EARTH SCIENCE INSTITUTE SARAJEVO

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CIP - Katalogizacija u publikaciji
Nacionalna i univerzitetska biblioteka
Bosne i Hercegovine, Sarajevo

551.432 (497.6) (084.3)

ČIČIĆ, Safet

Geological map of Bosnia and Herzegovina, R 1:300000 - Geološka karta Bosne i Hercegovine R 1: 300.000 / Safet Čičić ; [translation Saba Risaluddin]. – Sarajevo : Earth Science Institute, Institut za geologiju Građevinskog fakulteta, 2002. – 84 str. ; 23 cm + [1] list s geogr. kartom

Tekst na engl. i bos. jeziku. - Bibliografija: str. 43–51

ISBN 9958-9352-1-X

COBISS/BiH-ID 10990086

Na osnovu Mišljenja Ministarstva obrazovanja, kulture i sporta, Bosna i Hercegovina, Federacija Bosne i Hercegovine, broj: 04-15-1097-1/2002, od 04. 3. 2002. godine, a prema članu19, tačka 10. Zakona o porezu na promet proizvoda i usluga ("Službene novine Federacije Bosne i Hercegovine", br. 6/95, 25/97, 13/00 i 36/00) knjiga *Geologoška karta BiH R 1:300.000* je proizvod na koji se ne plaća porez na promet proizvoda i usluga

Front cover
Belerophone limestone of the Upper Permian (P_3) in the bed of the river Tavna Teočak, north-eastern Majevica (photo: S. Čičić, 1962.)

Prof. dr. SAFET ČIČIĆ

GEOLOGICAL MAP OF BOSNIA AND HERZEGOVINA R 1:300000

GEOLOŠKA KARTA BOSNE I HERCEGOVINE R 1:300.000

EARTH SCIENCE INSTITUTE SARAJEVO
INSTITUT ZA GEOLOGIJU GRAĐEVINSKOG FAKULTETA U SARAJEVU
SARAJEVO, 2002

I dedicate this book to my grandsons, Arman, Dina, Mirza and Emir, who were swept away by the winds of aggression to the far corners of the USA.

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GEOLOGICAL COMPOSITION AND TECHTONIC TERRAIN OF BOSNIA AND HERZEGOVINA, with Geological map 1:300,000

INTRODUCTION

This paper is a summary of a major monograph: *Geological Composition and Techtonic Terrain of Bosnia and Herzegovina, with a Geological map to a scale of 1:300,000.* It sets out a stratigraphy of the composition of the Phanerozoic (the Palaeozoic from the Silurian onwards, the Mezozoic and the Cainozoic), followed by techtonics and geological evolution. It comprises practically all the current knowledge on the lithofacial development, thick and extent of the geological elements that form the geological composition of Bosnia and Herzegovina. The paper is based for the most part on the Basic Geological Map of Bosnia and Herzegovina to a scale of 1:100,000, and the keys for individual entire and marginal sheets. Equally, every major published work and study has been consulted, and in particular doctoral dissertations written and published during the period 1960 to 2000. This map and key make it possible rapidly to obtain data on all essential issues in the fields of the stratigraphy, techtonics and geological evolution of this part of the Dinarides. In this regard, there were marked problems almost everywhere, which will be of significance in planning future regional geological research and study of the area.

The 1:300,000 geological map of Bosnia was made by **S. Čičić** between 1998 and 2000, as was the text of the monograph with its annexes. He had the support of the **Earth Science Institute of Sarajevo**, to which thanks are due for the layout and publication of this study of great importance for a knowledge of the geology of Bosnia and Herzegovina.

REGIONAL GEOGRAPHICAL FEATURES OF BOSNIA AND HERZEGOVINA

Bosnia and Herzegovina lies between the latitudes 42° 26' and 45° 15' N and longitudes 15° 44' and 19° 41'. It covers an area of 51,129 sq.km.

