4.2.2. GEOLOGICAL MAP OF BOSNIA AND HERZEGOVINA 1: 300.000; CONTENT AND APPLICATION

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4.2.2.1. Introduction

Geological map of Bosnia and Herzegovina, Sc 1: 300.000 was printed during year 2003. The map synthesized all important data and results obtained during Basic Geological Maps of B&H Sc 1: 100.000 mapping, different special studies and many doctorates and magistrates.

The terrain of Bosnia and Herzegovina consists of different igneous, metamorphic and sediment rock masses, from Silurian to Quaternary age. During evolution of 400 Ma, rock masses went through many changes with different preserved traces of Hercynian and Alpine folding cycles. Basic records, data and results about litho-stratigraphy and tectonic of Bosnia and Herzegovina, overview of Earth lithosphere fabric and general review of map using possibilities in knowledge, scientific and economic necessaries are presented in those papers.

4.2.2.2. Geological structure of terrain of Bosnia and Herzegovina

The Dinarides of Bosnia and Herzegovina belong to Mediterranean Sea region, South branch of Alpines. In the area of 51,129 km^2 different igneous, metamorphic and sedimentary rock masses of Phanerozoic Eon, developed in Palaeozoic, Mesozoic and Cainozoic age are represented.

- ## Palaeozoic periods

Formations of Palaeozoic are consisted in about 9% of territory of Bosnia and Herzegovina. It consists of different stone masses developed from Silurian to Triassic age.

Silurian – Outcrops of the rocks of Silurian age are notified on the left side of Drina River near Ustikolina. They are represented by plane-stratified shale with cherts, phylite shale with ichnophosiles and limestone. From this series, which thickness is 100-300 m, defined are conodonts, which indicates that these sediments were formed in the wider time period from middle Silurian to older Devonian. There are indications about existence of the formation of Cambrian – Orovician age in the outcrops at the village Crvice, left bank of Drina River, but they are still not researched enough or even cartographically classified.

Silurian – Devonian – Different shale, outflows and outcrops of rhyolite, quartzite and limestone, which thickness is up to 800 m, compose terrain of central Bosnia (Vranica, Bitovnja) in the area of about 1,000 km^2. This age is indicated by conodont definition, but at present, without possibility of closer classification.

Devonian – Formations of Devonian age were discovered in the southeast Bosnia around Prača and Goražde, then in Central Bosnia and in the vicinity of Jajce. Lower Devonian

and transitional sediments towards Middle Devonian are composed of limestone with corals and conodonts (G. Vakuf), and series of limestone, dolomite, meta-sandstone, chert and graphite shale (Prača, Šipovo). Thickness of this formation is notified in the wide range from 100 to 700m. Different clastic and carbonate sediments of Upper Devonian are clasiffied in Sana Palaeozoic, southeast Bosnia and river basin of Pliva.

Significant place in geological composition of Devonian of central Bosnia and Jajce surrounding area have rhyolite (quartz porphyry) and spilite and diabase are often represented in SE Bosnia, central Bosnia and Palaeozoic of Sana. Marble dolomites in the surrounding area of Gornji Vakuf and Begova Brezovača are represent even as deposits of very good quality architecture-decorative and building stone which more massive use is predicted during next decades.

Carboniferous– Different, mostly clastic formations of carbon, are represented in four different areas: a) East Bosnia, between Šekovići, Vlasenica and Srebrenica; b) southeast Bosnia, between Foča, Goražde and Trnovi; c) central Bosnia, and in the centre of Bitovnja and Vranica, from Konjic and Prozor to Donji Vakuf; d) west Bosnia, between Sanski Most, Prijedor and Bosanska Krupa. Thickness of clastic complex varies in the wide range, from 100 – 1,000 m. There are indications of Silurian formations in Sana Palaeozoic. Submarine thirls and solid spilite and tuffs are represented, that provided formation of marine deposits of iron ore, mostly siderite, then barite and mineralization of lead, zinc and mercury, at some places in economic concentration. Until now, continuity of Devonian – Carboniferous is proved at many localities. In accordance with previous knowledge, presence of Upper Carboniferous[*] was not notified in BH, so sedimentation of culmian flysch indicates folding and discontinuity of marine settling. It is supposed that carbon sediments were settled in the whole area of BH Dinarides. Their occurrences in four separate areas of Central and Inner Dinarides, are result of strong faulting and breaking in Hercynian and especially Alpine folding cycles.

Permian – Permian litho-facies have wider spread in the structure of mountains Bitovnja and Vranica; classic development of upper Permian is notified in NW part of Vranica, in the area of villages Bojska and Opare as well as in the surrounding area of Travnika. In the area of Bojska they are represented by phyllite with thin seams of limestone in lower and thick-bedded bluish limestone in the upper part. This part corresponds to the level of Bellerophon limestone (P_3^3), which is spread in the area of Kiseljak. Total thickness of these sediments is about 1,400 m.

Outcrops of upper Permian stones are also notified in the zone of Outer Dinarides, around Kupres and Šujica. They are represented by red and violet quartz sandstones, shale marl, porous limestone, breccias, gypsum and anhydrite. The same facies is represented in the terrains of SE Bosnia as a halo around carbon clastic stones in the evolution area from Central to Inner Dinarides. Those sediments are located in the tectonic – erosion discordance towards formations of Carboniferous what confirms break of marine settling and continental stage.

