramafic massifs) gabbro bodies intrude tectonic peridotites. In the River Rzav in Southeast Bosnia, cumulate gabbros and peridotites are included normal members of a preserved fragment of complete ocean fragment, about 3-4 km thick (Pamić&Desmons, 1989). In the Krivaja – Konjuh ultramafic massif, thickness of this formations range between 1200 and 2000 m. In the preserved Rzav oceanic fragment, its thickness is smaller and amounts about 500-600 m.

Major rock - forming minerals of cumulate peridotites are olivine, orthopyroxene, clinopyroxene and subordinate amphibole as in adjacent tectonic peridotites. The same minerals plus plagioclase are the major mineral of cumulate gabbros.

As distinguished from tectonic peridotite, the cumulate peridotites and gabbros are characterized by igneous texture and layered and structure. Petrology of cumulate gabbros and peridotites was studied in detail in the Krivaja – Konjuh massif and in Rzav oceanic fragment (Pamić, 1971; Pamić&Desmond, 1989). Genetically, it has been generally accepted that these rocks originate by gravitational setting and intersticial intercumulus minerals. The cumulate gabbros commonly have parallel structure as shown in separation of cm – dm layers, of different mineral modal composition, frequently with distinct gradation between leucocratic and melanocratic gabbros layers. However, with some cumulate gabbro bodies, massive gabbro varieties also occur.

In the Krivaja – Konjuh cumulate complex, in its lower parts predominate plagioclase wehrlite and plagioclase dunite, whereas dunite – harzburgite, dunite – lherzolite and dunite – wehrlite are predominant in the Rzav body. Upper parts of the gabbro – peridotite formation are composed of different gabbro varieties with sparse interlayers of cumulate peridotites. The most common are olivine gabbros and troctolites, whereas normall gabbros are more subordinate in the Krivaja – Konjuh than in the Rzav gabbro masses.

3) Diabase-dolerit formation Rocks of this formation also are subordinate when compared with tectonic peridotites. The best outcrops of the diabase-dolerites are found in the northern marginal parts of the Krivaja-Konjuh massif, where they are more than 1000 m thick and cover the surface area of about 20 km, and in the Rzav Valley where they are about 500 m thick (Fig. 25). However, the diabase-dolerites most commonly occur as smaller dismembered fragments included in the ophiolite melange. In some area, those are homogenous diabase-dolerite bodies, but in some other areas, the fragments are composed of diabase-dolerites in their lower parts which are capped by basaltic pilow lavas. Most of diabase-dolerite bodies are massive as examlified by those from the southern part of the Ozren (Rakovica River) ultramafic massif and the northern Krivaja-Konjuh margin (Ribnica River Valley). Some of the diabase-dolerite bodies are sheeted; this is best exampilfied in the Rzav Valley where in the sheeted complex, besides predominant diabase dolerites, ophitic gabbros are also included (Pami&Desmons, 1989; Pamić&Tomljenović, 2000).

Mineral assemblage of diabase – dolerites includes plagioklase, commonly labradorite, augite. Amphibole (actinolite hornblende and uralite) and quite suboridnate olivine. All these primary minerals are altered to various degrees in different secondary minerals.

Rocks of the diabase – dolerite formation are most commonly characterized by ophitic texture that is fine-grained in diabases, medium-grained in dolerites, and coarse-grained in ophitic gabbro. All these rocks are always massive in structure.

The most common rock type is amphibolite-augite diabase or dolerite or ophitic gabbro. Diabase – dolerites are commonly fresh, but within some bodies they are metamorphosed into metadiabase, metadolerite and ophitic metagabbro. The diabase – dolerite bodies, particularly those affected by higher degree of metamorphism are crosscut by veins and veinlets fielld by zeolites, albite, chlorite, calcite, tremolite and quartz (Pamić, 1996).

Fig. 25. Sheeted diabase, Ribnica area; Krivaja-Konjuh massif (photo. Hrvatović, 2004)

Chemical composition of diabase – dolerites is fairly equal; contents of SiO_2 most commonly vary between 47-49 %, CaO and MgO between 8 and 10 %, total iron content between 5 and 8 %, and Na_2O+K_2O between 2 and 3%. In chemical composition, these rocks can be correlated eith abyssal tholeiites from recent mid-oceanic ridges.

<u>4. Bazalt formation</u> The basalts occur as pilow lavas, brecciated pillow lavas and massive flows, which are in some places interstratified by pyroclastics and sediments, as for example, in the Mahnjača ophiolite complex between Žepče and Teslić. Besides that, larger basalt flows also occur top of tectonically undisturbed ophiolite profiles (e.g. the Rzav Valley and Ribnica Valley-at the locality Željava; fig. 26).

The mineral assemblage is essentially characterized by mineral pair-feldspar+augite which is to various degrees altered to chlorite and epidote; olivine is sparse, commonly almost completely serpentinized. Feldspar is plagioclase which is completely transformed into albite and various secondary minerals. Accordiagly, the basalts are represented by metabasalts, i.e., the spilites.

Fig. 26. Pillows in basalt ot the Krivaja-Konjuh massif at the locality Željava (photo. Hrvatović, 2004)

They are most commonly ophitic in texture within amygdaloidal structure. In subordinate porphyritic basalts the groundmass consists of smectite calcite, chlorite with subordinate epidote, quartz and zeolites (Pamić et al., 1979).

5. Rocks of metamorphic soles of tectonic peridotite bodies are represented by: a) the amphibolites originated from cumulate gabbros; b) the amphibolite related to diabase – dolerite, and c) metasedimentary rocks (Pamić&Tomljenović, 2000).

a) The amphibolites originated from cumulus rocks occur in the sole of larger ultramafic massif and their contact is characterized by interlayering of serpentinized peridotites and varieties of amphibolites, as examplified by the southern margin of the Krivaja – Konjuh massif (Fig. 23). Amphibolites with interlayered peridotites also occur as fragments, up to 10 km^2 in surface area, included into ophiolite mélange, as examplified by peridotite-amphibolite body at Mt. Skatavica. On hornblende concentrates from amphibolites, K-Ar ages of 174-157 Ma were obtained.

These amphibolite mases are represented by varieties of amphibolite which are in some places accompanied by pyroxenite schists and eclogites. Most commonly, they belong to amphibolite and granulite facies. Each of the single rocks shows cryptic variations in composition of predominate amphibole and plagioclase. In granulite facies amphibolites, hornblende is rich in pargasite – edenite component and it is accompanied by calcic plagioclase, pyrope garnet, in some places with corundum. In amhibolite facies amphibolites, amphibole is a «common hornblende» accompanied by intermediate plagioclase and almandine rich garnet. The marginal parts of Krivaja – Konjuh amphibolite zone at Vijaka are composed of retrograded greenchist facies amphibolites composed of actinolite and sodic plagioclase.

b) Amphibolites related to diabase – dolerites from smaller amphibolite zones that are largely composed of bimineralic amphibole+plagioclase rock vartieties. These rocks mainly originated under P-T conditions of amphibolite and epidote-amphibolite facies. The mineral assemblage includes «common hornblende» to actinolite and intermediate to sodic plagioclase.

c) Metamorphosed sedimentary sequences are found along the margins of some larger ultramafic massif, for example, the Mt. Borje massif. Contrary to amphibolites, these metamorphic sequences have not been sufficiently studied. This metamorphism might have taken place under the influence of solid but still heated ultramafic blocks during their emplacement and dismembering over neighbouring shales and graywackes.

3. Overstep formations

In the area between Žepče-Zavidovići-Maglaj, ophiolite melange, including ultramafic bodies, is disconformably overlain by rocks of the Pogari Formation (Jovanović, 1961), fig-27. The Pogari Formation is composed of breccia, conglomerates and coarse-grained sandstones and sandy marl. The coarse-grained clastics consist of ophiolites, amphibolite, graywacks, shale, chert and limestones, indicating that first emplacement of ophiolites must have taken place before the deposition of the Pogari Formation. Its structural features are wave-like lamination and graded bedding, and structural forms of washing down and imprersion, which among other characteristics has the features of fluvial sedimentation. Conglomerates of the Pogari Formation contain resedimented fauna from the Tithonian-Neocomian and Barremian limestones. Discovered fauna in conglomerates suggest that are clastics from Pogari Formation have been formed in late Barremian and Early Aptian.

The detrital component of the Pogari Formation consists reddish granitoids of presumed Variscan age. The granites belong to the alkali-feldspar varieties characterized by high silica (mainly 76-77 %). Low FeO_{tot} (about 0,7-0,8 %), very low MgO (about 0,2 %) and comparatively high Na_2O (about 4 %) and K_2O (about 4 %). Compatible trace elements are very low (Cr up to 10 ppm, Ni less than 1 ppm, V up to 2 ppm). Thorium is much higher (up to 8 ppm) than U (2 to ppm) whwreas Zr averages about 50 ppm.

m	Age	Lithology		Environments	Fossils
80	K_2^{2+3}		**Bedded limestone**	**Shollow marine**	**Orbitolina confusa, Cuneolina pavonia parva, Globotruncana arca arca,**
50-60	K_2^2		**Sandy marl, limestone, breccia,**	**Shollow marine to brakisch**	
>300	K_2^1		**Redish conglomerates, sandstones and breccia,** **Fe-Ni oolite**	**fluvial**	**Resediment fauna from Tithonian-Neocomian limestones**
	K_1		**Core wheatering serpentinite**	**land**	
	J_3		**Ophiolite complex**	**Ocean ridge**	

Fig. 27. Geological column Pogari Formation; Žepče-Zavidovići Hrvatović, 2004)

The same formation is development in Višegrad area (fig. 28)

The Dinaride ophiolite zone consist of Tithonian to Valangian reefal limestones in Vijenac and reefal limestones and clasitics in Olovo area (limestones of new carbonate platform formed ater obduction ophiolite).

"Vijenac Limestones" (near Lukavac) are transgressively and unconformably over serpentinite and the older rocks. Two types or levels of "Vijenac Limestones" may be separated (Rabrenović, 1985). First type or the lower level are crystalline massive limestones under main Barremian limestones, comprising about 75% of the limestone volume. This type is uncovered also in olistolitths in the clastics series. This levele content pseudotexturalids, calpionellae, tintionpsellae, radiolariae, minute gastropods, etc. Macrofossils identified are ellipsactiniae, minute nerinae, shells, echinoid, etc. This lower limestones level is transitional in age from the Tithonian to the Neocomian, bearing signgs of the Lower Cretaceous (Berriasian, Valanginian).

Second type ot the upper level are pinkish, white, massive, reef, recrystallized, downward brecciated limestones uncovered on the southhern Vijenac slopes. Low in brecciated limestones, several specimens of the echinoid species Pyrina incisa d'O r b., were found. Overlying are true Barremian reef limestones with nerineae: Nerinea gigantea d'H o m., F i r m., N. coquandi d'O r b.

In Olovo area are discovered Tihonian overstep formations which consist 2 members: 1) Lower member: clastics and 2)Upper member: reefal limestones ("Olovo limestones"). The clastics consist conglomerates, breccia and sandstones. In the limestones find macrofossils: Ellipsactinia ellipsoidea, Ptygmatis carpathica, Diceras cf. luci Defrance var. communis and microfossils: Bačinella irregularis, Naautoloculina oolitica, Macroporella sp., hydrozoe and corals.

m	Age	Lithology		Environments	Fossils
200	K_2^3		**Biomicrorudite, intramicrite, micrite, marls**	**Shollow marine with progradation**	**Pithonela ovalis, Cuneolina pavonia parva, Milovanicia dobrunensis, M. bosniaca**
200	$K_2^{1,2}$		**Limestone**	**Shollow marine with rudists**	**Hippurites resectus, Radiolites sp., Cuneolina cf. parva**
300	$K_2^{1,2}$		**Marly micrites, micrites, marl**	**Shollow marine with progradation**	**Pithonella ovalis**
250	K_2^1		**Marl, marly limestone, Sandstone-marly micrites**	**Shallow marine to brackish**	**Lima sp., Ostrea sp., Cerithium sp., Natica sp., Cardium productum**
10-40	K_2^1		**Conglomerates, sandstones, breccia, Fe-Ni oolites**	**Fluvial**	
	K_1		**Core wheatering serpentinite**	**Land**	
	J_3		**Ophiolite complex**	**Ocean ridge**	

Fig. 28. Geological column overstep formations in Višegrad area (Hrvatović, 2004, after Olujić 1980)

Conclusions

Based on data presented above the following conclusions can be drawn on the Dinaridic ophiolites (Pamić, 1996; Pamić&Hrvatović, 2000).

1) The Dinaridic ophiolites represented fragments of Mesozoic oceanic crustw hich was created in the Dinaridic Tethys over the period of about 150 Ma. Main mass of the oceanic crust was generated in the progressively opening Dinaridic Tethys from the Late Triassic to the Late Jurassic when processes of supraoceanic (intraoceanic) started which were accompanied by ophiolite obduction onto the Apulian margin. Afterwards the generation of the oceanic crust continued durring the Cretaceous and Early Paleogene in the reduced Tethyan realm, i.e., the back-arc basin (BARB). The final subduction processes of oceanic crust were accompanied by the second emplacement of phiolites which took place during the final Eocene collisional deformation which gave rise to the definitive structuration of the Dinarides and their uplift.

2) The predominant tectonic peridotites intruded as solid bodies as indicated by their structural – petrological features. Based on geothermometric and geobarometric calculations it can be concluded that lherzolitic melts were generated at 1050-1250 ^{o}C and 16-28 kbar.

3) The cumulate peridotite-gabbro formation is characterized by distinct rhythmic layering as result of comparatively slow crystal selting from a primary tholeiite basalt melt.

4) The Dinaridic ophiolites comprise comparatively smaller but massive diabase – dolerite bodies which are in some placies sheeted. As distinguished from other ophiolite complexes, some of the Dinaridic sheeted complexes include not only diabase and dolerite, but also ophitic gabbro dykes containing also olivine as major rock-forming mineral.

5) All the ophiolites were affected by ocean floor metamorphism: serpentinization of ultramafics, saussuritizations of gabbros and diabase – dolerites. The ophiolites were also affected by metamorphism during their emplacement as shown in the generation of amphibolites an account of primary mafic rocks. Rocks of the basalt formation underwent the strongest metamorphism shown in spilitization and zeolitization of primary caclic plagioclases.

Economically important mineral resources related to the Dinaridic ophiolites are decorative-building rocks, chromium, manganese, magnesite, nickel, cobalt, cooper, clay, corundum, garnet, talc, gold and mineral waters.

FORMATIONS OF ACTIVE CONTINENTAL MARGIN (SAVA-VARDAR ZONE)

The formations of the active continental margin of the Dinaridic Tethys are included into the Vardar geotectonic zone of the Dinarides. The Vardar Zone sensu stricto, as defined by Kosmat (1924), was separated in Macedonia as 40-70 km wide zone sendwiched between the Pelagonides and the present Serbo-Macedonian Massif. Afterwards it was extented further to the north and northwest as the Vardar Zone sensu lato (Aubouin, 1974), which can be traced along strike for about 900-1000 km from Thessaloniki in Greece along NNE direction. In deffects south of Belgrade to WNW direction and extends south of the Sava River in Bosnia up to the Zagreb – Zemplen Line in the northwest. For that reason it would be more appropriate to be called the Sava-Vardar Zone.

Based on recent data (Pamić et al., 1993,1998, 2002), the Bosnia part of the Sava-Vardar Zone consists of the formations as follows: 1) Cretaceous-Early Paleogene paraflysch; 2) Ophiolite mélange; 3) Late Paleogene regionally metamorphic sequences originated from surrounding Late Cretaceous flysch; 4) Synkinematic granitoids and 5) Post-orogenic volcanics. The Vardar Zone, particularly its northern parts are strongly by Neogene sediments of the South Pannonian Basin.

Cretaceous-Early Paleogene flysch formations

The oldest parts, which are poorly preserved, as for example in Mt. Majevica are represented to Turonian limestone, shale, calcareous shale, sandstone and breccia. In eastern parts of the Vardar Zone in Serbia, these oldest parts are represented by Lower Cretaceous clastic-carbonate paraflysch formations which can be traced along strike for about 250 km (Dimitrijević, 1995).

These formations and younger Late Cretaceous flysch sequences related to the Tethyan active continental margin were deposited in a trench of the presumed magmatic arc in which sedimentary turbidite fons originated (Jelaska, 1978). The turbidite sedimentation started in Campanian-Maastrichtian and continued trough the Paleocene and Early and Middle Eocene (Lutetian).

The flysch formations are best exposed in the Mts. Majevica and Trebovac where they from a horst – anticlinorium (Fig.29) whose crestal parts are composed of the ophiolite mélange with large peridotite blocks. In the eastern parts of Mt. Majevica, the flysch formations of the Jadar block. Here, Permian is represented by black Bellerophon limestones which are overlain by sandy and marly limestones interlayered with marly shales, shales and sandstones (Werfenian Beds). These are overlain by afossiliferous thick-bedded and massive dolomites with cherts and fossiliferous late Ladinian limestones. These limestones are unconformably overlain by Upper Cretaceous (Santonian-

Campanian) rudist limestones, in adjacent Kozluk area those are fossiliferous Campanian-Maastrichtian limestones. Geological column for this part of Mt. Majevica are represented in Fig. 29 .

It is a quite different situation in West Majevica where ophiolite mélange crops out in which are also included exotic fragments of Upper Cretaceous limestone. At Obodnica north of the Tuzla limestones contain Campanian-Maastrichtian foraminifers (Orbitoides, Siderolites). In this area there are reddish limestones with ammonites (Stephanoceras) “Early Jurassic in age and aptichus limestones”. In uppercourses of Tolisa River on northern slopes of Mt. Trebovac crop out rocks of Campanian-Maastrichtian flysch composed of turbiditic and hemipelagic sequences consisting of graded siltstones to coarse-grained sandstones in some places with foraminiferal limestones. At Drenova and Dragići between Gračanica and Doboj crop out Paleocene to Early Eocene limestones with flora (Lithothamnium, Lithofilium) and fauna (Discocyclina). On the Mts. Trebovac and Majevica Middle Eocene (Lutetian and Bartonian) are largely represented by shallow-marine marly shales which continue from Modrašnica to Veselinovac, Gnjica up to Rožanj where contain anthracitic coal-seams of paralic origin. These sediments accompanied with the coal contain gastropods (ceratides and others), mollusks and corals that are largely endemic as explained by paleogeorgraphic isolation. These middle Eocene formations contain abundant foraminifers, particularly nummulites and alveoline which have not to date been studied in detail. Here, thickness of Middle Eocene formations amounts up to 500 m Upper Eocene formations, up to 800 m thick, is represented by thick-bedded quartz sandstones and sandy marly shales with poor foraminiferal nicrofauna. At Lukavica nearby Gračanica Late Eocene foraminifers (discocyclinides and operculinas) were found. Wets of Jasenički Kiseljak in East Majevica, Late Eocene/Early Oligocene polen associated was found in platy limestones.

In lower parts of Mt. Majevica, the Eocene formations are more or less unconformably overlain by Oligocene (Chattian) coal-bearing formations with mammal Antracotherium and Cadurcotherium (Malez and Thanias) found in the coal-mine Ugljevik. Contact line between Oligocene and Miocene was nowhere reliably determined and that is why fresh-water formations of Mt. Majevica and the Lopare Basin which are up to 700 m thick, are grouped into Oligo-Miocene. These formations are subdivided into five lithological units. They chiefly contain flora (forest leafs and pollens not yet determined and fauna represented by poor remains of gastropods and ostracodes. Within the fifth unit in Slavinovići limestones, fauna of mollusks (Cobgeria antecroatica Katzeri and others) and gastropods (Clivunelidae) was determined. Rocks of units, which crop out along the central Mt. Majevica ridge from Srebrenik (Huremi) through “old” Majevica (Lamešić), Potraža (Banj Brdo) to the area northward of Priboj (Lipovački potok),

m	Age	Lithology		Environments	Fossils
550-800	$E_{2,3}$		Quartz sandstones, sandy marls, (flysch)	slope	Discocyclina, Operculina
500	E_2		Marly limestone, sandstones, thin beds of coal,	Shallow marine	Nummulites, Goniastraea, Plocophyllia, Lucina, Cerithium, Natica, Velates
700-1500	Pc,E_1		Alternating sandy limestone, sandstone, biocalcarenite and marly beds. (Turbidite)	Deep marine	Operculina sp. Discocyclins seunesi D. scalaris Distichoplax sp.
150	Pc		Thick bedded and massive limestones (peri-reef limestones)	Shallow marine	Operculina sp., Nummulites cf. fraasi Globigerina sp., Distichoplax
50-200	K_2^3		Platy limestones with chert nodules, Slamps folds and breccia, sandstones,	Shallow marine to slope	Globotruncana lapparenti tricarinata, G. stuarti, G. citae, G. arca.
				land	
	J		Ophiolite melange		

Fig. 29. Geological column Majevica reef and North Majevica Mt. (Geological Survey of Bosnia and Herzegovina, 1988)

reliably belong to Early Miocene. Lower Miocene formations of the Lopare Basin. In this basen is included during the Badenian in normal salt continental Paratethys. Actually, these processes took place by the end of the Early Miocene by the end of the Karpatian. Here, Upper Badenian is represented by parareefs composed water rolling caclareous shells and skelets originating from gastropods, mllusks, formainifers, corals, calcareous algas and others. These are well known “Leiten” limestones - *locus typicus* in the Viena Neogene basin in Austria. The limestone has a wide usage in architecture and agronomy.

