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# GEOLOGICAL STRUCTURE OF THE ROMANIAN CARPATHIANS

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*Associate Leader: R. Dimitrescu*

**Pre-Congress** **B12**

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# GEOLOGICAL STRUCTURE OF THE ROMANIAN CARPATHIANS


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## Introduction

The fieldtrip "Geological Structure of the Romanian Carpathians" strives to cross the major tectonic units of this segment of the Tethyan Chains, with the purpose of presenting a general approach to the tectonic and paleogeographic (paleotectonic) problems. Knowledge of Carpathian geology allows us to understand the prolongation of the Alps toward the Balkans and the Dinarides. In order to accomplish the above-mentioned tasks during the fieldtrip, a part of the significant geological cross sections in the East and South Carpathians as well as in the Apuseni Mts will be visited. Thus we will examine the tectonic units issued from the Tethyan Ocean - squeezed in the Main Tethyan Suture Zone or obducted on the continental margins – and their deformed continental margins.

In the areas crossed by the fieldtrip geological maps and older fieldtrip guidebooks are available. It should be remembered that in respect to the geological maps or other guides, in the guidebook proposed here more or less important differences are possible, determined by the progress of our knowledge and/or a better understanding of the geological processes.

Geological Map of Romania, scale 1: 200,000, sheets: Rădăuti, Toplița, Piatra Neamț, Odorhei, Brașov, Turda, Brad, Deva, Tg. Jiu, Baia de Aramă, Reșița.

Geological Map of Romania, scale 1: 50,000, sheets: Vatra Dornei, Pojorâta, Câmpulung Moldovenesc, Dămuc, Voșlăbeni, Miercurea Ciuc, Brașov, Zărnești, Codlea, Zlatna, Câmpeni, Avram Iancu, Biharia, Brad, Deva, Lupeni, Schela, Tismana, Obârșia Cloșani, Orșova, Reșița, Bocșa.

The Structure of the East Carpathians (Moldavia-Maramureș Area) by M. Săndulescu et al., 1981, Guide to Excursion B1.

Structural Relations between Flysch and Molasse (The East Carpathians Model) by M.Săndulescu et al., 1981, Guide to Excursion A5.

The Structure of the Apuseni Mountains by M.Bleahu et al., 1981, Guide to Excursion B3.

Metamorphosed Paleozoic in the South Carpathians and Its Relations with the Pre-Paleozoic Basement by H.Kräutner et al., 1981, Guide to Excursion A1.

The Structure of the South Carpathians (Mehedinți-Banat Area) by S.Năstăseanu et al., 1981, Guide to Excursion B2.

Excursion to South Carpathians, Apuseni Mountains and Transylvanian Basin. Description of stops by Berza et al., 1994 ALCAPA II.

Geology of the South Carpathians in the Danube Gorges (Romanian Bank) by Pop et al., 1997.

## General Geological Setting

### General Structure and Evolution of the Romanian Carpathians

(according to Săndulescu, 1980, 1984, 1994)

The Carpathians are a segment of the Tethyan Chains; toward west they join the Alps and toward south and south-east the Balkans and the Rhodope. The Carpathian Foreland includes several platforms (Scythian, Moesian) or cratons (East European) as well as the Cimmerian North Dobrogea Orogen (Figure1). The Carpathian Folded Area is the result of several tectogenetic events of different ages: Cretaceous (generating the Inner Zones named Dacides) and Miocene (the Outer Zones named Moldavides). Upper Cretaceous and/or Paleogene post-tectogenetic covers develop above the Inner Zones. The Pannonian and the Transylvanian, Neogene molassic depressions overlie important parts of the Inner Zones and a part of their post-tectogenetic covers. A Neosarmatian-Eopleistocene molassic asymmetric foredeep develops in front of the Orogen, partly (inner limb) superposed on its external zones (Figure 1). The Folded Area can be divided into several major tectonic ensembles:

The **Main Tethyan Suture Zone (MTS)** which groups together tectonic units constituted by Middle Triassic-Middle Jurassic ophiolitic complexes overlapped by sedimentary formations whose age (Middle and Upper Triassic, Jurassic or Upper Jurassic-Lower Cretaceous) is different from the age of the ophiolites they cover. The MTS which runs along the Vardar Zone (between the European and the Apulian continental margins) splits – from Beograd toward north or north-west - into two branches: the South Pannonian (separating the Apulian microplate from the Fore-Apulian one) and the Transylvanidian-Pienidian (situated between the European and the Fore-Apulian margins) (Figure2).

The **Fore-Apulian Microcontinent (FAM)** is situated on the opposite side with respect to the European margin, considering the MTS a major geotectonic axis of symmetry of the Tethyan Chains. The FAM groups together the Austroalpine, the Central West Carpathians and the North Apusenide units (Figure 1), as well as the units covered by the Pannonian Depression


BLACK SEA
BUCURESTI

*Figure 1 - Tectonic Sketch of Romania (acc. to Săndulescu, 1994). Carpathian Foreland: 1- East European Craton, 2 - Scythian (Sy) and Moesian (Mo) platforms, 3 - North Dobrogea Orogene. Carpathians: 4 - Inner Dacides (Northern Apusenides), 5 - Transylvanides, 6 - Pienides (5 + 6 - Main Tethyan Suture), 7 - Median Dacides (Crist. - Mesoz. Zone, Getic and Supragetic), 8 - Outer Dacides (Ceahlau- Severin), 9 - Marginal Dacides (Danubian), 10 - Moldavides, 11 - Post - tectogenetic covers, 12 - Neogene Molasse depressions and Foredeep, 13 - Up. Cret.- Paleoc. magmatic arcs, 14 - Neogene magmatic arcs, 15 - thrust - sheets, 16 - faults.*

(Figure 2).

The **European Continental Margin (ECM)** groups together the main part of the East Carpathians (the Pienides belong to the MTS) and the South Carpathians. There are two basic types of units: basement shearing nappes and cover nappes. The first type is built up of crystalline formations (metamorphics and sometimes acid and/or intermediate granitoids) and their normal sedimentary envelope (sedimented on the continental margin). This type of unit, which developed in the FAM too, constitute the Central East Carpathians (the Crystalline-Mesozoic Zone excepting the Transylvanian nappes which are obducted from the MTS - Figure 1,2), its correspondent in the South Carpathians (Getic-Supragetic ensemble) and the Danubian (Figure 1). The cover type of nappes are well developed in the Flysch Zone of the East Carpathians and in the Subcarpathians. In the South Carpathians only the Severin Nappe (situated tectonically between the Getic Nappe and the Danubian) is of this type.

**Geotectonic History.**

End-Proterozoic (Panafrican) cratonisation is recognized in the whole Carpathian Foreland and in the Carpathian Orogen as relics. This huge cratonic area, preserved actually in the East European Craton, was split south and west of the former within the Paleozoic mobile areas. The folded basement of the Scythian Platform proceeds from one of these, while the Paleozoic metamorphic series of the Carpathians comes from another branch. Within these branches, remnants of Paleozoic oceanic crust-bearing domains

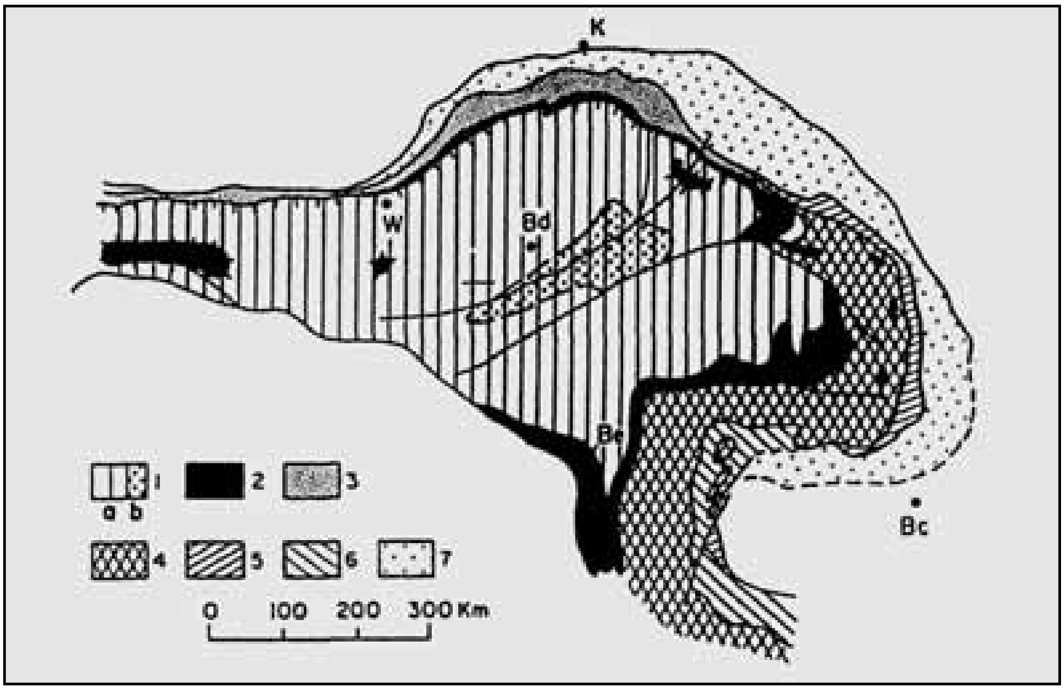


***Figure 2 - The major Tethyan sutures and continental areas in the Carpathian realm (post- tectonic covers is not shown) (acc. to Săndulescu, 1987). 1 a - Inner Dacides, 1/2 - Bükk Unit and correlative units, 2 - Major Tethyan Suture (Vardar, South Pannonian, Transylvanides, Pienides etc), 3 - Măgura Group (belonging to the suture, 4 - Median Dacides (Central East - Carpathians, Getic & Supragetic nappes), 5 - Outer Dacides (Ceahlău - Severin), 6 - Marginal Dacides (Danubian), 7 - Moldavides. Bc - Bucharest, Be - Beograd, Bd - Budapest, K - Krakow, W - Wien.***

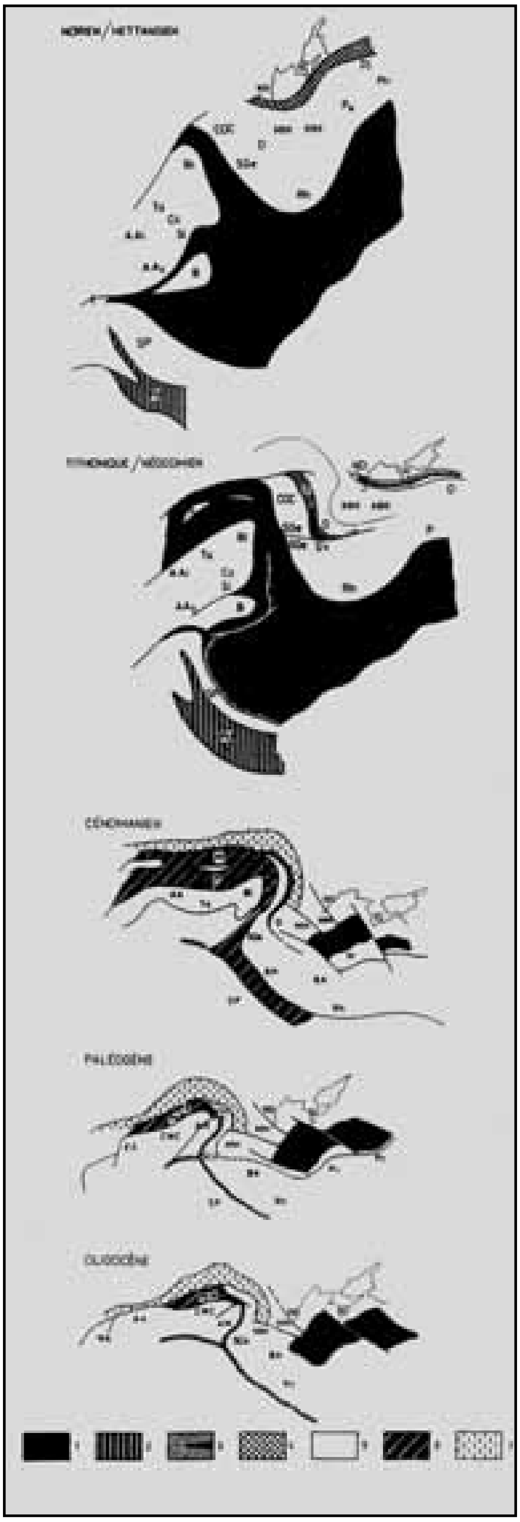

***Figure 3 - Palinspastic sketches of the Carpathians and their Foreland during the Mesozoic and Paleogene. 1 - Tethyan oceanic crust, 2 - Thinned and / or oceanic crust (Pindus), 3 - Thinned and oceanic (a) crust (Outer Dacides), 4 - North Dobrogea - South Crimea Cimmerian Aulacogene, 5 - Continental crust, 6 - deformed oceanic crust, 7 - Thinned crust of Moldavides. AA - Austroalpine, Aai - Lower Austroalpine, Aas - Upper Austroalpine, AM - Apuseni Mts., B - Bükk, BA - Balkanides, Bi - Bihor, Cc - Choc, Ch - Ceahlău, COC - Central East Carpathians, CWC - Central West Carpathians, D - Danubian, Dj - Djirula, EA - Eastern Alps, MM - Moesia, M - Măgura, ND - North Dobrogea, P - Pieniny Klippen, Pd - Pindus, Pn - Pontides, Rh - Rhodopes, SC - South Crimea, SCA - South Carpathians, Sge - Getic and Supragetic, Si - Silicicum, Sv - Severin, SP - Serbo - Pelagonian, Ta - Tatrides, WA - Western Alps.***

seem to be acceptable. A second large cratonisation occurs after the Early Carboniferous, including the Carpathians and parts of its Foreland.

The earliest riftings – Early Triassic – occur along the future Tethyan Ocean and in the North Dobrogea-South Crimea Aulacogene. The first one precedes the opening of the oceanic Tethys, the second one represents a possible pull-apart structure connected to the right-lateral strike-slip movements along the Tornquist-Teisseyre Lineament. Tethyan oceanic spreading starts in the Middle Triassic (in accordance with the age of the oldest ophiolites which were obducted from the Transylvanidian suture) separating the Fore-Apulian Microcontinent from the European Continental Margin. The spreading processes continue during the Late Triassic, Early and Middle Jurassic, the Pienidian segment of the Tethys opening and spreading during this last period (Figure3). Rifting processes occur during the late Early Jurassic and the Middle Jurassic within the European Continental Margin (the Black Flysch-Ceahlău-Severin Rift). The opening of the Tethys and the distension of the mentioned rift, accompanied by the north-eastern motion of the Moesian Block, determine the compressive deformation of the North Dobrogea-South Crimea Aulacogene. At the Middle/Late Jurassic boundary the Tethyan Ocean reaches its maximum size, the youngest ophiolites proceeding from it being of pre-Kimmeridgian age.

The earliest meaningful crustal shortening in the Carpathian Tethys was recorded in the latest Tithonian/earliest Neocomian. It consists of oceanic crust subduction below oceanic crust (Marianne type subduction), expressed in the calc-alkaline volcanism which occurs in some units of the Transylvanides

(South Apuseni). A largely developed tectogenetic event is the Meso-Cretaceous one. It involved the European Continental Margin generating the basement shearing nappes of the Central East Carpathians (Median Dacides) and a part of the oceanic Tethys expressed in obductions above the former (Transylvanidian Nappes). Meso-Cretaceous shortenings are also known in the Getic-Supragetic Domain, as well as in the Ceahlău-Severin Rift. The Intra-Turonian (Pre-Gosau) tectogenetic compressional events affected the Fore-Apulian Microcontinent (Inner Dacides), although mesocretaceous deformations are also recorded. The End-Cretaceous tectogeneses determined the final closing of the oceanic Tethys in the Transylvanidian sector and partially in the Pienidian one (Figure3). The European Continental Margin was affected by the End-Cretaceous deformations, too. At that time the South Carpathians recess-type bending was accomplished by the westward motion of the southern panel of the Moesian Platform, facilitated by the right-lateral slip of the Intra-Moesian Fault (Figs.1, 3). The motion of the Moesian Platform was accompanied by the underthrusting of the Danubian (Marginal Dacides) below the Getic and Severin nappes determining the consumption of the crust of the Severin sector of the rift, process which generated the Banatitic (calc-alkaline) Arc intruded in the overriding units, the Getic-Supragetic nappes respectively. A similar calc-alkaline ("Banatitic") arc develops within the margin of the Fore-Apulian Microcontinent, generated by subduction of the oceanic Tethyan crust below the continental crust of the yet deformed Inner Dacides (Figure 6 ).

Starting with the Early Paleogene, the mobile areas, receiving important turbiditic (flysch) sedimentation, remain the Pienidian (Pieniny + Măgura) and the Moldavidian domains (Figure 3) as well as some post-tectogenetic basins (e.g. Maramureș-Bârgău). The Pieniny-Magura Domain, with a partly consumed oceanic crust, ends southward on the North Transylvanian Fault, which separated it from the yet "sutured" Transylvanidian sector of the oceanic Tethys. The Moldavidian sedimentary Cretaceous and Paleogene-Lower Miocene basins develop above a thinned crust, which will be consumed during the Miocene together with the crust of the Ceahlău sector of the Ceahlău-Severin Rift, during the Miocene generating the East Carpathian Neogene Volcanic Arc. The south-west end of the Moldavidian troughs is connected to the Intra-Moesian Fault (Figure1). West of it the Paleogene formations, which generally show changed lithofacies with respect to the Moldavides, fill the Getic Depression. This represents a (proto-) foredeep of the South Carpathians (where Tertiary shortenings are not recognized).

**Geological Structure of the East Carpathians**

The Romanian East Carpathians are the natural southward prolongation of the Ukrainian East Carpathians. Conventionally the boundary between the East and North Carpathians is situated along the Dniester, San and Uj valleys, but from the geological point of view there are only minor changes (if they exist). Roughly the boundary between the East and South Carpathians shows the same features, but the correlation is more difficult because of the development of post-tectogenetic covers and a complex system of Quaternary Depressions.

The major geological ensembles of the East Carpathians are (innward-outward) (Figure 1) (Săndulescu, 1984, 1994): 1) The Pienides, situated north of the Transylvanian Depression and the North Transylvanian Fault; 2) The Crystalline-Mesozoic Zone (Median Dacides and Transylvanian nappes) and its post-tectogenetic cover (above which the Pienides are overthrust); 3) The Flysch Zone, showing an internal and an external zone; 4) The Subcarpathians. The innermost units of the Flysch Zone are grouped in the External Dacides, while the Moldavides group together the other units of the Flysch Zone and the Subcarpathians. Inward with respect to the Crystalline-Mesozoic Zone and crossing the Pienides, a Neogene Volcanic Chain develops.

**The Pienides** consist of cover nappes overthrusted above the Upper Cretaceous-Paleogene-Lowermost Miocene post-tectogenetic cover of the Crystalline-Mesozoic Zone, during the Burdigalian.

**The Crystalline-Mesozoic Zone** is built up of basement shearing nappes, each of them showing large developed metamorphic formations covered by a Mesozoic or Permo-Mesozoic sedimentary envelope. The nappes, of Meso-Cretaceous age, cover each other. They are (up/down) the Bucovinian Nappe, the Subbucovinian Nappe and the Infrabucovinian nappes. The metamorphics consist of several superposed series (partly tectonically as a result of Paleozoic tectonic events) (Tab.1) (Kräutner, 1983, 1985; Balintoni, 1985, 1997). The most important part of them are mesometamorphic and Precambrian. The youngest one (Tulgheș Series) is of Lower Paleozoic age and, perhaps, epimetamorphic. During the Middle Triassic a first paleogeographical differentiation took place: on

| Bucovinian/Subbucovinian Domain | Infrabucovinian Domain |
|---|---|
| | Cimpoiasa Series (Dev.-Low.Carbon.) |
| | Repedea Series (Ordov. – Silurian) |
| Tulgheş Series (Up.Vend.-Cambr.-Ordov.) | Gap |
| Negrişoara Series (Up.Proterozoic) | Gap |
| Rebra Series (Up. Proterozoic) | ? |
| — shearing surface of the Buc.+Subbuc.nps— | |
| | Bretila Series (Up.Proterozoic) |
| | — Shearing surf. Infrabuc. Nps— |

*Table 1 - Correlation Sketch of the Metamorphic Formations of the Centre. East Carpathians*

the Bucovinian-Subbucovinian domain shallow-water (mainly dolomites) carbonatic rocks are deposited, while on the Infrabucovinian domain basinal, weakly bituminous, dolomites and limestones develop. The Upper Triassic formations are absent (stratigraphic gap). The discordant Lower Jurassic is of shallow-water environment (hard-ground type or paralic), the Middle Jurassic is generally detritic. During the Tithonian-Neocomian time a second paleogeographical differentiation is recorded: along the external part of the Bucovinian domain a flysch trough develops, its arenites being supplied by some elevated parts of the Subbucovinian domain, while on the central Bucovinian domain and the Infrabucovinian one, pelagic limy sedimentation took place. A meaningful formation developed in the top of the Bucovinian sedimentary succession is the Aptian-Albian Wildflysch which contains the sedimentary klippen ("olistoliths") proceeding from the Transylvanian nappes which are tectonically superposed on the Wildflysch.

**The Transylvanian nappes** proceed from the Main Tethyan Suture Zone (Figs.1, 2) obducted during the Meso-Cretaceous tectogeneses. There are three main nappes (Perşani, Olt and Hăghimaş) with different lithostratigraphic successions and ages of the ophiolitic complexes from the basal part of the nappes (excepting the Perşani one proceeding from the rifting zone which precedes the opening of the Tethyan Ocean). Transitional successions between these three basic units may be also recorded.

**The Flysch Zone** groups together cover nappes built up essentially of sedimentary formations detached from their primary basement and overthrusted eastward above the underthrust Foreland (Figure 4, 5). The innermost nappes (Black Flysch, Ceahlău,Baraolt etc.) (Figure 1) contain only Tithonian-Cretaceous formations, the Paleogene ones building up their post-tectogenetic cover. The other units (the Moldavides) (Convolute Flysch, Macla, Audia, Tarcău, Marginal Folds) comprise Cretaceous, Paleogene and Miocene (Lower and Middle) sedimentary formations. The Subcarpathian Nappe (Figs. 1, 4, 5) is the outermost overthrust unit of the East Carpathians. It consists mostly of Miocene formations to which – in the core of some anticlines - Oligocene and exceptionally Upper Eocene ones are associated. The tectogenetic events which generated the actual structural features of the Flysch Zone and the Subcarpathians are: Meso-Cretaceous (overthrusting of the Black Flysch and Baraolt nappes and folding of the Ceahlău one), End-Cretaceous (overthrusting of the Ceahlau Nappe; slight folding of the Convolute Flysch Nappe), Intra-Burdigalian (overthrusting of the Convolute Flysch, Macla and Audia nappes), Intra-Badenian (overthrusting of the Tarcău Nappe and of the Marginal Folds Nappe) Intra-Sarmatian (overthrust of the Subcarpathian Nappe, the last important underthrusting of the Foreland).