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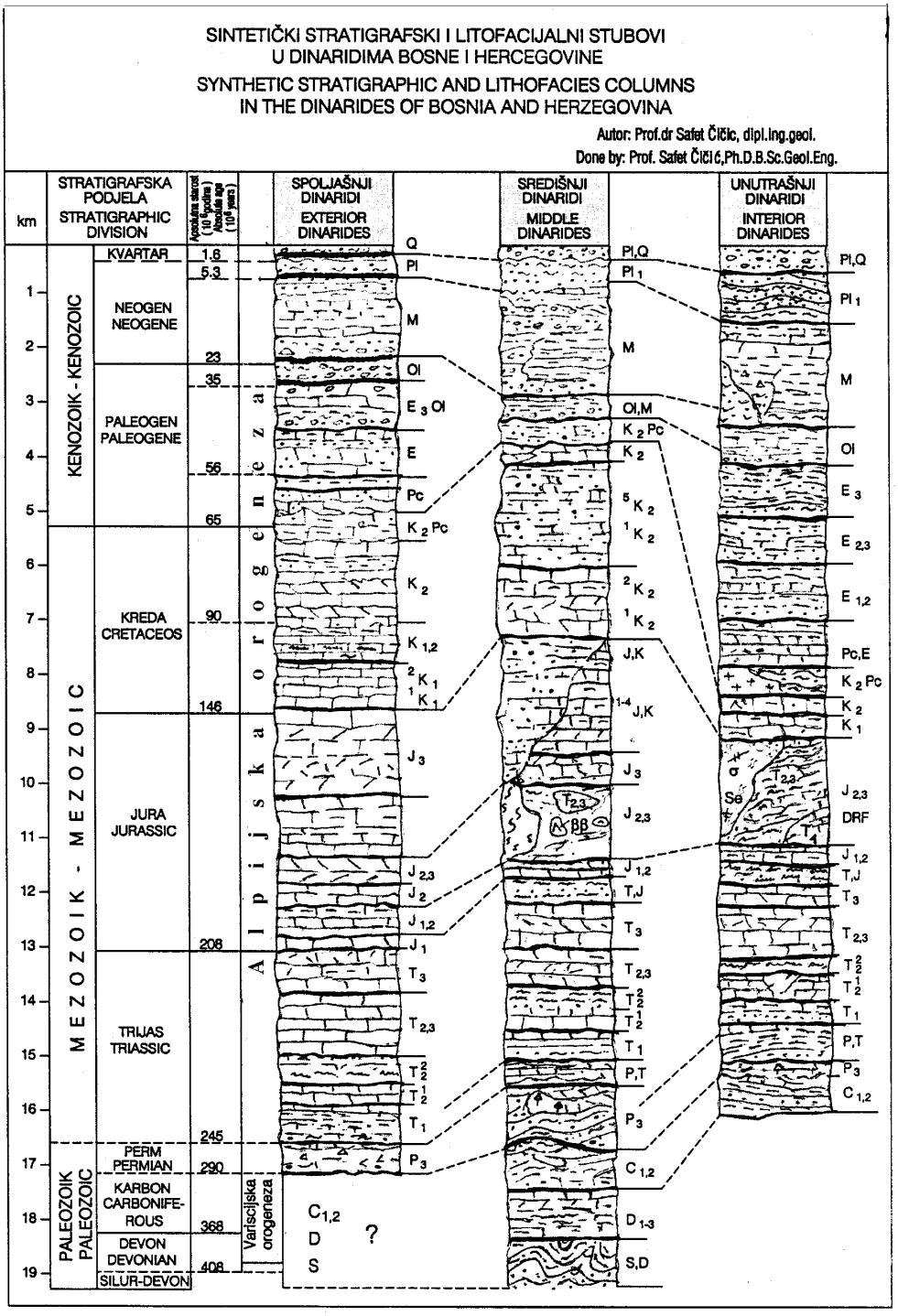
[*] **In the paper of A. Grubić and others (2000, pages 50 - 53) is notified that whole Carboniferous is represented in Paleozoic of Ljubija, mostly in facies of flysch habit and over them, transgressive and discordant, settled are sediments of middle Permian.**



Perm Triassic – in facies of red and violet sandstone and marl, then porous sandy and dolomite breccia limestone, than siltstone and greenish sandstone, is represented in different areas of Bosnia and Herzegovina. Very often with these stones represented are rhyolites, and veins and stocks of diabase and spilite especially in so called Travnik series. Presence of gypsum and anhydrite is characteristic for these sediments, in the series of terrigenous – lagoon sediments. Their evolution into sediments of lower Triassic is gradual. Mentioned statements indicate that Alpine folding cycles started

before upper, possibly in middle Permian what about indications exist. Thickness of Permian Triassic in different localities varies from about 150 to over 1,000 m.

Facts notified above represent that Palaeozoic sediments in Bosnia and Herzegovina are not studied enough, especially from the point of possibilities of more precise litho facies separation and stratigraphic leveling. In that way, future tasks are big and scientifically very responsible.

- ## Mesozoic periods

Different sedimentary, igneous and locally even metamorphic rocks compose over 70% of Bosnia and Herzegovina territory. They are of Triassic, Jurassic and Cretaceous age. As we would see, carbonate stones prevail, what indicates to prevailing lithoral to neritic regime in this part of Tethys.

- ## Triassic

Sedimentary and igneous rocks of Triassic are among most important formations of Mesozoic in BH.

Lower Triassic is, according watery fauna, divided in Seis and Campil beds or is classified on the level of this stage. Its older parts are composed of terrigenous and watery – lagoon sediments and content of limestone with Camplian fauna is increased in smaller scope. Thickness of lower Triassic varies at different localities in the range from 200 - 700 m. All sediments of lower Triassic are characterized with stratification and equalized development what makes parallelisation easier even between distanced localities in Dinarides.

Middle Triassic contains stones of Anisian and Ladinian stage. In the older stage (T_2^1) limestone and dolomites prevail, very often with fauna of all three zones of Alpine orogeny genesis. Thickness varies from 200 – 500 m, and exceptionally up to 1,000 m (Zvijezda, Tara). Facies variety is increased, so in older Ladinian it reaches its maximum. Trog is made through almost middle part of this part of Tethys in that period, which different products are slate, sandstone, chert, marl and limestone, with products of submarine volcanic activities – diabase and spilite, and impressed masses of gabbro and some other base and acidic stones. Over sedimentary – volcanic formations of Ladinian, carbonate sediments that gradually transform into Carnian (T_3^1) are settled. They often, due to absence of watery fossils, could not be classified, so they were classified as products of middle and upper Triassic ($T_{2,3}$), which thickness is 400 - 800 m. In sedimentary –volcanogenic complex, deposit of manganese, mercury, lead, zinc and barites are represented, very often of greater economic importance.

Upper Triassic – besides to mentioned Carnian, in all parts of BH, carbonates of Norian and Rhaetian stage were classified. But, they are not developed in all areas of Bosnia and Herzegovina because in the parts of east Bosnia (Milići, Srebrenica) and in the wider area of Grmeč, during this period, sea regression started, so very valuable deposits of bauxite were made in the dry land stage. Analyses of diffusion of carbonate facies of upper Triassic indicate that mainly dolomites are represented in northwest Bosnia, and in central part dolomites and limestone, while limestone prevails in the southeast parts with subordinating content of dolomites. Thickness of carbonates of upper Triassic is in the range 200 - 800 m.

- ## Triassic Jurassic

In intermediary Triassic Jurassic sediments, chert – radiolarite formation is classified, which is discovered in the band that is wide 1 - 15 km, from west parts of Kozara to

Nemila and Vranduk in the Valley of Bosna River. In finely stratified and intensively folded chert series, there are bands and lenticulars of slate and limestone with small jacks of manganese ore of good quality. Settling of chert series, which thickness is up to 500 m, was synchronized with earth's crust cracking in this part of Tethys and formation of trog where were deposited formations of diabase-chert formation and ophiolite complex.