Cretaceous – Early Paleogene formations continue westward to the Mts. Motajica and Majevica up to the northern slopes of Mt. Kozara where they are accompanied by penecontemporaneous basalts and rhyolites. The flysch zone goes on northwestward into Croatia (Kordun, Banovina, Mt. Medvednica) up to central Slovenia. In South Pannonian Basin in Slovenija, these formations accompanied with basalts and rhyolites occur as tectonic klippen onto Neogene formations. The nappes have roots in the Basin part of the Vardar Zone and thrusting is result of young Pliocene tectonism (Pamić, 1998).

m	Age	Lithology		Environments	Fossils
50	Pl		Quartz sands, clay with coal	Fresh water basin	
100	M_3^2		Marly clay, quartz sands and rarely marly limestones	Fresh water basin	
150	M_3^1		Oolite platy limestones, marly clay, marls, conglomerates,	Fresh water basin	
200	$M_{1,2}$		Conglomerateds, reddish sandstones, clay with coal, marly, marly limestones	Fresh water basin	
				land	
400	E_3		Flysch; sandstones, siltstones, marls, conglomerates,		
500	E_2		Marly sandstones, sandy limestones,	Shallow marine	Nummulites, Goniastraea, Plocophyllia, Lucina, Cerithium, Natica, Velates
800	E_1		Alternating sandstone, siltstones and marly beds. (Turbidite)	Deep marine	Operculina sp. Discocyclins seunesi D. scalaris Distichoplax sp.
300	Pc		Thick bedded and massive limestones (peri-reef limestones)	Shallow marine	Operculina sp., Nummulites cf. fraasi Globigerina sp., Distichoplax
250	K_2^3		Platy limestones with chert nodules, Slamps folds and breccia, sandstones,	Shallow marine to slope	Globotruncana lapparenti tricarinata, G. stuarti, G. citae, G. arca.
				land	
	J		Ophiolite melange		

Fig. 30. Geological column Trebovac Mt.(simplified after Jelaska, 1978)

m	Age	Lithology		Environments	Fossils
	Pc,E		**Sandstones, flysch**	**Deep marine**	**Operculina sp.** **Discocyclina seunesi** **D. sclaris**
120	Pc		**Thick bedded and massive limestones,**	**Reef**	**Operculina sp.** **Nummulites**
>100	K_2^3		**Platy limestones with chert nodules,** **Slumps folds and breccia,** **Platy limestones with chert nodules**	**Deep marine**	**Globotruncana lapparenti tricarinata,** **G.stuarti** **G. citae** **G. arca**

Fig. 31. Geological column Vučjak Mt. (simplified after Jelaska, 1975)

On the other side, Cretaceous – Early Paleogene paraflysch and flysch formations continue southeastward through South Serbia up to Mazedonia and Thessaloniki at the Aegean coast. Consequently, these formations represent the most characteristic member of the whole Vardar Zone which can be traced along strike for more than 1000 km.

Geological column for the Mts. Majevica and Trebovac

OLIGO-MIOCENE (CHATTIAN, AQUITANIAN, EARLY BURDIGALIAN)

In upper courses of the Gnjica River: reddish and greenish marls and conglomerates largely with serpentinite and chert pebbles; "Slavinovići limestones"; thick – bedded conglomerates and sandstones; platy sandstones; banded marls and marly clays; marls, marly limestones with subordinate sandstones and coal occurrences; reddish and greenish locky and nodular marls and coarse – grained conglomerates with pebbles of Eocene limestones and sandstones; i.e., the basal conglomerates; the formations are 700 m thick. The Ugljevik coal-mine: clays, sands, gravel; grayish marls with the second roof coal-seam; grayish marls; first roof coal-seam; marls with mollus fauna (30 m); main coal-seam (12-20 m) with the Antracotherium minus toot and Cadurrcotherium rakovec – Chattinian stage; sandy clays with gravel with sandstone lenses; basal conglomerates (50 m).

LATE EOCENE (PRIABONIAN)

Vitinica-Kozluk: grayish platy limestones with pllen; basal conglomerates disconformably underlain by Triassic and Cretaceous limestones.

Rastošnica: thick-bedded quartz sandstones alternate with reddish sandy marls with small foraminifers.

Paležnica at Lukavica nearby Gračanica. Limestones with foraminifers (Discocyclina, Operculina).

MIDDLE EOCENE (LUTETIAN, PRIABONIAN)

Upper courses of Gnjica River: sandy-marly sediments with foraminifers (Nummulites), corals (Goniastrea, Plocophyllia, Porites), mollusks (Lucina, Chana) and gastropods (Cerithium, Natica, Velates).

EARLY EOCENE (YPRESIAN)

West Majevica: limestones with foraminifers (Discocyclina).

LATE PALEOCENE (THAETIAN)

Bijela Rijeka (Duboki Creek at Srebrenik): limestones with foraminifers (Piriloculina) and algas (Corallinaceae).

LATE CRETACEOUS (CONIACIAN, SANTONIAN, CAMPANIAN, MAASTRICHTIAN)

West Majevica: Maastrichtian sediments with foraminifers; Campanian – Maastrichtian limestones with Orbitoides and Siderolites; Santonian – Campanian limestones with foraminifers (Globotruncana).

LATE JURASSIC (OYFORDAIN, KIMMERIDGIAN, TITHONIAN)

"Younger Jurassic" reddish limestones with Aptychus and Ammonidea.

MIDDLE TRIASSIC (ANISIAN, LADINIAN)

L a d I n I a n: Tavna limestones with mollusks (Myophoria).

EARLY TRIASSIC (SEISIAN AND CAMILPIAN)

C a m p I I I a n: Teočak – marly limestones with mollusk (Myophoria)
S e I s I a n: Teočak – sandy marly shales with mollusks (Myacites)

LATE PERMIAN (KAZANIAN, TATARIAN)

Teočak: dark gray limestones with gastropods (Bellerophon).

Ophiolite mélange

The Vardar Zone ophiolites mélange is characteristically associated with Cretaceous-Paleogene paraflysch and flysch sequences which cannot be found in the Dinaride Ophiolite Zone. The Vardar Zone also include some other specific metamorphic and igneous formations which will be presented in the next section.

All data presented above distinctly show that ophiolites from the Dinaride Ophiolite Zone and Vardar Zone display differences in their ages as well as in lithology and stratigraphy of genetically related formations. This is evidence that ophiolites from these geotectonic zones originated in different environments, i.e. the different geotectonic stage.

North part of Kozara Mt. (north Bosnia) representing as possible Late Cretaceous remnant of the Vardar ocean. The south part that is correlated with the Dinarides ophiolite zone. North Kozara comprises ultramafic magmatites, associated with a Late Cretaceous to Paleogene (?) ophiolitic melange. Pillow basalts are intercalated with scaglia-rosa type pelagic limestones that yielded an Upper Cretaceous microfauna (Karamata, et al., 2000).

The Vardar Zone ophiolite mélange displays higher degree of dismembering and among fragments are included fragments of Upper Cretaceous exotic limestones (e.g. Mt. Majevica), indicationg that its creation was related to post-Late Cretaceous tectonism, i.e. the subduction processes. In Bosnian parts of the Vardar Zone, in shale-silty matrix any index-fossils to date were not faund. However, in Mt. Medvednica in NW Croatia preserved angiosperm leafs were suggesting a minimal Early Cretaceous sedimentary age of shales and graywackes, whereas in interlayered basalt Late Cretaceous radiometric ages obtained (Pamić&Tomljenović, 2000).

On the northern slopes of Mt. Kozara in the area of Pogradci (fig. 32) nearby Bosanska Gradiška, the largest diabase-dolerite body, partly sheeted, of the Dinarides crop out. The age of dyke rocks from complex of Podgradci is 111 Ma (Rb/Sr isochrone, Karamata et al., 2000).

Based on differcuses between the mélanges of the Dinaride Ophiolite Zone and the Vardar Zone is can be concluded that these two ophiolite complexes originated in different environments. The ophiolites of the Dinaride Ophiolite Zone represent fragments of oceanic crust which was generating largely during the Jurassic. After Late Jurassic (before Tithonian) obduction of the ophiolites, in front of partly uplifted Dinarides, in the reduced Tethys generation of oceanic crust during the Cretaceous and Early Paleogene continued in back-arc basin (BARB) environments. Along this active Tethyan margin, in the trench in front of the presumed magmatic arc. Cretaceous-Early Paleogene sedimentary flysch sequences accumulated. By contrast, on the ophiolites of partly uplifted Dinaride Ophiolite Zone Urgon-type carbonate – clastic sequence were simultaneously deposited (Pamić&Tomljenović, 2000).

Fig. 32. Sheeted diabase, Podgradci near Bosanska Gradiška (photo Hrvatović, 2004)

<u>Regionally metamorphosed sequences</u>

In Bosnian part of the Vardar Zone Paleogene metamorphosed sequences, which originated from the surrounding Cretaceous-Early Paleogene sediments and accompanied penecontemporaneous volcanic characteristically occur. These metamorphic rocks make up most of Mt. Prosara (fig. 33) and are widespread in adjacent Mt. Motajica. Besides that, Paleogene metamorphic rocks were penetrated in several oil-wells in Semberija and adjacent parts of North Croatia.

In southern parts of Mt. Motajica, Upper Cretaceous-Early Paleogene flysch series and volcanic rocks with tuffs were progressively metamorophosed into slate, phyllite, greenschist, metasandstone, quartz-muscovite schist, gneis, amphibolite and marble (Fig. 33). Metamorphism took place under very low-, low- and medium grade P-T conditions (Pamić&Prohić, 1989; Pamić et al., 1992).

Adjacent Mt. Prosara is composed of Upper Cretaceous to Paleogene flysch series, which reveal a northwards increasing from very low to low grade regional metamorphism.

In the slates and phylites, a late Cretaceous-Early Paleogene microflora was determined (Pantić&Jovanović, 1970). K-Ar ages obtained on lower-and medium-grade rocks range between 48 and 38 Ma (Lanphere&Pamić, 1992).

Fig. 33. Metamorphic isoclinal folded rocks; Prosara (photo. Hrvatović, 2004)

The progression from nonmetamorphosed Upper Cretaceous sedimentary and igneous rocks up to amphibolite-grade rocks takcs place over a distance of a few kilometers. Based on textural arguments, mineral zonations, chages in the oxygen isotopic composition and geobarometric data explained by twoo phases metamorphism. In the first phase, regional syntectonic medium-pressure and low-temperature metamorphism affected a board zone, up to 3-4 km wide. This is overprint by contact metamorphism under increasing temperature and decreasing pressure during subsequent diapiric uplift of granite intruzion. Locally, this developed into a narrow andalusite zone of medium-grade metamorphism including local partial melting and the formation of migmatites (Pamić et al., 1992).

Synkinematic granitoids

Late Plaeogene regionally metamorphic rocks of the Vardar Zone are intruded by small- to medium-sized plutons. However, such plutons are more common in the subsurface as indicated by geophysical prospecting data (Labaš, 1975; Vukašinović, 1991). In Mt. Motajica croups out a granite pluton with the surface area of cca 50 km^2, whereas in adjacent Mt. Prosara numeorus dykes, commonly a few metre thick intrude Late Paleogene greenschist facies metamorphic sequences. Geological age of metamorphism and synkinematic granitoid plutonism is concordant to the age of 48,7 to 55,0 Ma obtained by Sr-isochrone dating (Pamić&Prohić, 1989; Lanphere&Pamić, 1992).

Late Paleogene granitoid plutons also occur further eastward (Mts. Cer and Bukulja) and they are particularly common in the southeastern parts of the Vardar Zone (Mts. Kopaonik and Željin), where they are accompained by penecontemporaneous volcanic rocks. The granitoids were penetrated by several oul-wells in northernmost parts of the Vardar Zone in Croatian Posavina covered by the Tertiary fill of the Pannonian Basin.

Late Paleogene granitoids of the Vardar Zone are mainly represented by granodiorits, monzogranites, quartz-diorites and monzodiorites as well as numerous Prosara vein granitoids of alkali feldspar granites and syenites and rare diorites (Lanphere&Pamić, 1992). Pamić et al., (2002) suggest that Motajica and Prosara granitoids belong to S-types and I-types. The conclusion is based on the isotopic values of stroncium and oxygen of the Motajica and Prosara granitoide.

Granites of Motajica are greisenised. They are located in the few interrupted zones along the east-west direction. Greisenisation affected with very different intensity normal granite, leucogranite and aplitic granite. Greisenization marked by strong silification and muscovitization affected less than 1% of pluton. It is characterized by minor and accesory molybdenite, wolframite, huebernite, schelite and fluorite. Economically significant are kaolin deposits formed in Pliocene-Pleistocene time (Jurković, 2004).

Microparagenesis of these magmatites, pegmatites, greisens and quartz veins are distinguished by U, Th, Ce, Y, P, Nb, Ta, B, Li, F, Be, Sn, Mo, W, Fe, Cu, Pb indicate the mantle origin of magma contaminated by relatively sterile lithospheric rocks. The most probable hypotesis of such a hybrid magma formation is the “slab break-of model” (Jurković, 2004). Deep erosion of Motajica granitoid pluton opened its acrobatholitic and epibatholitic level with numerous, but small pegmatite deposits.

Fig. 34. Granite – Motajica near Bosanski Kobaš (photo Hrvatović, 2004)

m	Age	Lithology		Environments	Fossils
	Q			Fresh water basin	
100	Pl_3		Gray and yellow clays	Fresh water basin	
	Pl_2			land	
250	Pl_1		Sands, gravel, silt, clays, silt-clays,	Fresh water basin	
150	M_3^2		Clays, marls and sands	Fresh water basin	
150	M_3^1		Marl, slate and rarely limestone	Fresh water basin	
220	M_2^2		Sandstones, marls and clays	Fresh water basin	
100	$M_{1,2}$		Marls, conglomerates and breccia	fluvial	
80	$M_{1?}$		Sands, marls and clays with coal	Fresh water basin	
				land	
300	Ol,M		Conglomerates, sandstones, marls and siltstone with coal	Fresh water basin	
150	E,Ol		Marls, siltstone, limestone	marine	
250	$E_{2,3}$		Sandstone, conglomerates, marls and siltstone	Deep marine	
300	$E_{1,2}$		Marly-sands limestone Marls, sandstone	Deep marine	
250	Pc,E		Sandstone, silt, marl, breccia, conglomerates		
1000	K_2		Flysch	slope	
				land	
	$T_{2,3}$		Limestones and dolomites	Shallow marine	

Fig. 35. Geological column Bijeljina area – Vardar zone (Hrvatović, 2004: acording datas oil-well)

Post – orogenic volcanics

The post – orogenic volcanics are very common in the Vardar Zone, particularly in their southeastern parts in Serbia and Macedonia. In its northwestern parts in North Bosnia these rocks are found in Mt. Majevica, where not yet studied, and in the area of the Srebrenica lead – zinc mine. Smaller post – orogenic volcanics are found in the northwesternmost parts of the Dinaride Ophiolite Zone adjoinging the southernmost part of the Vardar Zone. Such bodies occur in the area of Maglaj and particularly in the area of Mt. Mahnjača. In the whole Vardar Zone post – orogenic volcanics rocks are frequently interlayered in penecontemporaneous Neogene sediments of the Pannonian Basin. These Tertiary volcanic rocks occur as volcanic flows interlayered with Neogene sediments of the Pannonian Basin, subaerial stratovulcanos and small hypabyssal bodies.

In the area of Maglaj (Central Bosnia) volcanic rocks occur within ophiolites and genetically related sedimentary formations. There are several smaller volcanic bodes. Mainly rocks are dacites and andesites as the members of the high-K calc-alkaline series.

Post – orogenic volcanics rocks of the Vardar Zone to date were not geochronologically classified. Not yet published K-Ar data of cca 30 Ma were obtained for volcanic rocks from area of Srebrenica and Maglaj indicating Early Oligocene age of the volcanic activity. Based on a detailed geohronological division of post – orogenic volcanics from adjacent Pannonian Basin in Croatia (Pamić, 1997), it can be presumed that the volcanic post – Pannonian.

The Tertiary volcanic formations disregarding their different ages are represented largely by andesites, dacites and subordinate basalts. Most recent geochemical data indicate that predominant volcanics of the Srebrenica area are not andesites and dacites but K-rich latites, i.e. the rocks which belong to the shoshonite volcanic series which is characteristic for subduction areas.

POST – OROGENIC OLIGOCENE, NEOGENE AND QUARTERNARY FORMATIONS

In present structure of the Dinarides very important role have Oligocene-Neogene marine to fresh-water and coal-bearing basins originated after the final structuration and uplift of the Dinarides which took place by Late Eocene (Pyrenean) deformation:

Neogene intramontane fresh-water basins

In the Bosnia – Hercegovina parts of the Dinarides there are about same 150 smaller and larger fresh-water intramontane basins. Almost all of them are same in stratigraphy and lithology and in order to avoid repetitions here will be presented the Sarajevo-Zenica Basin which is the largest one in Bosnia and Hercegovina.

Sarajevo – Zenica Basin

Generation of the basin probably started during the Late Oligocene, most probably controlled by at that existed fault zone Ilidža – Kiseljak – Busovača – Travnik known as the Busovača fault (Fig. 12). Basement of the basin consist of rocks of Jurrasic – Cretaceous flysch originating along the Apulian passive continental margin and rarely Paleozoic rocks.

Basinal formations ca be divided into Oligo – Miocene, Early Miocene and Late Miocene formations. The Oligo – Miocene formations by basal conglomerates which are overlain by platy marls and fresh – water limestones with a coal-seam, about 2 m thick, which were explored at Koštane north of Breza (Fig. 36), Kraljeva Sutjeska, Bijele Vode north of Kakanj, Ponjihovo north of Mošćanica, Gračanica north of Zenica Basin and Poljanice north of Guča Gora. These footwall coal-bearing formationss can be correlated in age with Egerian formations in the Ugljevik Basin. In the Sarajevo – Zenica Basin, as in Tuzla and Lopare basins, the footwall limestones are overlain by «red suite» which is up to 600 m thick. The Oligo-Miocene formations by a suite, 200 m thick, which is composed of porous and bituminous limestones which in appareance are similar to «banded marls» of the Tuzla Basin. Further correlation with North Bosnia is not possible because this area was covered at that time by sea water.

Early Miocene formations of the Sarajevo – Zenica Basin start with the «main coalm – suite» up to 500 m thick (at Zenica) which is composed eight coal – seams; six of them are footwall, one is «main seam» and one is roof-seam. This suite is overlain by a «transitional» suite (600 m) composed of litstones, sandy marls, sandstones and conglomerates which are overlain by the Lašva Formation, about 1000 m thick, which is composed of thick-bedded conglomerates, sandstones and marls. In mouth area Lašva River into Bosna River, in these conglomerates originated well known «towers», up to 300 m high.

Early Miocene formations start with the Koševo suite (according to Koševo Hill in Sarajevo) which is composed of weathered sandstones, marls, clays and conglomerates and some low-quality coal. The coal crops out on Betanija Hill and at Kasindol nearby Sarajevo, and in the back of Mt. Trebević, and going northwestward of the basin the cola occurences are located close to the Busovača fault and were explored at Rakovica, Gomionica and Bukva nearby Vitez. Upper parts of Early Miocene are represented by «Orlovac» conglomerates, 200 m thick, which was mined from ancient times as millstone. Far from the Pannonian Basin, which never riched areas southward of the Spreča dislocation, this part of the basin includes endemic fresh-water fauna of mollusks and ostracods characteristic for Neogene fresh-water basins of the Dinarides. Congerias and clivunelides are found in rocks of the «transitional» suite and they are particularly abundant in the Koševo Formation in which were found fossil fishes exhibited in the Sarajevo Museum.