In relief, Bosnia and Herzegovina is composed of three geomorphological units: a) the Pannonian plain, covering the area between the Kozara and Majevica mountains to the south and the Sava river to the north. This undulating terrain, with the horst mountains of Prosara and Motajica, covers an area of 17,950 sq.km. or 35.1% of the total area of Bosnia and Herzegovina; b) the Dinaric mountain range, with an area of 28,940 sq.km. (56.6%); and c) the Adriatic zone, comprising the terrain in the lower and middle Neretva river basin, with an area aof 4,240 sq.km. (8.3%). The relief of Bosnia and Herzegovina, particularly as regards the central, Dinaric region, has the characteristics of a mountainous region. The altitudinal range is from approximately 120m in the Sava and Neretva river valleys to 2,386m (Magli mountain). In this region lie numerous mountains, river gorges (the Una, Drina, Neretva, etc.), karst fields and other forms of karst.

The hydrographic network belongs to the Black Sea basin (70%) and the Adriatic Sea basin. In the former the major rivers are the Una, Vrbas, Bosna, Drina and Sava, while in the Adriatic basin the major rivers are the Neretva and TrebišnJica. There are seventeen lakes in Bosnia and Herzegovina, of which seven are of karst-glacial origin, seven of glacial origin, one of karst origin and two of riverine: travertine-stalagmitic limestone origin.

The climate of Bosnia and Herzegovina differs according to region: the northern, Pannonian part has a continental climate; the central region has a temperate-continental climate; and the south and south-east a sub-Mediterranean and Mediterranean climate. In most of Bosnia and Herzegovina the winters are long and cold, with significant snowfalls.

GEOLOGICAL COMPOSITION OF THE TERRAIN OF BOSNIA AND HERZEGOVINA

Various sedimentary, igneous and metamorphic rocks of the Phanerozoic – the Palaeozoic, the Mezozoic and the Cainozoic – comprise the geological composition of this area. They are in evidence in three geotechtonic zones: the Outer, Central and Inner Dinarides. Here, one hundred and twenty-two lithostratigraphic members have been isolated and described, while eighty-five members have been contoured on the 1:300,000 geological map of Bosnia and Herzegovina.

EARLY PALAEOZOIC PERIODS

The Palaeozoic is represented on about 9% of the territory of Bosnia and Herzegovina, in four distinct areas: western Bosnia, central Bosnia, south-eastern Bosnia and eastern Bosnia. Several systems are isolated: the Silurian, Devonian, Carboniferous, Permian, and Permo- Triassic, of which the presence is noted in individual Palaeozoic areas.

CAMBRIAN-ORDOVICIAN

These strata are not isolated on the 1:300,000 geological map of Bosnia. Also mentioned as possibly early Palaeozoic are phyllite, metasandstone, serpentine and amphibolite, with outcrops around Tegara and in the Kolarska river, at the mouth of the Drina. Pollen and spores of the acritarch group have been identified from darkgrey calcareous rocks found in the Drina valley near the village of Crvice, which indicates that this stratum dates from the Cambrian–Ordovician period.

Upper Silurian (S_3) has been isolated on the left bank of the Drina, near the village of Ustikolina. It is composed of platy schist with chert, phillytic schist with ichnofossils, and calcareous rocks. This series is one hundred to three hundred metres deep. Conodonts and other fossils have been identified in the calcareous rocks, indicating that they date back to the middle and upper Silurian and to the transition from Silurian to Devonian.

SILURIAN–DEVONIAN (S,D).

Transition Silurian–Devonian strata have been identified in the Palaeozoic of central Bosnia, covering an area of some 1,000 sq.km. They are composed of diverse schists, rhyolites, quartzes and calcareous rocks. The thick of the sedimentary part of the Silurian–Devonian complex is some eight hundred metres. Its age is indicated by the presence of conodonts, but the elements required to classify this complex of rocks more precisely are still lacking.

DEVONIAN (D)

Various components of the Devonian system have been identified in the central Dinarides, particularly in eastern and south-eastern Bosnia. In

the Devonian as a whole there are present limestone, marble, dolomite and schist series from the river Pliva valley, and similar strata with barytic veins. The conodonts that have been identified indicate their Devonian origin. The thick of these strata is about 150 metres.

Dolomites and dolomitic limestones with corals and conodonts, widespread around Gornji Vakuf, belong to the **lower and middle Devonian ($D_{1,2}$)**. The transition strata from lower to middle Devonian, around Prača and Goražde, are composed of calcareous rocks, dolomites, meta-sandstones, chert and graphitic schists. Conodonts, algae and stromatoporides have been identified in them. The thick, in the profiles that have been discovered, varies from one hundred to 450 metres.