Finley stratified limestone was classified in intermediary Triassic Jurassic sediments with bends and nodules of chert. Poor remains of certain conodonts and foramnyphers did not, for the time being, provide closer definition of age of these sediments.

- ## Jurassic

Stones of Jurassic age (200 - 140 Ma) compose about 24 % of terrain of Bosnia and Herzegovina. They appear in all parts of our country but with great difference in litho facies development and genesis. It is proved that all three members of this system are represented.

Lias is classified in all three geotectonic zones: Outer, Central and Inner Dinarides. In lithologic composition of Lias limestone dominates with different content of dolomites, marl and rarely chert, slate and phyroclastic stones. Typical localities of development of Lias of Outer Dinarides are in Grmeč, in the area of Glamoč and Mostar (Čabulja, Čvrsnica, Prenj); in Central Dinarides, due to research and development of them, emphasized are localities in Zalomska rijeka, where most complete stratigraphyc analyses of Lias were performed, then in the valley of Sutjeska and tectonic opening of Hrčavka; in Inner Dinarides Lias is mostly represented by red balled limestone and marl; they are better researched in the terrains around Vlasenica, Han Pijesak and Sokolovići on Romanija, in the valley of Lim near Uvac and Ustibar.

Sediments of Lias are mostly concordant to carbon stones of upper Triassic. But, there are local discordances that introduce bigger paleogeographic changes of Dogger. Characteristics of Lias genesis in Dinarides of BH is that in the west parts, especially in Una river basin and SW Bosnia, dolomites often have higher content then limestone. Lias carbonate stones compose floor of diabase – chert formation what is confirmed on many localities in Central and Inner Dinarides.

Lower and middle Jurassic – This item consists classified packages of grey stratified to thick-bedded limestone with bands of dolomites and dolomite limestone. They appear in structure of mountains of Outer Dinarides, from Grmeč to Velež and Gatačka Bjelašnica, with slight changes in litho-facial genesis and habit. Besides to terrains of mountains Ljubuša and Plazenica, they are everywhere concordant to carbonates of upper Triassic. Their thickness is in the range from 300 - 800 m, most often about 450 m. Currently defined paleontological material did not make possible separation of Lias-Dogger carbonate stones. Their stratigraphic treatment was directed by the fact that younger Jurassic sediments lay concordantly over them.

Similar genesis of lias – Dogger sediments was confirmed in structural – facies unit Koprivna – Sanica, in the vicinity of Banja Luka, in the source of Pliva river and in surrounding area of Foča and Ulog in Central Dinarides and near Zavidovići, Han Pijesak and on Ravna Romanija in Inner Dinarides.

Middle Jurassic is classified only in the zone of Outer Dinarides, in the vicinity of Bihać, Drvar, Prenj, Velež and anticline of Lastva near Trebinje. It is represented by limestone with variable content of dolomites, and where were found some watery fossils. Besides

to that, they appear everywhere as middle package in the Jurassic column between Lias and Malm. Thickness of middle Jurassic carboniferous stones is about 400 m.

- ## Diabase – chert formation (DHF)

Formations of DHF are developed in Inner Dinarides, from Bosanska Kostajnica in the northwest to river Lim and Zlatibor. They appear in the area in width of 18 - 70 km, in the length of 275 km. In that frame, they are represented in the area of 9,950 km^2, more exactly 19.5 % of Bosnia and Herzegovina territory. Because of their complexness, litho-facies difference, way of appearance and other specific characteristic, they are the most researched geological formation in Bosnia and Herzegovina, even since the second part of nineteenth century.

DHF is composed of sedimentary, igneous and metamorphic stones. In the group of sedimentary stones, content of sandstone, greywacke and sub-greywacke, slates, marls, cherts and rarely limestone siltstone, quartz –sericite shale and other clastites prevail. On better-preserved profiles, they occur as stratified sediments with silos and outcrops of spilites and diabase. But, they most often occur as mélange, partially formed as sediment of trog, in the first stage of settling or as a mélange formed at the stages of spiring, abduction and/or outcrops of ophiolitic stones. Igneous and metamorphic stones are classified into two groups: a) spilite - diabase - gabbro - granite association, and b) peridotite – amphibolite association.

Stones of the first group appear in numerous localities as outcrops, necks, dykes, silos, and as clastic and olistolite in mélange of DHF. In the surrounding area of Ljubića, Teslića and Višegrad, spilite, diabase and gabbro seize area of 100 - 300 km^2.

Peridotite and amphibolite appear in stone massive in the area from about 10 to over 600 km^2. The biggest stone massives among them are massive of Snjegotina and Ljubići (about 50 km^2), Borje (80 km^2), Čavke (100 km^2), Ozren (300 km^2) and Krivaja – Konjuh massive (> 600 km^2).

For creations of diabase – chert formations of Dinarides of Bosnia and Herzegovina, following general conclusions can be emphasized:

- **DCF is sediment complex that was formed in the sea syncline (trog) where strong submarine volcanic activity had happened and spiring of basite of ocean crust, later abducted into terrains of mentioned ophiolitic massive;**
- **DCF was formed in Dogger and Malm ($J_{2,3}$), what is, besides to superposition, confirmed by fossil definition from several localities. Indications that further creation of this formation continues into lower Cretaceous are insignificant;**
- **Thickness of DHF was evaluated to 600 - 1.500 m, with significant differences in the early stages of this area.**

Problems of genesis, age, structure formation, thickness and other characteristics of DCF will remain for a long time on the top place of scientific studies and research projects, even significant moves and results have been reached especially through performance of General geological map 1:100,000. This is especially related to the terrain between rivers Vrbas and Bosna, Ozren and Krivaja – Konjuh massive and wider area around Višegrad.

Upper Jurassic is classified into three stratigraphic units: a) upper Jurassic in general, classified in the wider area of Grmeč, where is placed transgressively over carbonates of upper Triassic; in the wider area of Banja Luka and in the east Herzegovina. It is

represented by limestone and dolomites, which thickness is 300 - 500 m. b) Oxfordian – Kimmeridgian ($J_3^{1,2}$) stones are great in spread in Outer Dinarides, where are composed of dolomites, limestone and dolomite limestone with watery fauna. Between Olovo and Kladanj, package of breccia, conglomerate, sandstone and marl belongs to this stage and they are transgressive to the DHF. Over them is elipsactinian limestone in gradual transition. Thickness of Oxfordian – Kimmeridgian is 100 - 650 m. c) Kimmeridgian - portlandian ($J_3^{2,3}$) sediments are also represented by limestone and dolomites; in the SW Bosnia (Paklina, Ljubuša and Vran planina) classified are three carbonate packages in total thickness of 2,800 – 3,000 m, and in east Herzegovina (Ulog, Zalom, Gacko) limestone and dolomite of Kimmeridgian – Portlandian are thick about 600 m.