A clayish-sandy disconformably Late Miocene rocks and the northwestern parts of the basin (Lašva area) composed of Upper Cretaceous sediments. This suite consist of poorly cemented rocks of Pliocene age as indicated by pollen determinations. In lower parts the suite is composed of clayish sand and clays in which there are quite white varieties used for simple porcelan products; upper parts consist of quartz gravel and loam.

Mode of origin of thick and continuous coal-seam, particularly the main one and the roof one cannot be explaned by monoclinal sinking of the basen boltom. It is obvious that the monocline originated not before sediments of the main coal suite were not deposited. At that time also originated the longitudinal faults of tensional character and other transversal and longitudinal disruptures related to movements in basement of the basin. Comparatively mild folds large in lengths recognized in Late Miocene sediments might have been generated not before the Pliocene by horizontal movements along the Busovača fault. These movements were mainly dextral along the basin flank due to the horizontal strain activity.

It is interesting the occurrence of Upper Permian gypsum and Lower Triassic formations at Kondžilo fresh-water nearby Visoko. These formations are overlain by Noegene sediments probably due to diapiric mechanism.

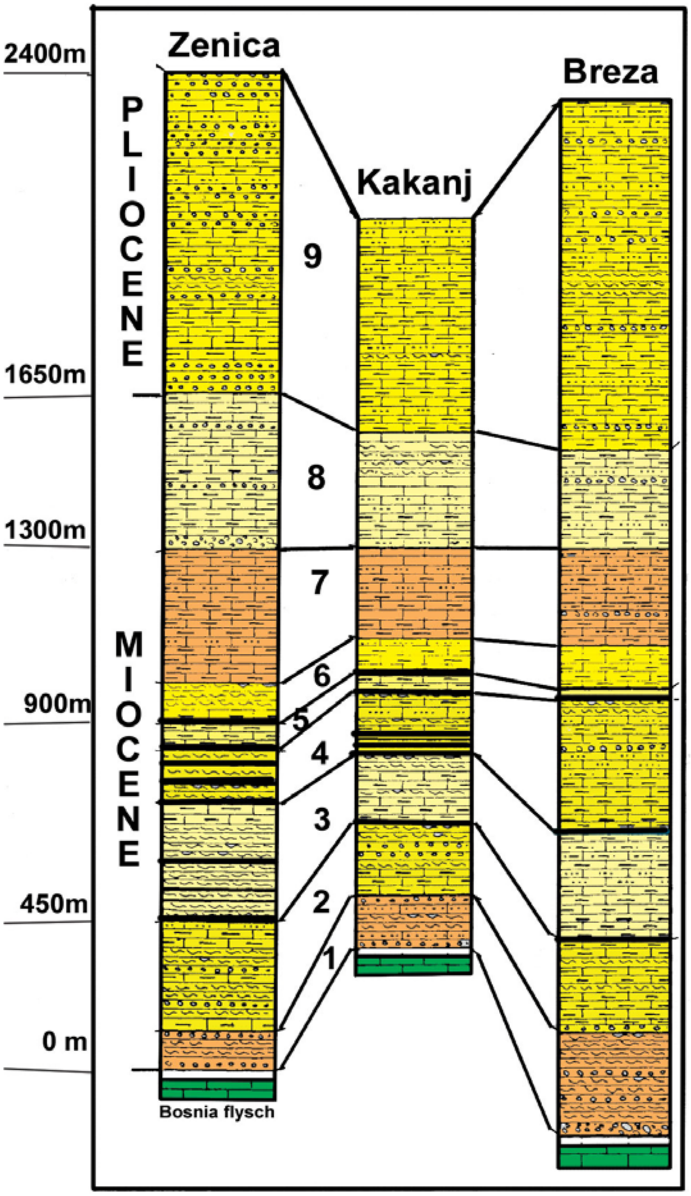


Fig. 36. Correlative geological columns for Neogene fresh-water Sarajevo-Zenica Basin (simplified after Čičić&Milojević, 1977)

1.M_1^1-conglomerates, brecciated sandstones, marly sandstones, sandy-clayey marls and clays; **2.M_1^2**-sandy limestones with interlayers of marls, conglomerates, sandy-marls clay and sandstones; **3.M_2^1**-clays, sandy-marly clays and sandy marls with (VII, VI, V, IV coal bed); **4.M_2^2**-clayey and sandy bituminous marls, sandstones and sandy-marly clays with coal (III, II, I and main coal bed); **5-6.M_3^1**-limestones and marls with carpolite and gliptostrobusidae and hanging wall coal bed; **7.$^1M_3^2$**-marls and sandstones with velutinopsidae; **8.$^2M_3^2$**-conglomerates, marls and sandstones; **9.Pl-**conglomerates, sandstones, sandy-clayey marls, sands, clay

Economically important mineral resources in the Sarajevo – Zenica as well as in other Neogene fresh-water basins are coals, thermomineral and mineral waters, clays, quartz gravels and sands, oil and uranium occurrences.

Miocene sandstones of the Sarajevo-Zenica Basin and water springs in its southwetern parts along the Busovača faults (area Rajlovac-Kondžilo-Hum Hill) have increased quantity of uranium, up to 500 gr/t. Some springs contain increased quantities of bromine and jodine indicating to the existence of a gas barrier along the tectonic line which preveted uranium migration or, alternatively, could be related to an oil-trap (Hrvatović, 1986).

Stratigraphic column for the Sarajevo-Zenica Basin

PLIOCENE

Bilalovac: clayish sands, clays, quartz gravels and loams.

LATE MIOCENE (SARMATIAN, PANNONIAN, PONTIAN)

Equivalents of S a r m a t i a n, P a n n o n i a n and P o n t i a n: Profile at Orlovac: various conglomerates for millstones and other clastics.
Počilica profile: marly and porous limestones with mollusks (Congeria)
Koševo profile: brick marls and other clastics; coal along the western margin of the basin from the north towards the south: Bukva nearby Vitez, Gomionica nearby Busovača, Rakovica, Kasindol and Bistrik nearby Sarajevo; upper parts of the Lašva Formation (suite) with conglomerates and marls.
Total thickness about 1000 m.

EARLY MIOCENE (OTTNANGIAN, KARPATIEN, BADENIAN)

Equivalents of B a d e n i a n: Lower parts of the Lašva Formation (suite) composed of conglomerates, sandstones and marls with mollusks (Congeria), 600 m thick; Transitional unit with slightly weathered marls interlayered with sandstones and conglomerates, 600 m thick.
Equivalents of K a r p a t i e n and O t t n a n g i a n: Main coal-zone with porous limestones with flora of forest leafs (Glyptostrobus, Laurus) and root coal-seam, 70 m thick; marls, snadstones and coal of the main coal-seam, 170 m thick; sandy clays and marls with six foot coal-seams with water flora (Carpolithes), 300 m thick.

OLIGO-MIOCENE (CHATTIAN, AQUITANIAN, EARLY BURDIGALIAN)

Northeastern parts of the basin: porous and bituminous limestones with land gastropods (Helix); red series, platy limestones and marls with the Košćanb coal-seam; basal conglomerates.

South Pannonian Basin

After the final Eocene deformations of the Dinarides resulting from underplating of Apulia beneath Tisia (the present Pannonian Basin terranes), started during the Oligocene (32-28 Ma) processes of transpression. In the area north of the uplifted Dinarides, a system of larger NNE-SSE and SSE-NNW oriented, larger shalow-to deep-water transtensional depressions came into evidence, in which marine, brakish and fresh-water sediments accumulated (the South Paratethys). Generation of these isolated basins were controlled by strong strike - slip faulting, predisposed generation of recent Drava and Sava depressions. Along these transcurrent faults intensive Oligocene andesite volcanic activity took place (e.g. andesites of the Maglaj and Srebrenica areas). These Oligocene sediments with penecontemporaneous volcanics represented in fact, at least partly, a basement on which subsequently started the evolution of the Pannonian Basin as indicated by data of oil-well drilling.

However, the Oligocene strike-slip faulting was also very within the uplift Dinarides. It gave rise to generation of numerous smaller and larger intramontane depressions in which, after strong climatic changes, started during the Neogene their filling, i.e. the generation of fresh-water Neogene basins. It is very probable that the large Busovača fault system came into evidence by this Oligocene strike-slipe faulting and thus predisposed the origin of the future Sarajevo-Zenica Neogene fresh-water Basin.

After the Oligocene transpressional deformation of the area northeast of the uplifted Dinarides, geodynamic processes controling the evolution of the Pannonian Basin changed fundamentally. Diapirism of the upper mantle and resulting attenuation of the lower continental crust was reflected in superficial parts by extensional rifting related faulting which aterted in Ottnangian and Karpatien (18-17 Ma) – Roxden et al. (1983). The extensional evolution of the South Pannonian was mainly predisposed by the original Drava and Sava fault system created during the Oligocene transpression. As result of the extension these terranes were transgressed by the World Sea and the first phases of the evolution of the Pannonian Basin took place in rifting-related, mainly marine environments. This rift-related Early/Middle Miocene filling of the Pannonian Basin was accompanied by synsedimentary volcanic activity which took place during the Karpatien and Badenian. The first rift-related stage of the evolution of the Pannonian Basin terminated by the end of the Sarmatian. After that follows the second evolutionary stage when continued Late Miocene and Pliocene intensive filling of the Pannonian Basin under fresh-water conditions.

Strong contractional tectonic activity occurred at the beginning pf the Pliocene (4-5 Ma). Reflection seismic data indicate that in the South Pannonian, units of the northernmost Dinarides (Vardar Zone) are thrust over the Tisia (Tari&Pamić, 1998). This is also evidenced by the fact that the Late Cretaceous formations of the North Dinarides were thrust in adjacent Slavonija over Neogene sedimentary sequences as young as Pannonian in age. Moreover, fold and thrust structures within the Late Cretaceous complex of the Mt. Motajica and Prosara display an obvious north vergence as contrast to predominant southwestern vergences characteristic for the Dinarides as a whole.

Tuzla Basin

The Tuzla Basin (Fig. 37) was studied by numerous authors and the most important papers were published by Katzer (1918, 1921), Soklić (1950, 1959, 1964, 1983), Stevanović (1953, 1958, 1960), Čičić (1970), Jovanović (1979), Vrabac (1989) Ferhatbegović (2004) and others.

Structurally, it is a graben-synclinorium positioned between the Mt. Majevica horst-anticlinorium in the north and the Spreča deep faults, i.e., the northern margin of the Dinaride Ophiolite Zone, respectively in the south. The area of the included during the Late Cretaceous, Paleocene and Eocene in the northernmost part of the Dinaridic Tethys («Vardar Ocen»), afterwards was affected by Pyrinean compressional deformation and Oligocene transpressional strike-slip faulting and, finally, was covered during the Early Miocene by a large fresh-water basin. This area was affected by the end od Karpatian by the second Mediterranean transgression of the normaly salt Parathetys and thus extending gradually southward and westward during the Badenian. The basin still existed during the Sarmatian, Pannonian and Pontian spreding further southward and westward but also eastward up to the Drina fault. The basin was separated already in Sarmatian from the Lopare Basin and Posavina by the Majevica and Trebovac islands, whereas its eastern parts (the Tuzla folded platean) emergend from at that time brackish Paratethys. This proces continued during the Pannonian and especially Pontian when more brakish sea transgressed in the meantime alredy originated Kreka Basin which was connected with Posavina along Gračanica, Tinja and Hoćan channels.

m	Age	Stages	Lithology	Environments	Fossils
400	Pl	Pliocene	Alluvial gleys with fossils in not-gleyed calcareous clays	**Fresh water (fluvial, lacustrin)**	mollusks (Pisidium), gastropods (Planorbis, Neritina, Valvata, Helix, Clausilia, Chondrula), ostracodes (Candona), and pollens of forest trees (Carya, Pterocarya, Cedrus, Kateeleria, Tsuga).
>600	M_3^2	Pontian	lignite-seam; gravel; quartz sands; clayish sands;	**Caspibrackish-paralic**	gastropods, mollusks (Limnocardium,Dreissenomya, Prosodacna), ostracodes and leafs and pollens of subtropical trees (Taxodium, Glyptostrobus, Laurus, Persea, Plattanus and Illex) in the main coal-seam cyclothem.
200	M_3^1	Pannonian	**Sandstones, marls**	**Caspibrackish – limnic**	mollusks (Limnocardium, Parvidacna), gastropods (Melanopsis), Congeria
300	M_2^2	Sarmatian	marly clays; oolithic limestones; marls, sandstones; conglomerates	**Brackish marine**	mollusks (Mohrensternia, Donax, Irus), gastropods (Cerithides), foraminifers (Elphidium, Porosononion) ostracodes, leafs of subtropical trees and others.
500	M_2^1	Badenian	marls, sandstones, conglomerates, tuffs	**Shallow marine**	foraminifers (Globigerinoides, Orbulina, Bolivina), mollusks (Pteropoda, Corbula, Aturia) corals (Balanophyllia,Ceratotrochus, Heliastrea, Porites) and echinidis
100	M_2^1	Badenian	Marlstone and sandstones		Ammonia viennensis, Nonion commune
-600	$^1M_1^4$	Karpatian	**-«Salt formation»** Halite; tenardite; anhydrite; banded marl	**Marine-lagoonal**	foraminifers
-200	M_1^3		**- Mottled series»** fresh-water and terrestrial gleyed clayish strata, sandstones and conglomerates and volcanic tuffs	**-fresh-water and fluvial**	-gastropods (Melania) and mammals (Mastodon angustidens)

200	M_1^2		**«Red series»** marls, sandstones, conglomerates, evaporites and clays	**Intertidal flats to lagoonal**	
100	M_1^1		**«Slavinovići limestones»** -bedded limestones	**Fresh water**	-Gastropods (Bythinia, Lymnea), -Ostracodae (Cypris)
750	Ol		Marl, siltstone, sandstone, conglomerates	**Fresh water**	
1200	$E_{2,3}$		Quartz sandstone, red marls,	**Slope**	Nummulites natica
300	$E_{1,2}$		Limestone, marls, coal	**Slope**	Discocyclina
550	Pc		Flysch	**Slope**	
				Land	
200	K_2^3		Massive and bedded limestone	**Shallow marine**	Orbitoides, Globotruncana
500	K_2		Platy limestone, marls, sandstone, breccia and conglomerates	**Slope**	Globotruncana
				Land	
50-100	J_3		Reddish limestone	**Pelagic**	Amonites
800-1000	$J_{2,3}$		Ophiolite melange		
?	J_1		Marl limestones		
?	$T_{2,3}$		Limestones, cherts		
?	T_2				
?	T_1		Quartz sandstones, siltstones, rarely limestones	**Fluvial to shallow marine**	Myacites
?	P_3		Bedded bituminous limestones	**Shallow marine**	Belerophon

Fig. 37. Geological column of the Tuzla Basin (after Soklić 1975, Čičić 1989, Vrabac 1999, Ferhatbegović 2004)

Deep oil-well explorations carried out during 1934-1950 provided data on age and composition of basement of Neogene formations. The following basement rocks were recorded. Upper Cretaceous clastics and carbonates (oil-well Tuzla-1), strata of Maastrichtian-Paleocene-Lower Eocene flysch (oil-well Požarnica), Middle Eocene strata with foraminifers, mollusks and corals, Upper Eocene quartz sandstones and red marls, but also fresh-water strata represented by «Slavinovići limestones which also crop out at the surface in most part of the basin. Lower Miocene comprises «Slavinovići limestones», Red and Moltled suites», and the Salt Formation itself, which is included, generally, into Aquitanian and Burdigalian or, according to the Central Paratethyan stratigraphic division, into Late Egerian, Eggenburgian, Otthnangian and Karpatien. It can be presumed that each of the four mentioned suites belongs to one of the four mentioned stages. The «Slavinovići limestones», which are anly 60 m thick, are characterized by desiccation fissures of dry lake mud and by the occurrence of fresh-water gastropods casts. These are covered by «red suite» largely composed of redeposited tropic soils transported by water and wind from slightly peneplanated, southerly located Dinarides. Intensive red colour is caused by abundant hematite admixtures. Some intensively greenish strata deposited in redox-conditions. Silty sediments predominate over poorly cemented conglomerates with predominant chert, peridotite and other silicate rocks pebbles. The overlying «mouuled suite», genetically related to renewed tectonic activity, was found by the same source area. Besides predominant ophiolite rocks also occur pebbles of Tithonian-Valanginian limestones with tintinides (Calpionella) which disconformably overlie ophiolite and related formations. In the «Mottled suite», besides pebbles, very common are large blocks (e.g. Pješivica nearby Tojšići). In adjacent low Podrinje area, intensive volcanic activity at that time took place and the basin was also field by volcanic ash transported by wind. Sediments of the «Mottled suite» contain plenty fossils, particularly gastropods (melanias), and at Gornja Tuzla parts of Mastodon augustidens were found. Pelite sediments of the suite are irregularly reddish and greenish flaky which is characteristic for muds flooded by alluvial fans. In the area of Soline, both the «Red suite» and «Mottled suite» are about 300 m thick.

Next are Karpatien sediments deposited after transgression of normally salt Central Paratethys from the Panonian Basin. Thickness of the Karpatien formations amounts at least minimally 300 m, namely, they were not as yet penetrated by drilling (oil-well ravna Trešnja -1). In this well drilled at Bukinje nearby Tuzla, rocks of the «Mottled suite» are represented by coarse-grained marine conglomerates with calcareous cement which are interlayered by clayish and slightly bituminous marls. Based on these data, somewhere between this location and Tušanj and Rasovac salt deposits might have existed a barrier dividing the sea from lagoon. In this interpretation one must heep in mind the role of subsequent tectonic movements of the block within the present folded plateau on which are positioned the salt deposits relative to the present North Kreka synclinorium and dextral transcurent of the flank of the deep Moluška strike-slip fault.

These sediments are conformably overlain by deep-marine Badenian mudy-clayish marls interlayered with some thing fine-grained sandstones. The marls content abundant fauna represented by foraminifers of gastropods, particulary the floating ones (pteropods) as well as small forms of gastropods, mollusks, nautilides (aturias) and echinides (briopsis). Upper Badenian coarse-grained contain coarser faunal forms with thicker shells originated in shallow-marine environments as also indicated by colonial-type corlas in the area between Lukavac and Gračanica. Thickness of Badenian formations recorded in deep-wells at Bukinje is about 500 and they are covered by Sarmatian brackish formations, up to 300 m thick. These formations are represented by clayish marls interlayered with sandstones and conglomerates with small gastropods and mollusks in lower parts and limestones with bigger mollusks with thicker shells in upper parts. As distinguished from Badenian marine fauna, brackish Sarmatian fauna is characterized bx small number of specia but big number of indivuduals. In the same deep wells at bukinje were also recorded Pannonian formations which were deposited in kaspi-brackish Pannonian Lake that covered the area of the present Kreka Basin. Pannonian is represented by quartz sands and calcareous clayish which the most characteristic fossils are represented by mollusks (Congeria, Limnocardium), gastropods (Melanopsis) and small crabs (Ostracodes).

In the Kreka Basin during the Pannonian six cyclothems were deposited fiwe of which in the area south of the Čaklovica ridge; all of them named by the terminal coal-seam. Each cycle was predisposed by renewed sinking of the Pontian Sea in which starts deposition of sands becoming gradually «mature» as shown by weathering of less resistent minerals and finally represented by pure quartz sands (more than 95 % SiO_2) composed of quartz and chert particles. These processes persisted until the final filling of the basin after which fresh-water swamp originated cut by snall streama. Afterwards such terranes were covered by high swampy forests which predisposed coal generation. The accumulation of lignine and cellulose lasted until a next sea ingression in the basen as result of sudden subsidence of the basinal bottom or, alternatively of penetration of the barrier which separated the basin from the Pontian Sea. In the Kakanj Basin Pontian formations are 600 m thick, but in future, due compaction and recrystallization the thickness will be decreased.