In the **middle Devonian**, a series of schists, recrystallized calcareous rocks and quartz-porphyry has been isolated in the Pliva river-bed near Šipovo, with a thick of some 700 metres. In the Prača and Osanička river basins (south-eastern Bosnia), a series of stratified schists, aleurolites and sandstones with a thick of 150 to 200 metres has been allocated to this period on the basis of certain characteristic conodonts. Upper Devonian has been isolated in the Palaeozoic of the Sana, of the Pliva river basin and in south-eastern Bosnia (Trnovo, Prača, Foča). In the Palaezoic of the Sana it is composed of sandstones, sub-greywacke sandstones, with lenses of spilites with baryte and siderite, dating from the Famennian (D_3^2) and with gradual transition to the lower Carboniferous. In the Perućica valley, a tributary of the Pliva, stratified dark-grey limestones and massive dolomites of the Frasnian and Famennian stages (D_3^1 and D_3^2) have been identified. In south-eastern Bosnia calcareous rocks, graphitic schists with chert, chert, and chert breccias belong to this level, with a thick of about fifty metres.

Rhyolites (quartz porphyry), created over a long timespan ranging from the Silurian to the Permian, play an important part in the geological composition of central Bosnia and the Jajce region (Jezero, Sinjakovo). They have survived in massive quantities and cover up to twenty square kilometres (the subvolcanic laccolith of Vranica). In these areas there are also effusive, extrusive and intrusive rocks, the product of rhyolitic acidic magma, later metamorphosed into quartz porphyry.

Diabases and spilites appear in the Sana Palaeozoic, alternating with carboniferous sediments, as the product of submarine volcanic activity. They are accompanied by tuffaceous schists and millimetric veins of albite. These rocks are to be found also in the Palaeozoic of central Bosnia, along with keratophyres. Diabases and spilites compose large areas of the terrain

of south-eastern Bosnia, overlying Devonian schists (Crna Rijeka, Kratina) and also encountered as interstratifications in the Carboniferous system. These rocks arose at the end of the Devonian and during the Carboniferous periods, but may also locally be to a marked extent younger Permian to Ladinian.

CARBONIFEROUS (C)

The Carboniferous (C) period has been identified in the Central and Inner Dinarides. In the Sana area, chiefly sedimentary deposits of the lower and middle Carboniferous form an area of some 1,000 sq.km. Three groups of facies are isolated: a) clastites composed of sandstones, greywackes, schists and, more rarely, conglomerates, where lenses and thin packages of limestone, dolomites and siderites, and of syngenetic spilites and tuffs are also found. The thick of the clastic complex is 600 to 800 metres; b) carbonates, chiefly in the middle and upper parts of the carboniferous system; c) marine mineral deposits, laid down alongside the facies of the previous two complexes, constituted in tandem with submarine volcanic activity. As well as iron ores, there are also economically important deposits of barytes, and outcrops of lead, zinc and mercury. It is possible that these deposits are significantly younger, and connected with Ladinian vulcanism (?).

Sediments of the **lower and middle Carboniferous ($C_{1,2}$)** form large areas of the terrain in south-eastern and eastern Bosnia. These are for the most part clastic products of the flysch type, with a thick ranging from one hundred to a thousand metres. Characteristic facies are dark-grey limestones, thick bedded quartzes, sandstones and lidites, as large lenses, together with members of the clastic complex. In eastern Bosnia, schists of various kinds predominate in the lower parts of the Carboniferous, while the central part is predominantly meta-sandstones of the greywacke and subgreywacke type, in which there are lenses and packages of black organogenic limestones, dolomites and dolomitic limestones. In the upper part, sandstones of the Birač formation predominate. Remains of conodonts and fossil flora indicate the lower and middle Carboniferous age of these deposits. Their thick ranges from four hundred to seven hundred metres.

Upper Carboniferous has not been identified anywhere. No Carboniferous deposits have been isolated in central Bosnia, although it is not impossible that they are present.