- **Jurassic, cretaceous and cretaceous – alaeocene flysch**

Flysch sediments are classified in three regions: a) Mala Kladuša - Bosanske Krupa - Grmeč; b) Banja Luka - Sarajevo - Kalinovik; c) Rakitnica - Avtovac - Volujak. Total length of this discontinued area is about 320 km, and terrain surface built by flysch is about 4,000 km^2.

a) **It was confirmed in the first region that flysch of Cretaceous (K_2), Senonian (K_2^3) and Cretaceous – Palaeocene (K_2, Pc) age. These sediments lay discordantly over different stages of Triassic – Jurassic carbonates what is consequence of settling stop and later tectonic movements. Flysch complex of Mala Kladuša and Koprivna makes sequences of finely stratified marl and marl limestone, with bends of calcarenite and reddish limestone with chert. Complete sequences of flysch are uncommon. Thickness of these sediments is 400 - 600 m.**

b) **In the terrains between Sarajevo and Banja Luka, on the ground of superposition, paleontological and settling facts, two flysch complex are classified:**

- Older complex of Jurassic – Cretaceous flysch (J_3, K), and

- Younger, Cretaceous flysch (K_2 and K_2^3).

Both complexes are further divided in accordance with lithofacies characteristics what is impossible to present in this short review. They make very difficult complex of sediments in total thickness of up to 3,500 m. They are intensively folded, crinkled, broken and overlapped what can be seen in the Geological map 1: 300,000[*]. Older group of flysch is classified in more details in wider area of Teslić and Banja Luka and in the north of Vareš, between rivers Stavlja and Ribnica.

Younger group of flysch of Cretaceous age have typical genesis in the area of mountain Vlašić, between Banja Luka and Jajce, and in the northeast edge of Sarajevo – Zenica basin. In their facies content of flysch in the area around Banja Luka, two packages are classified: (1) carbonate flysch (2) marl and calcarenites and in the area of Vlašić, five packages: (1) arenite – rudite package; (2) carbonate – marl package; (3) carbonate – marl – rudite package; (4) calcrudite – marl package and (5) marl package. From these sediments, in total thickness of 2,500 m, defined is macro and micro fauna characteristic for Turnian – Senonian ($K_2^{2,3}$) age.

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[*] **More complete insight into facies content, development and structure of these accreatation can be seen in the paper of S. Čičić (2002.), and especially from the interpreter of geological maps of those terrains 1: 100,000 and some other papers notified in the references of literature .**

c) **In terrains between Rakitnica, Avtovac and Volujak, in the area at over 450 km^2, Durmitor flysch is developed. Five packages are developed in it and they replace each other from NW towards SE: (1) base breccia, conglomerate and limestone ($^1K_2$), thick up to over 200 m; (2) limestone breccia and limestone ($^2K_2$), thick from about 100 m to about 350 m; (3) package of different colour stratified limestone, marl and calcarenite, thick 250 - 300 m; (4) sandstone and marl, with subordinated content of microconglomerate, greywacke and siltstone with local higher content of limestone breccia and marl limestone. Those sediments, thick 200 - 350 m, have typical characteristics of flysch, and marl and limestone contain globotruncane, fossils of rudists and others; (5) fifth package belongs to facies of breccia limestone. That is, in fact, typical flysch composed of breccia, conglomerates, limestone and marl limestone. Sequences, thick 2 - 5 m, change rhythmically and contain Inner structure: grading, lamination, byogliphes and others.**

- In NE slopes of mountain Crvanj, discordantly to Triassic – Jurassic carbonates, two packages of Turonian – Jurassic carbonates are classified, and two packages of Turonian – Senonian flysch are also classified: ($^1K_2$) – starting in limestone breccia, over which sequences of breccia limestone, marl limestone with bends of chert, calcarenite and marl alternate, in total thickness of about 500 m; ($^2K_2$) – lays concordantly to previous member; starting with breccia limestone, plane stratified limestone and calcarenite, followed by marl-sandy limestone and marl with phoraminiphers of Turonian – Senonian age. Triassic – Jurassic sediments are folded over them, which, in the shape of relatively narrow crest-like fold, separate them from similar sediments in the valley of Neretva.

Many indications, especially expressive similarity of lithofacies expansion and paleontological content, indicate to the similarity of these flysch and flysch from the surrounding area of Sarajevo. Younger movements, especially Pliocene, conditioned breakage of integrated flysch bends, formed in trog that is sub parallel to rift where is deposited DCF with stones of ophiolite complex. These also marked main research problems of further stage of these studies.

- Flysch of upper Cretaceous is also deposited in the area of north Bosnia, more exactly in Inner Dinarides. Their outcrops are preserved in the terrains from Kozara to Krnin Mountain in the southwest to contact with Miocene sediments in northeast. Newer data indicate that continuous settling was performed on these terrains in the age of Cretaceous – Palaeocene and even further until Oligocene.

- ## Cretaceous

During Cretaceous period, in this part of Tethys, besides to formation of flysch, performed was settling in lithoral, shelf and open seas – pellet regions. Carbonate packages were formed in that way and they are thick about 5.0 km, and they are the best-preserved parts of carbonate platform of Dinarides.

In lower cretaceous, three groups of carbonate packages are usually classified: ($^1K_1$) – lower cretaceous in general: limestone, dolomites, breccia and dolomite limestone. Those sediments are classified in the area in the zone of Inner Dinarides, from Bihać to east Herzegovina, then between Olovo and Han Pijesak and in the river basin of Drinjača. Notified wass thickness of these sediments in the range of 400 - 700 m; ($^1K_1$) – older lower Cretaceous: limestone, marl limestone, dolomites, and breccia and oolitic

limestone sometimes with inserts of sandstone and/or marl. These characteristic sediments have the widest spread in southwest Bosnia and east Herzegovina. They are concordant on clipeinas limestone; deposited in the period of Valanginian – Baremian – Hauterivian; containing watery fauna from that age. Their thickness varies from about 300 - 400 m (Bihać, Drvar) to about 700 m (Vitorog, Hrbljina); ($^{2}K_{1}$) – younger lower cretaceous: limestone, dolomite, limestone breccia, oolythic marl and sandy limestone. Those sediments appear in the same terrains from Grmeč to Popovo polje. They are deposited fro Hauterivian to older Alpine. Their thickness is 200 - 700 m.

Albian – Cenomanian ($K_{1,2}$) includes intermediary carbonate sediments between upper and lower Cretaceous. They are classified in Outer Dinarides from Grmeč to Popovo polje. They are composed of limestone, marl, calcarenite and breccia. Thickness of these sediments varies in the wide range from 200 - 550 m.