Sinking of the basin bottom continued in post-Pontian times. Central parts of the North Synclinorium subsided for additional 400 m, and at least for the same amount subsided the Spreča Valley as indicated by deep-wells drilled at Miljanovci (Tc-14 and 15). The penetrated formations are Plio-

Pleistocene gleys analogous to the ones from Posavina. Only in short intervals of these deep-wells ungleyish fossiliferous clays were prenetrated with swampy mollusks (Pisidium), fresh-water gastropods (Planorbis, Neritina, Valvata), land gastropods (Clausilia, Helix, Nondrula) and ostracodes (Candona). Registred pollen dust belongs to the representatives of recent forest (pine, juniper, berry, elm – tree and others) but also to some strange conifer trees (Cedar, Ceteleria, Tsuga) and decidous trees (Caria, Pterocaria). The Spreča Valley subsides throught the Quarternary and this was accompanied by uplift of its flanks. Uprise of Mt. Majevica in the north and the Mts. Javornik and Djedinska planina can be deciphered by surrounding terraces (abandoned alluvial plains) of the Spreča River and its tributories. Old terraces of the rivers Jala and Solina are preserved in Tuzla itself, as for example, the older one is Gradina on which the hospital located, and the younger Holocene one on artefacts of ancient dwellingers were found.

Fresh-water formations are covered by Late Karpatien and Badenian marine sediments which are overlain by Sarmatian brackish sediments and sweetened (caspi-brackish) Pannonian and Pontian formations.

<u>Stratigraphic column for the Tuzla Basin</u>

PLIO-PLEISTOCENE

Miljanovci in Spreča Valley: depressions composed of Alluvial gleys (400 m) with fossils in not-gleyed calcareous clays: mollusks (Pisidium), gastropods (Planorbis, Neritina, Valvata, Helix, Clausilia, Chondrula), ostracodes (Candona), and pollens of forest trees (Carya, Pterocarya, Cedrus, Kateeleria, Tsuga).

LATE MIOCENE (SARMATIAN, PANNONIAN, PONTIAN)

P o n t a i n – caspybrackish – limnic cyclothems (up to 5), 600 thick, composed of: lignite-seam; fine-grained river gravel; pure lacustrine quartz sand; clayish Pontian sand; marly clay originated in the pontian Sea with gastropods, mollusks (Limnocardium, Dreissenomya, Prosodacna), ostracodes and leafs and pollens of subtropical trees (Taxodium, Glyptostrobus, Laurus, Persea, Plattanus and Illex) in the main coal-seam cyclothem.

P a n n o n i a n – caspibrackish – limnic cyclothems with mollusks (Limnocardium, Parvidacna), gastropods (Melanopsis), ostracodes and others – 200 m thick.

S a r m a t i a n – brackish sediments represented by marly clay; oolithic limestone; marl and sandstone; clayish marl with sandstone and conglomerate interlayers; fauna of mollusks (Mohrensternia, Donax, Irus), gastropods (Cerithides), foraminifers (Elphidium), ostracodes, leafs of subtropical trees and others.

EARLY MIOCENE (OTTNANGIAN, KARPATIEN, BADENIAN)
B a d e n i a n – marls and sandstones with foraminifers (Globigerinoides, Orbulina, Bolivina, Streblus), mollusks (Pteropoda, Corbula, Aporrrhais, Aturia), corals (Ballanophyllia, Ceratotrochus, Haliastrea, Porites) and echinidis – thickness 500 m.

O t t n a n g i a n and K a r p a t i e n – marls and sandstones with formainifers (Globigerinoides, Uvigerina) and other fossils – in deep-well RT-1, 300 m thick (m a r i n e d e v e l o p m e n t). The Salt Formation with several cyclothems which have profiles going downwards: Halite; tenardite; anhydrite; banded marl (dolomicrite) and outside of that marl is volcanic tuff (l a g o o n a l d e v e l o p m e n t). The «Mottled suite» (equivalent of Ottnangian?) – fresh-water and terrestrial gleyed clayish strata, sandstones and conglomerates with gastropods (Melania) and mammals (Mastodon augustidens) and volcanic tuffs (L i m n i c – t e r r e s t r i a l d e v e l o p m e n t).

OLIGO-MIOCENE (CHATIAN, AQUITANIAN, EARLY BURDIGALIAN)
Tuzla folded plateau: «Red suite», «Slavinovići limestones», Požarnica oil-suite in composition and thickness identical to the foot of Slavinovići limestones (Gnjice profile).

MIDDLE EOCENE (LUTETIAN, BARTONIAN)
Požarnica: rocks in profiles from deep-wells.

Economically important mineral resources for exploration and explitation: coal, quartz sand, clay, oil and salt.

Pannonian Basin *sensu lato*
A zone with Sarmation can be traced along the southern margin of Posavina basins and around the Mts. Prosara and Motajica island and former Mt. Vučjak peninsula (Fig.31). The Sarmation formations cover large surface in Dubica and Prnjavor basins and in the Derventa area. In deeply subsides basins covered by Quarternary sediments, Sarmatian, Pannonian, Pontian and post-Pontian formations were recorded only in deep wells (fig. 38, 39, 40). Rocks of the mentioned stages simultaneously represent large sedimentary cycles starting with transgressions and terminating by regression of sea and certain orogenic movements, i.e., the orogenic phases.

In the South Pannonian Basin the following phases were registred: early Steirenian (Ottnangian), Late Steirenian (early and late ian), Moldavian (Badenian/Sarmatian), Predacian (Sarmatian/early Pannonian), Atician /early Pannonian/late Pannonian), Rhodanian (late Pannonian/early Pontian), Slavonian(lower and middle Paludian Beds), Vlaškian (below the very top of Pliocene) and East – Causian (Mindalian – Riesian interglacial period).

So Badenian so Sarmatian, Pannonian and Pontian formations reach their maximal thickness by the end of these stages as result of ocerflowing sedimentation.

After regression of the Pontian Sea all other water accumulation were transformed into fresh-water basins. Due to continuing uplift of the Dinarides all these basins were permanently filled by new terestrial material although their bottoms were affected by further sinking. They were transformed into alluvial plains covered by water during the rainy periods and exposed to sun during the dry periods. Most part of post-Pontian are represented, beside gravels, by muddy clays (loams) colored either in intensive blue-green or red depending on redox – or oxydizing environments. In the pedology this type of soil gley. In the area south of Brčko, thickness of these formations is 200 m as indicated, by structural drilling. These formations are marked as «South Pannonian gleyed suite» which covers comparatively larger surface areas. It is positioned between Upper Pontian formations in the foot and Upper Pleistocene formations in the roof suggesting its Plio-Pleistocene age is Dazien, Romania and Early Pleistocene and this approximately corresponds to the «Paludina Beds» of Slavonija (Fig. 39)

At Glavičice nearby Branjevo on the Drina River, a Late Pleistocene profile, 20 m thick, was studied in detail. This could be typical profile for the second Semberija-Posavina terrace stretching westernward from Branjevo along the terminal slopes of the Mts. Majevica and Trebovac where is 10-15 km wide. At Glavičice crop out clayish – marly strata with fresh-water gastropods which alternate with steppe dust with land gastropods. The largest thickness of the «second» terrace is in the area between Tinja and Gnjica rivers and it reaches up to the Sava River bed where is affected by river erosion. As distinguished from formations of the «South Pannonian gleyed suite», the preservation of the terrace suggests that the tectonic block on which it is located underwent epirogenic uplift. It is a quite different

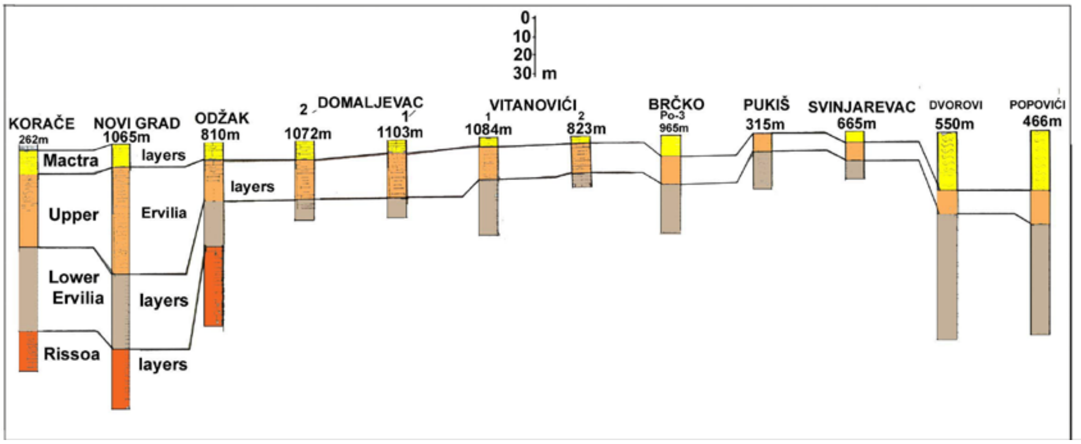


fig. 38. Corelation Sarmatian in oil-well (Posavina and Semberija - Vardar Zone) - after Soklić 1971

situation in the tectonic block in the parts of Posavina southward of Bosanski Šamac. Here, there no outcrops of Pleistocene and Early Holocene formations suggesting that this block sinks along mendering courses of the Tolisa and Briježnica rivers.

This part of the South Pannonian Basin is of interest for oil explorations. It was separated «upper structural etage» composed of Oligocene and Lower Miocene formations represented mainly by clastic sediments which cover comparatively large surface area in the South Pannonian Basin. Based on exploration data deep and the deepest parts were separated with favourable structural forms for which is belived that contain economically interesting oil and gas accumulations. This is the area southward of Bosanski Šamac and southwestward of Orašje in which Oligo – Miocene oil-bearing clastics are at depths of 1200-2000 m.

Economically intersant natural mineral resources for exploration and explitation are oil, thermal water, clay and gravel.

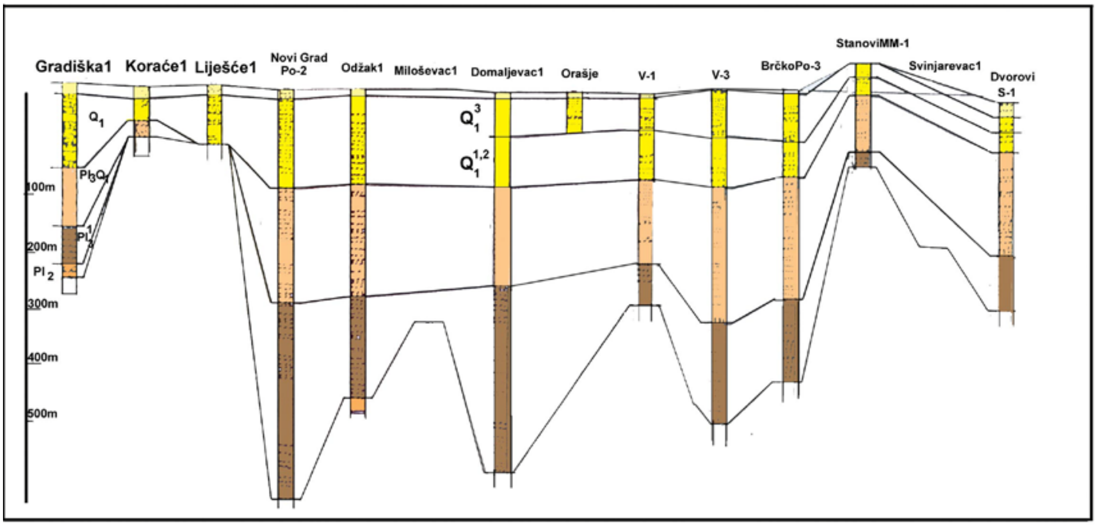


fig. 39. Postpontian sediments from Pannonian Basin (after datas oil-well, Soklić, 1971)

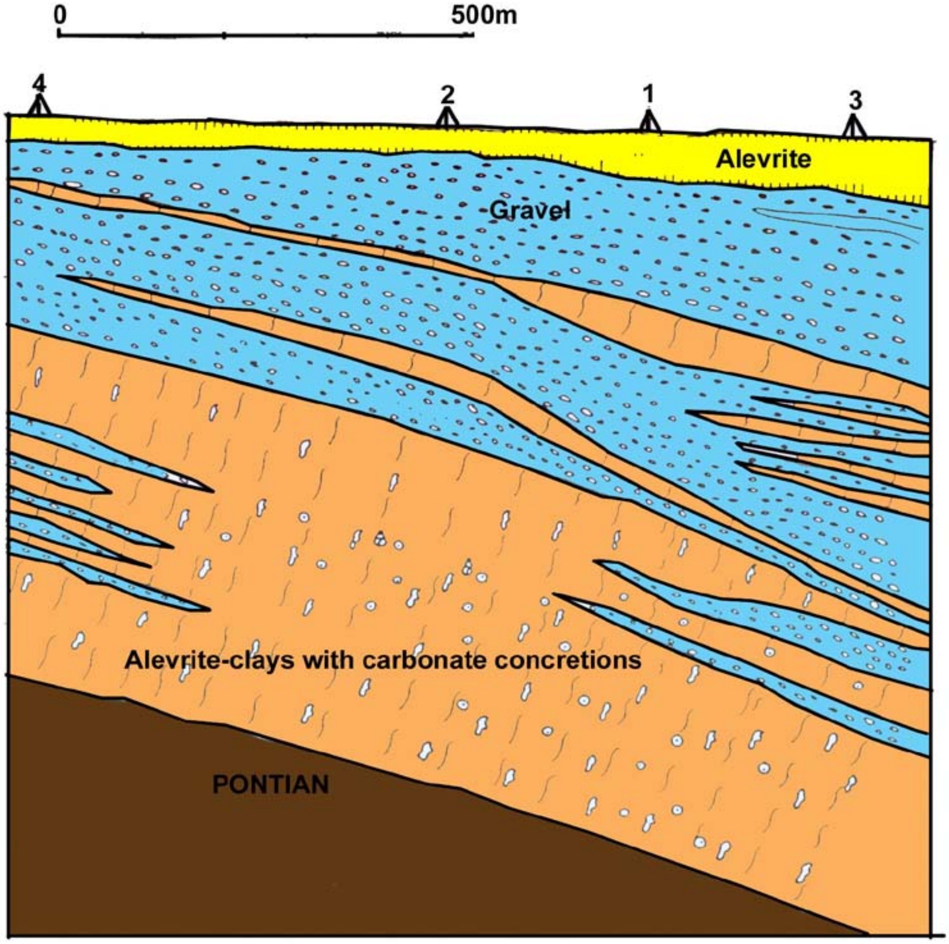


fig. 40 Geological cross-section Pleistocene sediments (Korače area-Pannonian Basin; Soklić, 1977)

Stratigraphical column for Posavina *sensu lato*

PLEISTOCENE (EARLY QUARTERNARY)
L a t e W ü r m i a n – Glavičice nearby Branjevo on the Drina River: silts with steppe gastropods; marly clay with gastropods on mollusks; river gravels – total thickness 20 m.

PLIO-PLEISTOCENE
D a z i e n, R o m a n i a n, early and middle Pleistocene: Stanovi southward of Brčko – glayed alluvial depressions (200-650 m).

LATE MIOCENE (SARMATIAN, PANNONIAN, PONTIAN)
P o n t i a n: caspy-brackish, in some places limnic sediments with mussels (Dreissena, Paradacna) and gastropods (Valenciennius), about 200-300 m thick.
P a n n o n i a n: sediments of the sweetened Sarmatian Sea with mussels, gastropods (Rodix, Provalenciennesia, Orygoceras) and ostracodes, about 100 m thick.
S a r m a t i a n: sediments of the Sarmatian brackish Sea with the profile going upwards: reefal olithic and sandy limestones; sandy marls; clayish marls; frequently bituminous with mussels (Abra, Ervilia, Mactra), gastropods, foraminifers and ostracodes, 170 m thick.

EARLY MIOCENE (OTTNANGIAN, KARPATIEN, BADENIAN)
O t t n a n g i a n:sandstones and marls with older congerias.
K a r p a t i a n: marls and sandstones with formainifers Globigerineides.
B a d e n i a n: marls and sadnstones with foraminifers (Orbulina, Spiroplectamina, Bolivina), gastropods, mussels (Amussium, Chlamys); reefal limestones with mussels (Chlamys, Glycimeris), gastropods (Ceriithida), echinids (Echinolampas, Glypeaster), foraminifers (Amphistegina) and algas (Lithothamnium).

OLIGO-MIOCENE (CHATTIAN, AQUITANIAN, EARLY BURDIGALIAN)
Brvnik nearby Bosanski Šamac: oli recorded in oil-well at depth of 230 m, Dvorovi nearby Bijeljine: oil clays and associated rocks at depths of 845 – 1050 m.

Economically interesting natural mineral rsources for exploration and exploitation: coal, quartz sand, clay, oil and thermomineral waters.

MAIN TECTONIC STRUCTURES AND DISCONTINUITIES

Position of the Dinarides within the Alpine-Himalaya orogenic belt

In the framework of classical but abandoned geosynclinal concept, Kober (1911) distinguished «two branches» within the Alpine-Himalaya belt and included the Dinarides, together with the Apennines, Southern Alps and Hellenides, in the «southern branch» whilst his «northern branch» embraced the Western-Eastern Alps, Carpathians and Balkan.

The extension of the Dinarides toward the Alps is not clearly defined. The External Dinarides and Southern Alps resulted from Eocene to recent deformation of the same paleogeographic domain namely the Apulian Plate south of the Periadriatic line often referred to as the Adriatic micro-plate (e.g. Schmid et al. 2004). However, some geologists (e.g. Carrulli et al. 1990; Placer 1998) place the structural boundary between them along the S-vergent Southalpine Thrust Front. To the East, the South Alpine Thrust Front faces the Internal Dinaridic lithologies occurring in the frontal parts of the Sava Nappe that can be traced westwards up to the Slovenian-Italian border (Mioč & Pamić 2002).

In previously proposed tectonic schemes (Kober 1952; Petković 1958; Herak 1986), the area between the northeastern External Dinarides, Southern Alps – Periadriatic Line in Sloveni was included in the northwesternmost part of the Internal Dinarides. Kober (1952) referred to this as the «Sava Fold Zone», a term which is still commonly used in Slovenian geology (e.g. Placer 1998). Cousin (1972), Mioč (1984) and Mioč & Pamić (2002) proposed that this zone is largely composed of allochthonous Paleozoic-Triassic units ia a part of the Sava Nappe, which is thrusted over the Internal Dinaridic units. The same zone corresponds with the westernmost extension of the Mid-Trans-Danubian Zone (Fülöp et al. 1987), Zagorje-Mid-Transdanubian Zone (Pamić & Tomljenović, 1998) or the Sava Zone (Haas et al., 2000) interpreted as tectonic assemblage composed of blocks derived from both the Eastern-Southern Alps and the Dinarides as a result of Tertiary (Oligocene-Miocene) lateral extension tectonics (Kázmer & Kovács, 1985; Ratschbacher et al. 1991).

The relationship between the Dinarides and Hellenides is much clearer. This is shown by the fact that all tectonostratigraphic units of the Internal Dinarides continue southeastward into the Hellenides (aldeit here differently named; e.g. Aubouin, 1973; Frasheri et al., 1996, Meco&Aliaj, 2000) suggesting that they must have originated from one and the same oceanic domain, i.e. the Dinaridic-Hellenidic Tethys (Pamić 2002) or the Vardar Ocean (Dercourt 1972; Stampfli 2000).

The boundary between the External Dinarides and non-deformed Adriatic microplate is covered by the Adriatic Sea. The Adriatic-Ionian Zone is positioned between them (Grandić et al. 1997), Dinarides and Carpathians are separated for about 400-500 km by the Tisia Megaunit which represents a large continental block (Fülöp et al. 1987) detached from Europe during the Berriasian (Márton, 2000). The boundary between the Dinarides and the South Tisia approximately coincides at the surface with the with the fault zone of the Sava Depression (Tari&Pamić, 1998). Based on field observation and refraction seismic data, the South Tisia dips to the southwest beneath the Dinarides at an angle of about 10-15^{o} (Tari&Pamić, 1998).

Main thrust structure of the Dinarides

Those parts of the Central Dinarides, which were not disrupted by Oligocene-Miocene strike-slip faulting are characterized by imbricated fold-and-thrust structures that display a distinct southwest vergence (see profile in Fig. 41a). Apart from small-scale tectonic complications, the tectonostratigraphic units presented above were thrusted one on top of the other, with the External Dinarides unit and Sava-Vardar Zone, corresponding to the lowest and the highest unit, respectivelly. This large-scale fold-and-thrust imbricationof the Dinarides formed since Late Jurassic up to Eocene collisional deformational phases.