**The Foredeep** is an asymmetric molassic depression situated discordantly above the Foreland elements and the external deformed part of the chain (Figure 1, 4). In the Carpathian Bending Area the inner limb of the Foredeep is folded. The deformations took place during the Lower Pleistocene tectonic event known as the Wallachian "Phase" .

**Geological Structure of the South Apuseni Mountains**

The Southern Apusenides correspond on general lines to the prolongation of the Major Tethian Suture Zone which in the Balkan Peninsula is also known as the Axios -Vardar Zone. Around Belgrade, a branch of

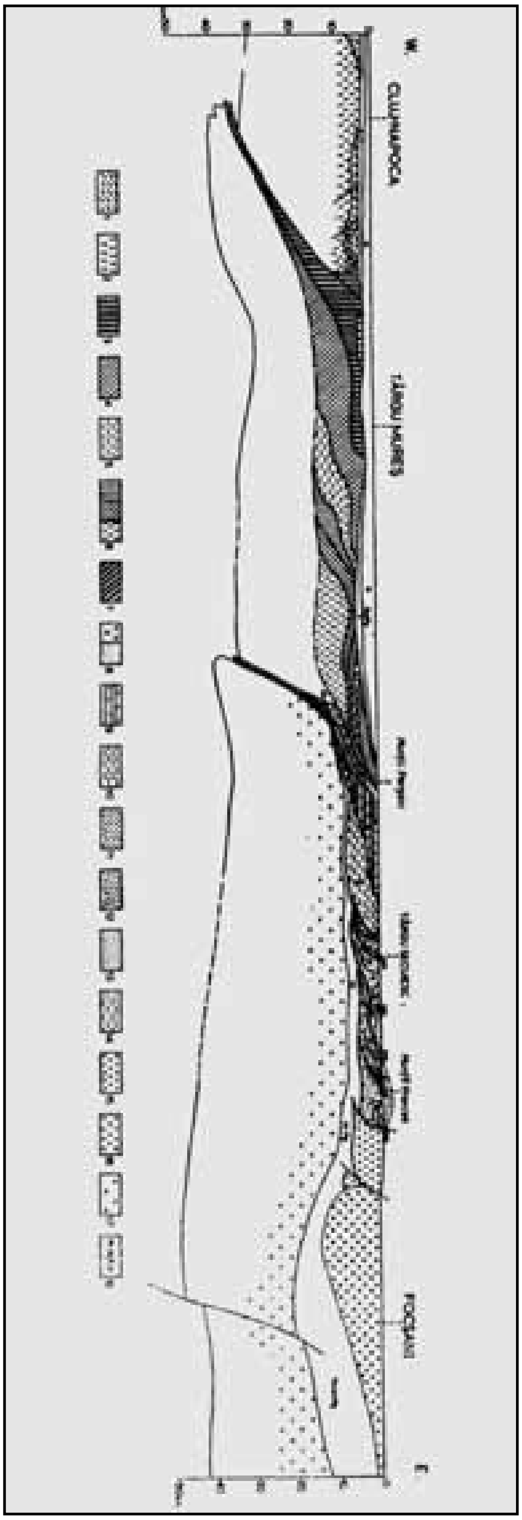

*Figure 4 - General cross - section through the Romanian Carpathians (acc. to Săndulescu, 1984). Inner Dacides (1+ 2) : 1 - Codru - Arieșeni nappe system, 2 - Bihor Unit; Main Tethyan Suture: 3 - Transylvanides: Median Dacides (4 - 6) : 4 - Bucovinian Nappe, 5 - Subbucovinian Nappe, 6 - Infrabucovinian nappes; 7- Remnants of the primary basements of the Flysch Zone in the Benioff paleoplane; Outer Dacides (8 + 9) : 8 - Black Flysch Nappe, 9 - Ceahlău Nappe; Moldavides (10 - 15) : 10 - Convolute Flysch, 11 - Macla Nappe, 12 - Audia Nappe, 13 - Tarcău Nappe, 14 - Marginal Folds Nappe, 15 - Subcarpathians Nappe; Foredeep : 16- Focșani Depression; Underthrusted elements (17 + 18) : 17 - Crystalline basement, 18- Sedimentary formations (Pz - Paleozoic, Mz - Mesozoic, Pg - Paleogene).*

the latter curving to the NE joins under the mainly Tertiary and Quaternary cover (Vojvodina-Banat) the complicated Southern Apuseni orogenic system emplaced mainly on oceanic crust; another branch, also concealed by younger formations, runs WNW along the Sava river (South Pannonian Suture - Săndulescu, 1980, 1984). North and South of the Southern Apusenides suture zone, units with continental basement represent its margins, called respectively Internal, Median Dacides.

The different units of the Southern Apusenides, mainly obduction nappes, consist of sedimentary Upper Jurassic and Cretaceous formations, at the base of which magmatic complexes of ophiolitic or island arc character were conserved. The age of the ophiolites is Middle Jurassic, whereas the calc-alkaline island-arc series belongs to the Upper Jurassic (Berriasian, at most).

From north to south, the tectonic units which will be crossed during the excursion are: Bucium Unit, Feneș Nappe, Techerău Nappe, Căbești Nappe and Bejan Nappe. We shall describe them according to Bordea, 1992 and Bleahu et al., 1981.

**The Bucium Unit** overlies a crystalline basement characteristic of the Northern Apuseni (Internal Dacides). The sedimentary sequence starts with the Ciuruleasa Formation consisting of black argillaceous shales with sandstone lenses in which an Early Cretaceous flora was found. A sandy calcareous-shaly flysch-like formation called the Valea Povernei Formation follows, of Upper Hauterivian-Lower Aptian age, established according to paleophytological data (Antonescu, 1973). The most characteristic term of this formation is a quartzitic sandstone with calcareous matrix and calcitic veinlets, interbedded with dark argillaceous shales. Graded bedding and parallel or

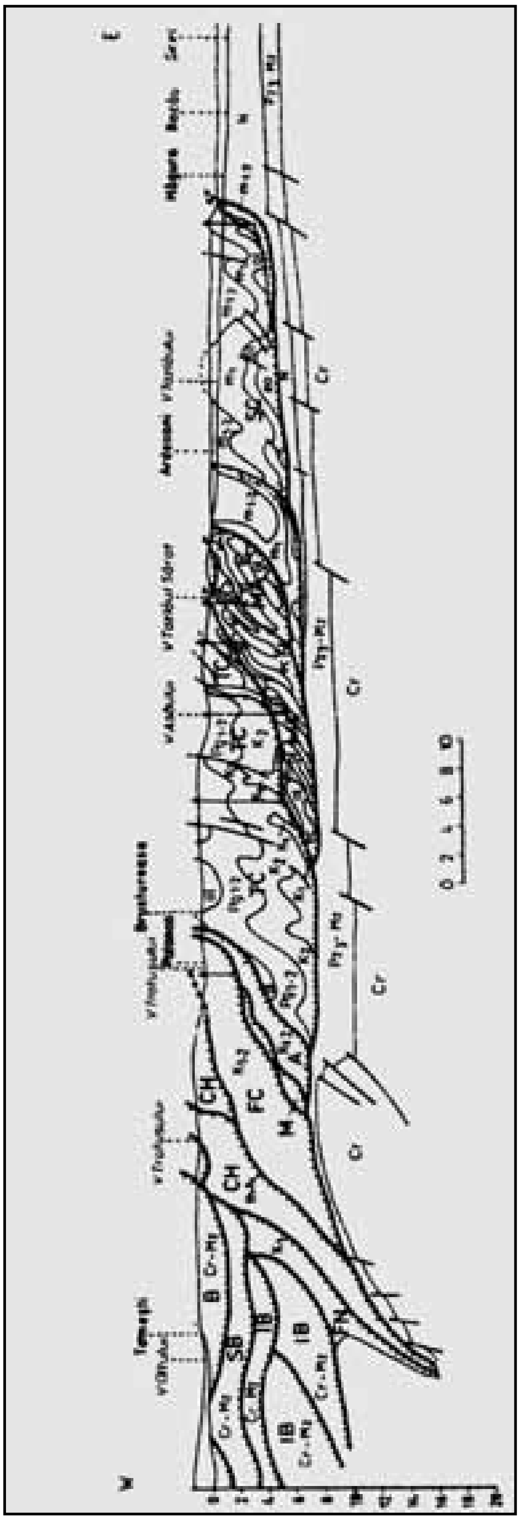

***Figure 5 - Synthetic cross - section through the East Carpathians (in central Moldavia) (acc. to Săndulescu, Stănică and Visarion in Săndulescu , 1994). B - Bucovinian Nappe, SB - Subbucovinian Nappe, IB - Infrabucovinian Nappe, FN - Black Flysch Nappe, CH - Ceahlău Nappe, FC - Convolute Flysch Nappe, M - Macla Nappe, A - Audia Nappe, TC - Tarcău Nappe, MA - Marginal Folds Nappe, SC - Subcarpathians Nappe, Cr - crystalline formations, Pz - 3 - Upper Paleozoic, Mz - Mesozoic, N - Neogene, Th - Tithonian, k 1 - Lower Cretaceous, k 2 - Upper Cretaceous, Pg 1 - Paleocene, Pg 2 - Eocene, o 1 - Oligocene, m 1 - Lower Miocene, m 2 - Middle Miocene.***

cross lamination can sometimes be observed.

Next, a shaly-calcareous flysch formation consisting of calcareous sandstones, calcarenites and calcirudites with intercalations of greenish-grey shales follows conformably. In the graded calcarenites elements of mafic rocks and of Neojurassic limestones can be observed. The Aptian age of this formation was demonstrated by *Brachiopods* (*Belbeckella gibbsiana*), *Orbitolinids* and a palynological association.

The sequence continues with the Soharu Formation, which could be characterized as a grey argillaceous flysch with Wildflysch episodes. It consists of siltstones and weakly calcareous sandstones, dark clays, calcirudites and conglomerates with pebbles of mafic rocks and limestones.

Micropaleontological evidence as well as *Ammonites* limit the age as Upper Aptian-Lower Albian.

A grey Lower Albian Wildflysch Formation with olistoliths of Upper Jurassic massive limestones and mafic rocks represents a lateral facies variation of the Soharu Formation. Besides the chaotic blocks of calcirudites, calcarenites, polymictic conglomerates, basic tuffs or jaspers, a paratypic flyschoid facies also occurs.

The Upper Albian is represented by the Pârâul Izvorului Formation. It consists of a grey flysch with evident graded bedding and convolute structure, the main rock types being micaceous sandstones and marls. The constraining macro-and micropaleontological data were found in the same formation occurring in another structural unit (the Curechiu Nappe).

At its upper part, the Pârâul Izvorului Formation passes into the ortho-quartzitic Negrileasa Conglomerates (Cenomanian).

The Senonian of the Bucium Unit overlies transgressively the previously described formations as well as the crystalline schists of the Northern Apuseni Mountains. It starts with a Upper Santonian Gosau Formation (*rudist*-bearing limestones) followed by

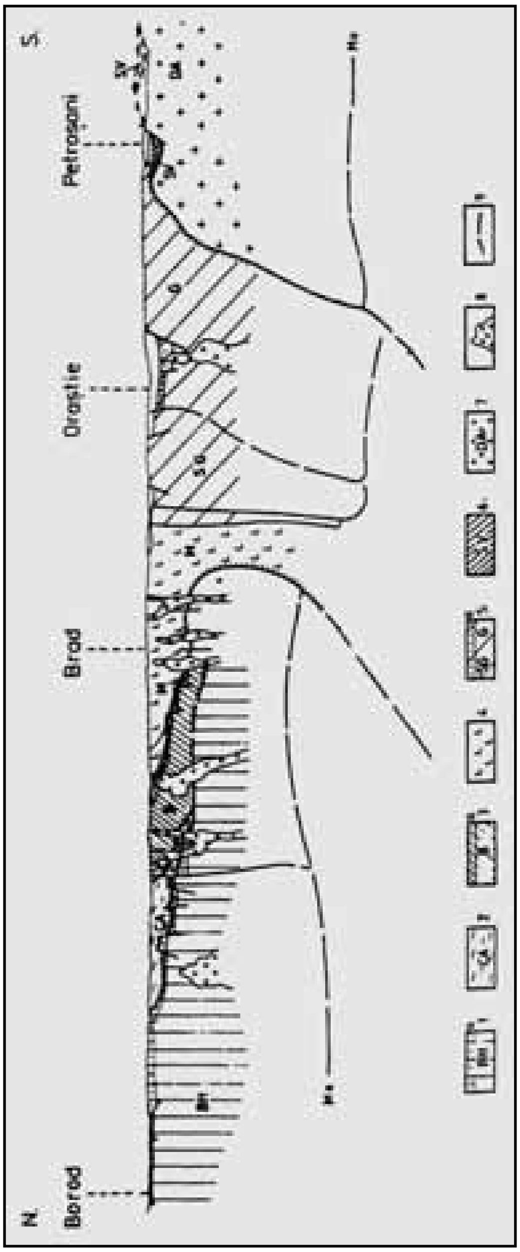


*Figure 6 - Structural cross - section through the Apuseni Mts. and the South Carpathians (acc. to Săndulescu, Stănică and Visarion in Săndulescu ,1994). 1 - Bihor Unit (BH) (a - sedimentary formations), 2 - Codru - Arieșeni nappes system (CA), 3 - Biharia nappes system (B) (a - Gosau Formation), 4 - Transylvanides (M) (Southern Apusenides) (Main Tethyan Suture), 5 - Getic (G) and Supragetic (SG) nappes (a - sedimentary formations), 6 - Severin Nappe (SV), 7 - Danubian (DA), 8 - Senonian - Paleocene calc - alkaline magmatites (Banatites), 9 - Moho Discontinuity.*

grey marls with *Inoceramus balticus* and a gritty-shaly micaceous flysch.

**The Feneș Nappe** is overthrown northwards onto the Bucium Unit and has an ophiolitic basement. It begins with the Feneș Formation, the most significant within the Southern Apusenides. It could be defined as a volcano-sedimentary calcareous olistostrome with flysch sequences, and starts with a thick turbiditic sequence of quartz sandstones and grey clays which towards the top grades into slumped clays with interbedded tuffs and spilitic lavas as well as with either massive bio-constructed or thin bedded micritic limestones. In the massive limestones, *Pachyodonts* were found providing proofs of their Barremian-Lower Aptian age.

The Feneș Formation grades up into the turbiditic Valea Dosului Formation, consisting of calcareous polymictic conglomerates, alternating with sandstones, green clays and mafic pyroclastites. In intercalated calcarenites *Orbitolinids* were found, indicating an Aptian age.

The Meteș Formation, overlying unconformably the two above-mentioned sequences, has a typical Wildflysch character. It includes two members: a lower one characterized by an olistostrome-like marly-silty facies with some interbedded turbiditic and coarse layered sandstones; an upper member which consists of breccias with silty-marly green, grey or reddish matrix and exolistoliths of ophiolitic rocks, Upper Jurassic massive limestones or granodiorites.

The Upper Aptian-Middle Albian age of the Meteș Formation was established according to macropaleontological and palynological studies.

Next follows the Valea lui Paul Formation, consisting of grey, loose sandstones which pass into sands. Micropaleontological and palynological studies have provided evidence of a Upper Albian-Cenomanian age.

The Senonian of the Feneș Unit is represented by medium or fine-grained sandstones and polymictic conglomerates. A megabreccia Wildflysch Formation follows, interpreted by some authors as an independent unit (Valea Mică-Galda Nappe).

**The Techerău Nappe** is developed in a widespread area in the western and the central part of the South Apusenides. It is the unit which shows a major part of the Tethian oceanic crust. Its basement consists of ophiolitic rocks as well as of an island arc calcalkaline series, which interfingers with Callovian *radiolarites*. The sedimentary sequence starts with these jaspers

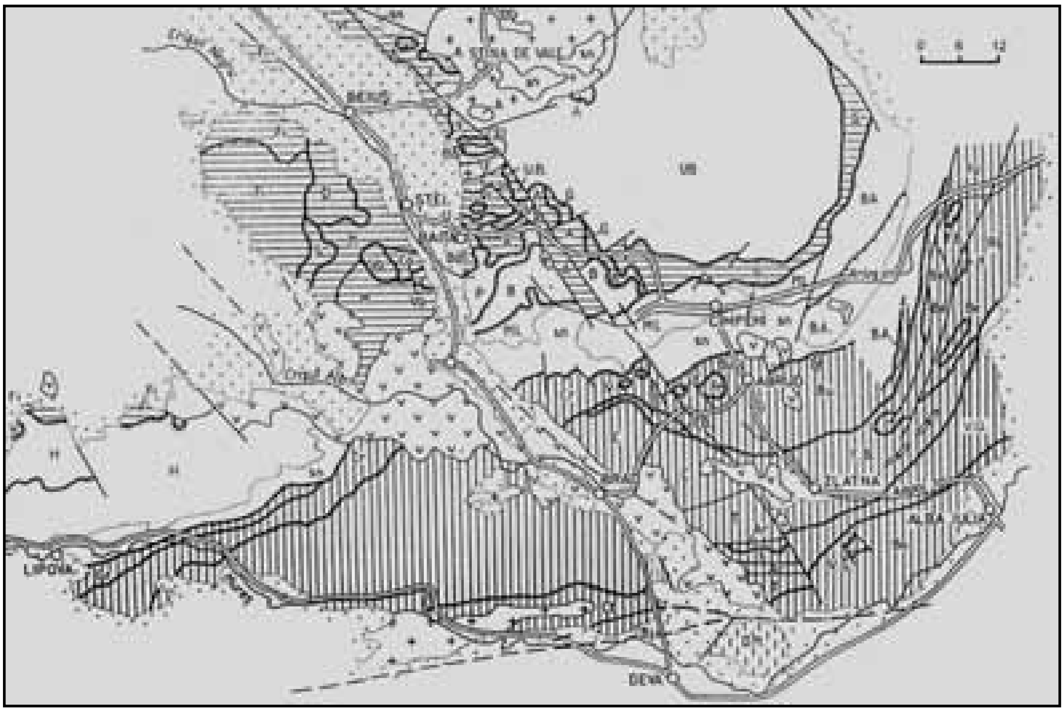


*Figure 7 - Structural sketch-map of the Apuseni Mountains. .... Neogene molasse cover; vvvv Neogene calc-alkaline magmatites; +++ Upper Cretaceous calc-alkaline magmatites; Sn, post-tectogenetic cover of the North Apusenides. Northern Apusenides: Biharia Nappes System – BA, Baia de Arieș Nappe; ML, Muncel-Lupșa Nappe; B, Biharia Nappe; H P, Highiș (H) and Poiana (P) Nappes; Codru Nappes System: Co, Colești Nappe; Va, Vașcău Nappe; M A, Moma (M) and Arieșeni (A) Nappes; Vt, Vetre Nappe; D Ba, Dieva (D) and Bătrânescu (Ba) Nappes; S F, Șasa (S) and Ferice (F) Nappes; U, Următ Nappe; Fi G, Finiș (Fi) and Gârda (G) Nappes; Vl, Vălani Nappe; UB, Bihor Unit. Southern Apusenides: Ri, Rimetea Nappe; Be, Bedeleu Nappe. Bedeleu Nappes System: Fu, Fundoaia Nappe; H, Hospea Nappe; Bj, Bejani Unit; Bo, Bozeș Nappe; V Ar, Vulcan (V) and Ardeu (Ar) Nappes; Cb, Căbești Nappe; VG, Valea Mică-Galda Nappe; T, Techerău Nappe; C, Curechiu Nappe; FB, Feneș-Blăjani Nappe; Cr Fr, Criș (Cr) and Frasin (Fr) Nappes; Gr, Groși Nappe; Bu, Bucium Unit. Median Dacides: DM, Supragetic Nappes*

followed by Oxfordian micritic limestones and massive limestones of Kimmeridgian-Tithonian age. Barremian -Aptian (?) marly or sandy limestones with *Orbitolinids* overlie the Upper Jurassic limestones as well as the eruptive rocks directly.

Wildflysch sequences consisting of dark clays containing olistoliths of Upper Jurassic and Urgonian limestones and mafic rocks directly overlie the basement in several places. In places, interbedded sandstones and marly sequences, ascribed to the Albian, are also present.

The following two units are bordered by EW trending vertical dislocations probably with a horizontal displacement, parallel to the South Transylvanian Fault. Consequently, their overthrusting character is impossible to evaluate.

**The Căbești Unit** begins with the Cpbești Formation, an olistostrome with quartz sandstone-shaly flysch - like sequences. It is ascribed to the Barremian, by comparison with the Valea Povernei Formation. It is overlain by the Fornpdia Formation, consisting of quartzose conglomerates which laterally pass into calcareous sandstones, ascribed to the Vraconian (uppermost Albian) due to the *Ammonites* found. The calclithitic sequence which follows, as well as reddish marls, are considered to belong to the Cenomanian, also due to *Ammonite* faunas.

**The Bejan Unit** is the southernmost one of the South Apusenides. The Bejan Formation consists of a Wildflysch with exolistoliths of basalts, Triassic and Upper Jurassic-Neocomian limestones embedded in black argillaceous clays with intercalations of basaltic

flows and pyroclastics. Its age was ascribed to the Barremian.
The Deva Formation which follows after an evident unconformity is represented by poorly sorted, loose, thick bedded sandstones interbedded with silty marls. According to palynological data, its age may be assigned to the Turonian and Senonian.
**The Bozeș Nappe** represents the uppermost unit in the south-eastern part of the Southern Apuseni. The Bozeș Formation represents its main lithostratigraphic term. It is a typical flysch formation in which the following rock types can be recognized: sandstones, silty marls and microconglomerates. Graded bedding, sole markings and *bioglyphs* are frequent. Towards the top, the flysch sequence is replaced by a molassic one, with conglomerate levels. The top itself consists of continental deposits. The age of the formation is ascribed to the Senonian, reaching the Maastrichtian, established on the basis of faunal remains and microfaunal studies.