Upper Cretaceous (K_2) is the best classified part of Mesozoic carbonates of Dinarides of BH. Upper Cretaceous in general as well as all stratigraphic members from Cenomanian to Senonian: (K_2) – upper Cretaceous in general: limestone, breccia, conglomerates, marl and organogenous limestone (Brdo near Duvno, Paklina, Ljubuša); rudist limestone (Čabulja, Velež); limestone with local participation of calcarenite, chert and conglomerate (Maglaj, Doboj, Gračanica). Thickness of described sediments is about 100 up to over 300 m; (K_2^{1}) - Cenomanian: Limestone and dolomites. They are each classified in the mountain Leotar near Trebinja. However, sediments of these levels are present in the wider area of Outer Dinarides, but they are, due to small area, included within the older ($K_{1,2}$) or younger Carboniferous packages; ($K_2^{1,2}$) – Cenomanian - Turonian: different limestone, of local intrabasin breccia. Limestone with chonrondonts reaches thickness of 460 m (Ljubuški, Cincar) and about 800 m (Dinara). Cenomanian – Turonian sedments have significant spread in east Bosnia. They are most often discordant on Triassic and DHF. Significantly good profiles of those sediments were discovered in the cuts of the road from Kladanj to Tuzla, in the valley of Drinjača (Cerska, Kamenica), Milići, where under them are well known deposits of bauxite, from Vlasenica to Ravna Romanija and Višegrad and near Vardište, where, between DCF and Cenomanian – Turonian carbonate clastic series, known deposits of nickel – iron ores are located. The first package ($^{1}K_2$) is composed of heterogeneous series of conglomerates, sandstone, slate and rarely limestone and chert. Series of limestone and marl of Cenomanian – Turonian ($^{2}K_2$) and micrite that partially belongs to Senonian ($^{3}K_2$) are placed over them. Thickness of these sediments is about 500 m. Turonian (K_2^{2}) is classified in several places from Vitorog to Trebinje and from Velež to Meka Gruda. It is composed of different types of limestone and dolomites subordinately. Thickness of Turoninan carbonates is 250 - 400 m.

Carbonates of intermediary Turonian - Senonian and Senonian sediments have significant participation in the composition of Outer Dinarides. Dominant facies are rudist limestone. In the surrounding area of Livno, they are, however, classified three types of facies: a) white crystalline limestone in the edge of Livanjsko Polje, thick about 450 m; b) breccia, marl, limestone and calcarenites in Dinara and Tušnica, thick about 300 m; c) rudiste limestone, thick 300 - 700 m. They, with slight changes of general habit, appear as the youngest member of upper Cretaceous (K_2^{3}) in the bigger part of Outer Dinarides, especially in their southwest part.

Thick-bedded limestone of Senonian is discovered under Palaeogene sediments in north Bosnia. Their outcrops, as well as bigger masses, are often placed in the horsts of Vučjak, Trebovc and Majevica. Cretaceous – Palaeocene flysch is settled over them,

that was until now, mainly, treated as a product of Eocene settling. Geology map of those terrains will suffer great changes after new systematic mapping and studying, what is very obvious.

Cretaceous – Palaeogene sediments are also classified in SE edge of Gatačko Polje but they are of a small area and poorly studied sediment.

- ## Cainozoic periods

Marine, lake, river and volcanic sediments compose 22% of Bosnia and Herzegovina territory. It is confirmed that they were formed in the parts of Palaeogene, Neogene and Quaternary.

Palaeogene (Pg) in general, thickness 80 - 100 m, is classified near Glavatičevo and Borovčići up to Kruševljani. Certain phoraminephere are classified from limestone that indicate that they are intermediary Cretaceous – Palaeocene sediments. Palaeocene (Pc) is classified only in Vitorog (Čardak Livada) in the core of syncline, composed of series of breccia, conglomerates, marl and calcrudite. Sediments have watery micro fauna; their thickness is about 400 m. Palaeocene - Eocene, is represented by dark grey stratified limestone; it has significant spread from Grmeč to Popovo polje. Limestone is discordant to Senonina carbonates and contact zone is marked by discontinued presence of bauxite deposit. From Teslić and Tešanj to Srebrenik, masses of limestone with micro fauna of Palaeocene and lower Eocene appear, and in Majevica developed are flysch sediments of Palaeocene with gradual transition from Senonian. Later researches presented that part of the flysch deposits from the base of sediments with layers of coal of Palaeocene – lower Eocene age. Thickness of these sediments in north Bosnia is in wide range from about 700 – 1,500 m. Eocene is divided into lower and middle Eocene ($E_{1,2}$); middle Eocene (E_2) and middle to upper Eocene (E_2). These sediments mostly have characteristics of flysch deposits. In Herzegovina, alveolitic – nummulitic limestone continually settled on Liburnian sediments and over that are clastite with characteristics of flysch. Middle Eocene (E_2) is classified in the smaller area around Bihać. This member has much bigger spread in Majevica, where it has characteristics of brackish sediments with thinner layers of bituminous coal. Transitional sediments of middle and upper Eocene ($E_{2,3}$) are developed on both sides of Neretva. Flysch series is of mainly clastic composition with characteristics of flysch, and it lies discordantly over Liburnian and alveolitic limestone. Their contact is characterized by deposits of bauxite, sometimes of significant economic value (Dabrica, Posušje, Tribistovo). Thickness of those sediments is 300 - 600 m. Thick bedded sandstone, marl and slate, with local lenses of quartz conglomerates, are classified in middle and upper Eocene of Majevica and Trebovac. From the upper part of this series, thickness 800 - 1.500 m, spore and pollen are selected (Jasenica), which indicates upper Eocene – lower Oligocene (E_3, Ol). Thick complex of conglomerate, calcarenite and marl is classified into this member in Herzegovina. These sediments are typically developed in mountain, after which they are called Prominian series. Present thickness of Prominian sediments varies from 200 - 600 m (Nevesinje); 900 m (Tihaljina) to 1.300 m (Livno). Oligocene is classified in Herzegovina, near Šujica and Mokronoge, in the north edge of Duvno basin. Besides to basal conglomerate, breccia, sandstone and calcarenite are also classified into its content. Relation of these sediments and basal – floor series of Duvno basin has not been defined yet. Their thickness is about 450 m. Oligocene in mountain Majevica, spread between Gornja Tuzla and Rastošnica, is composed of series of marl, slates, siltstone, sandstone with wavy channels and thick bedded sandstone, which is thick about 700 m. Thin layers of coal are also placed in the

lower part. It is possible that this was a relict of Eocene sea, which it had persisted until lower Miocene when it was classified into a group of salt-water lakes.