Deep refraction seismic data indicated that along the transect presented in Figure 3, indicate that the top of the allochthonous basement is located at depths of 8 to 13 km beneath the external parts of the Central Dinarides and at about 8-10 km beneath the Bosnian Flysch and the Dinaride Ophiolite Zone. By contrast, sediment thickness are of order of 3-5 km in southern parts of the Pannonian Basin. Similarly, the crust- mantle boundary rises from about 40-45 km beneath the External Dinarides to 30 km beneath the Dinaride Ophiolite Zone and to less than 25 km beneath the South Pannonian Basin (Fig.41a-Dragašević, 1977; Pamić et al. 1998).

Within the Dinarides the following main large structures can be distinguished (fig.41):

1)The Karst Nappe
2)The Glamoč-Drežnica-Gacko Nappe
3)The Bosnia flysch Nappe
4)The Ophiolite Nappe
5)The Raduša Nappe

6)Tectonic block Mid-Bosnian-Schist Mts.
7)The Una-Sana Nappe
8)The Golija Nappe,
9) The Durmitor Nappe;
10)The Sava-Vardar Nappe

The frontal parts of the thrust-nappe structures can be traced along strike for about hundred kilometres. Each of these thrust-nappe structures unit is internally folded, faulted and dissected by second order thrust about 50-100 km long, which separate part of one and the same tectonostratigraphic unit.

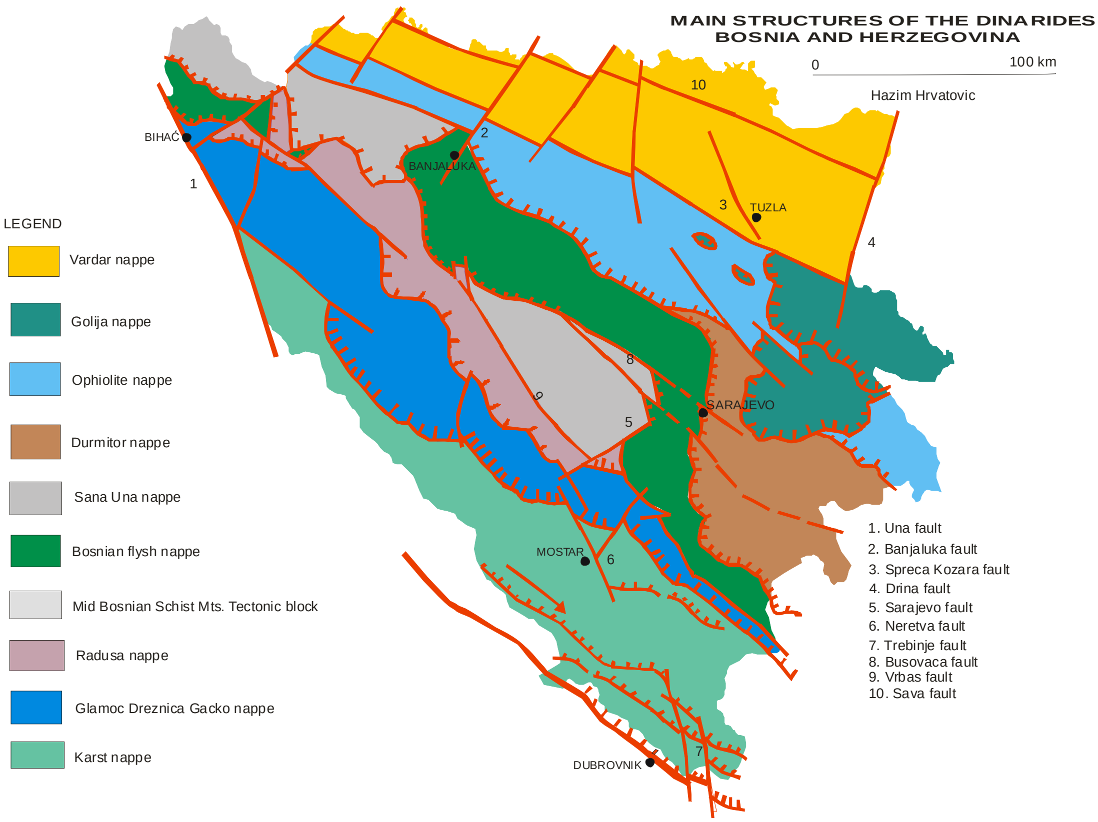


fig. 41. Main structures of the Dinarides of Bosnia and Herzegovina (Hrvatović, 2000)

The Karst Nappet, is the largest thrust sheet of the Dinarides, comprises the entire Dinaridic karst region, and is largely composed of Mesozoic to Early Paleogene carbonate platform sequences. Depeding on authors and regions, this thrust sheet has been referred to by different names. It was thrusted southwestward over the Ionian Zone. However, its sole thrust is largely concealed (Grandić et al. 1997). To the northeast the Karst thrust sheet is overvide by Glamoč-Drežnica-Gacko and Bosnia Flysch Nappes. In the southeasternmost Dinarides, the Karst thrust sheet overlies the Budva Zone which continues into Hellenides as the Cukali Zone (Albania).

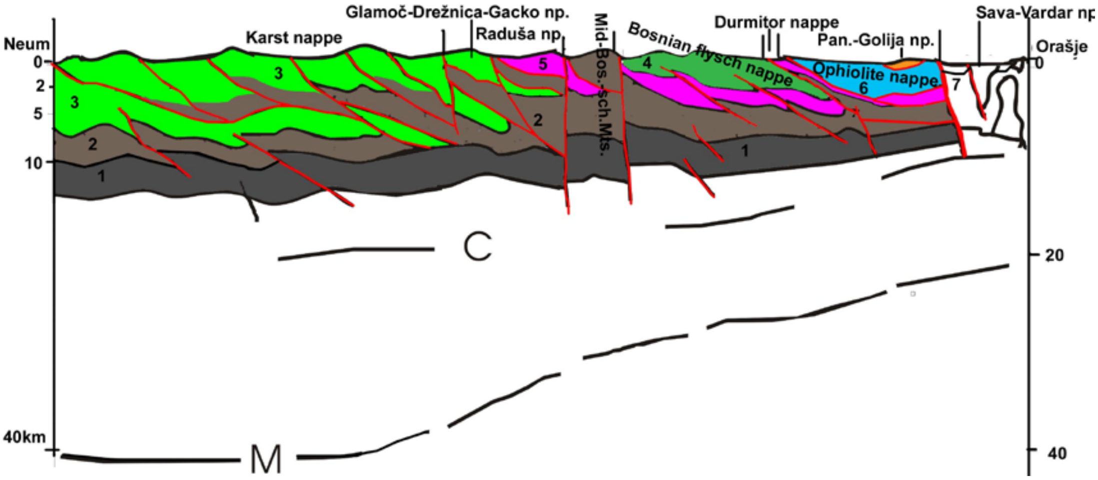


Fig. 41. a. Shematic geological cross-section of the Dinarides from Adriatic Sea to Sava river (Hrvatović, 2003).

1. Consolidated uppermost continental crust; 2. Paleozoic formations;
3. Dinaric carbonate platform (Triassic-Paleogene); 4. Bosnian flysch (Jurassic/Cretaceous; Late Cretaceous/Early Paleogene); 5. Alohtone Mesozoic formations (Internal Dinarides); 6. Ophiolite Zone; 7. Sava-Vardar Zone; C. Conrad boundary; M.Mohorovičić disconitunuity.

The Karst thrust sheet can be subdivided into two secondary thrust sheets, namely: a) the Adriaticum (Herak, 1986) which corresponds to the Autochtonous (Kober, 1952; Petković, 1958) or Gavrovo (Aubouin et al., 1970), and b) Dinaricum, which correspodens to the High Karst Zone (Kober, 1952; Petković, 1958) or Dalmatia Zone (Aubouin et al., 1970). The frontal parts of the Adriaticum extend from Middle Istria in the northwest and southeastward in he Adriatic Sea via Split and is exposed in the Budva Zona.

Dinaricum includes several larger second order thrusts (fig. 42, 43), about 50-100 km long each, the Ljubuški-Leotar in middle parts, and Fatnica-Grahovo in the southeastern parts of Dinaricum. The Dinaricum is cut off by the Skadar-Peć transversal fault and it does not continue into the Hellenides. On the other hand, the Adriaticum continues southeastward in Albania in form of a very narrow zone. On the figure show several second order thrusts in the Dinaricum.

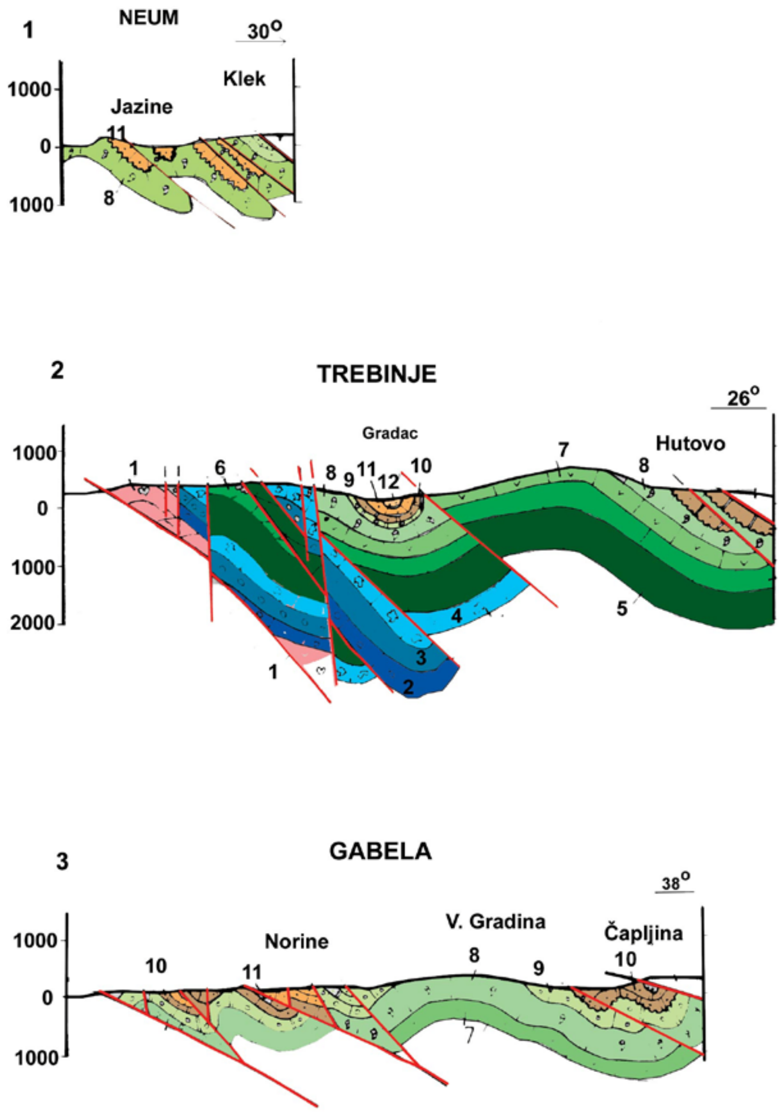


Fig. 42. Geological cross-section second order thrust (South Herzegovina) - simplified after Papeš, 1985

Legend: 1.Late Triassic dolomite; 2. Liassic limestones and dolimites with lihiotis and orbitopslele; 3. Doggerian limestones; 4. Malmian limestones with Clypeinae and Cladocoropsis; 5. Lower Cretaceous limestones; 6. Alb-Cenomanian limestones and dolomites; 7. Late Cretaceous with hondrodont; 8. Rudist limestones; 9. Paleocen-Eocen limestones; 10. Lower Eocene flysch; 11. Lower-Middle Eocene foraminiferal (alveoline, nummulites) limestones; 12. Late Eocene flysch.

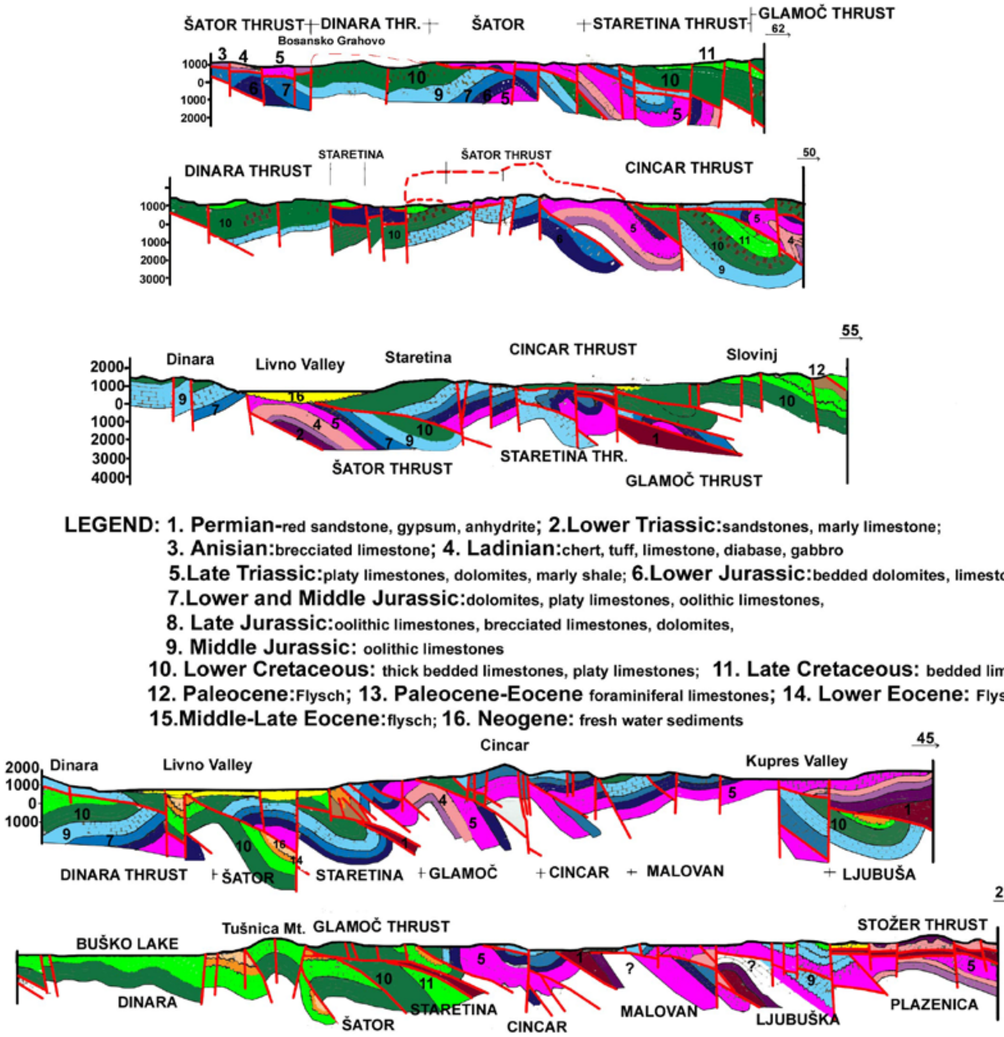


Fig. 43. Geological cross-section second order thrust Southwest Bosnia - simplified after Papeš, 1985

Glamoč-Drežnica-Gacko *thrust sheet is thrusted* over the Karst thrust sheet (fig. 44) and more specifically its Dinaricum part, and, in turn, is covered mainly by the Bosnia Flysch Nappe. In the northwest, the Glamoč-Drežnica-Gacko (part of the Una-Kuči Nappe), which is overridden by the Raduša Nappe, continues further northwestward to Una River.

The Glamoč-Drežnica-Gacko thrust sheet corresponds, at least partly, to the «zone pre-karstic» of the French geologists (Aubouin et al., 1970) and thus it has a transitional position between the External Dinarides. This unit consists largely of Triassic formations in which dolomites and limestones predominate over clastics and igneous rocks.

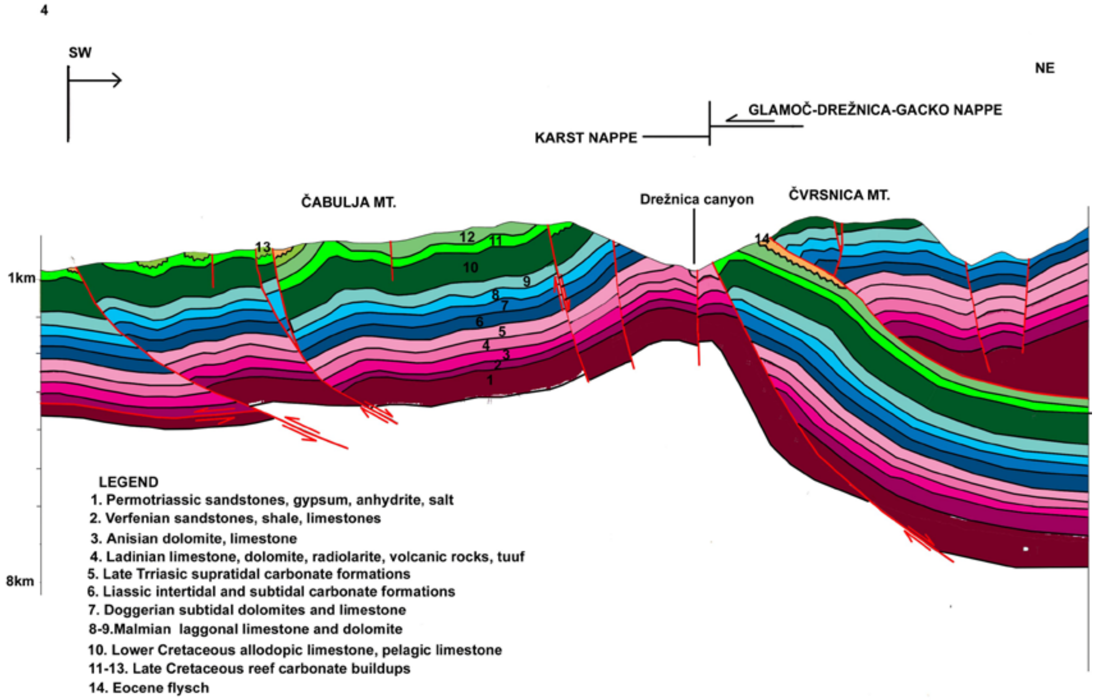


Fig. 44 Geological cross-section Drežnica - Mostar area, (Hrvatović2004, after Mojičević, 1966)

Bosnia Flysch Nappe, involving Late Jurassic to Early Paleogene sediments derived from the Adriatic passive continental margin , is underlain by Una-Kuči thrust sheet. Its southeastermost part starts from the Skadar-Peć fault and this zone extends northwesterward up to the Sarajevo transversal fault. The Bosnia Flysch thrust is best exposed in the Central Dinarides from Sarajevo to Banja Luka where is thrust by the Ophiolite thrust (Mojičević, 1978). The northwesternmost occurrences occur in Slovenija along the frontal parts of the Sava thrust (Cousin, 1972; Mioč, 1984; Mioč and Pamić, 2002) where they extend to the Slovenija-Italy boundary and further westward they join the Southalpine thrust fault.

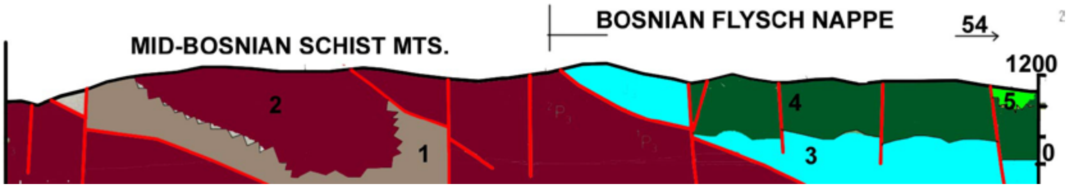


Fig. 45. Cross-section: Mid-Bosnian schist Mts. - Flysch Nappe (Vlašić area, near Travnik) – Hrvatović, 2004

1. Silurian-Devonian metamorphic formations; 2. Permian sandstones, limestones, gypsum and anhydrite; 3. Late Jurassic limestones; 4. Lower Cretaceous limestones; 5. Late Cretaceous flysch (Ugar group)

The *Ophiolite Nappe* is the largest Internal Dinaridic thrust structure (fig. 46). In the northwestern, Dinarides, the Ophiolite Nappe wedges outh in the area west of the Zagreb-Zemplin Line due to Adriatic indentation. In the Central Dinarides, the Ophiolite Nappe is best exposed whereas further southeastward it is covered by the Golija Nappe. In the southeastern most Dinarides, the Ophiolite Nappe joins the Mirdita Zone of Albania and the Subpelagonian Zone of the Hellenides, which in fact represents the southeasternmost extension.