**Mesozoic eruptive rocks.**

At the beginning of the eighties, Savu (1981) for the first time stated the clear distinction between the ophiolitic complex of the South Apusenides, consisting of a tholeiitic series, and an island arc volcanism forming a calc-alkaline series, emplaced in the same Carpathian unit.
The most recent data concerning both magmatic complexes are due to Saccani et al. (2001), Bortolotti et al. (2002) and Nicolae, Saccani (2003). We shall describe them according to the latter.
The ophiolitic sequence is characterized by: 1) an intrusive section represented mainly by small gabbroic bodies as well as scarce ultramafic cumulates; 2) a basaltic sheeted dike complex; 3) a volcanic sequence including basalts and rare pillow breccias; 4) very rare Callovian radiolarian chert.
Basaltic rocks display MORB patterns and a high-Ti magmatic affinity; all the geochemical features suggest that the ophiolites were generated in a mid-ocean ridge setting and that they can be correlated with the ophiolites of the Vardar-Axios zone. K-Ar ages of microgabbros, dolerites and basalts from the Mureș Valley (Techerău Nappe) fall between 138.9 ± 6.0 and 167.8 ± 5.0 M. a. (Middle to Upper Jurassic) (Nicolae et al., 1992).
The overlying calc-alkaline rocks are represented by massive lava flows including basalts, andesites, dacites and rhyolites, as well as by some granitoid complexes intruded into the ophiolitic sequences; they show locally high-K calc-alkaline affinity. This series represents a magmatic island-arc setting developed over the previously formed oceanic lithosphere. Relations with sedimentary formations constrain the age of the calc-alkaline series to the Upper Jurassic. No genetic relationship with the underlying ophiolitic rocks exists. A younger alkaline series consists of limburgites, trachyandesites (oligophyres) and trachytes (orthophyres) intercalated in the Lower Cretaceous Feneș beds.

**Microtectonics and metamorphism of the Feneș beds.**

Two folding phases developed during the time-span from Early Aptian to Late Maastrichtian. The D1 phase produced west-northwest-verging isoclinal to very tight folds, associated to a slaty cleavage. Illite and chlorite were formed, metamorphic conditions being close to the diagenetic zone/anchizone boundary. The subsequent D2 phase produced north-northwest- verging, parallel folds. The burial of the formation took place at a depth of 8-10 km (Ellero et al., 2002).
**Main tectonic features** The geotectonic evolution of the Southern Apusenides was typically polyphasic.
The Mesocretaceous tectogenesis involved two moments:1) the first one, in the uppermost Aptian, marked some unconformities in the Bucium, Feneș and Căbești Units; 2) the second, an intra-Late Albian one, was much more important and caused thrusting between some units. The Wildflysch character of some Albian formations pleads also for important compressive movements; 3) The pre-Gosau tectogenesis does not display evident structures. It is the Laramian tectogenesis that accomplished the structural framework of the Southern Apusenides. The overall transport direction of the nappes is a north- western one.
Concerning the Neogene tectonics, it is noteworthy that characteristic NW-SE structures can be considered also as tectono-magmatic alignments.

**Geological Structure of the North Apuseni Mountains**

The Northern Apusenides (Internal Dacides) group together units issued from the deformation of a continental crust. These units consist of metamorphic and granitic basements of Precambrian or Paleozoic age and of sedimentary Upper Paleozoic and Mesozoic formations.
**Bihor Unit.** It has to be underlined from the beginning that, although this fact is not compulsory, every Alpine tectonic unit having a crystalline "sole" is characterised by specific features of this metamorphic

basement.
For the lowermost Bihor Unit, this basement consists of the medium-grade Somes Series (micaschists, amphibolites, leptynites) and the retrogressive Arada Series (chlorite-sericite-albite schists, metarhyolites), both intruded by the Muntele Mare granitic massif. The ages of the metamorphism and of the intrusion are Paleozoic.
The sedimentary sequence of the Bihor Unit includes, (besides very scarce Permian) Triassic, Jurassic and pre-Senonian Cretaceous formations. The following specific lithostratigraphic features must be underlined:
-development of a carbonatic platform series from the Upper Werfenian to the base of the Carnian;
-absence of the major part of the Upper Triassic;
-Gresten paralic facies of the Lower Jurassic;
-marine sequence of the Middle Jurassic and of the base of the Upper Jurassic;
-development of a carbonatic platform in the Kimmeridgian and the Tithonic;
-lag of sedimentation at the base of the Cretaceous, marked by bauxites;
-calcareous neritic lithofacies of the Barremian and Aptian, passing into a marly sedimentation which continues in the Turonian.
The Bihor Unit corresponds to the Villàny Unit in southern Hungary and to the Tatride units in the Slovakian Carpathians, and is probably overthrust northwards onto the Tethysian Suture.
Codru Nappes System. A number of nappes are overthrust from the SE onto the Bihor Unit; they correspond to the South Hungarian Bekes Realm.
The first major unit, the **Finiș-Gârda Nappe,** has a metamorphic basement consisting of the Codru Granitoids and Migmatites, the oldest basic intrusions being pre-Hercynian (400 m. a.) according to Dallmeyer et al. (1994). As specific lithostratigraphic features, the following are to be mentioned:
-large development of the Permian, with felsic ignimbritic volcanism;
-complete development of the Triassic sequence, with Carpathian Keuper and Kössen facies in the Late and latest Triassic;
-marine, marly-calcareous facies of the Lower Jurassic;
-development of a flysch-type sequence in the Tithonian-Neocomian.
The **Următ Nappe** is developed similarly to the Finiș Nappe, with lithofacial variations at the level of the Jurassic, which is of wildflysch type.
The **Dieva-Bătrânescu Nappe** is characterized by:
- a complex magmatism in the Permian, with mafic rocks intercalated between two rhyolitic sequences;
- development of Reifling and Dachstein facies (until the Upper Norian);
- a lag at the level of the Jurassic.
The **Moma-Arieșeni Nappe** overlies all the other units including the Bihor Unit. The oldest formations of the former consists of the Lower Carboniferous Arieșeni Series (greenschists intruded by doleritic veins). The Upper Carboniferous and Permian molassic formations of reddish colour are well developped, including acidic eruptive products. The Middle and Upper Triassic formations, in calcareous facies, end with the Rhaetian.
The highest nappes of the Codru System display Triassic sequences in Hallstatt and Dachstein facies.
**Biharia Nappes System.** This group of nappes consists essentially of metamorphic formations of pre-Carboniferous age (Biharia Series: orthoamphibolites, chlorite-schists with albite porphyroblasts; Muncel Series: sericite schists, mylonitic granites, metarhyolites) overlain by the metaconglomeratic Upper Carboniferous Păiușeni Series.
**Post-tectogenetic cover.** The nappes building up the Internal Dacides (Northern Apusenides), characterized by a Turonian principal tectogenesis (similarly to the Slovak Central Carpathians or to the Eastern Alps) are post-erosionally overlain by the Senonian Gosau Formation. The post-tectonic subduction magmatism is represented by banatites.
**Banatitic Late Cretaceous magmatism.** In the Apuseni Mountains, an outstanding example of Late Cretaceous magmatism is the volcano-plutonic Vlădeasa Massif; a volcano-sedimentary formation is overlain by andesites, dacites and ignimbritic rhyolites, all crossed by quartz-dioritic and monzogranitic minor intrusions.
Southwards, a granodioritic-granitic batholith crops out only on restricted areas and is also associated to andesitic and rhyolitic minor intrusions.
**Neogene magmatism.** Neogene magmatic rocks in the Apuseni Mountains range in age from 14.8 to 7.4 M. a., their calc-alkaline composition varying from basalt-andesites to dacites, andesites prevailing; many plot at the edge of the adakite field (Roșu, 2001). They crop out along three main WNW - ESE to NW - SE trending lineaments (Brad-Săcărâmb, Stănija-Zlatna, Roșia Montană-Bucium), plus the Baia de Arieș zone.

**Geological Structure of the South Carpathians**

As results from the general introduction, the South Carpathians, which extend from the Prahova Valley in the east to the Timok Valley in the south, consist of the following main Alpine structural elements: Lower Danubian Units, Upper Danubian Units, Severin Nappe, Getic Units, Supragetic Units. Important pre-Alpine tectonic units (nappes) are involved and preserved in these Alpine nappes. The Danubian on the one hand, the Getic and Supragetic Units on the other hand, represent two sialic microplates, while the Severin Nappe, lacking a metamorphic basement, is related to a basin with oceanic crust. With the exception of the latter, all the main Alpine units consist of a metamorphic basement including Precambrian and Paleozoic rocks and of a sedimentary cover beginning with a Variscan molasse and including Mesozoic formations up to the Senonian.

South of the Danube, in Serbia and Bulgaria, the Danubian Realm corresponds to the Stara Planina, Miroc´ and West Porec´ Units (Krstic´, Karamata, 1992).

**Lower Danubian Units** The Lower Danubian units are represented by several pre-Alpine nappes with a common Upper Paleozoic-Mesozoic post-nappe cover; only in the south-eastern part of the area an important Alpine overthrust was recognized (Schela). The main pre-Alpine nappe (Retezat-Parâng Unit), consisting of a distinct sequence of polymetamorphic rocks (Drăgșan Group) intruded by granitoid bodies and covered by Lower Paleozoic low-grade formations, is overthrust onto metadetrital sequences of polymetamorphic rocks (Lainici-Păiuș Group), associated granites and low-grade Lower Paleozoic formations (Vâlcan-Pilugu Unit).

**Metamorphic basement.** The Drăgșan G r o u p is exposed in the Retezat Mountains in the north and in the Mehedinți-Vâlcan-Parâng Mountains in the south. Its main part is represented by an Amphibolite Formation, in which the dominant banded amphibolites are interlayered with biotite augen-gneisses, leptynites, mica gneisses and scarce serpentinites, crystalline limestones or kyanite-staurolite gneisses. Retrogressive events have caused alterations of amphibolites to greenschists over large areas. The volcano-sedimentary origin of the amphibolites from mafic igneous rocks and tuffs is evidenced by rock associations and chemical data.

The Drăgșan rocks are intruded by the Retezat, Parâng and Culmea Cernei plutons, dominantly granodiorite bodies with biotite-hornblende diorites or biotite ± muscovite granites occurring in restricted areas.

Zircon U-Pb data on an intercalated augengneiss have given an age of 777 ± M.a. for the emplacement of the protolith of the gneiss, while Nd model ages for the amphibolites range from 717 M.a. to 817 M.a. (Liégeois et al., 1996). Major and trace elements from the Drăgșan amphibolites consistently display an island arc signature. K-Ar model ages of the Drăgșan rocks or the associated granitoids range between 325 and 97 M.a. (Grünenfelder et al., 1983), showing later reworking.

The Lainici-Păiuș Group is exposed in the same two areas mentioned above (Retezat and Mehedinți-Vâlcan-Parâng Mountains). The main features of this group are the sedimentary origin and the invasion of granitoids as a number of large plutons, countless small bodies and various migmatites.

Two formations were recognized: a lower Carbonate- Graphitic Formation, consisting of crystalline limestones and dolomites, sillimanite-andalusite-cordierite-graphite mica gneisses, amphibolites and calc-silicate gneisses, and an upper Quartzitic and Biotite Gneiss Formation.

The two main types of plutons intruded into the Lainici-Păiuș Group are the Șușița type and the Tismana type. The former is made up of medium-K calc-alkaline granodiorites and tonalites; the latter (Tismana and Novaci) belong to the shoshonitic series, displaying a complete range of compositions from ultramafic to felsic rocks. Widespread mingling-mixing relationships give rise to a variety of facies. A liquid line of descent from the diorites to the granites was reconstructed. The intermediate and felsic rocks are commonly porphyritic (Duchesne et al., 1998).

The ages of the various syn-to late-kinematic granitoid intrusives in the Lainici-Păiuș basement are in the 588 - 567 M.a. range (U-Pb zircon ages). The regional LP- HT metamorphism is probably not much older (Liégeois et al., 1996).

**Lower and Middle Paleozoic** very low-grade formations**.** Although the presence of the Cambrian in the Lainici-Păiuș Group was advocated, the evidence is not convincing. The oldest Paleozoic sequence, the Upper Ordovician age of which was proved by paleontological evidence (*Corals*, *Crinoids, Brachiopods* as well as *Acritarchs* and *Chitinozoans*) is the Valea Izvorului Formation (quartzites, metaconglomerates and slates); notwithstanding its scarce development, it serves to constrain the age of the high-to medium-grade metamorphic formations underlying it.

A younger sequence is the Valea de Brazi Formation (metaconglomerates, sandstones, slates) attributed to the Devonian.

**Upper Paleozoic and Mesozoic.** The formations overlying the Variscan and pre-Variscan basement are the following: Permian red-beds; Lower Jurassic Gresten facies deposits (conglomerates, sandstones); Middle Jurassic sandstones with carbonatic matrix; Upper Jurassic-Lower Cretaceous massive limestones; Middle Cretaceous shales (Nadanova beds); Upper Cretaceous turbidites, reaching into the Senonian.

A special mention has to be made of the northern part of the Lower Danubian Mesozoic displaying very low metamorphism: the Liassic Schela Formation (metaconglomerates and phyllites with chloritoid and pyrophyllite); the Upper Cretaceous volcaniclastic sandstones with prehnite and pumpellyite.

**Upper Danubian Nappes**

**Metamorphic basement.**

The Upper Danubian Nappes are exposed in the northern and western parts of the Danubian Window.

The Zeicani Group represents the polymetamorphic basement of several nappes and consists of a prevailing amphibolitic sequence, with associated leptynites and mica gneisses (± kyanite, staurolite) generally affected so strongly by retrogression that they look like greenschists or sericite schists. Berza and Seghedi (1983) compare this group with the Drăgșan Group of the Lower Danubian.

The metaterrigenous Măgura Marga Group consisting of a prevailing quartzitic sequence, muscovite plagiogneisses, amphibolites, is highly migmatised. It was compared by Berza and Seghedi (1983) to the Lainici-Păiuș Group of the Lower Danubian.

The two groups of metamorphic rocks (and others with restricted extension) are intruded by granitoid plutons (Muntele Mic, Sfârdinu, Cherbelezu, Ogradena, etc); special mention has to be made of the mafic-ultramafic Tisovița-Iuți complex. The dextral Cerna-Porečka Reka fault system with a horizontal displacement of 40 km (trending NE) has dismembered a formerly much larger ophiolitic body, the southern part of which consists of the Deli Iovan massif of Serbia.

The K-Ar model ages of samples from the Upper Danubian metamorpfic rocks and associated granitoids range between 447 and 96 M.a., demonstrating Variscan and Alpine reworking of the basement (Grünenfelder et al., 1983).

**Lower and Middle Paleozoic** very low-grade formations are represented by the following: Nijudimu-Râu Alb Formation (Ordovician-Silurian phyllites, conglomerates, sandstones, mafic tuffs); Brustur Formation (probably Silurian conglomerates); Râul Rece-Drencova Formation (Devonian conglomerates, sandstones, slates, mafic tuffs and flows); Sevastru Formation (Lower Carboniferous limestones, slates, sandstones, mafic volcanics). With the exception of the latter which bears macrofaunal remains (*Spiriferidae,* etc), the ages of the former formations are constrained by palynological associations.

But south of the Danube, in the Stara Planina Unit, the oldest fossiliferous formation is found as blocks in a Devonian olistostrome; its Arenigian age is constrained by *Acritarchs*. In the same unit, the Upper Silurian and the Devonian could be parallelized with the Drencova Formation, the age of the former being proved by *Tabulate Corals*.

**Upper Paleozoic and Mesozoic**

The formations overlying the Variscan and pre-Variscan basement are developed in two main zones: Svinița- Arjana and Cornereva-Mehadia.

The following are to be mentioned: Upper Carboniferous coal-bearing conglomerates, sandstones and slates; Permian red-beds with rhyolitic volcanic and volcaniclastic rocks; Lower Jurassic coal-bearing conglomerates, sandstones and slates ("terres noires"), sometimes developed in Schela anchimetamorphic facies; Middle-Upper Jurassic, represented either by a volcano-sedimentary formation with mafic and alkaline lava flows, pyroclastic deposits, limestones and shales (Arjana), or by limestones (Svinița); Upper Cretaceous flysch (Arjana).

The intensity of Alpine metamorphism varies in these formations between high-grade diagenesis and low-grade, increasing eastwards.

Severin Nappe. The Severin Nappe in the South Carpathians consists of obducted slices generated in a rift with oceanic or thinned continental crust, formed in the Jurassic on the European margin. It includes a Upper Jurassic tectonic melange (olistoliths of basalts, gabbros, serpentinites, harzburgites, crystalline schists, limestones, in a matrix of siliceous marly pelagic deposits-anchimetamorphic Azuga beds), and Upper Jurassic-Lower Cretaceous flysch deposits (Sinaia beds: distal limestone turbidites with a microfauna of *Calpionellids*). In Serbia, this unit corresponds to the Kosovica and Sub-Kosovica Nappes (Grubić et al., 1997).

**Getic Nappe Metamorphic basement.**

The Lotru Group represents the basement of the main part of the Getic Nappe, extending over more than 300 km in length and 80 km maximal width on

Romanian territory. It consists of a thick sequence of polymetamorphic rocks, mainly in amphibolite facies (sillimanite-kyanite-staurolite-garnet-bearing micaschists and plagiogneisses, orthogneisses, leptynites and amphibolites), as well as of dismembered ophiolitic slabs of metaperidotites, metagabbros; a siliceous manganiferous formation with tephroite concentrations; only in the deepest horizons are calcareous or dolomitic rocks found e.g. Armeniş; tectonic inclusions of anisofacial rocks-eclogites and granulites-are hosted in places). An elaborate subdivision of this group is still in progress.

The bulk of K-Ar ages as well as the preliminary $^{40}Ar$ / $^{39}Ar$ results "suggest that regionally penetrative high-temperature mineral assemblages and associated ductile structural elements are likely related to Late Variscan tectonothermal activity" (Dallmeyer et al., 1994). Isolated pre-Variscan mineral ages still suggest a Precambrian age of the protoliths as well as of a first metamorphism of the Lotru Group. The main part of the Getic corresponds in Serbia to the Kučaj Nappe and in Bulgaria to the Srednogorie.

**Lower and Middle Paleozoic (?) low-grade formations.**

**The Miniş Formation** is a monotonous metaterrigeneous sequence (mainly chlorite-biotite-quartzitic schists) with minor bodies of metarhyolites.

The Buceava Group (Ordovician?) includes a discontinuous slab of metabasaltic rocks with associated black shales, siltites, carbonatic rocks, metapsephites and metapsammites.

In Serbia, the Lotru Group corresponds to the Osanica "Series"; it is overlain by an anchimetamorphic Ordovician, beginning with Čaradoc, with *Trilobites, Brachiopods* and *Acritarchs*. The sequence continues with the Kučaj-Cernogorje Flysch (Devonian) bearing *floral* remains and *Conodonts* and with a Lower Carboniferous, both non-metamorphic (Pantić, 1963).

The Sicheviţa granitoid massif (Brnjca in Serbia) is the most important of the Getic Realm, its length in the north - south direction on both sides of the Danube being about 100 km. It post-dates the Paleozoic formations in the Banat region. Two magmatic suites can be distinguished, a plagioclasic and mafic one (including trondhjemites and tonalites) and a predominantly potassic-felsitic one (including leucogranites, monzogranites, granodiorites). Isotopic age determinations gave results of 237 - 310 M.a. (K / Ar) and 328 - 350 M.a. (Rb / Sr and U/ Pb).

Another small granitoid intrusion in the Lotru Group, e.g., is exposed at Criva (329 M.a. K / Ar) in the southern Poiana Ruscă. Older intrusions are found as orthogneiss associated with the crystalline schists.

**Upper Paleozoic and Mesozoic formations.**

The post-Variscan formations of the Getic Nappe, exposed mainly in the Reşiţa-Moldova Nouă zone, begin with Upper Carboniferous coal-bearing conglomerates and sandstones, followed by Permian black shales and red sandstones.

A new transgression begins with the Lower Jurassic coal-bearing detrital sequence, continued with Middle Jurassic marls or sandstones, Upper Jurassic limestones, Lower Cretaceous marls and Urgonian limestones. The Upper Cretaceous is represented either by red marls, by a volcano-sedimentary formation (Rusca Montană basin), by sandstones and red clays with *Dinosaurs* (Haţeg), or as conglomerates, sandstones and marls (Vânturariţa, Olăneşti).

**Reşiţa-Sasca-Gornjak Nappe.** The following structural unit is characterized by the presence of Triassic formations. In Serbia, its basement consists of an anchimetamorphic Devonian-Lower Carboniferous flysch, with *Corals, Tentaculites*, *Orthoceratids* and *Pelecypods*, including olistoliths with Late Silurian *Orthoceratids* and *Crinoids* (Dimitrijević, 1997). Upper Carboniferous conglomerates and Permian black shales and red sandstones are overlain by Lower-Middle Triassic conglomerates followed by fossiliferous dolomites and limestones, the Jurassic being similar with the same formations of the Reşiţa-Moldova Nouă zone.

Supragetic Nappes. The Supragetic Units can be divided in Western and Eastern ones; the former appear in Banat while the latter are exposed in the Făgăraş Mountains, east of the Olt.

**Western Supragetic Units Metam orphic basement.**

**The Bocşiţ a - Drimoxa Formation** consists mainly of garnet-bearing paragneisses with oligoclase porphyroblasts, and amphibolites overprinted by retrogression. It corresponds probably to a part of the Locva "Series" exposed at the entrance of the Danube into Romania. Its age could be Upper Precambrian to Lower Paleozoic.

The Caraş Group includes the Naidăş-Rafnic volcano-sedimentary Formation at the base, the Dognecea-Zlatiţa terrigenous Formation and the Tâlva Mare quartzitic Formation, all exposed either in the Bocşa Massif or in the Locva Massif (SW Banat). The characteristic feature of the Caraş Group is the development of a bimodal magmatic association: rhyolites, gabbros, dolerites (Iancu, 1982, 1986; Iancu, Mărunţiu, 1994). The metamorphic parageneses point to a polymetamorphic history.

The **Moniom Group** consists of the volcano- sedimentary Valea Satului Formation (Upper Devonian-Lower Carboniferous). It includes mainly mafic metatuffs with interlayered metapelitic and carbonatic rocks, scarce acid metatuffs and small bodies of gabbros and diorites-granodiorites.

Their metamorphism is low-grade (Iancu, 1982; Iancu, Mărunţiu, 1994).

In Serbia, the highest structural unit corresponding to the Western Supragetic is the Morava Nappe. The main part of its basement consists of the "Vlasina Series" (Dimitrijević, 1997). It is overlain at Bosilegrad, in south-eastern Serbia, by the anchimetamorphic Lisina beds, the Tremadocian age of which is constrained by *Brachiopods.* Consequently, the Vlasina Series could be compared to the Locva "Series" or to the Bocşiţa-Drimoxa Formation.

**Mesozoic formations.** The Bocşiţa-Drimoxa Formation is overlain, west of Reşiţa, by limestones, the age of which could be ascribed to the Upper Jurassic-Lower Cretaceous.