Neogene (Ng) is characterized by presence of lake, lagoon, marine, brackish and Caspian-brackish facies. In the wider area of Miocene, in the territory of Bosnia and Herzegovina, swamps and salt-water lakes existed where coal deposits were formed. Lower Miocene (M_1) (Egerian Egenburgien, Otnangien and Karpatian) is the period when the oldest lake sediments with brown coal were deposited. They are the best developed in Sarajevo – Zenica, Banovići and Ugljevik basin. They consist main coal seam that is the best developed in those three basins. In the period of lower Miocene, strong volcanic activities had occurred and they produced dacite – andesite massif of Srebrenica, in the area (with phyroclastite) of about 100 km^2, and tuffs in the east Majevica and Tuzla basin. Lake system continued its existence until the end of Miocene; in three mentioned and more other basins (Miljevina, Mostar, Gacko, Livno, Bugojno, Jajce, Kamengrad, etc.) deposited are different marl limestone and/or clastic strata, often with significant coal reserves, consisted in 1 – 3 seams of brown coal. Lake - lagoon facies are deposited in lower and middle Miocene in Tuzla and Lopare basins. In the first one they are of sedimentary typical lagoon facies (red and banded series) with deposits of stone salt (halite) near Tuzla and south parts of Majevica (Tušanj, Tetima, Lipnica).

Marine facies of Miocene compose north parts of Bosnia, from B. Kostajnica at Una to Kozluk near Zvornik. They are deposited in the south part of Pannonian basin. Classified are marine strata of Baden (reef limestone, streaked marl and, subordinately, clay); brackisc sediments of Sarmatian (thick bedded limestone, marl, clay and conglomerates); Pannonian sandstone, marl, clay, marl and bioclastic limestone, with known Caspian-brackish fauna.

Pliocene (Pl) – Lacustric facies are classified in Livno and Duvno basins in two packages: a) ($^1Pl_1$) older package: clay, sandy marl, coal clay, lignite and quartz sands; b) younger package: coal and sandy clays, thick about 200 m. In upper Miocene, lake depositing process was stopped because of what was older lignite package discordant on lacustric facies. Thickness of this package is about 250 m. It consists 19 coal seams out of which 12 seams are thicker than 1.5 m and have productive value. Exploitation reserves are in mining districts Čelebići and Prolog – Livno basin and Kongora – Duvno basin.

Marine facies of Pliocene are of Pontian age ($Pl_1{}^1$). Different types of clay, marl, lignite seams and quartz sand represents them. Clay and sand is exploited in Prijedor area, and quartz sand and lignite in Tuzla basin; Pliocene deposits of Kreka and Dubrave are characterized by rhythmic development of lignite series: clay – lignite – quartz sand. Four rhythms are classified in total thickness of 1,000 – 1,200 m.

Pliocene sediments with lignite are also developed in Stanari basin, where lignite, marl and gravel are also exploited. Clay, sand, marl gravel has significant spread in terrains between Sava River and mountains in the south. Classic locality is Kadar on the left bank of Sava River.

Plio-quaternary (Pl, Q) – sediments of Plio-Quaternary are deposited in shallow old depression, from Prijedor to Semberija. They are composed of clays of different colours, gravel, often cemented into thick beds of conglomerate, sand and siltstone. Thickness of these deposits is up to 100 m, and in old depressions (Vitanovići, Spreča field, between Živinice and Tuzla) even up to 500 m.

Quaternary (Q) is classified in three groups of facies: glacial, aquatic and slope. The first ones are preserved in high parts of Bjelašnica, Treskavica and Prenj; aquatic sediments belong to sub-aquatic fluviatic, lacustric and swamp facies; in the slope group are diluvial, eluvial, proluvial and slope-aquatic facies. All three groups are characterised by many specific characteristics that is not possible to present in this short review.

4.2.2.3. Tectonics of Bosnia and Herzegovina

- ## General notes

The Dinarides stretch from the northwest towards southeast, from Karavanke to Prokletije, more exactly between peri-adriatic and Peć dislocation zone. They are limited by Serbian – Macedonian mass in the east and Adriatic Sea in the west. Dinarides are huge geotectonic category that, in its bigger part, lays discordantly on the formation of Hercynian folding cycles. They as well as Alps in whole are characterized by specific facies development and tectonics. That is result of long evolution, from upper Permian to Quaternary, during which new sedimentary and igneous formations were exposed to several changes of mainland and sea, stages of subduction and folding, deep breaking of earth's crust and reverse faulting. All of that was happening in continual changing of physical and morphological condition of earth's crust that lasts in the period of about 260 Ma. Original cause of those activities was disintegration of Gondwana mainland and Africa's plate passing under Dinarides, in the speed of 2 - 4 cm/year, what lasts even now. Globally, movement was in the direction from south towards north, with increased intensity from east towards west. That was, according many opinions, main reason for change of direction in the Dinarides trend from primarily east – west to present direction northwest – southeast. That direction is, as presented in Fig. 4.2.2.2, dominant as well as direction of inclination towards northeast as a consequence of Africa's plate passing under Euro-Asian plate and subduction of Adriatic sub-plate.

Territory of Bosnia and Herzegovina in whole belongs to the Dinarides mountain district. Tectonic style and folding characteristic features of those terrains are identical to corresponding demonstration in Dinarides with specific characteristics that can appear in this area, especially considering its location between Adriatic Sea in southwest and Pannonian sediments in southeast.

- ## Geophysical characteristics of terrain

In accordance to results from deep seismic test boring, thickness of earth's crust in Dinarides is the highest in the bordering zone towards Albania where its thickness value is 47.7 km, and the smaller value is in southeast part of Adriatic sea, about 27 km (T. Daragačević, 1980, p. 100). The highest depth up to Mohorovčić discontinuity on the territory of Bosnia and Herzegovina is between Livno and Kotor Varoš (40 - 42 km), and the smallest is from Prnjavor to Derventa and Sava (30 - 25 km). Thickness of sedimentary stone is the highest in the triangle Livno - Čitluk - Jajce (8 - 10 km), and the smallest in the area of Bijeljina and Foča (2 - 4 km). Thickness of earth's crust and sediments cover in the Dinarides of BH is the highest in the zone of Outer Dinarides, while medium heights of terrain is mostly in the zone of Central Dinarides. This is not confirmed by wide opinion of mutually dependant of these factors.