The Ophiolite Nappe which includes oceanic crust of the Dinaridic can be subdivided into: a lower Radiolarite and and upper Ophiolite mélange nappes. Based on its lithology and tectonic position, the Radiolarite unit can be correlated with the Cukali Zone of NE Albania, including the Budva Zone (?), which involve Middle Triassic to Late Cretaceous sequences.

The upper Ophiolite Mélange Nappe can be further subdivided into a lower part that includes the Borje-Konjuh ultramafic massifs of the Central Dinarides, which continue southeastward and join the Western ophiolite zone in Mirdita, whereas the upper parts comprise the Ibar-Kosovo ultramafic massifs of the Southern Dinarides. That southeastward unit (Shallo et al. 1990). The lower part of the Ophiolite melange Nappe overrides the Radiolarite unit and in turn is overridden by the Sava-Vardar Nappe in the north and northeast.

The Sava-Vardar Nappe forms the northernmost unit of the Dinarides can be tracced along strike for about 700 k m, and that continues for a further 700-800 km southeastward into Hellenides. The Sava-Vardar Nappe overlies the Ophiolite Nappe in the north, Golija Nappe in the southeast, and the Pelagonides in the southeasternmost areas. Its southeastern parts are largely covered by Neogene fill of the South Pannonian Basin. The Sava-Vardar Nappe is bounded to the north by South Tisia Block. Field relations and geophisical data indicate that South Tisia dips under the Sava-Vardar

Nappe at a very low angle (Pamić, 1998). Back-thrusting, involving and the Pannonian Basin occurred during the Pliocene (Horvath et al. 1996; Pamić et al. 1998). Further to the south Sava-Vardar Nappe is overridden by the Serbo-Macedonian Massif and further southeastward by the Rhodope Massif.

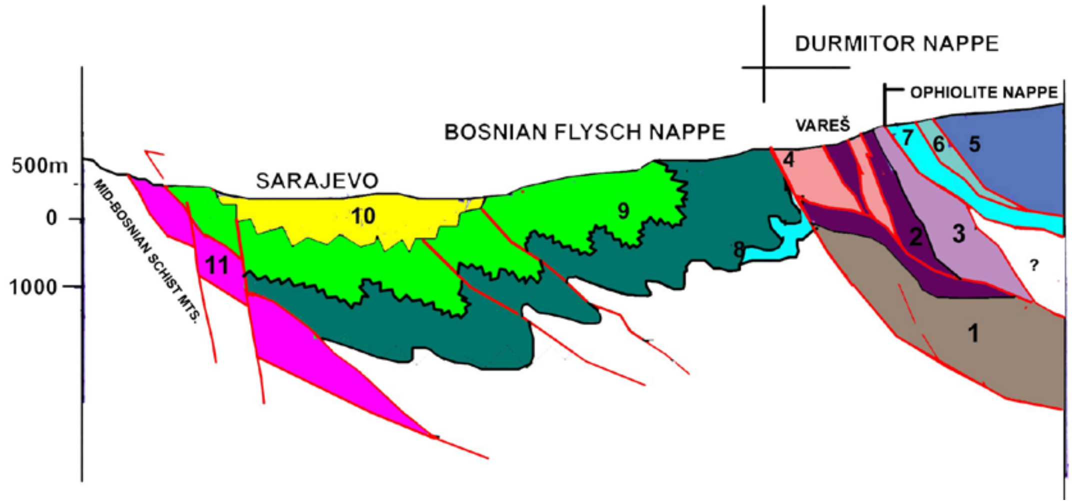


Fig. 46. Cross-section from Sarajevo to Vareš (Hrvatović, 2004)

1. Paleozoic formations from East Bosnia; 2. Lower Triassic siliciclastics sediments; 3. Anisian limestones ; 4. Ladinian chert, breccia, tuff, Fe,Mn, Pb,Zn - ore, limestones:
5. Ophiolite melange; 6. Wild flysch; 7. Base of the Bosnia flysch; 8. Jurassic-Cretaceous paraflysch (Vranduk group); 9. Late Cretaceous-Early Paleogene flysch (Ugar group); 10. Sarajevo-Zenica fresh-water sediments; 11. Triassic formations

The Dinarides include large regionally-scaled nappes, which continue into the North Hellenides. There are t*he Pannonian-Golija-Macedonia and Durmitor-Korabi nappes.*

The Pannonian-Golija-Macedonia Nappe, which can be traced along strike for about 700 km, includes most disconnected Paleozoic terranes of the Internal Dinarides. In the northwestern Dinarides it is represented by the Variscan Banovina (Croatia) and Una-Sana complexes, e.g. the Sana-Una Nappe (Maksimčev&Jurić, 1974), and is included in the Pannonian Nappe (Miladinović, 1974)-fig. 47. In the Central Dinarides it is represented by the Golija Nappe, which is composed of the Drina-Ivanjica Paleozoic formations. Its southeastern extension is formed by the west-verging Macedonia Nappe and continues in the Hellenides where consists of Neoproterozoic units in the Pelagonide and Cambrian to Carboniferous unit in Western

Macedonia.

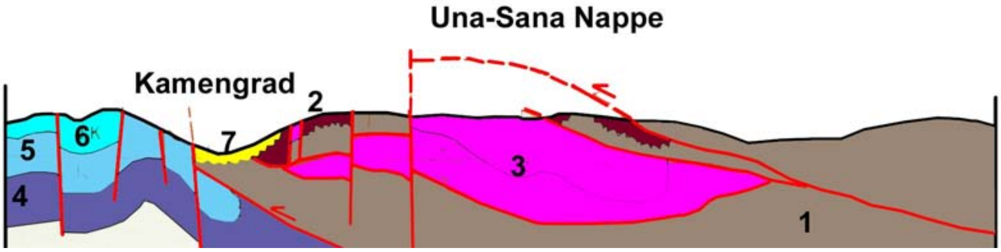


Fig. 47. Geological cross-section Una-Sana area (Hrvatović, 2004)
1. Paleozoic formations Una-Sana; 2. Permian sandstones, gypsum, anhydrite; 3. Late Triassic carbonate rocks; 4. Middle Jurassic massive and bedded dolomites and limestones; 5. Late Jurassic limestones; 6. Jurassic-Cretaceous dolomites and limestones; 7. Neogene fresh-water sediments.

The Pannonian-Golija-Macedonia Nappe probably corespond to the continuation of the Sava Nappe of Slovenia which joins westward the South-Alpine Overthrust (Carulli et al., 1990; Placer, 1998) in Italy. On the other hand, the Pannonian-Golija Nappe continues southward in the Hellenides, and taken as whole, represents a first order tectonic element that is, about 3000 km long, as alredy hinted by Miladinović (1974). It parallels the suture zone between Tisia-Moesia and Adria (Fig. 1).

The Durmitor Nappe, which is characteristic for the southeastern Dinarides, is composed largely of Triassic carbonates accompanied by subordinate clastic, siliceous and igneous rocks. However, it also includes the Foča-Prača Paleozoic complex of southeast Bosnia, the Lim Paleozoic-Triassic complex of Montenegro, and its southeastern extension, e.g. the Korabi Zone in North Albania (Pamić&Jurković, 2002; Meco and Aliaj, 2000).

The frontal parts of the Durmitor Nappet, which tectonically overlie the Bosnia Flysch Nappe in southeastern Montenegro, can be traced southeastward up to the Skadar-Peć fault. In its northeastern extension the Durmitor Nappe up to the transversal Sarajevo fault whose sigmoid shape defines its northwestern branching; further to the northwest it terminaties overthrusting the Dinaride Ophiolite Nappe (fig. 46).

The small Raduša Nappe, has an ambigous position(fig. 48). It was separated in the Central Dinarides. The Raduša Nappe, which can be traced along the NW-SE strike for ca, 150 km, is thrust over the Sava-Kuči thrust into in to the south whereas in the north it underlain along its northeastern margin by the Bosnia Flysch Nappe, whereas its frontal parts overridde the Glamoč-Drežnica-Gacko Nappe.

The southwestern part of the Raduša Nappe are composed largely of Triassic carbonates and subordinate coeval clastic and igneous rocks, and scarce Permian sediments. In its frontal parts commonly expose Middle/Late Permian evaporites which probably lubricated its basal thrust plane.

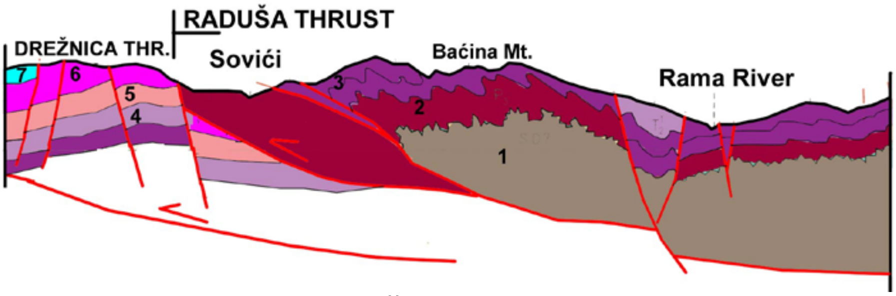


Fig. 48. Cross-section Raduša Nappe (Baćina Mt. Area) – Hrvatović, 2004

1. Silurina-Devonian metamorphic formations; 2. Permian sandstones, gypsum, anhydrite; 3. Lower Tirassic siliciclastics sediments; 4. Anisian limestones; 5. Ladinian chert, tuffs, limestones; 5. Late Triassic carbonates; 6. Lower Jurassic carbonates

In the northern part of the Raduša Nappe is joins the Paleozoic complex of the tectonic block Mid-Bosnia Schist Mts. These are bounded to the southwest by the longitudinal Voljevac fault which is a young structure that developed during Tertiary srike-slip faulting, by reactivation od a thrust.

Main fault structure

Thrust structure are cut by Voljevac, Busovača, sarajevo, Spreč-Kozara, Neretva, Una, Drina and other faults.

<u>Vrbas-Voljevac fault</u> defines the southwestern part the Mid-Bosnian Schist Mts. This very significant dislocation stretches from Prozor in the southeast towards the northwest in the Vrbas Valley and in the area south of Banja Luka it terminates jointing the northwesternmost part of the Busovača fault. The Vrbas-Voljevac fault zone, strecthing NW-SE, is a few hundred wide as recognized by satellite and aerophotos. Thi dislocation separates Paleozoic formations of the Mid-Bosnian Schist Mts. from surrounding Mesozoic, mainly carbonate rocks. The fault zone is partly covered by post-orogenic Neogene sediments of the fresh-water Bugojno Basin. In Triassic sediments spatially related to the Vrbas-Voljevac fault zone, volcanics of Triassic spilite-keratophyre association are very common. In these Triassic formations the mineralizations of barite, tetrahedrite, Au, Hg, Cu and quartz are found. It is very probable that this large dislocation originated by Oligocene transpressional strike-slip faulting, and it is also probable that it was reactivated during the subsequent Neogene tectonic phases.

Busovača fault defines spatially the northwestern boundary of the Mid-Bosnian Paleozoic complex toward the Neogene Sarajevo-Zenica Basin. This large fault located between these two different geological units is easily detectable on satellite images and aerophotos. The Busovača fault can be traced along strike from Ilidža nearby Sarajevo to the Travnik area where is partly covered by the Mt. Vlašić thrust parth of the Bosnia Flysch Nappe); in the northwest it terminates at Mrkonjić Grad.

Along this fault numerous mineral and thermomineral water spring occur as wellas various mineralizations (quarzt, barite, Cu, Fe, Au). The fault predisposed the generation of the intramontane Sarajevo-Zenica neogene Basin. It is characterized both by vertical and horizontal movements. Along the margin of the Sarajevo-Zenica Basin vertical movements up to 1500-1700 m were registred. These vertical movements were accompanied by significant horizontal movements, when longiotudinal transpressional faults originated. Comparatively mild diagonal long folds found in the Miocene fresh-water Sarajevo-Zenica Basin might have originated due to dextral movements of the basinal flank of the Buusovača fault by horizontal strain activity (Hrvatović, 1997).

In the area between Busovača and Kiseljak the existence of the Busovača fault was suported by geophisical prospecting data (magnetism and gravimetry). These data indicate that the Busovača fault represents a dislocation zone dipping towards the axis of the Neogene Sarajevo-Zenica Basin. In the area of Ilidža, Kiseljak area and Klokot spatially related to the Busovača fault, in basement were penetrated by deep wells Triassic limestones and dolomites, and pre-Devonian metarhyolites and metaclastics. In most of the deep-wells flow-fluxes of gas and thermomineral water were registered.

Sarajevo fault stretches in NE-SW direction which is perpendicular to the NW-SE strike of the Dinarides. It can be traced from Konjic on the Neretva River in the southwest up to Mt. Sarajevo Ozren in the northeast were is covered by the Paleozoic-Triassic nappe. It is very probable that it joins the Drina fault in the northeast and the Neretva fault in the southwest. The Sarajevo fault runs along the southeastern boundary of the Mid-Bosnian Schist Paleozoic-complex. Combined creation of this fault and the Busovača fault predisposed the generation of the Sarajevo-Zenica intramontane depression susequently filled by Neogene fresh-water formations. The Sarajevo fault also disrupted surrounding Triassic formations and the formations of the passive continental margin.

Neretva fault which approximatelly has N-S direction, transects the complete Mesozoic carbonate platform sequences that are perfectly exposed in the Neretva valley. This is a few kilometre deep fault as indicated by the occurence of Scythian clastics detached from basement.

Drina fault stretches along the Drina Valley area where subsided rocks of its western flank.

Spreča-Kozara fault represents the northern boundary of the Dinaride Ophiolite Zone which predisposed generation of the South Panonian margin. In parts of the dislocation konwn as the "Spreča Depression" in the area between Doboj and Živinice, it is morphologically characterized by a system (sub) parallel faults forming, as a whole , a the regional fault zone. On satellite images the zone can be traced from Doboj to Derventa and the Slavonija Mts. in the west and along the margins of the Mts. Javor and Romanija in the east and further eastward up to Drina and Užice in Serbia.

Along this fault vertical displacement up to 2000 m were registered. Along its strike occur numerous mineral and thermomineral water springs and various kinds of mineralization (Cu, Pb, pyrite and others).

Una fault , first described by K. Šikinić (1964) and Chorovicz (1969), was at the beginning identifed in the Una River Valley where is easily recognozable in relief in the Martin Brod-Ripač-Bihać area. This is a deep fault which reflects in structure of this part of the Dinarides. Along its strike geological formations spanning between late Permian and Late Cretaceous with spring of the mineral and thermomineral waters can be found. Its eastern block was affected by younger tectonism.

Banja Luka fault stretches along the Vrbas River Valley towards the sava River in the north and further northward transects the Slavonian Mts. and continues in Hungary and, thus it has a regional significance. In River Vrbas Valley parts its western block subsided which gave rise to the creation of the Quaternary Lijevče Polje Depression. The Banja Luka seismogenic zone is apparently related to these tectonic movements.

Other faults comprise a large number of faults identifed both in the fild and aero-photos.

In the carbonate platform (External Dinarides) occur NW-SE striking reverse faults which mark Paleogene structutres of the area of Posušje, Široki Brijeg, Bileće and Trebinje. In this group are included longitudinal faults which predisposed generation of Tertiary depression, i.e., the intramontane basins, as well as the transversal faults in the area of Drvar, Glamoč, Čapljina, Mostar, Ljubinje and Trebinje.

In North Bosnia along the northern margin of Mt. Majevica is important a fault with E-W direction which controlls uplift of this mountain.

Fault structures are of a particular interest from the point of view of seismic activity. Based on seismic and seismotectonic data (Janković, 1987) concluded that, among tectonically active faults, seismologically the most active are the Banja Luka fault and Spreča-Kozara fault, particularly the parts of their mutual crossing.

Seismicity

Acording to the representation of the seismicity status event (historical, instrumental from 1901 to 2004) and to the 4 categories of focal depths, the earthquakes are grouped in table 2.

Table 2

Earthquakes epicentres from 1901 to 2004 years					
		Foacl depth (km)			
Number of event	Magnitude	0-10	11-20	21-30	>30
2	>6		1	1	
10	5,6-6,0	3	4	2	2
14	4,6-5,0	6	4	2	2
78	4,6-5,0	48	16	10	3
162	4,1-4,5	125	29	13	3
406	3,6-4,0	363	38	4	1
118	3,1-3,5	108	6	2	22
Total:790		653	92	34	11

Acording to the classification of epicentres earthquakes, there are a few epicentre areas:

- The area of North Bosnia with Banja Luka is characterized by intensive seismic activity (magnitude 6,4), followed by area of Tuzla, Derventa and Skelani.
- The area of Central part of the Dinarides (Jajce, zenica-Žepče, Sarajevo, Treskavica and Prača. The most intense earthquake is registred on Mt. Treskavica (magnitude 6,0).
- The area of External Dinarides (carbonate platform) where is a series of epicentres earthquakes in areas: Ljubinje-Stolac-Mostar-Široki Brijeg; Trebinje-Hutovo Blato-Ljubuški–Tihaljina; Trebinje-Bileća-Gacko and Tomislavgrad-Livno.

Sesmic activities are associated with deep faults; strikie-slip faults and reverse faults (fig. 49)

Seismotectonic activity

The area of Bosnia and Herzegovina is located NE from active compressional geotectonic contact between the Adriatic mass and the Dinarides. The Adriatic mass, as part of Africa, is impressed between Apenines and Dinarides along strike-slip active faults. Earthquakes recorded in the part of the Dinarides of Bosnia and Herzegovina is originated by relase of energy from subduction of Africa and Evropa plates. This energy, as a primary source of the tectonic energy, are delivered as a seismic energy over the seismogene structures (Fig. 49; table 3).

According to the activities during tha last 100 years, the Bosnia and Herzegovina was divided into 5 seismogene zones and 57 potential seismoactive structures (Fig.49, table 3). Their lengths are between 6 km to 40 km.

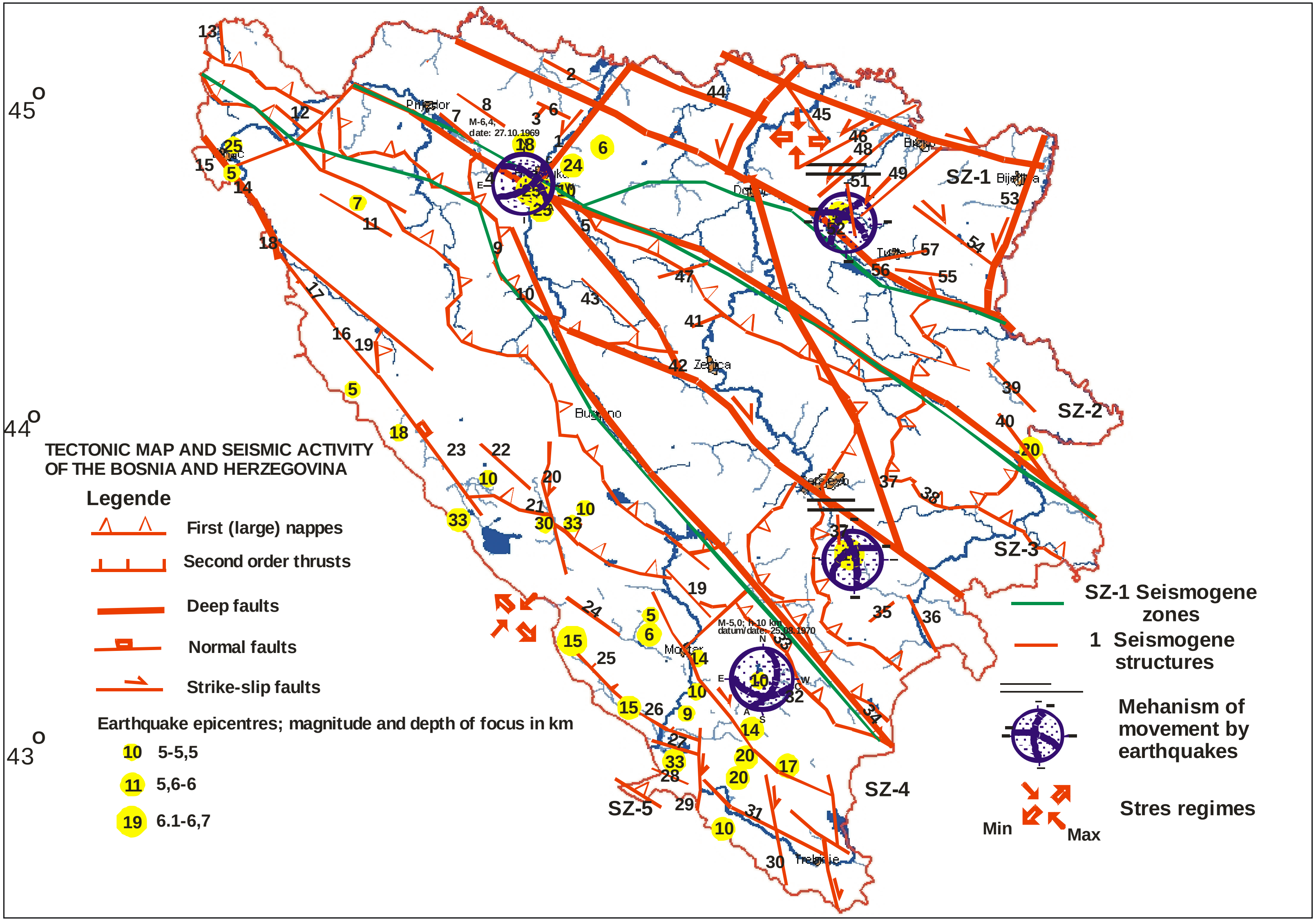
Comparing the tectonic data with recorded epicentres of earthquakes, it is obvious that there ia a mutual between tectonic structures and earthquakes. On the basis data it can concluded that the stronger seismic activity occurs at the boundaries of geotectonic units (directions NW-SE), then along the longitudinal dislocation (directions NW-SE), at the intersections of transversal faults (directions NE-SW and N-S).