**Eastern Supragetic Units. Metamorphic basement.** East of the Olt, the Supragetic basement is represented mainly by two groups: Cumpăna and Făgăraş.

The **Cumpăna Group** is composed of the Cumpăna linear Gneiss (originating in a polymetamorphic granite), the Cozia Augengneisses and the Măgura Câinenilor Micaschists (+ kyanite, staurolite).

The **Făgăraş Group** consists of a sequence of micaschists, crystalline limestones and dolomites, para-amphibolites and graphite schists; an intensive retrogressive overprint developed over large areas.

The **Leaota Group** is considered by Săndulescu (1984) and others as belonging to the Getic Nappe. Its sequence consists of the Voineşti Formation (Upper Precambrian, according to palynological data), similar to the Bocşiţa-Drimoxa Formation, the Bughea Amphibolite, the Lereşti Formation (definitely Lower Ordovician, according to palynological data) of albite-porphyroblast schists and albite gneisses and the Căluşu Formation (Devonian ?) consisting of greenschists. The Bughea Amphibolite is intruded by the Albeşti Granite (473-486 M.a., K / Ar).

**Serbo-Macedonian Massif.** The Serbo-Macedonian massif falls outside our observation area. It is considered by some authors (Săndulescu, 1984; Dimitrijević, 1997) as part of the same structural unit as the Supragetic. However the two units are separated by a major shear zone (Dušanovo, Rozaj-Bovan or Vrvi Kobila line, Kräutner, Krstić, 2002). North of the Danube, the western parts of the Vršac (Serbia) and Buziaş (Romania) crystalline "islands" belong to the Serbo-Macedonian massif str.s.

**Main tectonic features.** Similarly to the South Apusenides, the geotectonic evolution of the South Carpathians was polyphasic: 1) During the Mesocretaceous tectogenesis, the Getic Nappe was overthrust onto the Severin Nappe. 2) During the Laramian tectogenesis, the Severin Nappe bearing the Getic Nappe "piggy-back" was overthrust onto the Danubian (Codarcea, 1940). The overthrust of the Upper Danubian onto the Lower Danubian as well as that of the Western Supragetic onto the Getic probably belong to the first phase. Each of the main Alpine units described above is complicated by pre-Variscan, Variscan and even Alpine subunits. The age of overthrust of the Eastern Supragetic is controversial.

**Banatitic Late Cretaceous magmatism.** In the Romanian South Carpathians, the Upper Cretaceous magmatism was mainly intrusive and developed along three lineaments; it is represented by calc-alkaline plutons (granodiorites, granites, diorites) as well as by hypabissal minor intrusions of porphyry quartz-diorites, monzogranites, andesites, dacites, rhyolites and lamprophyres. Only in the Rusca Montană Upper Cretaceous basin overlying both the Getic and Supragetic an andesitic volcano-sedimentary formation is exposed. Isotopic K / Ar ages are comprised between 91 and 65 M.a. (Berza et al., 1998).

## Field itinerary

### DAY 1

**Suceava - Gura Humorului - Câmpulung Moldovenesc - Vatra Dornei**

**Aims** : This is one of the northernmost profiles (excepting the Maramureş) across the whole East Carpathian structure. Along it there is the possibility to examine the Subcarpathians, the Flysch Zone and the Central East Carpathians (with their superposed nappes). The XV$^{th}$ century frescoed Voronet monastery will be visited.

From Suceava the fieldtrip leaves toward the west, following main road no. 17. Until Păltinoasa, about 30 km from Suceava, the Sarmatian formations of the Foreland will be crossed. At Păltinoasa, the frontal part of the Flysch nappes is well expressed.

## Stop 1.1:
**Păltinoasa Quarry.**

On the left-hand bank of the Moldova, at Păltinoasa, a sequence crops out of the Lutetian - Bartonian formations of the Păltinoasa "Rabotage" Slice. The most important part of this sequence is represented by the Păltinoasa Sandy Limestone of Lutetian age (Ionesi, 1971). It is equivalent to the Paszieczna and Doamna limestones (see Tab.I). On the top of the quarry, above the Păltinoasa Sandy Limestone, lies the Strujinoasa Formation, a variegated shaly - clayey formation, in which red - purple clays are dominant. The Lutetian / Bartonian stratigraphic boundary is situated within the Strujinoasa Formation.

Upstream, in the town of Gura Humorului, the front of the Tarcău Nappe will be crossed. In front of the Tarcău Nappe the Păltinoasa "Rabotage" Slice is situated. Furthermore, all along the front of the unit such "rabotage" slices are common, until the East Carpathians Bending Area (Vrancea Mts.). In the Gura Humorului area boreholes situated on the external part of the Tarcău Nappe, penetrated in the Păltinoasa "Rabotage" Slice and, crossing a narrow Subcarpathian Nappe, reached the underthrust Foreland, there represented mostly by the Scythian Platform. Similar geological situations were drilled northward in the Putna Valley (near the Roumanian / Ukrainian boundary).

## Stop 1.2:
**Voronet.**

In Voroneț, along the river with the same name, the **Paszieczna Limestone** (Lutetian) crops out. It is a pelagic lithographic white-yellowish limestone, with cherts and, sometimes, with resedimented *Nummulites.* They are followed by the Plopu Formation (see the next stop).

In the southern part of the village the **Voroneț Monastery,** founded in the XV$^{th}$ century by Stephen the Great, Prince of Moldavia, will be visited. The outer and the inner walls are covered by frescoes.

## Stop 1.3:
**West of Gura Humorului.**

At 1.6 km upstream from the western end of Gura Humorului a profile open on the left-hand bank of the Moldova allows us to examine the Lutetian-Rupelian succession, specific for the external part of the Tarcău Nappe (Sucevița lithofacies). Above the Lutetian Paszieczna Limestone, follows the two-component, dense rhythmically turbiditic sequence ("hieroglyphic beds-type flysch") of the Plopu Formation (Uppermost Lutetian-Priabonian). Red and purple clayey shales (an equivalent of the Strujinoasa Formation) are inlayered in the lower third. The Eocene / Oligocene boundary is situated within a sandstone sequence (Săndulescu et al., 1987). The lower part of it - the **Lucăcești Sandstone** - shows inlayerings of "Globigerina marls" (white compact marls rich in planktonic microfauna, nanoplankton and silicoflagellates of Late Priabonian age), while the upper part - the **Fierăstrău Sandstone** – has inlayerings of dark bituminous siltstones and/or clays (containing nanoplankton and silicoflagellates of Earliest Rupelian). The sandstones are both orthoquartzitic (oligomictic), the Lucăcești one also containing grains of glauconite. The **Lower Menilites with Brown Marls** is the next lithostratigraphic unit. It is built up by well-layered bituminous silicolites (menilites), which proceed from the diagenesis of the Diatomaea rich muds. Dark brown bituminous marly limestones (the so called "Brown Marls") are associated with the Lower Menilites. Very thin intercalations of bituminous clays or siltstones also occur. The **Lower Dysodilic Shales** follow between the Lower Menilites and the Kliwa Sandstone. They are dark-coloured bituminous clays or clayey siltstones, very thinly layered in sub-mm. sheets ("paper-sheeted"). Intercalations of cm. to decimeter-fine quartzitic sandstones occur. Massive orthoquartzitic sandstones – **Kliwa Sandstone** - develop in the top of the succession of this outcrop. The quartzitic grains of the Kliwa Sandstone are of aeolian origin, subsequently transported and resedimented in the outer part of the Moldavidian sedimentary basin. The source of this detrital material was situated in the Foreland, a conclusion documented by the lithic fragments of "Green Schists" (Dobrogean type) included in the arenites. Of the same origin as the Kliwa Sandstone are also the Lucăcești and the Fierăstrău sandstones. The first three lithostratigraphic units of the Oligocene belong to the Rupelian. The boundary between the Rupelian and the Chattian runs within the Kliwa Sandstone. The complete succession of the "Bituminous Lithofacies with Kliwa Sandstone" above the Kliwa Sandstone consists of: the Upper Dysodilic Shales (the Oligocene/Miocene boundary runs within their lithostratigraphic unit), the Upper Menilites (without "Brown Marls"), the Goru-Mișina Formation (coarse-grained rocks rich in "Green Schists" debris), the (lower) Evaporitic Formation (Burdigalian) (Săndulescu and Micu, 1988).

## Stop 1.4:
**Frasin.**

The locality of Frasin is situated at the confluence of Suha Bucovineană with the Moldova. On the left-hand (northern) bank of Moldova, in an imbricated structure, also belonging to the Tarcău Nappe, several Senonian and Paleocene sequences crop out. The **Hangu Formation** is a Senonian calcareous turbiditic (flysch) formation. Two-components (limy arenites/marls) or three-components (limy arenites/marls/marly or lithographic limestones) rhythms are developed. The graded-bedded arenites show at their basal part grains of "Green Schists", limestones and fragments of *Inoceramus*. Ammonites, inocerams and a rich pelagic foraminifer assemblage (Ion-Săndulescu, 1975; Antonescu et al., 1989) document the Senonian age for the Hangu Formation. The Paleocene is represented by the **Putna Formation**. This is a sandy/marly flysch with a two-component rhythms in which the sandstones are rather dominant in thickness. The arenitic material is of polymictic type (as for the Hangu Formation) containing "Green Schists" too. The Paleocene age (Antonescu et al., 1989) is supported by a rich pelagic microfauna and by scarce examples of *Dyscocyclina*. The Straja Formation is younger than the Putna one. It is a variegated flysch built up by two-component rhythms in which the arenites are polymictic, with a silica matrix and the pelites are red-purplish, green and grey. Glauconite may be frequent in the sandstones. The age of this formation is (according to the microfaunal content) Uppermost Paleocene-Lower Ypresian. The source area for the Straja arenites is external (Foreland), as well as for the whole Cretaceous-Paleogene-Lower Miocene succession of the external part of the Tarcău Nappe as well as those of the Marginal Folds and Subcarpathian nappes.

## Stop 1.5:
**Vama.**

The locality of Vama is situated in an area corresponding to the inner subunit (digitation) of the Tarcău Nappe, the Vama Digitation respectively. On both banks of the Moldova River the Paleogene formations of the digitation crop out. The oldest sequence (cropping out) is the **Moldoviţa Sandstone**. It represents a sandy flysch with mica-rich arenites, which prevail in respect to the clayey pelites, within two-component rhythms of 30-100 cm. The arenitic material proceeds from an internal (Carpathian) source situated in the Central-East Carpathians and the innermost nappes (Black Flysch, Ceahlău) of the Flysch Zone. The age, according to the agglutinated foraminifera associations, is Lower-Middle Eocene, possibly uppermost Paleocene also. Some red-purplish shales are inlayered at different levels. Above the Moldoviţa Sandstone follows the Plopu Formation (see Stop 1.3). The Lower Oligocene sequences are developed in two lithofacies. In the external scales of the Vama Digitation, above the Plopu Formation, the **Lower Menilites** and the **Lower Dysodilic Shales crop out,** as in the more external zones (see above). In the inner scale of the Vama Digitation above the Plopu Formation the **"Shaly Horizon"** with grey, dark-grey and blackish clays and silts, thin sandstone inlayering and also rare, sideritic pelagic limestones are developed. It is an equivalent of the Lower Menilites and Lower Dysodilic Shales. In the inner parts, the Fusaru Sandstone follows. This is a massive, micaferous sandstone, lithologically similar to the Tarcău Sandstone, proceeding from the same source area (Carpathian). In the outer part of the Vama Digitation the Fusaru Sandstone is mixed with Kliwa Sandstone, stressing out their interfingering. The youngest sequence is the **Vineţişu Formation,** a two-component flysch with limy arenites, often convolute, and marls. The Oligocene/Lower Miocene boundary runs within it (fide Săndulescu et al., 1995).

In Prisaca Dornei the front part of the Audia Nappe, which overthrusts the Tarcău one, is well expressed in relief.

## Stop 1.6:
**West of Prisaca Dornei.**

On the left-hand bank of the Moldova River, 700 m west of the western border of Prisaca Dornei village, massive sandstones representing the **Prisaca Sandstone** crop out. This is the youngest formation of the Audia Nappe in this area; its age is Maastrichtian-Lutetian (Săndulescu et al., 1992). The arenitic material of the Prisaca Sandstone, polymictic, rich, mica-bearing, proceeds from the Carpathian source. In the analysed outcrop it is possible to observe "soft pebbles" ("galets mous") of "Black Shales" reworked by the fluxoturbiditic currents - perhaps in submarine canyons - from the Lower Cretaceous "Black Shale" Formation of the same sedimentary basin. 100-200 m downstream from the outcrop slided variegated shales may be observed which represent the condensed sequence of the Vraconian-Lower Senonian (the "Variegated Clay" Formation) situated between the Prisaca Sandstone and the "Black Shale" Formation.

The town of Câmpulung Moldovenesc, about 10 km long, develops along the Moldova Valley, more or less parallel to the tectonic structures.

## Stop 1.7:

**Câmpulung Moldovenesc – Izvorul Alb brook.**

The frontal part of the Bucovinian Nappe is well exposed in the lowermost part of the Izvorul Alb Brook, at the periphery of the town. At the same time it corresponds with the anticlinorium which limits the external limb of the Rarău Syncline. In the Izvorul Alb brook a complex of anticline folds are marked by the outcropping of the Anisian massive dolomites (shallow water, with intratidal "cracking breccia" zones). With a large erosional gap the **Pojorâta Formation**, which is a two-component flysch sequence, 700-800 m thick, follows. The arenites are polymictic (subgreywackes) with limy or marly matrix, the lutites are marls. Red and yellowish marly pelagic limestones are intercalated at different levels. The age of the Pojorâta Formation is Tithonian-Neocomian, stressed by their *Tintinnides* and *Aptychus* content (*Lamellaptychus beyrichi, L. beyrichi* var. *fractocostata* and *Lamellaptychus gr.*A and *Calpionella alpina, C. elliptica, Tintinopsella carpathica* - cf. Turculeţ, 1971; Săndulescu, 1973; Săndulescu et al., 1976). Above one of the dolomitic anticlinal cores, between them and the Pojorâta Formation, red-purplish silts may be observed. They may be an equivalent of the **"Radiolarite Beds"** of Callovian-Oxfordian age, which in other areas of the Rarău Syncline are well developed. The filling of the Rarău Syncline and consequently, the youngest sedimentary formations of the Bucovinian Nappe, is represented by the Wildflysch Formation of (Upper Barremian ??) Aptian-Albian age (Mutihac and Bratu, 1965; Săndulescu, 1975). It can be examined along several km in the Izvorul Alb Brook, upstream of the confluence with the Limpede Brook (the dolomites quarry). Wildflysch is a mixed formation with a dark-coloured, clayey or siltic-clayey matrix in which sedimentary klippen from different rocks of different ages are incorporated, but all older than the matrix. In the Bucovinian Wildflysch Formation the sedimentary klippen – of very different sizes - belong to the different lithofacies of the Transylvanian Nappes (basic and ultrabasic rocks, Middle and Upper Triassic limestones and dolomites, Lower and Middle Jurassic sandy-marly rocks, Upper Jurassic-Neocomian and Urgonian (Barremian) massive limestones) (Săndulescu, 1975, 1976; Săndulescu et al., 1981). The sedimentation of the Wildflysch Formation precedes the "arrival" – at the end of the Albian - of the Transylvanian Nappes, the sedimentary klippen involved within the wildflysch proceeding from the front of the nappes in movement.

From the Izvorul Alb Brook or from the suburbs, downstream from the town of Câmpulung Moldovenesc it is possible to see the Rarău Mts. The white cliffs which are visible correspond to the Middle Triassic dolomites and the Urgonian limestones, tectonic outliers of the Transylvanian nappes.

## Stop 1.8:

**West Sadova.**

On the left-hand bank of the Moldova River, 120 m west of the railway/national road crossing, an anticline of the Bucovinian Nappe can be examined, marqued by the outcropping of the "Aptychus Beds" Formation of Tithonian-Valanginian age. This formation consists of well bedded, white, yellowish, grey or red-purplish lithographic limestones, sometimes with cherts. Typical assemblages of Tintinnides (*Calpionella alpina, C. elliptica, Crassicolaria massutiniana, C.parvula* followed by *Tintinopsella carpathica, Calpionellites darderi and Calpionellopsis simplex* - Săndulescu, 1976) corroborated with the Aptychus fauna (Turculeţ 1971) support the above-mentioned age. The "Aptychus Beds" Formation is, more or less, a stratigraphic equivalent of the Pojorâta Fm., but with a more internal position, stressing that the arenitic material of the latter has an external source in respect to the paleogeographic position of the Bucovinian Nappe, the source being situated in the area corresponding paleogeographically to the Subbucovinian Nappe. On the western limb of the complex anticlinal structure of West Sadova the Muncelu Sandstone (conglomerates and coarse grained sandstones outcropping in a large quarry) of Hauterivian age, develops. This Sandstone is recorded also, slighty discordant (?) above the Pojorâta Formation.

The Wildflysch Formation constitutes, normally, the filling of the Rarău Syncline, but with an asymmetrical position: the post-Triassic formations known on the outer limb of the syncline are absent on the inner one where the wildflysch lies directly on the Triassic dolomites and the "Radiolarite Beds", both cropping out in Pojorâta in several quarries. From Pojorâta the fieldtrip follows the Moldova Valley upstream to Breaza. In this tract the road crosses the metamorphic formations of the Bucovinian Nappe and, once more, the Rarău Syncline.

## Stop 1.9:

**Breaza Ultramafic Tectonic Outlier (the visit of the Breaza tectonic outlier will be conditioned by the time and weather situation).** Above the Wildflysch Formation of the northen sector of the Rarău Syncline, ultramafic rocks which represent a tectonic outlier of the Transylvanian nappes are developed (Săndulescu, 1973; Săndulescu and Russo - Săndulescu, 1981). It is located in the axis of the syncline, which has an asymmetric shape in this area, with the external limb less developed than the internal one. On a left-hand tributary of the Moldova River, in Breaza, in front of the church, the following cross-section may be examined: on the first 300 m the **Sinaia Formation** of the Ceahlău Nappe (Tithonian-Neocomian calcareous flysch) crops out; it is overthrust by the **metamorphic** rocks of the Bucovinian Nappe, overlapped by Anisian dolomites and Callovian-Oxfordian (?) (or Ladinian?) **"Radiolarite Beds"**; the **Wildflysch Formation**, as a rule, represents the filling of the syncline. On the summits situated north of the brook the **peridotites** and **serpentinites** of the Breaza Tectonic Outlier crop out. This nappe outlier may be an equivalent of the Olt Nappe, which also contains ultramafic rocks of Ladinian/Carnian age. Further northward in the Păltiniș Summit conglomerates and coarse-grained sandstones of Cenomanian age are preserved from erosion. They seal the tectonic contacts between the Transylvanian and Bucovinian nappes and between the latter and the Ceahlău Nappe.

The field-trip returns to Pojorâta and enters the Putna Brook (left tributary of Moldova River). Both slopes of the Putna Valley consist of metamorphic rocks of the Tulgheș Series, which belongs to the Bucovinian Nappe. At 4 km along the Putna Valley within a tectonic window the sedimentary formations of the Subbucovinian Nappe are exposed.

## Stop 1.10:

**Putna Valley Tectonic Window.** The oldest formations cropping out are the Anisian dolomites. Thin red siliceous silts, possibly Ladinian, certainly Triassic, cover the dolomites. The youngest sequence known in the window are Lower Jurassic (according to the silicoflagellate assemblages) **limonitic sandstones** with **blackish siltstone** intercalations. The Subbucovinian sedimentary rocks are tectonically overlapped, at 50 m above the brook, on its slopes, by the Tulgheș Series formations. Massive metamorphosed dolomites, which may belong to the Rebra Series, tectonically transported at the base of the Tulgheș Series, can be examined at the eastern border of the window. In the thalweg of the Putna brook, in front of a small tributary, a thin bank of graphite quartzites and schists crop out. The rocks belong to the "Median Complex" (Tg2) of the Tulgheș Series. Descriptions after Kräutner in: Sndulescu et al., 1981. The western border of the window is a vertical fault with a displacement of about 500 m (controlled by a borehole situated 100 m west of the fault). The borehole was drilled in the Bucovinian Nappe and reached the Subbucovinian Anisian dolomites.

The fieldtrip continues upstream, westward. At the Valea Putnei Railway Station the erosional contour of the Bucovinian Nappe is stressed by the tectonic superposition of the metamorphic formations of the nappe above the Subbucovinian sedimentary formations which shows the same lithostratigraphic succession as in the Valea Putnei Tectonic Window.

In the Mestecăniș Pass (1083 m in altitude), which is reached 5 km west of Valea Putnei Railway Station, a beautiful view opens out on the Bistrița Mts. and the Bistrița Aurie Valley, where the deepest Central East Carpathains unit, the Iacobeni Nappe, the highest of the Infrabucovinian nappes crops out within a tectonic window.

From the Valea Putnei Railway Station up to Mestecăniș Pass and from there down until the western margin of the Mestecăniș Village, the road crosses the Tulgheș Series of the Subbucovinian Nappe.

## Stop 1.11:

**Puciosu Valley Cross Section.**

Along the national road, which runs on the right-hand slope of Puciosu Brook, the basal sequence of the Subbucovinian Nappe and the sedimentary formations of the Iacobeni Infrabucovinian nappe are exposed. Upstream-downstream it is possible to examine: (1) the **Black Quartzitic Formation** (TG2) of the Tulgheș Series of the Subbucovinian Nappe (Bercia et al., 1975) represented by sericitic-quartzitic and chloritic-graphitic schists, with two levels of black quartzites; thin intercalations of metabasalts or limestones and calcschists, are known, south and north of Puciosu Brook. The black quartzites mark the level of syngenetic manganese ores, which consist of Mn-carbonate and silicates, enriched in Mn-oxydes in the oxidation zone. The principal mines are located some kilometers southwards; (2) the **"Argestru Formation"** (see also below), built up of metapsammites and phyllites with intercalations of metabasalts; (3) weak bituminous ("stinking") Anisian dolomites

and limestones. Up on the slope, with a large stratigraphic gap, Middle Jurassic limy sandstones follow (Săndulescu, 1976).
Before the first houses in the Iacobeni locality, downstream from a right-hand tributary, a small window of Infrabucovinian Anisian dolomites are exposed underneath the metamorphic rocks of the "Argestru Formation". The western border of the window is a vertical fault. About 350 m downstream the well-layered Anisian dolomites crop out in a large quarry. At its uppermost part, massive dolomites seem to cover the layered dolomites with tectonic disconformity.
Downstream, west of the large dolomite quarry, towards the Bistriţa Aurie River, blocks and fragments of **Lower Triassic quartzitic sandstones and conglomerates** as well as **purplish siltic clayey shales** occur. Near the confluence between Puciosu Brook and the Bistriţa Aurie River, along the road to Ciocăneşti, an outcrop of muscovite-quartz schists with chloritised biotite can be examined. It is ascribed to the **Bretila Series**, which also crops out several hundreds of meters upstream on the left-hand bank of the river, where gneisses may be recognized too. In the metamorphic schists axes of mesoscopic folds trend N 20 W / 10 NW. Descriptions after Kräutner in: Săndulescu et al., 1981.
The tectonic framework and the age of the "Argestru Formation" was subject of controversy. Firstly it was considered a lithostratigraphic Paleozoic unit which builds up an independent tectonic unit ("Argestru Unit") situated between the Subbucovinian Nappe and the Infrabucovinian nappes. Afterwards the "Argestru" sequence was considered an equivalent of the Rebra Series or later of the Bretila Series, squeezed in both interpretations at the base of the Subbucovinian Nappe (Kräutner, 1980, 1988; Balintoni, 1985, 1997).