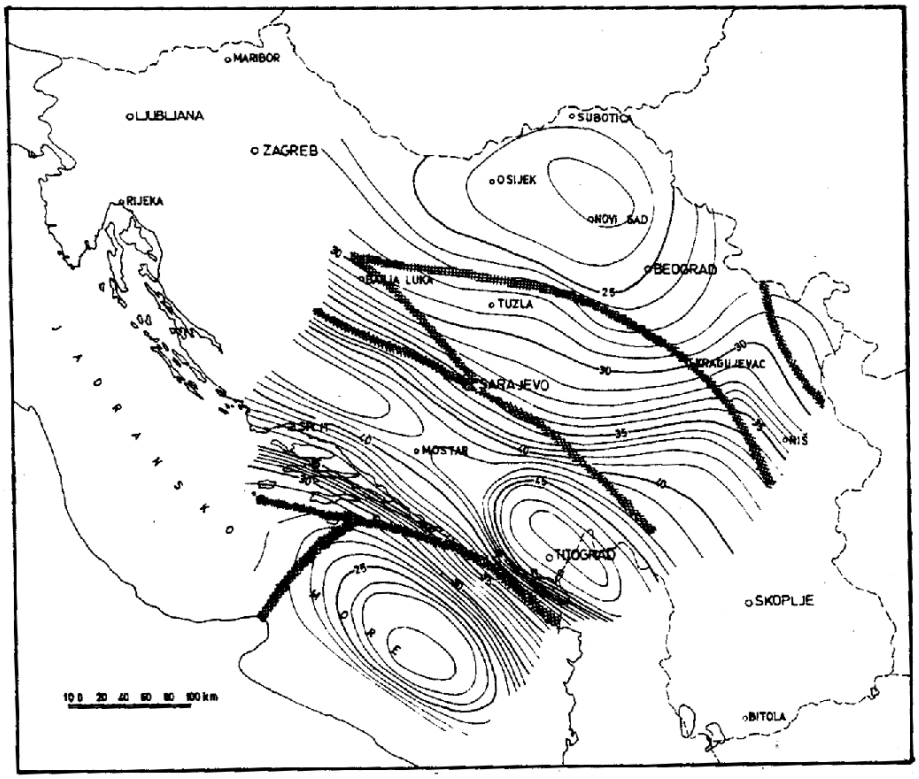

Fig. 4.2.2.1. Map of the earth's crust thickness of the Dinarides according to the DSS results (T. Dragačević, 1974.)

Among the most possible intervals of changes of speed and density in complex sediments of Dinarides, stated are:

Type of sediments	Density (gr/cm^3)	Thickness (m)
Alluvial sediments		1,200 – 1,500
Eocene flysch	2.65 – 2.75	3,000 – 4,000
Older clastic stones	2.65 – 2.75	5,400 – 6,100
Limestone dolomite stones	2.60 – 2.75	4,800 – 6,500
Halogeneous stones	2.95 – 3.00	5,500 – 6,500

Thickness of earth's crust is higher in Dinarides than in the area of Adriatic Sea and Pannonian basin. Thickness is the highest in Outer Dinarides, little less than 50 km.

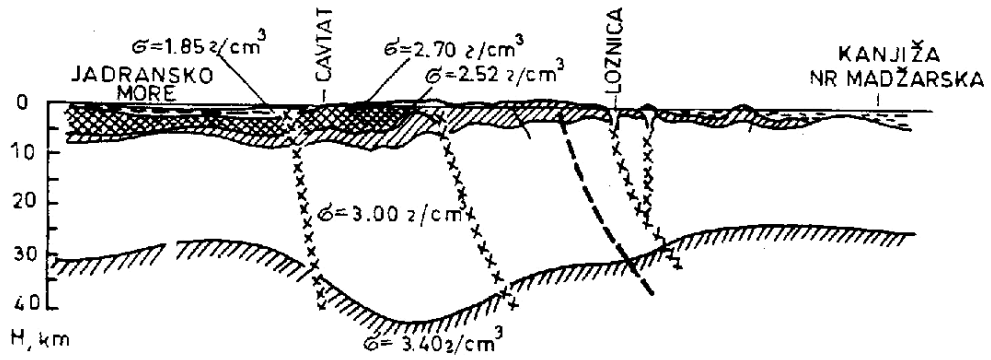

Fig. 4.2.2.2. Seismological cross-section of the earth's crust along the cross- section Adriatic sea - Cavtat - Loznica - Kanjiža, according T. Dragačević (1974.)

Considering problems of composition of earth's crust on the territory of Jugoslavia, Dragačević's opinion was that there are not any grounds for the statements of existence of Beniof zones, where big thickness of earth's crust, what should be expressed by gravimetric minimum of great size. Without denying possibility of rather bigger horizontal movement of blocks, author gives advantage to wavy movement of earth's crust, which in certain zones have gigantic proportions (1974, pp. 69 - 71).

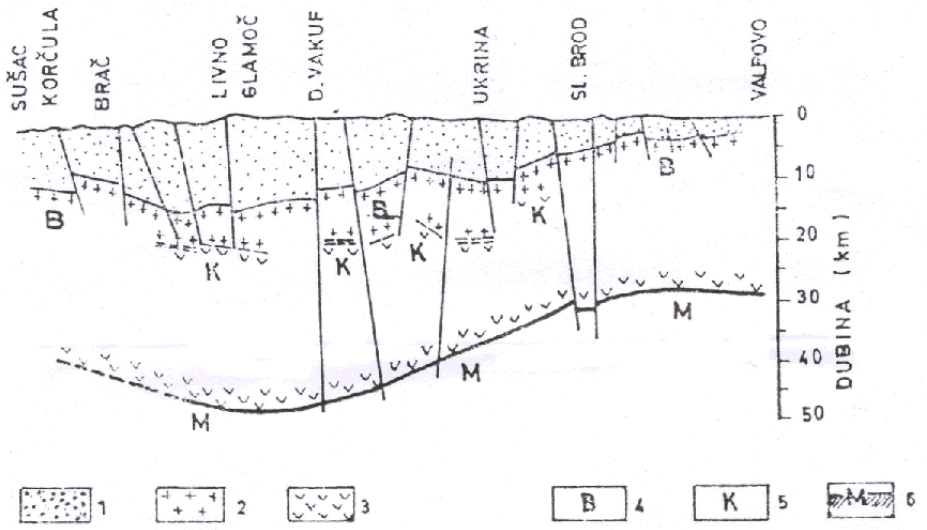

Fig. 4.2.2.3. Geological cross-section of deep seismic recording (Jelić, 1982)
1. Epidermis, 2. Granit layer, 3. Basalt layer, 4. Basement,
5. Conrad discontinuity, 6. Mohorovicic discontinuity

Performing analysis of value increase of heat flow through different geological areas, in dependence of density of stones, Jelić concluded its significant increase regarding the decrease of thickness of epidermis layer more exactly with getting closer to Mohorovčić discontinuity (Fig. 4.2.2.3.). But, and profile of Jelić, that is placed northwest from profile of Dragačević (Fig. 4.2.2.2.), it presents similar trend in morphology of Moho layer and decrease of thickness of epidermis and granitic layer from Adriatic Sea towards Pannonian basin.