PERMIAN (P)

The Permian (P) is developed in central Bosnia, in the Vranica mountain system, and in south-eastern Bosnia, principally in the peripheral areas of the Romanija mountain. It is represented solely by the upper Permian and transitional Permian-Triassic deposits. Three series of strata are isolated: a) the Bojska series, composed of phyllites ($^1P_3$) in the lower and primarily of carboniferous deposits in the upper part ($^2P_3$); b) the Oparska series, composed of clasts and carbonates corresponding superpositionally to the upper part of the Bojska series; c) the Travnik series (P, T), formed of strata of sandstones, aleurolites and porous calcareous rocks. The most common igneous rocks are sills and interstratifications of rhyolite, together with veins and small stocks of diabases and spilites. The upper parts of all three series are most likely isochronic, though this has not been adequately determined by research and studies to date. The thick of the Permian product of central Bosnia ranges from 600 to 1,400 metres.

The terrigenous-lacustrine product of the upper Permian is widespread in the Pliva and Vrbas river basins, and in the peripheral areas of Jahorina and Romanija mountains. Here porous limestones and anhydrous gypsum with large deposits of high-quality gypsum are found.

PERMO–TRIASSIC (P,T)

The Permo–Triassic (P,T) has been isolated in several places in the Central Dinarides, and is also found in the zone of the Central Dinarides. It is throughout chiefly composed of red sandstones, shales, porous limestones and quartz sericitic and aleurolitic schists in various ratios. The absence of fossils and referential lithofacies has made it impossible successfully to classify the Permo–Triassic. The thick of these deposits has a wide range, from some 150 metres to more than one thousand metres.

THE MESOZOIC ERA

Mesozoic rocks are present in more than 70% of the territory of Bosnia and Herzegovina. They are represented by diverse sedimentary and igneous products of the Triassic, Jurassic and Cretaceous periods.

TRIASSIC

In the Dinarides of Bosnia and Herzegovina, in particular in the central region, there are various well-formed facies of all three Triassic epochs.

The **lower Triassic (T_1)** is differentiated into Sayan (T_1^1) and Campillian (T_1^2) strata, in localities with characteristic fauna. However, this was often impossible, and as a result the relevant deposits were identified as lower Triassic generally. The older part of the lower Triassic is composed of terrigenous and marine-lacustrine sediments, in which there is a noticeably greater presence of conglomerates, breccias, sandstones, shales, marls and sandy limestones. In places they include molluscs of the kinds characteristic of Sayan strata. The thick of the Sayan deposits ranges from two hundred to four hundred metres. In the upper part of the lower Triassic there is a gradual increase in the proportion of carbonates, so that calcareous rocks predominate in the upper levels of the Campillian. They are accompanied by certain crustaceans and ammonites, which confirms that they date from the Campillian. The thickness of these deposits varies widely, from 100 to 500 metres, and of the lower Triassic as a whole from 200 to 700 metres. The development of these deposits is uniform, which facilitates the drawing of parallels between widely separated localities in the Dinarides.

The **middle Triassic (T_2)** is represented by the rocks of the Anisian (T_2^1) and Ladinian (T_2^2) stages. They have been isolated, classified and contoured in every part of Bosnia and Herzegovina. The Anisian (T_2^1) is composed of carbonate facies, lying concordantly with the Campillian strata. Local transgressive positions of Anisian limestone relative to the Campillian (in the Drvar area) are also noted, but are the exception. Massive thick bedded limestones, with algae, rhyncholites, spirifers and ammonites, form much of the terrain in the Dinarides, alternating vertically and laterally with dolomites. Their thick is from two hundred to five hundred metres, only rarely exceeding 1,000 metres (Zvijezda, Tara).

At the end of the Anisian the conditions of sedimentation altered. A trough formed running north-west/south-east, in which vulcanogenic-sedimentary rocks were deposited, known by the compound name of porphyro-chert series. Thus Ladinian (T_2^2) began, in the parts of the Dinarides where the trough existed, with sandstones, schists and chert, with sills, veins and stocks of porphyrite (andesite) and quartz- porphyrite (dacite), spilites, diabases and gabbro. Outcrops and deposits of manganese, barytes, lead, zinc and mercury, often of economic importance, are also known in these strata. From the middle Ladinian onwards this channel became closed, and the deposition of carbonates continued, which was a continual process on the margins of the channel. The thick of the vulcanogenic-sedimentary complex varies from 250 to 400 metres, and of the carbonates up to five

hundred metres. The undifferentiated carbonates of the middle Triassic have a thick of from 400 to 800 metres or more.