Seismoenergetical capacity of the seismogenetical structures (table 3)

Nr.	Name	Length(km)	Magnitude (M)	Depth of focus-h (km)	Intensity in epicentre I_o-MCS^o
1	Banja Luka	40	6,6	18	9,0
2	Laktaši	40	6,5	10	9,0
3	Dragočaj	38	6,4	10	9,0
4	Banja Luka-Prijedor	36	6,3	15	8,5
5	Bastasi	8	4,5	20	5,0
6	Laktaši II	19	5,5	10	8,0
7	Prijedor	5	4,0	10	5,5
8	Kozara	9	4,7	15	6,55
9	Sanski Most-Vrhpolje	11	4,92	10	6,55
10	Mrkonjić Grad	25	5,9	10	8,3
11	Bosanski Petrovac	9	4,5	10	6,1

12	Bosanska Krupa	8	4,5	10	6,25
13	Cazin	8	4,5	10	6,25
14	Bihać	12	5,0	10	6,25
15	Klokot	13	5,0	10	7,15
16	Ključ	15	5,3	10	7,45
17	Grahovo	15	5,1	15	7,2
18	Osječenica	19	4,8	15	6,55
19	Dinara	40	4,8	15	6,75
20	Kupres	10	4,8	10	7,0
21	Duvno	13	5,1	15	7,5
22	Livno	10	5,1	10	7,3
23	Buško jezero	10	5,0	10	7,2
24	Posušje	10	4,6	15	6,4
25	Tihaljina	10	6,0	15	8,0
26	Ljubuški	27	6,0	10	8,8
27	Široki Brijeg	8	4,5	10	6,5
28	Hutovo	10	5,0	15	7,0
29	Stolovi-Slano	15	4,8	10	7,0
30	Trebinje	15	4,5	10	6,5
31	Ravno	10	4,8	17	6,0
32	Stolac	27	6,0	17	8,5
33	Nevesinje	10	4,8	6	7,6
34	Gacko	11	4,9	10	7,0
35	Zelengora	11	4,9	7	7,0
36	Foča	10	4,8	7	7,0
37	Treskavica	27	6,0	19	8,0
38	Han Pijesak	20	5,6	6	8,5
39	Milići	10	4,8	6	7,0
40	Skelani	22	5,7	6	8,5
41	Žepče	10	4,8	4	8,0
42	Zenica	10	5,0	10	7,0
43	Travnik	10	4,8	10	7,0
44	Derventa	8	4,6	17	6,0
45	Modriča	15	5,3	8	7,7
46	Gradačac	15	5,3	8	7,7
47	Usora	18	5,5	10	7,7
48	Vučkovci	10	4,8	7	7,2
49	Maoča	15	5,3	7	7,9
50	Tinja-Moluhe	12	5,0	10	7,0
51	Srebrenik	11	4,9	10	7,0

52	Duboštica	7	4,4	7	6,1
53	Bijeljina	20	5,6	10	7,9
54	Sapna	12	5,0	10	7,0
55	Kalesija	18	5,5	10	7,7
56	Živinice	15	5,5	10	7,4
57	Tuzla	11	4,9	10	6,8


TECTONIC MAP AND SEISMIC ACTIVITY OF THE BOSNIA AND HERZEGOVINA
Legende
First (large) nappes
Second order thrusts
Deep faults
Normal faults
Strike-slip faults
Earthquake epicentres; magnitude and depth of focus in km
10 5-5,5
11 5,6-6
19 6.1-6,7
SZ-1 Seismogene zones
1 Seismogene structures
Mehanism of movement by earthquakes
Stres regimes
Min
Max
45°
44°
43°
M-6,4; date: 27.10.1969
M-5,0; h-10 km datum/date: 25.08.1970
SZ-1
SZ-2
SZ-3
SZ-4
SZ-5

GEODYNAMIC EVOLUTION

The best outcrops of Paleozoic and Mesozoic tectonostratigraphic units of the Dinarides are found on the territory of Bosnia and Herzegovina. In the present structure of the Dinarides the Alpine distinctly predominate tectonostratigraphic units over the Paleozoic ones in an approximate relation 4:1.

Paleozoic evolution

Paleozoic complex of the Dinarides are dismembered and in tectonic contact with the surrounding and more predominant Mesozoic-Tertiary formations. Based on the current division of the Europan Paleozoic complexes (Fluegel, 1990), the Paleozoic complex of the northwestern and northern parts of the Dinarides (e.g. Sana-Una and Drina **IN 3**) are included in the Betic-Serbian zone, those of their southern and southeastern parts (e.g. Mid-Bosnian Schist **IN 1**., Mts. and Foča-Prača **IN 3**) in the Noric-Bosnian zone, and those of the South Tisia (e.g. Sava-Drava interfluve) in the Mediterranean crystalline zone.

According to Pamić&Jurković geodynamic interpretation, processes of rifting initiated evolution of the Paleotethys might have started during the Early Silurian, locally in the Cambrian-Ordovician, on a pre-Variscan yet identified basement. The rifting is indicated by the occurrence of metabasalts interlayered in Cambrian-Ordovician metaclastics and in rare alkali-feldspar rhyolites interlayered in Silurian metasediments of the Mid-Bosnian Schist Mts (**IN 1**).

Opening of the Paleotethys started probably in Late Silurian/Early Devonian times and it gave rise to its differentiatio, i.e., the generation of different geotectonic setting which can be correlated with the ones from recent oceans. Shelf area (carbonate platform) originated along the Gondvana margin as indicated by the occurence of Devonian platform carbonates within the Variscan complexes of the Mid-Bosnian Schist Mts.

Based on field relations, stratigraphy and geochronology it can be concluded that the peak of the main Variscian collisional event occurred by the end of the Namurian and in the Westphalian. During this main Variscian deformation earlier protolithic formations were metamorphosed mainly under greenschist facies (in the Dinarides).

It is hard to say if between the passive and active continental margins existed on single opean ocean realm. If it did exist, complete profile of oceanic crust, i.e., the ophiolites was not generated as indicated by lithologies found in isolated Paleozoic masses of the Internal Dinarides. However, in some of these Paleozoic complexes, lydites (cherts) assiciated with metavolcanics are common and they are probably related to the “Visean lydite event” as in the whole Variscian Europe (Ziegler, 1990). But these lydites and metavolcanics occur very frequently redeposited in post-Variscian conglomerates and breccias. And thus, based on lithologies, these Paleozoic complexes might have been generated, at least partly, in ocean realm of the Paleotethys.

In the Variscian Europe Late Carboniferous is characterizied bay large and strong dextral strike-slip and transform faulting and extension that resulted in generation of numerous intracontinental sedimentary basins in which marine to fresh-water sedimentation took place on the continental crust thickened by Variscian orogeny (Ziegler, 1990; von Raumer & Neubauer, 1993). This is also manifested in all post-Variscian formations of the Dinarides characterized by a prominant facies differentiantion as show by: 1) carbonate platform formations, 2) marine clastic-carbonate formations, 3) marine clastic formations grading into red beds (Foča-Prača), 4) lagoonal evaporite formations (Durmitore Nappe), 5) continental-littoral beds (Permian and Lower Triassic clastics sediments).

This is compatible with well studied Permian terranes of the Variscian Europe. Tectonic activity which took place after the main Variscian deformation gave rise to Early Permian regional regression and prominant dextral and sinistral transcurrent faulting in the exhumed variscian orogen. The transpressional faults deeply cut into the Variscian basement, controling and predisposing the origin of isolated basins and local volcanic activity (Ziegler, 1990 and others).

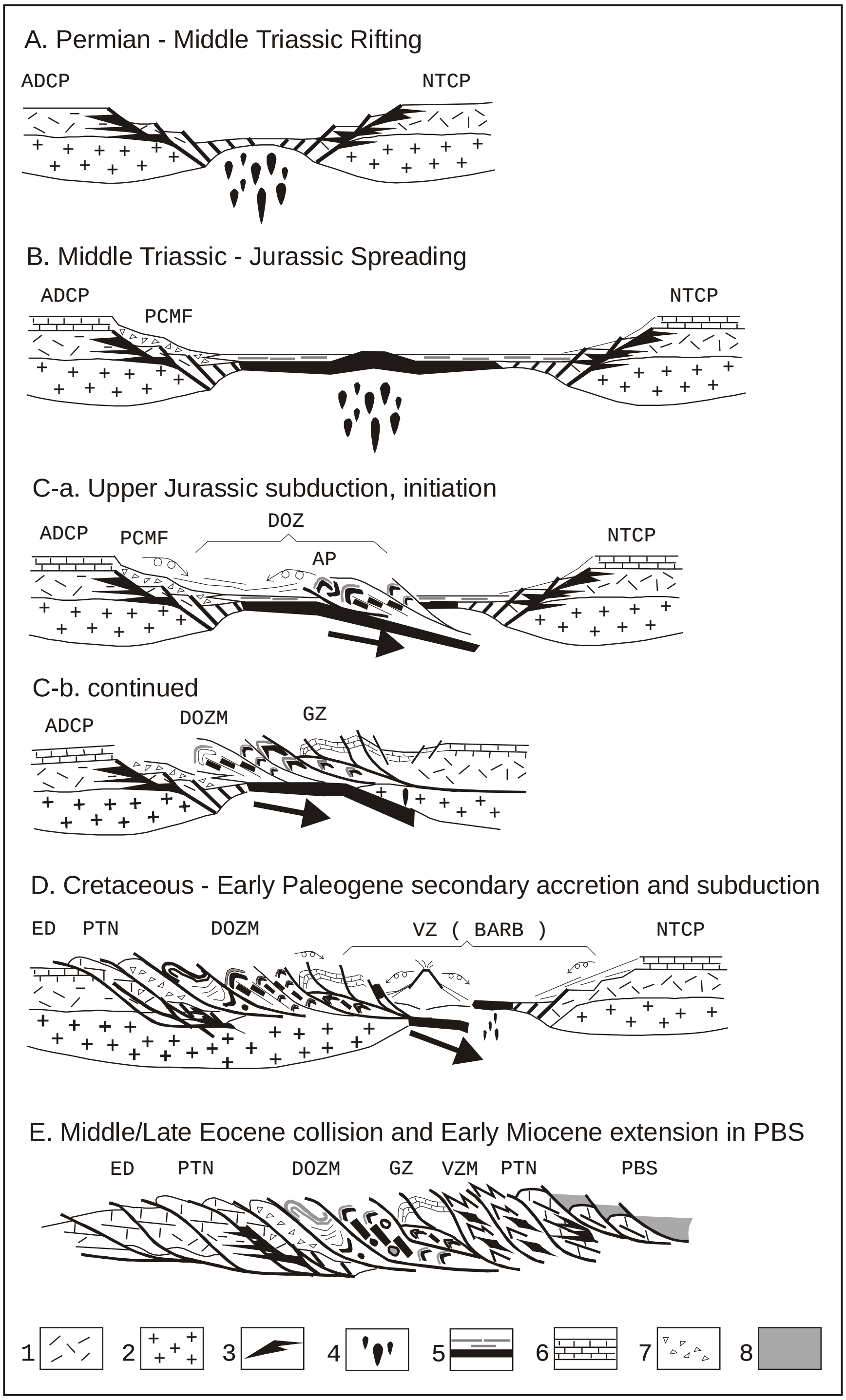


Fig. 49. Tenative graphic presentation of the geodynamic evolution of the Central Dinarides Pamić et al., 2001)

It is extremely difficult to consider the problem of restoration of all these dismemered Paleozoic formations of the Dinarides in the orriginal Paleotethys.

Variscan and post-Variscan formations of Pangea represented the basement on which processes of Alpine rifting were taking place. However, the Paleozoic complexes which originated along the North Gondwana left accreted along the North Apulia during the Late Triassic phase of the Tethyan opening. For that reason it is extremely difficult to evaluate geodynamic evolution of the Paleozoic complexes during the subsequent phases of the Alpine cycle, particularly of those incorporated in the present structure of the Internal Dinarides. These paleozoic complexes included in the Drina-Ivanjica block (Dimitrijević, 1982) or the Golija Zone (Rampnoux, 1970) are thrust with southwestern vergence on the Dinaride Zone ophiolites obducted in Late Jurassic-Early Cretaceous suggesting thus that their roots must have been somewhere northward along the South Laurassia. This Early Cretaceous stacking of Paleozoic-Triassic nappes gave rise to penecontemporaneous metamorphic overprint which, however, did not affect the paleozoic complexes within the External Dinarides and Tisia (Milovanović, 1984; Palinkaš et al., 1996; Pamić, 1998).

Mesozoic-Early Paleogene evolution

The Dinarides have depositional histories, beginning in the Late Permian-Early Triassic with continental rifting and deposition of siliciclastic sediments and restricted marine environment of evaporites and local organic lagoonal mudstones.

These processes might have been related to the inherent instability of Pangea and the global inception of the Gondwana rifting which had taken place after Variscian suturing of Gondvana and Laurassia (Ziegler, 1990). On the Dinaridic carbonate platform and within the Paleozoic-Triassic nappe occur discrete zone, hundred metre long, of Triassic rift-related igneous rocks which mark the traces of rifts transceting the Pangean Paleozoic basement. This rifting activity was possibly accompanied by the development of a large “thermal dome”. At a later stage these rift arches started slowly to subside and that was accompanied by the deposition of clastic sediments, containing in places evaporites. These initial Middle/Late Permian rifting phases are characterized in a few places by very weak magmatic activity. Later, during the Scythian, acelarated graben subsidence was accompanied by an increased influx of terrigeneous material and only in a few places by coeval weak volcanic activity (Pamić, 1984).

The onset of the Anisian was marked by a regional (eustatic ?) transgression resulting in the establishment of exstensive carbonate shelves on the Dinaridic platform as a part of the large Apulian-Taurus platform (Marcoux et al., 1993). Strong reduction in the input of terrigenous material and its subsequent complete termination is the result of a regional transgression.

Magmatic activity peaked during the Ladinian, as consequence of accelerated rifting activity, causing subsidence of probably isolated, narrow basins in which deep-water chert, pelites and micrites were deposited. Synsedimentary, rift-related, volcanic activity, basically of the continental crust orrigin, varied in intensity along reactivated rift faults. On rift shoulders between the basins, carbonate platform sedimentation continued. On uplifted blocks, bauxiteswere deposited durring short periods of their emergence. Along the distal margin of the Dinaridic carbonate platform strong volcanic activity was accompanied by intrusions of plutonic rocks, ranging in composition from gabbro to diorite to granosyenite and granite.

Only in the western parts of the Central Dinarides (e.g. Jajce-Ključ) volcanic activity continued up to the Early Norian. There are no traces of magmatic activity in carbonate platform sequences after the Norian. With this, the Adriatic-Dinaridic carbonate platform and its passive margin were established.

Opening of the Dinaridic domain of the Tethys may have started by the end of the Late Triassic and/or the beginning of the Early Jurassic. It is quite conceivable that the Ladinian-Late Triassic isolated rift basins, located along the Adriatic-Dinaridic platform margin, caused a predisposition for the location of a future sea-floor spreading centre. On the other hand, rift zones located in the platform interior aborted simultaneously. Along the carbonate platform margin, the oldest radiolarite sequences, interlayered with tholeitic basalts, are Middle-Late Triassic age, indicating that in the Dinaridic Tethys pelagic deep-water conditions were established alredy prior the onset of sea-floor spreading, i.e., before the Jurassic.

During the Late Triassic-Early Jurassic, the continental slope of the Adriatic-Dinaridic carbonate platform started to develop. Clastic and carbonate sediments were continuosly deposited along this slope and its margin during the Jurassic and Cretaceous. The carbonate platform supplied the continental slope with carbonate detritus, wheares siliciclastic material was probably derived from a northerly located source area and transported southwardly by turbidite currents as indicated by paleotransport directions. Sedimentary sequences of this passive continental margin interfinger northwestward with penecontemporaneous radiolarite, shale and micrite deposited in an open-ocean environment, indicating intermittent breaks in the sediment supply from the self to the continental slope (e.g. southern flans of Mt. Vlašić).

Sea-floor spreading may lasted in the Dinaridic Tethys over a period of 70-80 Ma, from the Late Triassic until the Late Jurassic/Early Cretaceous. The complete ophiolite profile preserved in the Mt. Varda area nearby Višegrad (Pamić&Desmond, 1989), which is up to 5000 m thick, is similar to the thickness of oceanic originating along modern spreading centres in the present oceans (Coleman, 1977). This indicates obduction of the entire oceanic crust onto the Apulian passive continental margin formations.

It is difficult to model active continental margin of the Dinaridic Tethys because the Mesozoic-Early Paleogene formations of the northwestern Vardar Zone are mainly covered by Tertiary sediments of the South Pannonian Basin. Anyhow, graywackes and shales, and olistostrome melange probably originated durring the Late Triassic (?) and Jurassic/Early Cretaceous on the slope and at the foot of an active continental margin where basic volcanism was also very active as indicated by common interlayering of volcanics with sediments. In the area of the active continental margin, an indented relief with several rises and troughs existed facilitating the operation of the olistostrome mechanism.

Processes of subduction must have started in the Late Jurassic (before Tithonian) as indicated by first ophiolite emplacement accompanied by the generation of “metamorphic sole” composed of amphibolites originated on account of cumulate gabbros and diabase-dolerites. Only locally, high-pressure metamorphism took place as indicated by blueschist fragments included at the base of Late Cretaceous flysch of the northern Dinarides (Vardar Zone). During, the emplacement rocks of oceanic crust were dismembered to various degree and ophiolite fragments were included inolistostrome melange. This strong Alpine deformation was brought about by plate reorganization which gave rise to the northwest migration of the Apulian microplate (Fourcade et al., 1993).

The obducted ophiolites partly emerged, underwent weathering and erosion. The erosion products were re-deposited during Early Jurassic/Early Cretaceous to Late Cretaceous in shoals and depression located between the emerging ridges. The occurence of blueschist olistoliths and pebbles at the base of the Late Cretaceous flysch sequence suggests that rapid exhumation must have taken place during the first post-emplacement period

(Pamić&Tomljanović, 2000). These Late Jurassic-Cretaceous overstep sequences of the northern marginal parts of the Dinaride Ophiolite Zone were not charged by only detritus from adjacent ophiolite terranes but also with enigmate Paleozoic(?) red granites (Pogari Formation) probably from northerly located Euroasian margin.

The influence of the European margin also was strong in the eastern parts of the Dinarides in which the Golija Zone (Rampnoux, 1970), composed of allochthonous Paleozoic-Triassic formations is included. Namely, it is possible, and very probable indeed, that emplacement of this southeast-verging Paleozoic-Triassic nappe of this part of the Dinarides took place during a younger phase of this Late Jurassic-Early Cretaceous deformation. This opinion is supported by the fact that the ophiolites are overthrust by the Paleozoic-Triassic formations which, in turn, are unconformably overlain by fossiliferous Urgon type Lower Cretaceous sediments containing re-deposited ophiolite fragments. This interpretation implies that the Paleozoic-Triassic formations derived from the southern Eurasian margin.