## DAY 2

**Vatra Dornei – Bicaz - Lacul Roşu - Gheorghieni - Miercurea Ciuc**

**Aims:** Along the Bistriţa Valley, south-east of Vatra Dornei, the formations which built up the inner units of the Flysch Zone (the Ceahlău, Convolute Flysch and Audia nappes) can be examined, as well as the inner part of the Tarcău Nappe. In the upper Bicaz Valley the Hăghimaş Syncline (Bucovinian Nappe and Hăghimaş Transylvanian Nappe) will be crossed.
From Vatra Dornei the fieldtrip follows the Bistriţa valley downstream. Until Broşteni it crosses the Central East Carpathians nappes (Crystalline-Mesozoic Zone). The Infrabucovinian, Subbucovinian and Bucovinian nappes crop out represented by their metamorphic formations.

### Stop 2.1:
**Broşteni-Cotârgaşi.**

At the downstream margin of Broşteni and 700 m upstream, the confluence of Cotârgaşi Brook with the Bistriţa River, the frontal contour of the Bucovinian Nappe crosses the Bistriţa Valley. 200 m upstream of this contour a small tectonic window is opened in the metamorphic formations of the nappe; within this window Anisian dolomites crop out. They belong to the sedimentary sequence of the Subbucovinian Nappe. The dolomites were transported as a tectonic outlier ("lambeau de charriage") by the Bucovinian Nappe. Such situations are frequent all along the frontal contour of the Bucovinian Nappe (see also Stop 2.10). Downstream from the front of the Bucovinian Nappe the innermost unit of the Flysch Zone – known in this area - crops out. It is the Cotârgaşi Unit (Scale). The Cotârgaşi Formation can be examined in a large outcrop where well-bedded pelagic micritic or marly limestones are exposed; they show relatively rare intercalations of polymictic graded bedded sandstones. In the Cotârgaşi Formation at different levels and with different thicknesses, polymictic (amphibolites, micaschists, chloritic phyllites, quartzites, Triassic and/or Jurassic dolomites and limestones) limy breccias and/or microbreccias, are inlayered. From the lower and middle part of the formation poor Tintinnide associations (with *Calpionella alpina, C.elliptica, Tintinopsella carpathica*) stress the Tithonian-Neocomian age. The upper third, where the breccias prevail, may be Hauterivian or even Barremian.
Following its tectonic position between the Central East Carpathian nappes and the Ceahlău one, the Cotârgaşi Unit may be correlated with the Baraolt Nappe known southward in the inner Bend Area. In fact the lithofacies of the Cotârgaşi Formation shows some similarities with the isochronous sequences of the Baraolt Nappe.
The fieldtrip proceeds downstream. For more than 20 km the Bistriţa Valley crosses the Sinaia Formation of the innermost sub-unit (digitation) of the Ceahlău Nappe, the Ciuc Digitation respectively.

### Stop 2.2:
**Sinaia Formation in the Bistriţa Valley.**

The **Sinaia Formation** (4-5 km in thickness) is a calcareous flysch, with turbiditic two- and three-component rhythms (limy sandstone / marls, silty marls / marly limestones, limy sandstones / marls / marly limestones), 25-75 cm thick. The sandstones are polymictic, the marly limestones are pelagic, micritic, containing Tintinnides at different levels. Generally, taking into account the whole Ceahlău Nappe, the Sinaia Formation can be divided into three members. The lower one is dominantly pelitic (marls and siltic marls) with inlayerings of marly pelagic limestones and scarce sandstones. In the limestones *Calpionella alpina* (frequent*)* and *C.elliptica* were found, the age considered as Tithonian. The median member shows the typical lithofacies of the Sinaia Formation (see above) and represents 75-80% of its thickness. The presence of *Calpionella elliptica, Tintinopsella carpathica, Calpionellites div.sp.* was determined, supporting the Berriasian-Valanginian age. The Upper Member , Hauterivian in age (with *Peregrinella peregrina)*, is represented by a two-component flysch (limy sandstones and dark coloured marls) characterized by inlayerings of limy polymictic breccias (meso- and epizonal metamorphics, Triassic and/or Jurassic dolomites and limestones, quartzitic sandstones). The Sinaia Formation shows frequent diaclases filled with calcite and also some zones of schistosity.

## Stop 2.3:

**Ugra Formation at Săvinești locallity.**

The Barremian-Aptian formations of the Ciuc Digitation are represented by a turbiditic and fluxoturbiditic sandy flysch – the Ugra Formation. In the 30-150 cm thick, two-component rhythms, sandstones (65-90 %) prevail over marls or silty marls. The arenitic material is polymictic (subgreywacke-type) (quartz and quartzites, meso- and epizonal metamorphics, Triassic and Jurassic limestones and dolomites, as well as mafics and ultramafics) its source area being situated inward relative to the sedimentary trough.

Downstream of Săvinești near Topliceni the field trip enters the Durău Digitation, external in respect to the Ciuc one. The specific formations of this sub-unit of the Ceahlău Nappe, above the Sinaia Formation, are the Piscu cu Brazi Formation and the Ceahlău Conglomerates.

## Stop 2.4:

**Piscu cu Brazi Formation at Poiana Teiului.**

On the right-hand bank of the Bistrița River, 1 km upstream of the large viaduct from Poiana Largului, and also on the western bank of (antropic) Bicaz Lake, the **Piscu cu Brazi Formation** crops out. It is a two-component flysch, with rhythms 10-50 cm thick. The sandstones are polymictic (same composition as the Ugra sandstones – see above), the pelitic component is marly or silty marly. Toward its upper part the Piscu cu Brazi Formation grows more massive with 0.5-1.5 m of sandstone (Poiana Maicilor Sandstones). The age of the Piscu cu Brazi Fm. is Barremian-Aptian according to the different ammonitic faunas recorded at different levels (fide Săndulescu, 1990). The Poiana Maicilor Sandstones are developed in the Upper Aptian. The youngest formation of the Durău Digitation are the Albian Ceahlău Conglomerates, which built up the Ceahlău Mts., visible south of Bicaz Lake.

At Poiana Teiului a calcareous isolated rock is situated at the northern end of Bicaz Lake (near the viaduct). It is built up of Urgonian limestones with *Pachyodonta* and *Orbitolina* (Barremian-Lower Aptian) and represents a tectonic slice, pulled out from the outer margin of the Outer Dacidian trough – the Peri-Moldavian Cordillera - and transported to the base of the Ceahlău Nappe. From Poiana Teiului the fieldtrip proceeds along the north-eastern slope of Bicaz Lake.

## Stop 2.5:

**Frontal contact of the Ceahlău Nappe / Convolute Flysch Nappe.**

About 4 km downstream from the Poiana Teiului viaduct, the fieldtrip reaches the erosional contour of the tectonic contact between the outernmost part of the Ceahlău Nappe and the youngest formations of the Convolute Flysch Nappe. **Massive micaferous sandstones** representing the outermost sub-unit of the Ceahlău Nappe (? the Bodoc Digitation) is overthrust above the **Upper Convolute Flysch Member** (two-component turbiditic rhythms, 10-20 cm, with more or less frequent inlayerings of red marls). The age of this lower sequence of the Upper Convolute Flysch Member is Vraconian-Cenomanian; in some other areas of the East Carpathians, where this Member is fully developed, the micropaleontological assemblages specified a Vraconian-Lower Senonian age (Săndulescu J., 1976; Antonescu and Săndulescu, 1985; Săndulescu et al., 1993).

## Stop 2.6:

**Cotumba Sandstone and Lețești Conglomerates.** About 1.6 km downstream along the national route, massive sandstones with conglomerates and microconglomerate intercalations crop out. The massive sandstones represent the **Cotumba Sandstone**

situated at the middle part (Middle- and a part of the Upper Albian) of the Convolute Flysch Formation. It is a quartzitic-micaferous sandstone, graded bedded or with fluxoturbiditic features, showing thin to very thin (joints) intercalations of dark or grey marls. The **Leţeşti Conglomerates** develop as lenses of different sizes within the Cotumba Sandstone. They are dominantly quartzitic, with few lithic fragments represented by metamorphic schists. The source area of the Cotumba Sandstone and of the Leţeşti Conglomerates, as well as for all arenites of the Convolute Flysch – represented by the Peri-Moldavian Cordillera - are situated on the inner border of the Convolute Flysch sedimentary trough.

## Stop 2.7:

**Lower Convolute Flysch Member at Chiriţeni.** 3.5 km downstream from the preceding stop, several outcrops of Convolute Flysch may be visited. This is a two-component flysch, with rhythms of 10-25 cm of arenites (limy or marly sandstones, graded bedded, frequently with convolute laminated bedding at the upper part) and pelites (marls or silty marls, dark, grey or green). According to the micropaleontological and palynological assemblages, this Lower Convolute Flysch Member is of Lower and partly of Middle Albian age. In the Bicaz Lake area the Lower Convolute Flysch constitutes the frontal part of the nappe, overthrusting the Audia Nappe.

## Stop 2.8:

**"Black Shales" Formation in the Audia locality.** The Audia locality and brook are situated in the Audia Nappe outcropping area. The main formation known in this nappe, developed in the so-called "Silesian Lithofacies", is the "Black Shales" Formation of Barremian-Albian age (according to the palynological assemblages and the ammonitic faunas). This Formation may be divided into three sequences: Member with pelosiderites (lower), Shaly Member (middle) and Quartzitic Sandstones with glauconite Member (upper). The specific lithology is represented by black or dark-grey clays and silty clays. Different inlayerings make the difference between the different members: calcareous sandstones and sideritic limestones (pelosiderites) in the lower member, black jaspers (lyddites) in the middle and largely developed graded bedded quartzitic sandstones in the upper one. The sandstones also contain lithic fragments of Dobrogean type "Green Schists", which is proof that the source area of the arenites is situated within the Foreland (actually underthrust – Figure - below the nappes of the Flysch Zone). The "Silesian Lithofacies" is also known in the more external nappes (Tarcău and Marginal Folds) and represents the outer development of the Flysch Zone sedimentary basin. It was sedimented in euxinic conditions, the dark shales having a relatively high content of bituminous material.

A few hundred of meters downstream from Stop 2.8 the field-trip penetrates into the Tarcău Nappe outcropping area. The Hangu Formation (see Stop 1.4) crops out in numerous points. 700-800 m before reaching the Bicaz Dam the "Black Shales" Formation crops out in the core of the Cârnu Anticline, a structure of the Tarcău Nappe.

## Stop 2.9:

**Tarcău Sandstone at the Bicaz Dam.** The Bicaz Dam is built on massive Tarcău Sandstone. The latter can be examined near the western margin of the dam. It is a typical sandy flysch with two-components (quartzose-micaferous, with rare lithic fragments, arenites and clayey lutites) rhythms of 30-120 cm.. The age of the Tarcău Sandstone (total thickness of about 3-4 km) is Upper Paleocene-Middle Eocene (Lutetian), according to the micropaleontological data (agglutinated foraminiferas assemblages); at the Bicaz Dam the uppermost level of the Tarcău Sandstone (with *Cyclammina amplectens* and *Sphaerammina subgaleata*) crops out also showing red clay intercalations. The Tarcău Sandstone is followed by a two-component flysch (limy sandstones / marls and clays) with rhythms of 10-25 cm of Upper Eocene age – the **Podu Secu Formation** – with inlayerings of **Globigerina Marls** (see also stop 1.3) at the terminal levels. The **"Shaly Horizon"** of the lower part of the Oligocene and the **Fusaru Sandstone** (see Stop1.5) follows.

From the Bicaz Dam the field-trip reaches the town of Bicaz and from there it turns westward along the Bicaz Valley. It will cross the whole inner part of the Flysch Zone in reverse sense (Audia, Convolute Flysch, Ceahlău nappes) as the field-trip crossed them in the Bistriţa Valley.

## Stop 2.10:

**The front of the Bucovinian Nappe at the locality of Bicazul Ardelean .**

On the right-hand bank of the Bicaz River, at the confluence with the Dămuc Brook in the western part of Bicazul Ardelean, the front of the Bucovinian Nappe as well as a tectonic ("rabotage") outlier carried from

the Subbucovinian sedimentary envelope, are well exposed (Săndulescu, 1975).
In the Subbucovinian outlier the following lithostratigraphic succession can be examined : **Anisian dolomites** representing the main part of the outlier/ **Lower Jurassic (?)** coarsegrained **quartzites/Middle Jurassic sandy limestones** with *Trocholina* div.sp., *Bositra buchi,Zeilleria* div.sp., *Parkinsona parkinsoni* etc. Discordantly, thin bedded **Tithonian limestones/ limy polymictic breccias** with inlayerings of **marly limestones**. Along the frontal part of the Bucovinian nappe such "Rabotage" Outliers crop out frequently (cf. Stop 2.1 too). Another lithostratigraphical succession with respect to the Gura Dămucului shows: Callovian-Oxfordian radiolarites, Tithonian-Neocomian pelagic limestones, with breccias inlayerings in the Neocomian. This two types of successions proceed from different parts of the Subbucovunian domain, with different paleogeographic evolutions. A third type of Subbucovinian lithostratigraphy may be considered the Putna Valley succession (Stop 1.10).
The Frontal part of the Bucovinian Nappe is represented by metamorphic formations of the Tulgheș Series (sericitic-quartzitic and sericitic-graphitic schists with inlayerings of metabasalts and porphyroids).

## Stop 2.11:

**The External Limb of the Hăghimaș Syncline :** At 1,5 km west from the Bucovinian front, upstream along the Bicaz Valley, the massive **Anisian dolomites** mark the outer limb of the Hăghimaș Syncline. **Lower Triassic quartzitic sandstones** discontinously develop at their base. A pre-Barremian or even - taking into account the general structure of the outer limb of the syncline – pre-Late Jurassic imbrication may be demonstrated on the left-hand bank of the Bicaz where a scale involving Middle Jurassic rocks may be examined. With an angular discordance, the Wildflysch Formation follows, with a similar lithologiy to that of the Rarău Syncline (see Stop 1.7).
The Wildflysch Formation is tectonicaly overlapped by the outliers of the Hăghimaș Transylvanian Nappe (the big limestones quarries upstream from Stop 2.11). Both Wildflysch Formation and Transylvanian Nappe are transgressively covered by the **Bârnadu Conglomerates** (Vraconian ? – Cenomanian) which constitute the Post-Tectogenetic Cover. The conglomerates crop out along the road 2 km upstream from the quarries. The Hăghimaș Transylvanian Nappe can be examined in the Bicaz Gorges (Cheile Bicazului) upstream until the eastern margin of the touristic locality of Lacu Roșu.

## Stop 2.12:

**Bicaz Gorges (confluence with the Bicăjel Brook).**
In the area of the confluence between the Bicaz with the Bicăjel the Tithonian-Neocomian succession of the Hăghimaș Nappe is exposed (Săndulescu, 1975). The Tithonian is represented by massive light coloured neritic limestones which contain gastropods (*Nerinea*), foraminiferas (*Trocholina alpina, T.elongata, Kurnubia, Kilianina,* etc.), calcareous algae (*Salpingoporella anulata*) as well as *Elipsactinia, Cladocoropsis mirabilis, Clypeina* div.sp., *Actinoporella podolica* etc. The Berriasian is represented by well layered pelagic limestones with *Calpionella elliptica, Tintinopsella carpathica, Calpionellopsis oblonga, Neocomites neocomiensis, Berriassiella privasensis*. The Neocomian has a similar lithology (massive neritic limestones) and follows clearly above the Berriasian formations. Downstream from the confluence (about 600 m ), the Neocomian limestones are covered, with a slight discordance, by Urgonian-type ones (white, yellowish and light reddish limestones and calcarenitic breccias which contain Pachyodonts [*Requienia* div.sp. *Toucasia carinata*], large foraminiferas [*Orbitolina conica*] as well as calcareous algae and briozoarians; the age of these limestones is at least Lower Barremian, possibly Barremian as a whole but not younger because they are inbedded as sedimentary klippen in ([Upper Barremian ??] Aptian formations of the Wildflysch).

## Stop 2.13:

**"Cheile Bicazului" Tectonic Half - Window.**
On the left-hand (northern) slope of the Bicaz River around the Chalet "Cheile Bicazului" (Bicaz Gorges) erosion has exposed a tectonic half-window from which the **Wildflysch Formation** crops out below the Hăghimaș Nappe. At the base of the latter, bodies of **mafic and ultramafic rocks** emplaced (Săndulescu and Russo-Săndulescu, 1981). Along the left-hand bank of the Bicaz River the following succession may be examined: above the Wildflysch, pillow-lava basalts and amygdaloid basalts, overlapped by siltic siliceous shales and red marls (Kimmeridgian), representing the first sedimentary levels above the Middle Jurassic oceanic crust. The succession continues with the massive Tithonian limestones. On the left-hand slope of the Bicaz River, 300 m behind the Chalet at the base of the Hăghimaș Nappe are transported serpentinites which also proceed from the obducted

oceanic crust emplaced at the base of the Transylvanian nappes.
From the Chalet “Cheile Bicazului” the fieldtrip continues upstream. After 2 km crossing the massive Tithonian limestones the road arrives at the inner erosional contour of the Hăghimaș Nappe and enters the inner limb of the Hăghimaș Syncline. There the Mesozoic sequence of the Bucovinian Nappe crops out largely.

## Stop 2.14:

**Lacu Roșu - Bucovinian Middle Jurassic-Triassic formations.**

Along the northern bank of the Lacu Roșu (Red Lake), a lake generated in 1837 by a natural dam formed by a huge landslide of the right-hand slope of the Bicaz Valley, the following geological section (upside/downside) may be examined: **sandy limestones** (several hundred meters) with massive layering (Aalenian-Bajocian) / **oolithic-hematitic silty limestones** (50-200 cm) containing condensed fauna of Sinemurian-Carixian age / **rauhwacke dolomites** and **limestones** (20-70 m) with calcareous algae (Upper Anisian-Lower Ladinian) / massive Anisian dolomites.
In the filling of an inward overturned syncline, situated westward in respect to the previously analysed sequence, above the Middle Jurassic sandy limestones, well layered **radiolarites** of Callovian-Oxfordian age are exposed.

## Stop 2.15:

**Hăghimaș Granitoids.**

Below the Anisian dolomites or the Lower Triassic quartzitic sandstones and/or conglomerates of the inner limb of the Hăghimaș Syncline, the basement of the sedimentary formations consists of compact red augengneisses, with fine intercalations of biotite-muscovite paragneisses. Their general attitude is N 50-67 W/55 NE. The red gneisses consist of quartz (35%), orthoclase (49%), oligoclase (11%) and biotite (5%). A gradual transition can be seen from red orthogneisses to gray granular gneisses, which also carry garnet. The augengneisses are interpreted as laminated granitoids.The Hăghimaș Granitoids are a part of the Bretila Series which is overthrust above the Tulgheș Series, during the Paleozoic (a Caledonian or a Hercynian tectonic event). This overthrust, corresponding to the Rarău Nappe, is a structure of the metamorphic basement of the Bucovinian Nappe and was not involved in the Mesozoic tectogeneses (N. Stan, 2000).
The fieldtrip reaches the Pângărați Pass (1257m) situated on the main East Carpathian crest, separating the Transylvanian hydrographic basins from the Moldavian ones. From the Pângărați Pass a panoramic view of the Volcanic Chain and the Gheorgheni Quaternary Depression opens westwards. Eastwards the Mesozoic Hăghimaș Syncline with the Hăghimaș Nappe in the axial part shows its panoramic view. From the Pângărați Pass downstream along Belcina Brook (left-hand tributary of the Mureș River) the metamorphic formations of the Tulgheș Series of the Bucovinian Nappe are crossed. Below it the Negrișoara Series, belonging also to the Bucovinian Nappe metamorphic basement crops out in several points. The Pietrosu Gneisses (cropping out 4 – 4.7 km east of Gheorgheni), a schistose gneiss with relict phenoclasts of violaceous quartz can be examined. From Gheorgheni the fieldtrip turns toward south proceeding to Miercurea Ciuc. After crossing the Gheorgheni or Ciucul de Sus (Upper Ciuc) Quaternary Depression, situated between the Volcanic Chain (west) and the Crystalline-Mesozoic Zone (east), 11 km from Gheorgheni in the village of Voșlabeni, the median part of the Rebra Series crops out.

## Stop 2.16:

**Voșlăbeni Quarry – Rebra Series (middle sequence).**

The Rebra Series is the lowermost series known in the metamorphic basement of the Bucovinian Nappe. The same position is recorded in the Subbucovinian Nappe. The Rebra Series is divided into three Formations. The middle one – named in this area the **Voșlăbeni Formation** – consists of dolomitic marbles with tremolite and talc, exposed in the Voșlăbeni quarry. From Voșlăbeni to Miercurea Ciuc metamorphic formations (mainly Rebra Series) of the Bucovinian Nappe will be crossed as well as the Ciucul de Mijloc (Middle Ciuc) Quaternary Depression.

## DAY 3

**Miercurea Ciuc - Brașov - Sibiu**

**Aims**: In the Brașov and Perșani Mts. it is possible to approach the problems concerning the correlation of the East and South Carpathians.
From Miercurea Ciuc the fieldtrip proceeds southwards, downstream along the Olt Valley. In the suburbs of the town, on the left-hand slope of the valley small quarries are opened in lava flows of py-

roxene- and hornblende-andesites of Upper Pliocene ? – Lower Pleistocene age, which belong to the calc-alkaline volcanic arc of the East Carpathians. After crossing the Ciucul de Jos (Lower Ciuc) Quaternary Depression, the Olt River (and the fieldtrip) crosses the south-east end of the volcanic chain. At Tuşnad spa, east of the valley, the Sfânta Ana volcanic structure is well preserved. It is a very young volcano of Pleistocene or even Holocene age. Downstream, in the Micfalău area, on the right-hand slope of the Olt Valley, two subvolcanic bodies of basaltoid andesites (Lower Pleistocene) are exposed in two large quarries. On the left-hand slope and tributaries, Lower Cretaceous flysch formations of the Ceahlău Nappe are developed. At Malnaş the tectonic contact between the Ciuc Digitation and the Bodoc Digitation (both sub-units of the Ceahlău Nappe) is crossed. From Ghidfalău the Olt River runs within the Sfântu Gheorghe Quaternary Depression, filled - as the whole complex developed Quaternary depressions of the inner part of the Carpathian Bend Area - with Upper Pliocene-Pleistocene formations.