- **Deep structure of dinarides of Bosnia and Herzegovina**

In geotectonic structure of Bosnia and Herzegovina we have classified three big units – zones: Outer, Central and Inner Dinarides (Fig. 4.2.2.4.). This kind of tectonic regioning was determined mostly by presence of two great reversed faults: High Karst and Durmitor reversed fault. Face of High Karst reverse fault represent borderline between External and Central Dinarides, and face of Durmitor reverse fault represents borderline between Central and Inner Dinarides.

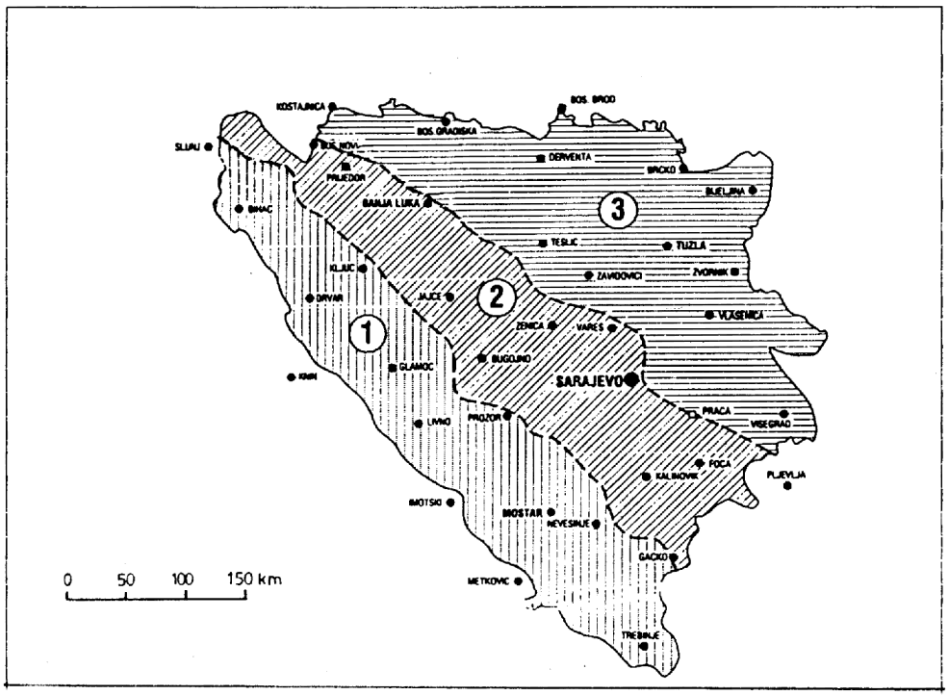

Fig. 4.2.2.4. Geotectonic reonisation of the Dinarides in Bosnia and Herzegovina

1. OUTER DINARIDES: Mesozoic carbonate, Tertiary flysch and molasse. 2. CENTRAL DINARIDES: Palaeozoic clastics and eruptive rocks, Mesozoic carbonate, Jurassic-Cretaceous flysch and Neogene molasse. 3. INNER DINARIDES: Palaeozoic and Mesozoic clastics rock and carbonate Jurassic diabase-chert formation with ophiolitic rock and melange, Cretaceous and Palaeogene flysch and granite, Neogene andesite dacite, and lacustrine, lacustrinelagoonal and marine molasse.

Formation of represented geotectonic structure of Dinarides of Bosnia and Herzegovina, within Dinarides in whole, is a consequence of three paradigms:

a) Formation process of Tethysa during the end of Ordovician and in Silurian, about 450 Ma ago, when those terrains became part of that spacious ocean;

b) Relative continuity of settling and development of this part of the earth's crust through three folding ciclus: Caledonian, Hercynian and Alpine;

c) Performance and crucial influence of geotectonic processes caused by collision and African plate passing under European plate, from Triassic age until the present times.

Stated facts, exact and without doubts, eliminate needs for consideration of this issue within the frame of two previously represented models: fixionism and mobilism. Dynamics in the development of folding, magmatism and settling and their continuity,

are absolutely represented and proved in grater scope during development of Alpine cycles. So, there are elements of fixionism and mobilism, but consequences of movement of tectonic plates, continents, are globally dominant especially in formation of folding structure of Dinarides, and before that in determination of conditions of geosynclines regime, formation of large intrabasins syncline as well as many other circumstances that conditioned and profiled flows of represented geological evolution.

Dinarides are as an entirety moved in the direction of African plate passing under European plate. In that way, formed is great folding structure, with tectonic form of complex fold, which lies down in the direction SW-NE, where three described structures are separate:

- **Syncline of Outer Dinarides,**
- **Anticline of Central Dinarides,**
- **Monocline of Inner Dinarides.**

During Mesozoic and Palaeogene age, especially until from the end of Cretaceous to Miocene, formation of tectonic structure of Dinarides was significant. Dominant folding were followed by deep longitudinal breaking (B. Grahovo - Livno - Trsteno; Vrbaski, Busovački, Sprečko-Kozarački, Modrički, and finally, Sava fault). Because of that processes that also caused formation of Pannonian basin, high mountain structure was not formed here as in Alps and the Great Caucas. Central Dinarides lifting caused strong break of carbonate platform and its erosion in the bigger space. Within the parallel process of Mesozoic formations are subducted in the zone of area of formation of diabase – chert formation, which with all significant characteristics correspondence accretion mass, formed from oceans crust and Mesozoic formations in two contact micro plates in the north margin of this part of Tethys.

Big folds represented in Dinarides of BH, as High Karst, Durmitor, Pannonian, are parts of Dinarides fold in totality. Their faces are opened in the zones of highest pressure and stress, and in zones of lifting where is eroded or where part of sediments of carbonate platform of Dinarides is considerably moved.

Structure of this part of Dinarides is exclusively marked with big cross breaks, like there are: Split - Bihać - Karlovac; Banja Luka; Sarajevsko; Drina and Neretva. They belong to younger Neogene stage of compression and breakage of carbonate platform of Dinarides. They contributed, besides to other things, occurrence of Palaeozoic formations with traces of Hercynian folding in east and southeast Bosnia, central Bosnia and Bosanska Krajina.

Folding stages remain as form for presentation of compaction during this long geological period, without consideration of principles of theory of tectonic of plates. They are not sharply limited, but they are mutually penetrating, mixing with each other, as a part of complete and continual geological process, and their factography, reliability and number are increasing from age to age, from older to younger formations.

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Note: **Notified papers are only the most important used papers. More detailed data is given in references in previously mentioned papers and monograph "Geological composition and Tectonic of Bosnia and Herzegovina " (Čičić, 2003.).**