The **upper Triassic (T_3)** has been uncovered and preserved over a large area, particularly in the Central Dinarides zone. Here limestones and dolomites have been deposited, with occasional clasts. Local fluctuations in sea-level and the terrestrial stage occurred, when deposits of bauxite originated in Grmeč and Romanija (Milići). Analysis of the extensive facies of the upper Triassic indicates that in northwestern Bosnia dolomites are predominant, in the central region dolomites and limestones are the predominant rocks, and in the south-east limestones predominate with a lesser presence of dolomites. The thick of the carbonates and clasts of the upper Triassic ranges from 200 to 800 metres, and of the undifferentiated middle and upper Triassic exceeds 1,200 metres (Sarajevo – Višegrad). Classification into strata has been carried out in a small number of sites, when findings of molluscs made it possible to identify the Carnian and Norian-Rhaetian sediments.

Triassic–Jurassic (T, J). In the transition Triassic–Jurassic strata a series of primarily chert sediments has been isolated. These manifest themselves in the shape of an unbroken belt of one to fifteen kilometres in width and about 110 km long, from the southern slopes of Kozara mountain to the river Bosna, near Nemila. From there on as far as Rogatica these strata or their equivalents are not isolated.

Interstratifications of shales, silicified limestone and small nodes of manganese of high quality appear in finely stratified and much seamed chert. On the southern slopes of Borja mountain, approximately in the middle of the chert series, an agglomeration of shales and siliceous marls appear, some fifteen kilometres long, locally divided into two parts. Between Višegrad, Prača and Rogatica finely stratified limestones are isolated, with interstratifications and nodules of chert. Conodonts of the middle and upper Triassic have been identified from the calcareous chert series, and foraminiferae characteristic of the upper Triassic and Lias have been found in the stratified limestones with chert in the region of Prača. The chert series is basically of diabase chert formation. They precede the formation of a trench in which diabase-chert formation rocks and equivalent were formed.

The thick of the Triassic and Jurassic chert series is 400 to 500 metres, and of the limestone with chert 150 to 300 metres.

JURASSIC (J)

Rocks of the Jurassic period form about 24% of the territory of Bosnia and Herzegovina. They are found in all three epochs (Lias, Dogger and Malm), with marked differences in distinct zones.

The **lower Jurassic – Lias (J_1)** is prominent in all three zones of the Dinarides of Bosnia and Herzegovina. Its composition is predominantly limestones and dolomites, but other facies are also locally apparent. The calcareous rocks include characteristic fossils that make it possible to classify the Lias into strata, sub-strata and fossil-bearing zones. Thus on Čabulja mountain dark-grey limestones have been isolated, interstratified with bituminous marls and schists in the lower Lias (J_1^1), and dark-grey limestones with a thick of 210 metres in the middle Lias (J_1^2), while darkgrey limestones interstratified with dolomites have been identified as transition Lias-Dogger sediments. A similar process has taken place in the broader Mostar region, where Lias carbonates play an important part in the geological composition of the terrain. The most detailed classification of Lias strata has been carried out in the anticlinals of the Zalomka river, between Gacko and Nevesinje, to the extent that it has also been possible to classify the Lias in detail in other parts of the Dinarides. The thick of the carbonates of the lower Jurassic in south-eastern Herzegovina is 300 to 400 metres. The Lias is also widespread in certain parts of the Inner Dinarides, particularly in south-eastern Bosnia where it is most commonly developed in a facies of reddish breccioid limestone with ammonites (Majevica, Han Pijesak, the Lim valley and so on), which are basically of diabase-chert formation. The depth of the Lias in these areas is from ten to one hundred metres, which is related to techtonic movements, the degree of erosion and so on.