Between Hărman and Braşov, south of the Depression, it is possible to reconstruct (if the weather is favourable), along the skyline, a cross-section of the Ceahlău Nappe and the front of the Getic Nappe.

## Stop 3.1:

**Săcele - Jurassic formations in the front of the Getic Nappe.**

In the town of Săcele, the main part of Bonloc Hill is built up of Jurassic formations similar to those of the whole Postăvaru Mts.-Codlea-Piatra Craiului Mts. area, which belong to the Getic Nappe. After a few siltic black shales of the Grestner Lithofacies of the Lower Jurassic, Middle Jurassic **quartzitic sandstones** follow, hosting a sill of trachytes, also of Middle Jurassic age. The Upper Jurassic is represented by massive neritic limestones. The absence of the Callovian-Oxfordian radiolarites which are usually developed in the other parts of the Getic Domain, accentuates the existence of a stratigraphic gap in the frontal part of the Getic Nappe.

The Săcele Jurassic Getic formations are overthrust above the **Piscu cu Brazi Formation** (see Stop 2.4) of the Ceahlău Nappe.

Braşov is one of the main towns of Transylvania. It is an early medieval city with many important vestiges. The Black Church is a famous Catholic church built in the XV$^{th}$ century in Gothic style. The building material consists of limy sandstones, which were worked out from quarries around Teliu village (east of Braşov) and are massive sandstones intercalated in the Piscu cu Brazi Formation of the Ceahlău Nappe. The organ of the church is one of the biggest organs in the Catholic or Protestant churches in Transylvania. Council Square is the old centre of the burg, with a city museum. South of the Black Church, upstream, is the Orthodox Saint Nicholas Church, where the first Romanian printing occurred.

## Stop 3.2:

**Braşov – Ladinian limestones in Dealul Melcilor Quarry.**

Dealul Melcilor Hill is the northern end of Tâmpa Hill, not far from the centre of town. On its eastern slope **Ladinian organogenous massive limestones** are exposed in an old quarry. They constitute the core of an E-W oriented anticline belonging to the Getic Nappe. Above the Ladinian limestones the **Gresten Lithofacies** of the Lower Jurassic follows (black siltic shales dominate with intercalations of quartzitic sandstones); a sill of arfvedsonite granite porphyry is intruded in a black siltic sequence. The Middle Jurassic is represented by **quartzitic sandstones**, while the Kimmeridgian-Tithonian by the **massive Stramberg limestones.** Tâmpa Hill consists of these limestones as does the north slope of the Dealul Melcilor.

From Braşov the fieldtrip proceeds to the village of Cristian (6 km toward south-west) situated in the western foothills of the Postăvaru Mts.

## Stop 3.3:

**Cristian – Anisian limestones (Guttenstein type).**

North of Râşnov, at the southern margin of the village of Cristian in an old quarry, well layered limestones crop out, blackish or dark-grey, slightly bituminous ("stinking"), frequently with diaclases. Their Anisian age is documented by ammonitic fauna and by the palynological assemblages. The Guttenstein-type Triassic was folded before the Lower Jurassic; Gresten-type formations overlie the Triassic formations with angular discordance .

The Anisian limestones of Guttenstein type, of the Cristian-Vulcan area, may be correlated with the Anisian dolomites and limestones of the Iacobeni quarry (Stop 1.12). Consequently it is possible to correlate the Getic Nappe (to which the Cristian section belongs) with the Infrabucovinian nappes of the Central East Carpathians.

## Stop 3.4:

**Râşnov – Upper Jurassic limestones.**

About 7 km south of the Cristian quarry, in the center of Râşnov, massive neritic Stramberg-type Kimmeridgian-Tithonian limestones crop out in a cliff-like hill. The specific feature of the Cetăţii Brook outcrop (at Râşnov) consists of a changed lithofacies of the lower part of the carbonate sequence (well-layered limestones, probably Kimmeridgian-Lower Tithonian. Such situations are scarce, but emphasize that in some areas sedimentation starts with basinal lithofacies, synchronous with the massive neritic one, passing upwards to neritic, generalized lithofacies.

On the top of the limestone relief, in the XIV[th] century , a peasant fortress was built, which is one of the several defence fortresses built around Braşov.

From Râşnov the fieldtrip returns to Cristian and from there proceeds west crossing the Bârsa Plain (which corresponds to the Bârsa Quaternary Depression) until Vulcan .

## Stop 3.5:

**Vulcan – Anisian / Spathian boundary.**

At the western margin of the village of Vulcan, 250 m from the Vulcan-Holbav road, in a small old quarry, limy shales and thin black limestones, weakly bituminous crop out. With a thickness of 10-30 m, they develop at the base of the Guttenstein-type Anisian limestones. From the stratigraphical point of view they are situated at the boundary between the Middle Triassic (Anisian) and the Lower Triassic (Spathian).

From Vulcan village the fieldtrip follows a local road until Holbav village and west of it.

## Stop 3.6:

**Dealul Merezi (Merezi Hill) – metamorphics of the Voineşti Formation.**

In several small outcrops, on the western slope of Dealul Merezi in the eastern suburb of Holbav, feldspathic quartzites and retrogressed micaceous paragneisses are exposed. They belong to the Voineşti Formation of the Leaota Group.

## Stop 3.7:

**Holbav – Lower Jurassic in Gresten Lithofacies.**

130 m upstream on the Bisericii Brook, in Holbav, in several mining, the rocks which constitute the Gresten lithofacies developed in the Holbav area may be examined: quartzitic sandstones, coarse-grained sandstones with quartzitic grains and coal-bearing siltic matrix, coal-bearing clays or clayey silts, sideritic limestones. In the middle part of the Gresten lithofacies, in the Holbav area, alkaline rocks (alkali-basalts, trachytes, camptonites, bostonites) are inlayered as lava-flows or sills. This volcano-sedimentary formation is a specific feature of the Holbav Gresten Lower Jurassic and is absent in the other zones where the Gresten Lithofacies is known (Cristian, Braşov, Săcele).

## Stop 3.8:

**Holbav Gneiss west of Holbav.**

150 -200 m downstream from the westernmost houses of Holbav, large outcrops of the Holbav Gneisses may be examined. They consist of augengneisses with centimetric pink or white augen of K-feldspar, interpreted either as migmatites or as orthogneisses derived from porphyric granites.

The **Holbav Gneiss** is overthrust above the Lower Jurassic. This overthrust coresponds to the frontal part of the Supragetic nappes, the Şinca Nappe respectively. Northward the frontal overthrust of the Supragetic nappes can be followed, in outcrop, until the Dealu Mare Fault (easternmost segment of the South Transylvanian Fault) (Figure1). The Supragetic nappes correspond, in the Central East Carpathian area (Crystalline-Mesozoic Zone) to the Subbucovinian and the Bucovinian nappes.

The fieldtrip returns to Vulcan and from there continues northwards to Codlea. The Măgura Codlei Scale is well expressed in the relief. It is constituted mostly of Upper Jurassic massive neritic limestones (Stramberg-type), which preserve at their base Callovian - Oxfordian radiolarites and Middle Jurassic calcareous sandstones. The Măgura Codlei Scale is thrust in front of the Subbucovinian (Şinca) Nappe.

From Codlea, where a medieval fortified church marks the center of the locality, the fieldtrip turns west, entering the Vlădeni Couloir. This is well expressed in the flat and lower relief. The southern margin of the Vlădeni Couloir is represented by the Dealu Mare Fault (see above). This fault is marked by a sharp morphology corresponding to the elevation of the southern border of the Couloir, which is in fact a half-graben, tilted at its southern part. The Vlădeni Couloir filling consists of Upper Cretaceous conglomerates and coarsegrained sandstones and of marls (Senonian), thin and discontinous developed Eocene formations (sandstones and marls) and Oligocene-Lower Miocene dominantly marly lithofacies, slighty bituminous.

Near Perşani village the south-east border of the

Transylvanian Depression is crossed by the national road which is followed by the fieldtrip. In some quarries on the slope, north of the road, the Dej Tuff crops out. It is a general marker of the basal sequence of the Depression clearly followed in boreholes and on the seismic lines.

## Stop 3.9:

**Panoramic view of the innermost part of the Carpathian Bend Area.**

From Şercaia village it is possible to have a panoramic view of the Perşani Mts., the Vlădeni Couloir, the Dealu Mare (South Transilvanian) Fault and the north-eastern end of the Făgăraş Mts. The highest visible relief of the Perşani Mts. corresponds to a large domal anticline (Gârbova Anticline) in the core of which metamorphic formations of the Bucovinian Nappe crop out. On the north-western slope (left-hand slope of Gârbova Mts.) the whole sedimentary succession of the nappe develops. The south-eastern slope is overlain by the Upper Cretaceous post-tectogenetic cover of the Bucovinian Nappe. It corresponds to the northern limb of the Vlădeni Depression. The Dealu Mare Fault is well expressed in relief (see above). The Făgăraş Mts., with the beautiful panorama of their skyline, correspond - with a small exception - to the Subbucovinian Nappe. On a small area at Şinca Nouă and Vârful lui Petru (the latter visible as the highest peak on the skyline), a tectonic outlier of the Bucovinian Nappe is preserved.

From Şercaia to Sibiu the fieldtrip runs across the southernmost part of the Transylvanian Depression. Southward (left-hand) the Făgăraş Mts. border the Depression. Northward the hills are built up of Sarmatian and, mostly, Pannonian formations.

Sibiu is also an important medieval town. The Evangelic Cathedral was built in the oldest part of the town, where the medieval architecture was well preserved. Parts of the defence works of the XV$^{th}$ - XVI$^{th}$ centuries are also well preserved. The **Ortodox Cathedral** was the first one built in Transylvania, showing an architecture similar to that of Saint Sophia in Constantinople. The **Brukenthal Museum**- is the oldest painting exhibition, opened one year before the Louvre.

# DAY 4

**Sibiu - Alba Iulia - Câmpeni**

From Sibiu to Alba Iulia the fieldtrip runs along the southern border of the Transylvanian Depression. After crossing Alba Iulia, the fieldtrip enters the Ampoi Valley.

## Stop 4.1:

**Şard - Miocene molasse**.

The oldest formations belonging to the Transylvanian Depression, cropping out in the Alba Iulia area, are exposed in Şard, on the right-hand bank of Ampoi Brook. Conglomerates, microconglomerates and coarsegrained sandstones of red or grey colour may be examined. The pebbles and grains are of different types, proceeding from the Miocene erosion of the South Apuseni Mountains.This molassic formation is older than the Dej Tuff (Lower Badenian). Consequently they may be correlated with the Hida Formation which is of uppermost Burdigalian/lowermost Badenian age.

After Şard, along the Ampoi Valley the fieldtrip runs across the Feneş Unit of the South Apuseni Mts. (Transylvanides).

## Stop 4.2:

**Ampoi Valley - the Meteş Formation**.

The Upper Aptian -Albian sequence of the Feneş Nappe is represented by the **Meteş Formation**. This is a typical wildflysch formation, the sedimentary klippen ("olistoliths") being represented by ophiolitic and sedimentary rocks which proceed from the inner (southern and eastern) units (Techerău-Drocea and its prolongation east of the Brad Depression, or the Trascău Nappe).

The outcrops of the Meteş Formation show a layered (turbiditic) or massive siltic matrix and sedimentary klippen of: basalts, calc-alkaline rocks, Oxfordian, Tithonian and/or Urgonian (Barremian-Lower Aptian) limestones.

The road continues across the same Meteş Formation, the landscape dominated by characteristic "Klippen" of Upper Jurassic limestone olistoliths. Between Poiana Ampoiului and Presaca Ampoiului, the area is built up by the Fenes Formation, but the favourable exposures are situated on the left (northern) affluents and slopes.

At Presaca Ampoiului, after crossing a fault, the road enters the Valea lui Paul Formation in which some Upper Jurassic olistoliths can be observed (Bleahu et al., 1981).

## Stop 4.3:

**Feneş valley. Very low-grade Feneş beds**.

Along the Feneş valley siltic clayş chemolitic limestones, greywackes, spilites, are exposed; they are very slightly metamorphosed. This formation is considered (Bleahu et al., 1981) volcano-sedimentary-olistostrome, with sequences of turbiditic rocks. The age of the Feneş Formation is probably Tithonian-Barremian.

## Stop 4.4:

**Petringeni. Faţa Băii conglomerates and volcanites (Paleocene).**

The molasse deposits of the post-tectonic Paleogene-Miocene Zlatna basin, transgressive on the Cretaceous Flysch are represented by the **Faţa Băii** conglomeratic **Formation.** The polymictic conglomerates admit intercalations of sandstones, red clays, as well as interlayered lavas and volcaniclastics of rhyolitic and andesitic composition. The rhyolitic flows, sometimes brecciated, consist of plagioclase, sanidine, quartz and biotite. The andesites are amphibole-and pyroxene-bearing. The thickness of the lava flows does not exceed 50 m. Paleocene age was confirmed radiometrically and biostratigraphically. Westwards the age of the sedimentary and volcanic formations extends well into the Miocene (E. Roşu in Udubaşa, 2001 ed.).

At Zlatna, at the crossroad to Almăş, Senonian formations are exposed in a small quarry, consisting of sandstones, microconglomerates and conglomerates with pebbles of quartz and limestones.

Upstream from Izvorul Ampoiului the valley crosses the tectonic contact between the Feneş Nappe and the Bucium Unit, the latter being represented by the Upper Albian Pârâul Izvorului Formation (coarse convolute sandstones, marls and clays).

The road traverses the watershed between the Ampoi and Arieş basins at Dealul Florii.

## Stop 4.5:

**Confluence Abrud valley - Cerbu valley.**
**Soharu Formation (Upper Aptian-Lower Albian).**

An overturned Wildflysch sequence of the Bucium Unit can be examined in a small quarry. The sequence consists of grey-greenish convolute shales alternating in the higher levels with calcarenites and calcirudites. Conglomerates with calcareous cobbles and green tuffaceous-clayey matrix are also exposed, as well as greenish or violaceous siltites (S. Bordea, 1992).

# DAY 5

**Câmpeni - Petru Groza - Brad - Deva**

## Stop 5.1:

**Vadu Moţilor. Contact between Lupşa and Gârda Nappes**.

After Paleozoic marbles exploited in a quarry and a rather monotonous sequence of either sericitic or chloritic schists, for several kilometers, at Vadu Moţilor, south of the confluence with the Neagra valley, at the base of the Muncel Nappe, chlorite-sericite schists with an intercalation of tuffogeneous amphibolites are exposed, dipping 35°SE.

North of the confluence, silvery-violaceous laminated conglomerates crop out with strongly flattened pebbles, the schistosity dipping southwards. Their age is Upper Carboniferous-Lower Permian; the conglomerates belong to the Finiş -Gârda Nappe, the basement of which consists of the Codru Granitoids, exposed upstream (Bleahu et al., 1981).

Further on, the road runs across the Codru Granitoids and migmatites of the Gârda Nappe, as well as across violaceous quartzitic sandstones and conglomerates belonging to the Bihor Unit, the basement of which consists of retrogressed chlorite-sericite schists (Arada Series). The contact between the two units is a vertical fault.

## Stop 5.2:

**Albac Gorge. Skythian-Anisian boundary in the Bihor Unit**.

At the confluence with a small left-hand tributary decimetric beds of Skythian violaceous or white quartzitic sandstones are conformably overlain by Anisian yellowish-white bedded dolomites. The abrupt contact suggests a break in sedimentation (Bleahu et al., 1981).

## Stop 5.3:

**Zugăi Gorge, Bihor Unit. Detrital formation at the base of the Ladinian**.

After crossing for a longer distance massive, brittle yellowish-white Anisian dolomites, a detritic formation is exposed along the road for about 100 m, its sequence being as follows: dolomitic breccia with clasts of black dolomites; white limestone breccia with rounded pebbles of Wetterstein limestones and of Anisian black limestones (regionally unknown in outcrops); violaceous argillaceous or marly shales, appearing yellow or grey when weathered, with interbeds of violet quartzitic sandstones.

The top of the sequence consists of massive greyish-white Wetterstein limestones.
The detritic formation presented above gives evidence of a continental environment deposition, the limestone pebbles and the violet clays possibly representing a karst infilling.
Some hundreds of meters upriver, the Wetterstein limestones overthrust by Codru Granitoids and migmatites of the Gârda Nappe are transformed into calcite mylonites (Bleahu et al., 1981).

## Stop 5.4:

**Scărișoara - Gârda. Upper Carboniferous-Lower Permian of the Gârda Nappe**.

After crossing laminated Codru granitoids and migmatites and a horst exposing Wetterstein limestones in a half-window, the road reaches the first sedimentary term of the Gârda Nappe, namely the Laminated Conglomerates, the Upper Carboniferous-Lower Permian age of which was evidenced by palynology. They consist of flattened, mainly quartz pebbles in a violaceous slaty matrix. An oblique foliation may sometimes be obseved. Upsequence follows laminated violet or green rhyolitic ignimbrites and violet shales with interbeds of red micaceous sandstones (with hyeroglyphs) (Bleahu et al., 1981).
Measurement of the pebbles has shown that the strain was predominantly an extensional one, but in places the main deformation was flattening (Dimitrescu, 1995).

## Stop 5.5:

**Gârda de Sus - confluence with Iarba Rea. Lower Permian of the Gârda Nappe.**

After crossing again, due to the Gârda major fault, the Anisian dolomites of the Bihor Unit, the road continues across the formations of the Gârda Nappe, the place of the Laminated Conglomerates being taken by a breccia consisting of fragments reaching 20 cm in length of gneisses, muscovite, schists quartz and quartzites included in a shaly matrix. They are believed to be an alluvial deposit, without fluvial transport and present a striking similarity to the "Conglomerati di Dosso dei Galli" of the Southern Alps and with the Medódoly (Kopersady) breccias of the Tatrides (Bleahu et al., 1981).

## Stop 5.6:

**Confluence with the Buciniș valley. Arieșeni Nappe overthrusting the Gârda Nappe**.

After crossing a spectacular gorge cut across a syncline of Skythian violaceous quartz conglomerates and sandstones overlying the Permian micaceous or feldspathic sandstones and shales, at the confluence with the Buciniș valley the contact between the Gârda and the Arieșeni Nappes is exposed. The former is represented by laminated conglomerates, sandstones and rhyolites, while the latter consists of green phyllitic schists of Lower Carboniferous age, the attitude of their schistosity being about EW with southern dip (Bleahu et al., 1981).

## Stop 5.7:

**Arieșeni. Greenschist Formation (Upper Carboniferous).**

From the front of the Arieșeni Nappe overthrust examined at the previous stop, the road crosses exclusively the Lower Carboniferous greenschists of this unit. The large outcrops reveal the schistosity of the Arieșeni Formation showing various dips, generally towards W and NW.
At km 40 + 350 m of main road nr. 75, in an exposure about 10 m long on the left side of the Arieșul Mare, a subhorizontal exposure may be observed consisting of weakly metamorphosed conglomerates with strongly rolled pebbles, composed predominantly of quartz and with greyish-green quartzitic matrix; the metaconglomerates admit an intercalation of greyish-green sandstone and overlie green pelitic schists cropping out just at the water level. The alternation of the lithological horizons expresses the $S_0$ bedding of the rocks, on the planes of which no foliation has developed; the attitude of the graphically determined bedding is approximately N 45° W / 12° SW. Directly measurable foliation planes correspond to a schistisity $S_1$ (flow cleavage) oblique with respect to the bedding; its attitude here is N 70°W / 45°SW. Along this foliation small faultings of the lithologic horizons occur locally. The intersection lineation trends N 67°W / 04°NW.
The regional trend of the stretching lineations, marked by the elongation of the pebbles in the Greenschist Conglomerates of the Arieșeni Nappe, is NW, signalling the direction of Alpine tectonic transport in the Northern Apuseni (Dimitrescu, 1995).

## Stop 5.8:

**Arieșeni. General view of the Biharia Massif.**

The whole crest of the Biharia Massif is built up of the formations of the Biharia Nappe consisting of the Biharia crystalline series. It overlies horizontally the Poiana Nappe made up of a narrow strip of metacon-

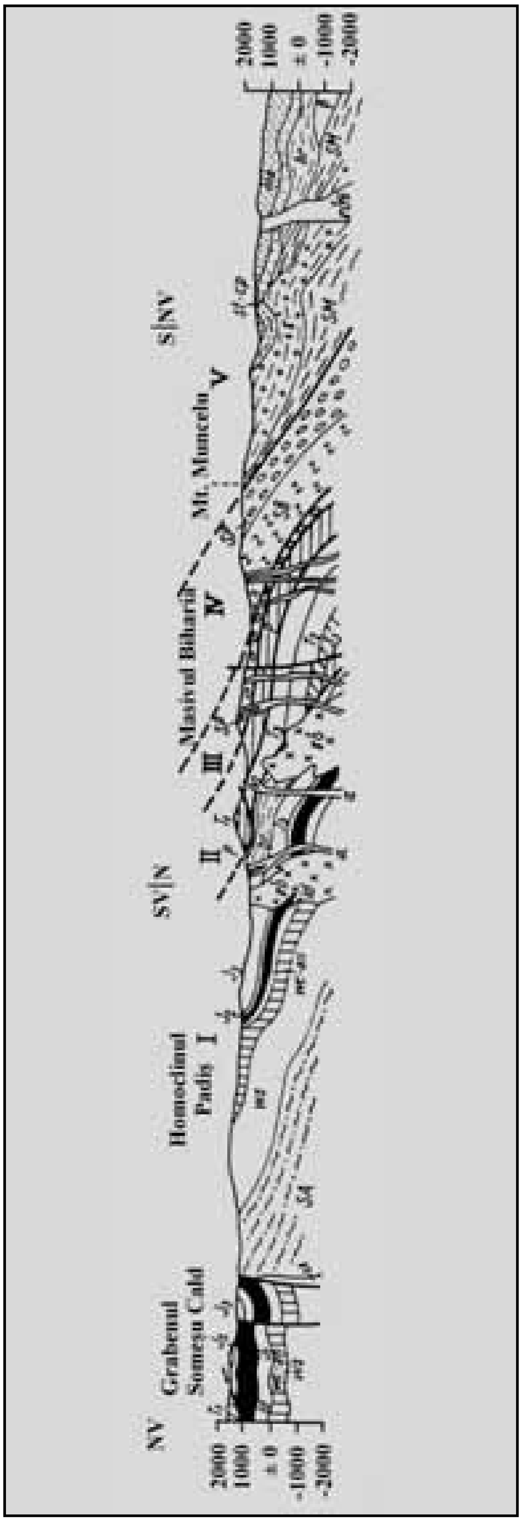

*Figure 8 - General cross-section in the Bihor Mts (M.Bleahu in Ianovici et al., 1976)*
*I Bihor Unit: SA, Arada Series; ws, Seisian; wc-an,Campilian-Anisian; ld,Ladinian; J1, 2, 3 , Jurassic; br, Barremian. II Arieșeni Nappe: P, Permian; T1,Werfenian; III Poiana Nappe: SP, Păiușeni Series; IV Biharia Nappe: SB, Biharia Series; SP, Păiușeni Series. V Muncel Nappe: SM, Muncel Series; g, granitoids.*
*Southern Apusenides: b, ophiolites; br, Barremian; st-cp, Santonian, Campanian; ma, Maastrichtian.Post-tectogenetic formations: gd, granodiorites; a, andesites; gdp, granodiorite porphyry.*

glomerates and sericite-phyllites (Upper Carboniferous-Păiușeni Series). The Poiana Nappe overlies the Arieșeni Nappe, which covers the whole area lying at the foot of the Biharia Massif; this nappe consists of the Arieseni Greenschists Formation and the reddish-violet formations of the Upper Carboniferous-Lower and Middle Permian.