Late Jurassic subduction initiated the gradual closure of the Dinaridic domain of the Tethys and the development of a magmatic arc which axis located north of the obducted ophiolites. In the trenc associated with this magmatic arc Cretaceous-Early Paleogene flysch sequences accumulated. It can be presumed that creation of oceanic crust continued along the arc structure ("secondary accreation") as indicated by Middle to Late Cretaceous ages of the ophiolite fragments included in ophiolite melange. Persisting subduction processes along this arc-trench system were the driving mechanism for continued magmatic activity from a continental crustal source (Pamić et al., 1999). This indicates that continental crustal rocks were also subducted, metasomatically reactivated and thus took part in magma generation. The southwesterly vergence of the Dinaridic NW-SE-trending folds and thrust suggest a north-to north-east dipping subduction.

All these formations genetically related to this narrowed Cretaceous-Early Paleogene formations in the present structure are included in the Vardar Zone. Based on correlation with recent subduction areas and geochemical data this Cretaceous-Early Paleogene arc-trench structure can be correlated with back-arc basins from recent oceans. This back-arc basin probably formed the westernmost part of the huge north Tethyan subduction zone stretching eastwards to Greece, Turkey, Iran and Afghanistan (Camoin et al., 1993).

Next collisional deformation took place in Late Eocene (50-45 Ma) which was accompanied by termination of subduction processes and the uplift of the Dinarides. This phase was characterized by: 1) generation of the Vardar Zone ophiolite melange and second ophiolite emplacement on top of the Dinaride zone ophiolites which were obducted during the first Late Jurrasic obduction, 2) medium-grade metamorhpism of Late Cretaceous-Early Paleogene flysch sequences with accompanying ingeous rocks, and 3) synkinematic granite plutonism. With this Eocene final orogenic phase, the structuration of the Dinarides was completed.

Post-orogenic Alpine evolution

Eocene final deformation gave rise to definitive structuration of the Dinarides and their uplift which in turn caused the separation of the Tethys into the Mediterranean and Paratethys. This initial post-orogenic phases were strongly controlled by Tertiary NNW rotation of Apulia and its indentation into Eurasia. This gave rise a strong N-S reduction of Variscan and Alpine tectonostratigraphic units and its reduction amounting 200-500 km (Ziegler et al, 1996). These processes reflected in a transpressional phase characterized by strong strike-slip, mainly dextral faulting (Laubscher, 1983). In the area north of the uplifted Dinarides these strong strike-slip faulting produced a system of smaller and larger transpressional depressions oriented mainly in NE i ESE directions in which during the Oligocene shallow-to deep-water, marine, brackysh to fresh-water sedimentation took place. Along the North Dinaride margin these dextral strike-slip faulting the incipient Sava and Drava transpressional faults which apparently represent the east-southeastern prolongation of the Periadriatic Lineament and thus a predisposition for the generation of future depressions. The Spreča-Kozara dextral fault is part of this regional dextral strike-slip fault system. This strike-slip faulting was accompanied by penecontemporaneus Early Oligocene volcanic activity which took place not only in northerly located Oligocene transpressional basins but also along the northern margin of the Dinarides (e.g. area of Maglaj and Srebrenica).

Oligocene strike-slip faulting was very active within the whole area of the Dinarides. It manifested in generation of smaller and larger transpressional depressions as precursors of Neogene fresh-water basins. The largest transpressional faults are the Bosovača fault which predisposed the origin of the Sarajevo-Zenica depression and the Vrbas-Voljevac fault which predisposed the origin of some smaller Tertiary depressions (e.g. Bugojno some others). Within the Adriatic-Dinaridic carbonate platform the Oligocene strike-slip faulting produced several larger and smaller karst valleys, as for example, the livno Valley, Nevesinje Valley, Dabar Valley and others. In some of these coarse-grained Promina Beds accumulated as precursors Neogene fresh-water sedimentation.

After the Oligocene transpressional deformation of the area north of the uplifted Dinarides, geodynamic proceses controlling the evolution of the Panonian Basin changed fundamentally. Diapirism of the upper mantle and resulting attenuation of the lower continental crust manifested in epidermal parts in exstensional processes which gave rise to the evolution of the Panonian Basin(Royden et al., 1983). The Oligocene transpressional faults, e.g. the incipient Sava Depression represented sites from which the initial extension commenced.

The Neogene evolution of the South Panonian Basin can be divided in two main phases. In the first synrifting phase, which started in Otnangian-Karpatien (19-18 Ma), first fresh-water and later marine sedimentation with synsedimentary volcanic activity took place. Three volcanic phases can be distinguished: 1) Karpatien with trachyandesites (shoshonites), 2) the strongest Badenian which gave basalts, andesites, dacites and rhyolites, and 3) post-Badenian with alkali basalts. In the Tuzla Basin at that time started marine transgression accompanied by volcanic activity (east Mt. Majevica). Besides nerithic Late Karpatien formation here also occur penecontemporaneous lagoonal salty and mottled continental formations (Soklić, 1978).

Following the Late Sarmatian sea level low stand, sedimentation in the evolving Pannonian Basin was dominated by Late Miocene and Pliocene lacustrine fresh-water deposits (Horvath et al., 1996). This second phase marks the final filling of the Panonian Basin.

Within the uplifted Dinarides, simultaneously with the Neogene evolution of the South Panonian Basin took place fresh-water filling of intramontane basins originated by the Oligocene strike-slip faulting. However, these intramontane basins originated by a pull-apart mechanism. The Neogene fresh-water filling of the intramontane basins took place in humid climatu environments which favored accumulation of large quantities of coals. In the Sarajevo-Zenica Basin, a tectonic phase manifested in marin faultings W-E directed fold structures took place on the boundary between the Koševo Formation and Orlački conglomerates.

However, strong contractional activity occurredat the begining of the Pliocene (5-4 Ma). Reflection seismic data indicate that in the South Pannonian Basin, units of the northernmost Dinarides (Vardar Zone) are thrust over the Tisia block. This change of the lithosphere structure in the area adjoining the South Pannonian Basin and the northernmost Dinarides must have taken place in post-Pannonian times. This is evidenced by the fact that the Late Cretaceous magmatic-metamorphic-sedimentary units of the North Dinarides were thrust in Mt. Požeška Gora in adjacent Slavonia over Neogene sedimentary sequences as young as Panonian in age. More over, fold and thrust structures within the Late Cretaceous-Early Paleogene complex of the North Dinarides display an obvious north vergence as distinguished southwestern vergences characteristic for the Dinarides as a whole. The post-Panonian movements fit with the ideapresented by Horvath et al. (1996) that strong tectonic deformation must have taken place by the beginning of the Pliocene in the whole Panonian basin. This deformation phase is probably the expression of the continued convergence of Africa-Arabia with Europe.

It is likely that during the Pliocene tectonism, wrench faulting played an important role. Thus, it is conceivable that, for example, along the Banja Luka- Našice NNE-SSW-trending strike-slip fault, the Late Cretaceous complex of the North Dinarides was transported northward by about 30 km from its root in the North Dinarides and was thrust onto Neogene sequences of Mt. Požeška Gora.

Large climatic fluctuations occured by the end of theTertiary which terminate by glacial processes. Simultaneously, uplift of the Dinarides is still in progress and they underwent to erosion. At high mountains (Prenj, Čvrsnica, Vranica) numeorus remnants of glaciation were found. Rivers transport detrital material which accumulates in valleys filling terranes affected by subsidence. Karst valleys on the carbonate platform, which represented during the Neogene lakes and swamps, become during the Quaternary which disappear in underground smaller rivers along the SW margin of the karst valleys and again come out along their NE margins. Karst valleys positioned at high altitudes represented the base for glacial processes by which, during the interglacial, karst rivers were filled by huge quantities of glacial detritus.

In the South Pannonian Basin, Quaternary river sedimentation continued. At that time the Tuzla Basin intensively subsides and this was accompanied montain uplift along its margin. Intensity of vertical movements is indicated by the overturned of the Plio-Pleistocene gleyed suite in the Spreča Valley and by the position of alluvial terraces along its margin. The inverse positin of these young formations may have originated by only tangentional pressures during the last Pasedenian tectonic phase.

In Posavina in Brčko area a fault Riasian-Wurmain in age was recorded by deep drilling (Soklić, 1970, 1979). Epirogenic canyons in the Spreča Valley, Modrac at Lukavac and Madjarska Vrata at Doboj originated after third terrace of the Spreča River. The Kreka Basin sinhed by the end of Middle and by the beginning of Late Pleistocene for 37 m as indicated by the diffrence in altitudes of terraces at Kreka in relation to those at the mouth of Soline at Tuzla (Soklić, 1970).

DISTRIBUTION OF MINERAL DEPOSITES

Bosnia and Herzegovina a typical mining country in which numerous mineral deposits and countles occurences of various metallic and non-metalic mineral raw materials are found. Exploration, exploitation and processing of natural mineral resources has a long tradition in Bosnia and Herzegovina, started by Celts, Illyrians and Romans later, to Middle Age Bosnia, Otoman and Austro-Hungarian Empire to present, had been conducted at many places.

The formation and distribution of mineral deposits in space and time are closely related to historical development of various structural elements of the earth's crust. The experience of mining industry had shown that the distribution of mineral deposits obeyed certain regularities such as:

(1) the beltwise, zonal distribution of mineral deposits
(2) association of define types of mineral deposits with magmatics rocks of definite compositions, and
(3) occurence of define types of mineral deposits in define types of structural regions. The global zoning is related principally plate boundaries and other plate tectonic features. The belts of mineral deposits may occur along boundaries of structural units, zones of major faulting, or along presumed large breaks within the basement (lineaments ?).

Deposits related to Adriatic carbonat platform

The carbonate platfomr includes numerous and very significans bauxite deposits genetically related to several hiatuses. The oldest are boehmite or boehmite-diaspore bauxites underlain by Anisian-Ladinian karstified sediments and overlain by Carnian sediments (Mt. Grmač). In the same area, economicaly very important Senonian boehmite bauxites are underlain by Albian-Cenomanian-Turonian limestones and overlain by Santonian-Maastrichtian sediments (Bosanska Krupa and Jajce mining).

Early Paleogene boehmite (hydrargillite) bauxites in the Mostar area (Herzegovina) are underlain mostly by Late Createcous limestones and overlain by Palaeocene-Lower Eocene sediments. In the Mostar area there are economically very important Late Paleogene bauxites underlain by Late Createcous or Early Eocene sediments.

Deposits related to passive continental margin

Passive margin are characterized by thick sedimentary successions along continental margin. Mineral deposits related to these environments are technical stone and thermomineral and minerals waters (Kakanj and Dabravine).

Deposits related to Ophiolite Zone

The Dinaride Ophiolite zone contain economic vein magnesite deposit in the Mts. Konjuh, Ozren, Borje, Čavka and Kozara. All magnesite deposits and occurences of the Ophiolite zone in Bosnia have nearly the same mineral and chemical composition, structure and texture as well as the same mode of occurrence.

Magnesite varying in the degree of crystallinity, is the only major mineral of magnesite deposits. Silica minerals: quartz, chalcedony, and opal. Contry rocks of magnesite deposits and occurrences are for the most serpentinites and only in some places amphibolites and gabbros being commonly in the contact with serpentinites.

Large chrysotile-asbestos and talc deposits formed by granitoid hydrothermal activity, are found in serpentinized lherzolites in Bosansko Petrovo Selo area.

Chromite, low-quality, deposits are found in lherzolites associated with pyroxenites, in Duboštica naer Vareš.

Other mineral deposits found in Ophiolite zone are due to hydrothermal activity (nikl, cobalt and gold associated with listwaenites?, magnesite and weathering nikl-cobalt laterites (Vardište, Živinice).

The diabas masses have been detected inside of Dinaride Ophiolite zone in area of Ribnica and Podgradci. According to the results of the laboratory examinations of stone, aggregates for production of concretes and asphalt concretes for working out of upper bearing leyers of road constructions for all groups of traffic loads, working out of abrasive leyers of roads and highways of all groups of traffic loads.

Deposits related to Durmitor Nappe, Una-Sana and Golija Nappe, and Mid-Bosnian Schist Mts.

This nappe include numerous and different mineral deposits and ore occurences of quartz, quartzite, barite, iron, gold, antimonite, fluorite, gypsum-anhydrite, lead-zinc-barite, manganese, cinnabar and others.

Mineral deposits include the hydrothermal, skarn, sediment, volcanic, metamorphic and residual deposit.

Hydrothermal Deposits are widespread in the volcanic, dominantly rhyolite. They include Sb-Zn-Hg-W quartz veins, gold-quartz veins, gold-bearnig pyrite, mercury-bearing tetrahedrite, barite veins, quartz veins and others. Those hydrothermal deposits occur in Silurian, Devonian and Late Permian rocks of the Central Bosnia (**IN**-1, 2, 4, 5, 25).

Skarn Deposits Mineralized contact endometamorphic low-manganese magnetite skarns are developed around Triassic plutonic bodies (**IN** 19, 20) in the contact zone with carbonate rocks.

Sedimentary Deposits . In Late Permian sediments (**IN** 4) of the Mid-Bosnian Schist Mts and Northwestern Bosnia and Southeast Bosnia are developed anhydrite-gypsum mineral deposite which are economicaly very important.

Volcanic-sedimentary deposits In the Middle Carboniferous are found siderite-ankerite deposits, surficially deeply limonitized and enriched in Fe, are mined in several mines in the Una-Sana area (**IN** 3). This deposits are economically very important.

Metamorphic Deposits In Silurian metasediments in Mid-Bosnian Schist Mts (Konjic area) pyrophylite deposits are found. It is one of the bigger deposits in Bosnia and Herzegovina. Estimated reserves in the deposit of approximately 23 million tons.

Also quartzite deposits in Silurian metasediments are found. Quartz deposits very economically intersesting have been found in the source area of River Vrbas. There are discovered secondary and primary deposits in the total reserve of 10 milion tons.

In the this nappe are related and Rifts deposits. Rift in continental setting may form by continental rupture. Principal mineral deposits occuring in rift-related environments are: Lead-Zinc-Barite deposits and Volcanic manganese deposits.

Lead-Zinc-Barit sulfide deposits includes Vareš mine in the Middle Triassic formations. This is Alpine type deposits. This deposits most commonly occur in sedimentary succesion deposited. In this area are developed huge bedded siderite-hematite mineral deposits in the Middle Triassic formations.

Residual deposites represented manganese and barite deposits. A residual Mn deposit are developed in Middle Triassic sediments of Northwesternmost Bosnia (Bužim area). A significant number of residual barite deposits related to diluvial layers in the Mid-Bosnian Schist Mts.

Deposits related to formations of the active continental margin (Sava-Vardar Zone)

The mineral deposits in collisional zone can be divided into two types: 1) those formed prior to the main pulse of tectonism and 2) those generated as a result of the tectonic and associated metamorphic activity. The ferst group are deposits of convergent boundaries. The second group includes deposits associated with collision granites, dacite and andesite.

Collisional-related magmatism and its hydrothermal activity produced vein silver-bearing and zinc deposits in the area Srebrenica and kaolinite deposits in the area Srebrenica propilitized dacite body and the Mt. Motajica granite.

Granites in this collisional zone content uranium occurrence, area Mt. Motajica.

In this zone occur are thermomineral water which are economically very important (Semberija).

Deposits related to postorogenic intramontane basins

In postorogenic intramontane fresh-water basins several large sub-bituminou coal deposits are found in Central Bosnia (Sarajevo-Zenica Basin), and North Bosnia (Banovići). Large Miocene lignite deposits are found near Tuzla (Kreka coal mine) in the area Mostar and inside several smaller fresh-water basins located on the carbonate platform (Gacko, Livno, Duvno and other). Some of them supply several large thermoelectric power stations.

In the Tuzla area there are large Miocene rock salt deposits consisting of halite. A large quartz sand deposites occur in the Tuzla and Prijedor area. Porcelain and refractory clay deposits are found and exploited in Sarajevo-Zenica and Prijedor Basin.

Deposits related to faults

Mineral deposits related to faults are geothermal system. (Fault Spreča-Kozara, Busovača, Sava and others)

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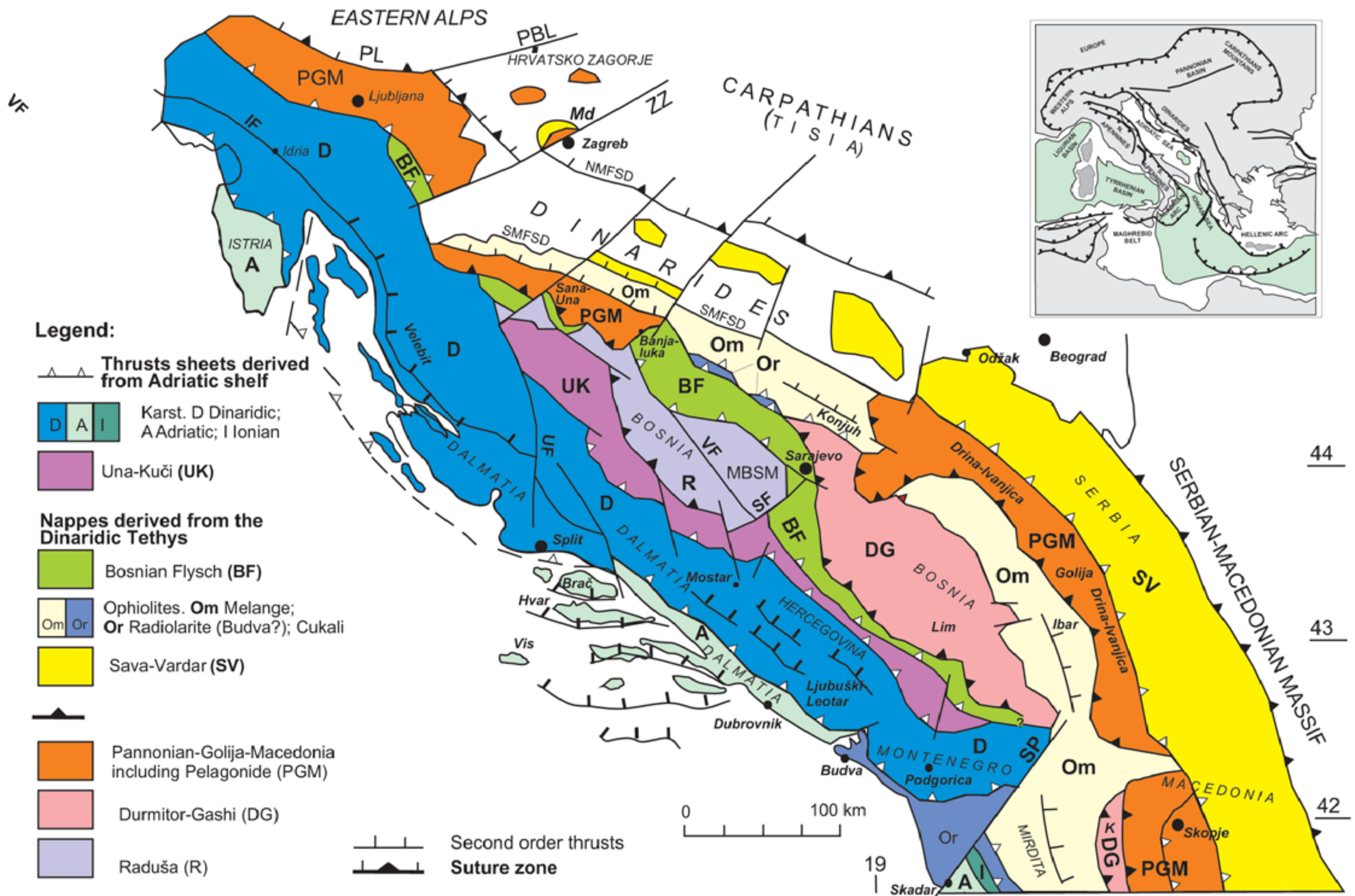

Large faults: NMFSD North marginal fault of the Sava Depression; PL Periadriatic Line; S Sarajevo fault; SMFSD South marginal fault of the Sava Depression; SP Skadar-Peć; VF Voljevac fault; UF Una fault; ZZ Zagreb-Zemplin fault

Tectonic map of the Dinarides (Hrvatović, 2003)