In front of and under the Biharia (Cucurbăta) MicăPeak, a lower peak covered by wood, rises. It is the Stânișoara Peak, which consists of banatitic granodiorites piercing the whole pile of Permian formations. The intrusion determined a contact metamorphism changing in large areas the red colour of the Permian into black (“Black Series”) (Bleahu et al., 1981).

## Stop 5.9:

**Arieșeni. Unconformity Upper/Lower Carboniferous**.

After leaving the centre of Arieșeni, at km 36 + 550 m, after the confluence with the Șteului valley, in a large exposure the unconformity between the Laminated Conglomerates (Carboniferous-Lower Permian) and the Arieșeni Greenschists (Lower Carboniferous) may be examined. In this exposure the pelitic greenschists are overlain by laminated conglomerates containing as pebbles weakly rolled quartz fragments included in a violaceous-silvery sericitic matrix; the conglomerates alternate with schistose quartzitic sandstones and argillaceous violet phyllites.

The attitude of the common schistosity $S_1$ of both formations is N 40°W / 35°SW. The $S_0$ bedding of the greenschists, graphically plotted according to a slight banding is N 40°E / 38°NW, the trend of the intersection lineation being EW / 30°W.

The attitude of the bedding of the laminated conglomerates cannot be observed here. However 200 m upriver, this attitude put in evidence by pebble grading and by shaly interbeds is NS / 60°W (trend of inter-

section lineation: N53°E/ 36°SW). The regional trend of the stretching lineations marked by the elongation of the pebbles in the Laminated Conglomerates of the Arieșeni Nappe is also north-western, confirming the direction of the Alpine tectonic transport.
The strain of the pebbles was exclusively an extensional one, as measurement of their shape has shown, the intensity of deformation being medium.
Comparing the Es parameters for the pebbles of the Greenschist conglomerates with those of the Laminated Conglomerates in the Arieșeni Nappe, it may be concluded that the former were more intensely deformed (Es = 0.55 - 1.22 versus 0.55 - 0.80), having undergone an older Midcarboniferous tectonic phase that did not affect the latter. On Flinn's diagram, the majority of the pebbles shows a k~1, the strain having been a plane one in the Laminated Conglomerates of the Arieșeni Nappe (Dimitrescu, 1995).

## Stop 5.10:

**Bubești Hill. Permian Vermicular Formation. Banatitic sill.**

At km 32 + 120 m, on the left slope of the valley above the road, the Permian is represented by red micaceous sandstones and argillaceous shales. In the sandstones, bioglyphs of burrow - fillings type can be observed. The Permian is pierced by a banatitic andesite sill.

## Stop 5.11:

**Piatra Muncelului. Lamprophyre dykes crossing Urgonian limestones**.

After reaching the main watershed of the Apuseni Mountains, the road leaves the Arieș hydrographic basin and enters the Crișul Negru basin, intersecting reddish Permian and quartzitic Lower Triassic formations.
After a number of road windings and hair-pin bends across Lower Jurassic detrital formations changed into hornfelses ("Black Series"), a fault is traversed and then white massive limestones of Barremian in Urgonian facies belonging to the lowermost Bihor Unit are continuously exposed.
At km 21 + 50 m, three almost vertical lamprophyre dykes striking about NS are intruded into the limestones. The thickness of the dykes ranges between 1 and 3 m; the eastern one presents at its contact a breccia about 1 m thick, composed of angular fragments of white limestones (recrystallized as marbles) and of igneous rocks, enclosed in a calcareous-gritty cement.
The lamprophyres correspond to odinites, consisting of basic plagioclase and augite, the ground-mass having an intergranular texture. It is worth noting the presence of pyroxenes as phenocrysts (Bleahu et al., 1981).

## Stop 5.12:

**Arieșeni - Băița road. Contacts Arieșeni Nappe / Următ Nappe / Bihor Unit.**

In the last outcrops of the limestones (km 20 + 60 m) numerous *Coral* traces as well as remnants of *Megalodonts* are to be observed; then, at the road surveyor's cabin, the road crosses from the Bihor Unit into the Următ Nappe. The latter consists of slight micaceous shales, yellowish quartz sandstones and greyish calcarenites, all of them assigned to the Lower Jurassic.
Further on, the road leads again into the Arieșeni Nappe consisting mainly of the Permian violaceous rocks. Red coloured rocks are gradually replaced by black coloured ones ("Black Series") due to the thermal action of the banatitic body intruded here at a small depth (Bleahu et al., 1981).

## Stop 5.13:

**Băița Bihorului. Rhyolites in the black Permian**.

On entering the old mining locality of Băița Bihorului, opposite the first houses, on the right slope, a rhyolitic body is exposed. Its colour is light grey, due to thermal metamorphism with very slight violaceous hues at places. The rock presents a feebly pronounced foliation; the attitude of the layering is approximately N 20°E / 40°SE; two main joint systems are observable. The footwall consists of blackish vermicular micaceous sandstones, while in the hanging wall, the contact with black argillites and quartzites may be observed ("Black Series").
Past the town of Băița, on the right-hand side, the formation of the Bătrânescu Nappe appear contacting the Arieșeni Nappe along a fault. Skythian quartzites followed by dolomites and limestones of Middle Triassic age can be noticed. Finally the road reaches the Beiuș Depression with outcrops of Pliocene.

## Stop 5.14:

**Vașcău. Permian ignimbritic rhyolites**.

Ignimbritic rhyolites are exposed about 400 m west of the Vașcău railway station. White feldspar and quartz crystals about 1-3 mm in size are conspicuous, as well as leafy biotite, included in a greenish-grey schistose matrix. Characteristic "fiamme" are often noticed in the latter (N. Stan in Borcoș et al., 1980).

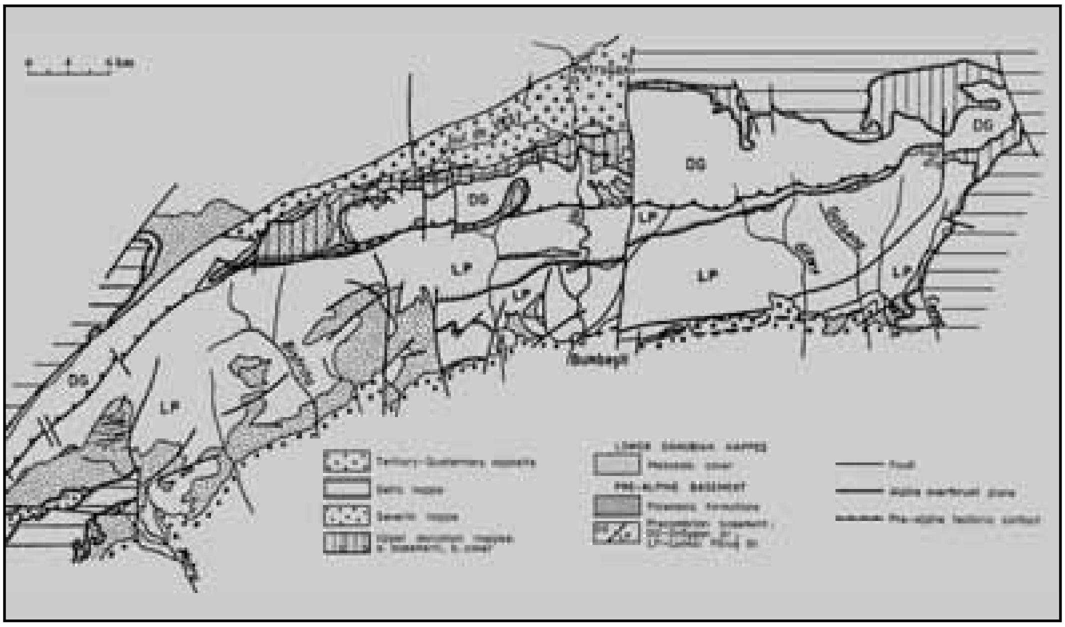


*Figure 9 - Simplified map of Vâlcan-Parâng Mts. (T.Berza and V.Iancu, 1994).*

## Stop 5.15:

**Dealul Mare. Metaconglomerates of the Păiușeni Series.**

The road crosses the divide between the hydrographic basins of the Black and the White Criș; at this point, the metaconglomerates of the Poiana Nappe are exposed.

Measurements on their pebbles indicated an extensional strain for the whole Poiana Nappe, in one point only the strain is a flattening one.

The road continues across the Miocene post-tectonic basin.

Between Brad and Vălișoara upriver the Luncoiu valley on both sides of the main road, Mesozoic island-arc (U3-K1) andesitic-basaltic volcanics (basalts and andesites are associated with gabbros, but also with dacites, rhyolites as well as with orthophyres and oligophyres as pyroclastics) as well as the Miocene molasse deposits represented mainly by the red "Almasu Mare gravels" (Badenian) are exposed; the latter belong to the Brad-Săcărâmb sedimentary basin where the Neogene volcanics are widely developed.

In the Dealul Mare col the characteristic landscape of volcanic peaks is to be seen.

At Vălișoara, the Upper Jurassic andesitic and basaltic flows and pyroclastics are overlain by Upper Jurassic calcareous olistoliths and by Aptian Wildflysch formations.

Downstream the Vălișoara valley, after the island-arc complex beginning at Săliștioara the road crosses ophiolitic rocks belonging to the Techerău Nappe, porphyritic basaltic lavas with augite phenocrysts, andesites with hornblende as well as porphyroclastics (aglomerates and tuffs) are conspicuous (Savu et al., 1986).

Some "Klippen" of Upper Jurassic and Urgonian limestones can be noticed.

Succeeding the ophiolitic complex, after an EW striking fault, the Căbești Formation (Barremian-Lower Aptian) is exposed, namely black gritty shales with intercalations of siliceous sandstones; they belong to a particular unit, the Căbești Unit (Bleahu et al., 1981).

## Stop 5.16:

**Fornădia. Mesocretaceous unconformity.**

A small hill marks the unconformity between the Căbești Formation, represented by strongly disturbed quartzitic sandstones and clayey shales and the gently dipping Fornădia Beds (Vraconian-Cenomanian). The latter start with quartzitic micro-conglomerates and calclithites. The coarse bedding becomes thinner (15-50 cm) towards the top of the formation. In thin slides *Paraphillum primaevum* is frequent.

After another EW oriented fault, the road reaches the area of the Bejan Unit, in which the Bejan Formation is characteristic. This formation consists of

black argillaceous shales with olistoliths of Jurassic basalts, Upper Triassic and Upper Jurassic micritic limestones, interbedded with basaltic flows, pyroclastics and epiclastics and sandstones, representing an olistostrome.
Along the Mureș valley, again after an EW trending fault, outcrops of the Deva Formation can be examined. The conglomerates, massive sandstones and marls are of Coniacian-Santonian age, constrained by micropaleontological data (Bleahu et al., 1981).
The fieldtrip reaches Deva, a town dominated by a hill built up by a Neogene amphibole andesite (+ biotite volcanic neck) with a ruined fortress of the XV$^{th}$ century on its top.

## DAY 6

**Deva - Tg.Jiu - Turnu Severin**

From Deva, the fieldtrip reaches Hunedoara, a town famous in the country not only for its metallurgical plants but also for the beautiful castle, built in the middle of the XV$^{th}$ century. Its foundations rest on a cliff of Lower Carboniferous crystalline dolomites belonging to the Supragetic Units of Poiana Ruscă. Underlying the dolomites, low-grade iron deposits were mined representing the basis for the local metallurgical industry.
From Hunedoara, the road crosses the Neogene Strei basin.

## Stop 6.1:

**Crivadia Bridge. Getic Nappe: Lotru basement and Mesozoic cover.**

Between Crivadia and Bănița, national road 66 crosses the Getic (Austrian) Nappe represented by the **Lotru Group** basement and the Lower Jurassic-Lower Cretaceous cover. Aalenian-Bathonian sandstones and bioclastic limestones are followed by bioclastic limestones with siliceous deposits (Lower-Middle Callovian) and Upper Jurassic-Aptian pelletal and micritic Urgonian limestones (T. Berza, in: Berza et al., 1994).
Before entering Petroșani, the Lotru Group is exposed, consisting of micaschists and micaceous paragneisses with muscovite, biotite and garnet. They are sometimes affected by retrogression, by which the primary minerals are substituted by sericite and chlorite.
The Petroșani Tertiary basin follows, with red Aquitanian conglomerates and coal-bearing Chattian sandstones.

## Stop 6.2:

**Gambrinus Motel. Liassic Schela Formation.**

At the confluence of the Eastern and the Western Jiu (km 125 on national road 66 ), a small road after 150 m leads to the Gambrinus Motel. The Liassic Schela Formation is exposed along a forest road beginning immediately before the motel. It consists of black metapelitic and metapsammitic rocks of Gresten type. On the southern slope of the Vâlcan Mountains, the

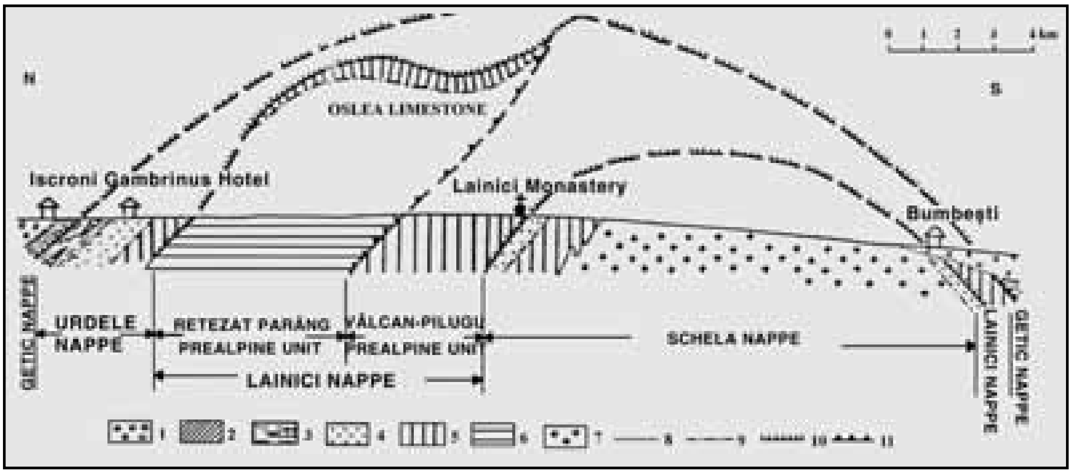


*Figure 10 - Schematic cross-section along the Jiu Gorges (Berza, Drăgănescu,in Berza et al.,1994). 1,Tertiary deposits; 2,Lotru rocks; 3,Upper Cretaceous Flysch with Lupeni limestone klippen;4,Schela Formation;5,Lainici-Păiuș rocks; 6,Drăgșan amphibolites; 7, Șușița Pluton; 8,unconformity; 9, "decollement"stratigraphic boundary; 10,Alpine overthrust; 11, pre-Alpine overthrust*

same formation bears fossil flora.
The dominant attitude of the schistosity in the black phyllites is N 75°E / 40°SW; it represents an axial plane foliation of concentric decimetric and metric folds trending N 22°E / 30°SW (B 1), accompanied by a faint crenulation lineation with the same attitude. Younger chevron folds trend N 50°W / 75°SW (B 2). Along B 1, conspicuous boudins of quartzose material can be observed, due to contrast in competence; they indicate a tectonic transport top-to-NE. A parallel system of short centimetric quartz veins lead to the same conclusion.

## Stop 6.3:

**Km 118.500 on national road 66. Amphibolitic Formation of the Drăgșan Group.**

A typical leptyno-amphibolitic formation is exposed, with an alternation of millimetric to centimetric black and white layers dipping 45°SE. All proportions between 100% hornblende and amphibole-free oligoclase + quartz layers can be found. Biotite, garnet and muscovite are frequent. Scarce layers of mica-gneisses occur in the amphibolites (T. Berza, in: Berza et al., 1994).

## Stop 6.4:

**Cârligul (Cornul) Caprei bridge, km 115.500. Pre - Alpine tectonic contact between two distinct basements (Lainici - Păiuș and Drăgșan) of the Lainici Nappe.**

The last outcrops of the Drăgșan Group are fine- to large-grained massive garnet amphibolites (metagabbros), preceded by serpentinites (metaperidotites). Downriver to 100 m north of the bridge, the retrogression is limited to fracture zones, frequently with quartz veins. Near the bridge, contrasting mechanical properties of carbonates and silicates and pervasive deformation produced black (amphibolite) or white (leucogranite) boudins in the marbles.
On the following hundreds of meters downriver to km 114.500, the road exposes para-amphibolites, mica-gneisses, graphitic metapelites and silicate

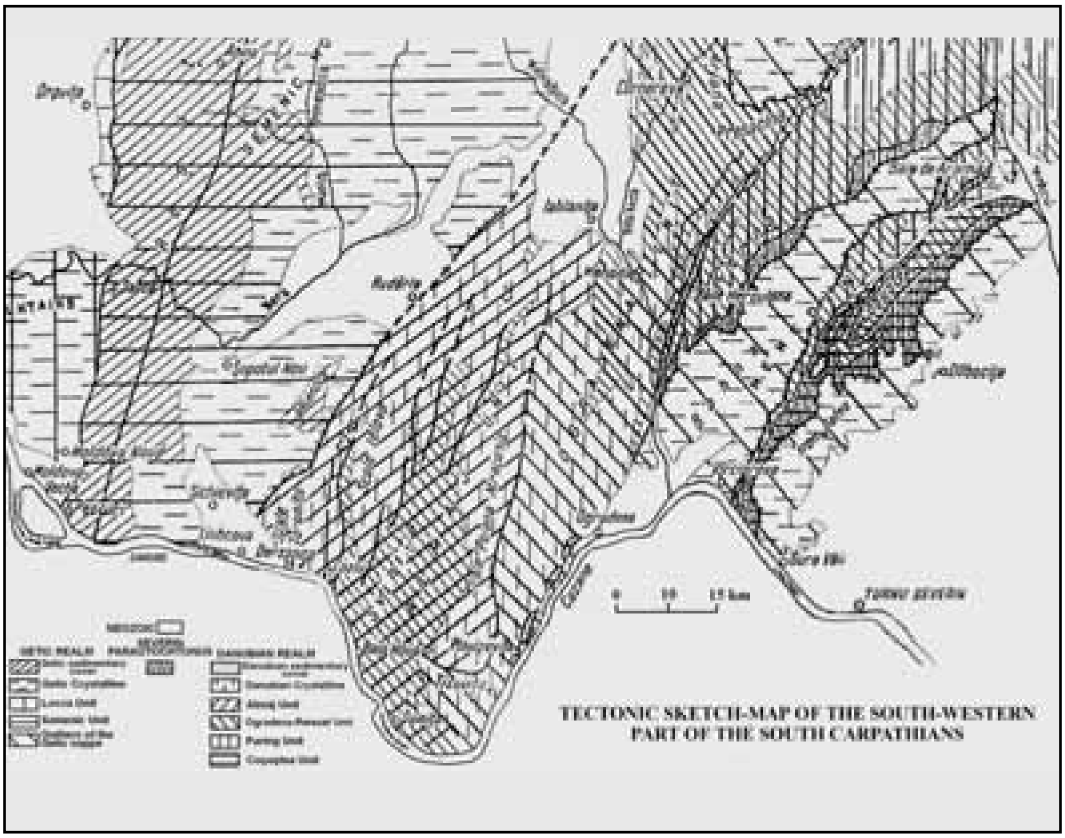


*Figure 11 - Tectonic sketch-map of the south-western part of the South Carpathians. (Codarcea et al.,1968).*

marbles with ubiquitous leucogranite injections; the entire sequence is strongly sheared, with a steep foliation and EW - trending horizontal lineation. Manolescu (1937), Pavelescu et al., (1964) and Berza et al., (1983) ascribe this carbonatic-graphitic sequence to the Lainici-Păiuș Group, while Savu et al., (1984) consider it as part of the Drăgșan Group (T. Berza, in: Berza et al., 1994).

## Stop 6.5:

**Km 111. Lainici-Păiuș Group in the Lainici Nappe.**

Downriver to km 106 (Lainici Monastery), the Jiu Gorges are carved into the Lainici-Păiuș Group, exposing its Quartzitic Formation (an alternance of various quartzites, biotite gneisses and mica-gneisses). Leucogranitic injections and various migmatites are widespread. The general aspect of the rocks is mylonitic, with a pervasive north-dipping mylonitic foliation and retrograde greenschist facies recrystallization. Several porphyritic dykes are emplaced in this sequence. Relict mineral assemblages of an early high T-low P metamorphism (Precambrian) are preserved in places (andesine, garnet, sillimanite, andalusite, cordierite, hornblende), strongly overprinted by later greenschist retrogression (albite, chlorite, tremolite, epidote, stilpnomelane) (T. Berza, in: Berza et al., 1994).

## Stop 6.6:

**Km 105. Rafaila - Lainici-Păiuș gneisses and Schela Formation.**

At the Rafaila Cross, the left bank of the Jiu shows mostly Quaternary deposits at the mouth of a left-hand tributary, with huge blocks of sandstones and conglomerates and smaller debris of pyrophyllite-chloritoid slates (famous occurrence of chloritoid). The Liassic age is well documented by plant remains further west. The Schela Formation is overthrust southwards by the Lainici-Păiuș Formation (Lainici Nappe). On the next 500 m of the road, rocks of the Lainici - Păiuș Group are exposed: quartzites ± plagioclase ± biotite ± muscovite ± garnet ± diopside alternate with mica gneisses ± sillimanite. The latter may reach 2 cm in length and show a strong horizontal EW-trending lineation. Dikes of porphyritic microdiorites show a pervasive Alpine mylonitization.

The first outcrops of Șușița granitoids begin at km 103.700, the rocks being foliated and altered, being transformed into quartz-albite-K feldspar-muscovite-chlorite-stilpnomelane-epidote mylonites.

Down to the Runc brook, the granitoids have been affected by a Hercynian schistosity. They are laminated and transformed into sericite-chlorite "orthoschists"; the K feldspar megacrysts resist better to the deformation processes (T. Berza, in: Berza et al., 1994).

## Stop 6.7:

**Km 97. Șușița granitoids.**

The Șușița pluton consists of biotite granites and biotite- hornblende granodiorites and tonalites. The texture is more or less massive. It is the longest pluton of the South Carpathians (50 km in length).

After leaving the Jiu Gorges the fieldtrip proceeds across the Neogene formations of the Getic Piedmont.

## Stop 6.8:

**Tismana monastery. Tismana granite.**

The porphyritic coarse-grained Tismana granites consist of microcline, plagioclase (An 30), quartz, biotite and accessories. The K-feldspar megacrysts reach lengths of 10 cm; the plagioclases do not exceed 1 cm. Equigranular granodiorites also crop out in the vicinity of the hydroelectric adit. A subhorizontal metric vein of aplitic rocks crosses the granitoids. Associated in the same magmatic suite meladiorites are exposed, upriver consisting of clinopyroxene, brown hornblende, biotite, plagioclase (An 40-50), interstitial quartz, apatite. The fabric is massive. Static retrograde mineral alterations include formation of chlorite, prehnite, epidote.

The Mesozoic cover consists of Liassic conglomerates and arkosic sandstones (T. Berza, in: Berza et al., 1994).

The church of the **Tismana monastery** was built in the XIV$^{th}$ century; its other buildings date from a much later period.

## Stop 6.9:

**Brebina valley at Bratilovu, km 48 along the Baia de Aramă - Băile Herculane road. Getic Nappe overlying the Danubian.**

Between Brebina and Titerlești, the road crosses the uppermost term of the Lower Danubian cover, namely a Upper Cretaceous Wildflysch formation, consisting of a highly broken sequence of turbidites showing a block-in-a-sheared matrix texture. The olistoliths include Mesozoic rocks, basalts, serpentinites and crystalline schists, while the matrix consists of siltites and argillaceous shales.

The deformational history includes tectonic shearing

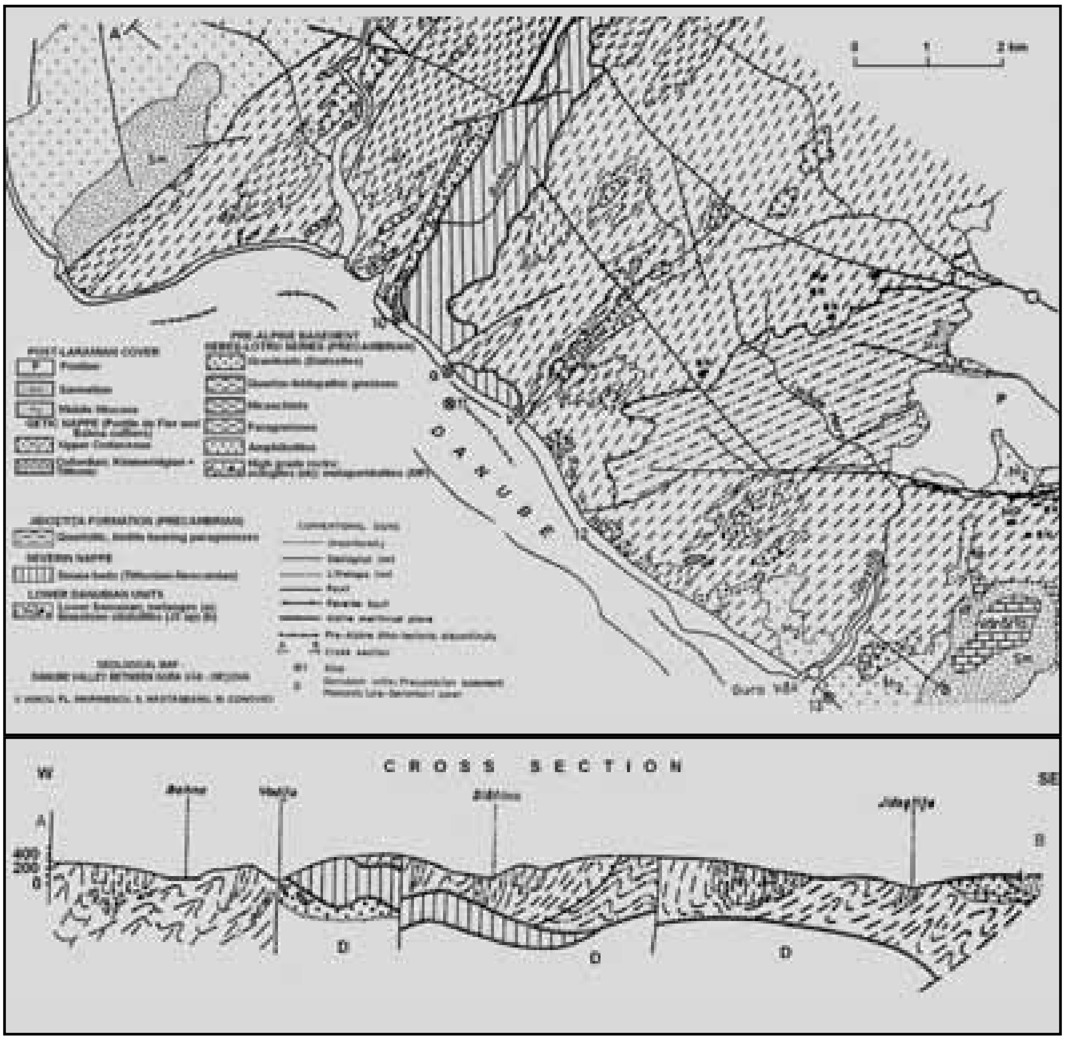


*Figure 12, 13 - Geological map and cross section-Danube Valley between Gura Văii and Orșova (V.Iancu, Fl.Marinescu, S.Năstăseanu, M.Conovici in Pop et al.,1997).*

and gravitational mass transport. Shear-sense indicators suggest dextral shearing, connected to a major EW -trending dextral strike-slip fault (8-10 km of horizontal displacement). (A. Seghedi, in Berza et al., 1994).

In Bratilovu, the mylonitic rocks with western dips of the Lotru Group belonging to the Getic Nappe crop out.

Across the villages of Mărășesti and Stănești, the road exposes outcrops of crystalline schists of the Getic Bahna outlier.

## Stop 6.10:

**Obârșia Cloșani. Km 52-56. Severin Nappe.** The Severin Nappe in this area is represented by the Obârșia Complex, a melange formation with ophiolites and siliceous pelagic deposits (radiolarian cherts) assigned to the Upper Jurassic-Lower Cretaceous.

The ophiolitic rocks are basalts (in places with pillow texture), dolerites, harzburgitic ultramafites and minor gabbros, pervasively sheared and disrupted. Geochemical features suggest MORB -tholeiites. The rocks preserve fresh pyroxenes. Along the Brebina valley, spotted basalts show low-temperature metamorphism in prehnite-pumpellyite facies. Other secondary minerals of the sheared rocks include chlorite, epidote, albite, calcite and zeolites. The structural elements of the ophiolites consist of slickensides and S-C fabrics, with a penetrative scaly-cleavage. Flat lying banded mylonites develop on basalt protoliths along the western border of the nappe. Sheared green rocks are traversed by epidote-quartz-albite veins (A. Seghedi, in Berza et al., 1994).

The road continues across Neogene formations till Drobeta -Turnu Severin. This town was built at the emplacement of Trajan's bridge over the Danube (105 A.D.), one pillar of which can still be seen. Medieval ruins can also be visited.

## DAY 7

**Turnu Severin - Timişoara**

### Stop 7.1:

**3.5 km west of Gura Văii, km 352, between the Scarpia (Padina Mică) and Ungureanu viaducts. Pre-Alpine polymetamorphic basement of the Getic Nappe: Lotru Group.**

The road crosses the Iron Gate outlier of the Getic Nappe, on which the Iron Gate Dam is built. The Lotru Group consists of metaterrigeneous micaceous paragneisses and micaschists associated with amphibolites, quartz-feldspar gneisses and scarce marble lenses. The outcrops display up to three fold generations, $S_1$ layering, $S_2$ dominanat transposition foliation and a $S_3$ crenulation cleavage, mineral and intersection lineations.

Relict mineral assemblages (biotite, garnet, staurolite, kyanite) characterizing a first barrovian metamorphism M1 are overprinted by a sillimanite + biotite + muscovite association M2 of intermediate low-pressure type. The dominant S2 foliation has a general NE-SW attitude, while the mineral (stretching) lineations lie between ENE and ESE.

The Iron Gates outlier of the Getic Nappe crosses the Danube southwards into Serbia (Sip) (V. Iancu, in: Pop et al., 1997).

### Stop 7.2:

**Slătinicu Mare viaduct (km 354) and Oreva viaduct (1.3 km westwards). Tectonic contact at the sole of the Getic Nappe (Bahna outlier ) with Lower Cretaceous turbidites (Sinaia Beds) of the underlying Severin Nappe**.

Metamorphites of the previously examined Lotru Group, with small bodies of sheared diatexitic granites, overlie the Sinaia Beds, lying in the core of a large scale open antiformal fold. On the eastern end of the viaduct, the outcrop consists of crystalline schists of the Lotru Group, while on its western end the Sinaia Beds are exposed.

The Sinaia Beds include mostly distal turbidites; thicker sandstone beds up to 40-50 cm occur in the vicinity of the Slă˘tinicu Mare viaduct. Grey pelagic limestones form thin interbeds. *Chondritid* ichnofauna is often preserved in siltstones and mudstones. The age of the sequence is ascribed to the Upper Tithonian- Lower Valanginian, according to *Calpionellids*.

The structural style of the Sinaia Beds consists of tight to isoclinal recumbent folds (B 1) strongly refolded by steeply dipping normal folds (B 2). The recumbent folds are strongly disrupted by normal folding and they are often preserved as isolated dismembered fold hinges. Various types of kink- and chevron-folds with axial planes steeply dipping E or W are common. Slaty cleavages are seldom visible in the pelitic interbeds. Sandstone beds may show fracture cleavages fanning in fold hinges. Younger structures are high angle normal faults.

The relationships between the Lotru Group of the Getic Nappe and the Sinaia Beds are exposed on the right-hand bank of the Slătinic valley, where the metamorphic rocks show pervasive brittle deformation. The tectonic contact can be followed uphill, where the metamorphic rocks of the Lotru Group build up the top of the hills, while the road is cut across sedimentary deposits. 300 m east of the Oreva viaduct, strongly sheared and brecciated metamorphites reappear in the core of a tight synformal fold; a steeply dipping shear band foliation occurs in both formations, several meters away from the contact (A. Seghedi,V. Iancu, in : Berza et al., 1994; Pop et al., 1997).

### Stop 7.3:

**Km 357, Vodiţa viaduct - Vârciorova viaduct. Tectonic contact between the Severin Nappe and the Danubian Domain.**

At the confluence with the Vodiţa valley, the Lotru Group is exposed.

The oldest sedimentary deposits exposed eastwards are massive grey limestones strongly jointed and crossed by numerous calcite veinlets, exhibiting in places a pseudobreccia aspect. Their age is ascribed to the Upper Jurassic-Lower Cretaceous, by comparison with the Cerna-Coşuştea zone. These deposits represent a huge olistolith embedded into a paratypi-


*Figure 14 - Geological sketch of the Bârzava Valley (Moniom-Bocşa) (Iancu, Năstăseanu in Năstăseanu et al., 1981). 1, Quaternary; 2, Neogene; 3, Banatitic magmatites.Locva Unit:4, Upper Carboniferous and Lower Cretaceous; 5, Lower Carboniferous(Cârşie Formation); 6, Devonian, volcano-sedimentary formation:a, metapelites; b, metatuffs and metatuffites; 7, metamorphoseded igneous rocks; 8, Ordovician(?), Tâlva Mare Quartzites;Bocşa Unit: 9, Upper Carboniferous and Middle Jurassic-Lower Cretaceous; 10, Precambrian-Lower Cambrian,Bocşiţa-Drimoxa Formation; 11, Precambrian,Tâlva Drenii Formation. Reşiţa Nappe:12, Upper Carboniferous.*

cal Wildflysch Lower Senonian Formation consisting of red and green marls, black shales and of a sequence known as Vârciorova Sandstone. The latter consists of massive calcareous sandstones, grading up to stratified sandstones, with interbeds of conglomerates and microconglomerates, including unsorted lithoclasts of gneisses, quartzites, micaschists and limestones.

Trace fossils occur within the pelitic terms, mainly *Chondritids*. The major constituents of the sandstones are plagioclase and quartz; detrital micas are muscovite and partly chloritised biotite. The carbonate cement is micritic to largely recrystallized.

Walking eastwards the overlying Severin Nappe (known in Serbia as the Kosovica Nappe) consists of Azuga Beds = Kasajna Beds in Serbia (red and green shales, displaying sometimes a phyllitic aspect; red radiolaritic cherts, manganese cherts, sandy calcarenites and sandstones), their age being ascribed to the Upper Jurassic, and by the previously examined Sinaia Beds.

The overthrust plane of the Severin nappe is marked by mylonites. Before the construction of the new road, the lower part of the nappe contained small exposures of ophiolites.

A comparable succesion was described by Grubic´ (1992) in the Dzevrin hill in Serbia, south of the Danube.

A vertical fault separates the Danubian from the Bahna outlier of the Getic Nappe, the latter being prolonged south of the Danube into Serbia (Tekija). Orşova is built upon a Miocene basin (V. Iancu, A. Seghedi, in: Pop et al., 1997).

## Stop 7.4:

**Bela Reka valley. Mehadia. Lower Lias**.

At the southern entrance into Mehadia, on the left-hand bank of the Bela Reka river, the Lower Lias is exposed. It overlies transgressively the Permian, represented by red conglomerates with argillitic matrix; in the dominating Străjiuţul hill, Permian eruptive rocks crop out. The Lower Lias consists of an alternance of conglomerate banks, quartzitic breccia and sandstones, grey or blackish, with black gritty shales as intercalations (Codarcea et al., 1961).

## Stop 7.5:
**Bela Reka valley. Middle Lias.**

Upstream the Bela Reka valley, black shales with gritty intercalations of the Middle Lias crop out, characteristic for the Gresten facies. Their age is constrained by faunas with *Ostrea cymbium*, *Belemnites paxillosus, Pholadomya sturi*. Upwards they grade into the Upper Lias, with *Posidonia bronni* (Codarcea et al., 1961).

## Stop 7.6:
**Timiş valley between Teregova and Sadova Veche. Armeniş Formation of the Lotru Series.**

The lowermost term of the Lotru Series consists of nodular sillimanite-bearing biotite gneisses, pearl-gneisses, quartz-feldspar gneisses, amphibolites and amphibole-gneisses, marbles and calc-silicate rocks (Savu, 1970; Săbău, 1994). Pegmatite veins are frequent. The top of the formation is represented by the thin Piatra Scrisă amphibolite level, overlain by almandine, kyanite and staurolite bearing micagneisses and schists (Săbău, 1994).

## Stop 7.7:
**Moniom. Relations between the Getic Reşiţa Nappe and the Supragetic Moniom Nappe.**

Leaving Moniom, the (Westphalian C.) Doman Beds of the Reşiţa Nappe will be crossed up to the Cârşie Hill, where they are overthrust by the metamorphic rocks of the Moniom Nappe along the Oraviţa tectonic line. The uppermost term of the Reşiţa Nappe is represented by the Carboniferous Cârşie Formation. It consists of metaconglomerates, metasandstones and phyllites. In the former, the pebbles decrease in size westwards. The stretching lineations are materialized by the N30 - 40°E / 10 -30°NE trending elongations of the pebbles. Analysis of the finite strain put in evidence its high intensity (Rf > 2,5) and its plane character. The Oraviţa tectonic line represents a post-Supragetic Nappe dextral transcurrent fault, inducing a simple shear in the Carboniferous formations (M. Dimitrescu, 2000).

Westwards along the Bârzava river, the Devonian Valea Satului Formation of the Moniom Nappe consists of chlorite-epidote-actinolite-albite schists (± quartz, sericite, calcite) representing mylonitic basic metatuffs, metatuffites and metaaglomerates, with intercalations of carbonatic and graphitic rocks, acid metatuffs also being present, as well as metagabbroic intrusions.

The described formations exhibit subhorizontal initial stratification surfaces ($S_0$) and almost vertical $S_2$ cleavages.

The Valea Satului Formation was parallelized with the Leşcoviţa "Series" exposed along the Danube (V. Iancu, in: Năstăseanu et al., 1981).

## Stop 7.8:
**Colţan tunnel. Bocşa Nappe overthrust onto the Moniom Nappe.**

Along the Bârzava valley, above the Colţan railway tunnel, the Valea Satului Formation of the Moniom Nappe is overthrust by the Bocşiţa-Drimoxa Formation of the Bocşa Nappe. The latter formation consists of muscovite-chlorite-albite plagiogneisses, with biotite and garnet relics ( mainly enclosed in plagioclase porphyroblasts); it crops out about 200 m west of the forest chalet. The rocks exhibit intrafolial transposition folds, the limbs of which are cut by a S2 foliation with a westward dip. Westwards, the plagiogneisses alternate with rare microcline augengneisses and orthoamphibolites (V. Iancu, in: Năstăseanu et al., 1981).

The Mesozoic cover of the basement formations is represented by marbles, the age of which is ascribed to the Middle-Upper Jurassic-Lower Cretaceous.

The Bocşiţa-Drimoxa Formation was parallelized with the Locva "Series" exposed along the Danube (V. Iancu).

## Stop 7.9:
**Bârzava valley - Bocşa Nouă. Banatitic massif.**

The contact zone between the Bocşa banatitic pluton and the intruded Supragetic augen-and plagiogneisses is exposed. A first intrusion of micromonzodiorite porphyry is penetrated by a granodiorite, carrying xenoliths of both crystalline schists and eruptive rocks. The micromonzodiorite porphyry of the early magmatic stage (Western Unit) contains large hornblende and biotite phenocrysts. The monzogranites and granodiorites Medium Unit consists of zoned plagioclase (20-35 % An), microcline, quartz, biotite and hornblende (Russo-Săndulescu et al., 1975; in Năstăseanu et al., 1981).

The respective K - Ar ages of the succesive intrusions are 87 m.y. (B 1) and 80 - 81 m.y. (B2) that is, intra - Senonian.

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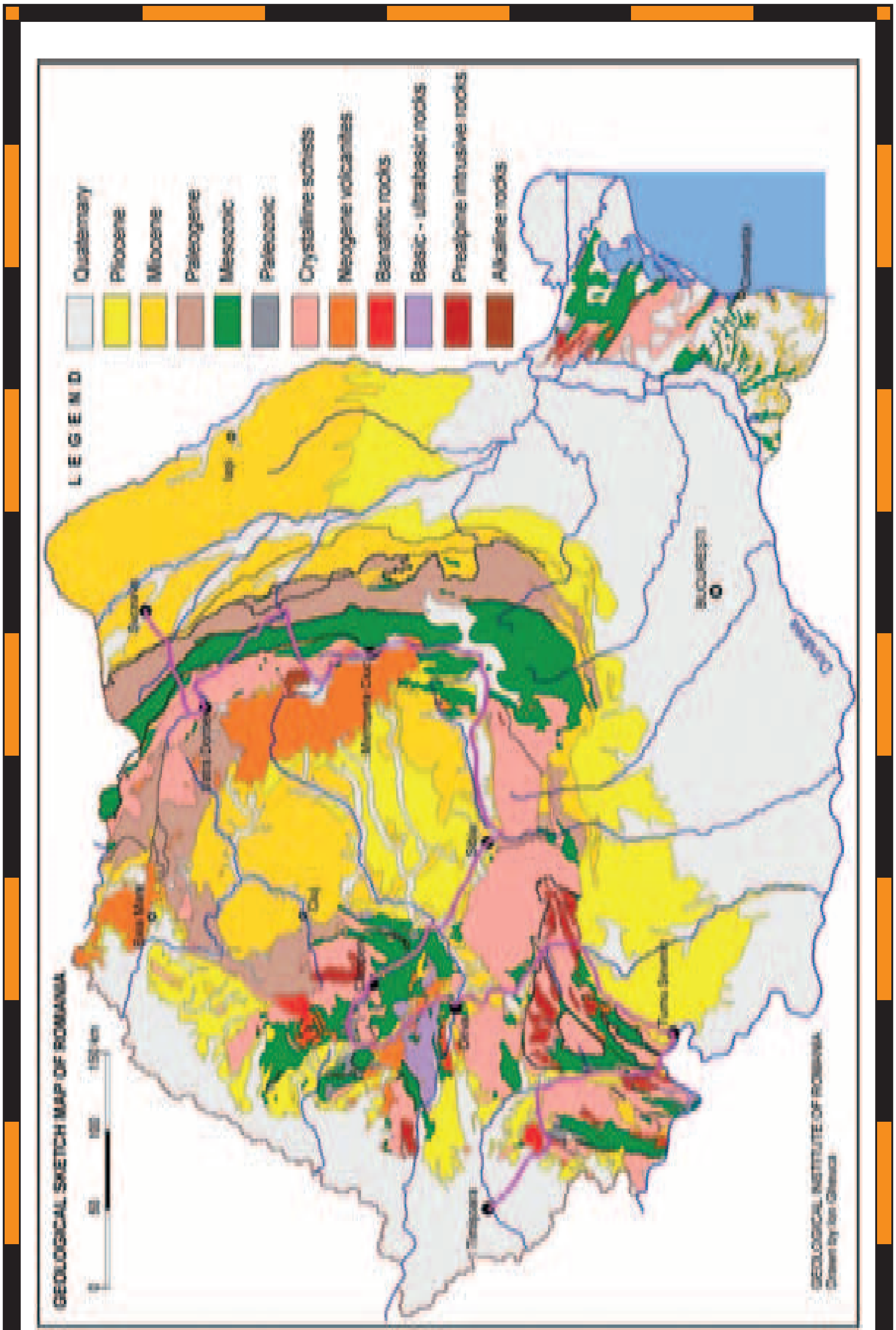
Back Cover:
*field trip itinerary*

# FIELD TRIP MAP

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