JURASSIC DIABASE–CHERT FORMATION

A Jurassic diabase-chert formation appears in the zone of the Inner Dinarides, as a belt running north-west/south-east, eighteen to seventy kilometres wide, from Bosanska Kostajnica to Uvac on the Lim, 275 km long. Various rocks of this formation appear over an area of some 9,950 sq.km. or 19.5% of the territory of Bosnia and Herzegovina. There are differences in its lithofacial development, as a result of which it has been distinguished into and described in four areas of development: a) Bosanska Kostajnica – Kozara; b) Banja Luka – Doboj – Žepče; c) Doboj – Olovo – Sokolac; d) Sokolac – Višegrad – Vardište. In the description the specific

features of the composition of this formation and its relation to older and younger rock complexes are highlighted.

a) **Bosanska Kostajnica – Kozara**. This area covers about 2,100 sq.km., but exposures of diabase-chert formation are found on no more than two to five percent of this area, since they are covered by younger strata. The diabase-chert formations are composed of sedimentary, igneous and metamorphic rocks. The principal rocks in the sedimentary group are greywacke and sub-greywacke sandstones, shales, marls, chert and, more rarely, limestones and aleurolites. The igneous rocks are spilites and diabases, in the form of small-particle clasts, blocks of a metre or a decimetre in size, and as sills in sediments and concordant intrusions in larger bodies of gabbro. To the north-east of Kozara a gabbrodolerite body with a surface area of some 15 sq.km. and a thick of about 1,400 metres has been uncovered. A concordant relationship between this corpus and the Triassic, Jurassic chert from the foothills has been established locally. Serpentines and serpentinized peridolites appear to the northwest of Prijedor and in the Kozara mountain range, probably as olistolites in the techtonic mlange of this area and as diapyrites thrust into the complex of sedimentary rocks.

A general feature of the rocks forming the diabase-chert formation between the Una and the Vrbas rivers is pronounced crumbling, fragmentation and intermingling. In the Kozara mlange, blocks of Triassic carbonates, eruptives and ultrabasites of various sizes, which are composite olistolites, have a particular place. The techtonic mlange arose from the basal rocks, and from the sediments and ophiolites of the diabase-chert formation in the stages of displacement and settlement of the ophiolite masses and later techtonic movements.

b) **Banja Luka – Doboj – Žepče**. Diabase-chert formation rocks compose almost three-quarters of this terrain, situated between the rivers Vrbas to the west and Bosna to the east. Here too, sedimentary, igneous and metamorphic rocks compose the diabase-chert formation. The predominant sedimentary rocks are sandstones, shales, chert, limestones and breccias. Quartz-sericitic schists and phyllites are more widespread around Skatavica, to the south-west of Uzlomac mountain and around Gornja Snjegotina. Here too appear greater concentrations of schistose rocks, arising from the metamorphosis of sedimentary members of the diabase-chert formation, under the influence of heated peridotite masses during the stage of compression.

The igneous and metamorphic rocks of this area are separated into two groups: **a) spilite-diabase-dolerite-gabbrogranite association; b) peridotite-amphibolite association**. The rocks from the first group appear throughout the area, as breaches, necks, dykes, sills, synsedimentary bodies in the series of sandstones, shales and chert, and as mixed clastic and olistolitic rocks. Spilitic bodies of kilometric extent are to be found in the Ljubić and Teslić area, and hectometric bodies of diabases in mlange, while diabases, dolerites and gabbros form large parts of the terrain in Borja mountain.

Peridotites and amphibolites appear in about ten massifs of from ten sq.km (Vrbanja) to fifty sq.km. (Snjegotina, Ljubić), eighty sq.km. (Borja) and one hundred sq.km. (Čavka). These massifs are as a rule broken up into small blocks and are techtonically related to their surroundings. Their thick is up to five hundred metres. Serpentines are found alongside the margins of ultramafic massifs; lherzolites form more than nine-tenths of the composition of the peridolitic massifs, while enstatites-dunites are found in the south-western edge of the Borja massif, as a kilometric body. Also found in these areas are listvenites, quartz-carbonate rocks constituted during the process of hydrothermal metasomatosis by the displacement of serpentine. A larger mass of amphibolite with a surface area of about 25 sq.km. is to be found near Skatavica, and also form part of the above and other ultramafic massifs.

c) **Doboj – Olovo – Sokolac**. In this extensive area (3,300 sq.km.), primarily composed of Triassic carbonates and various diabase-chert formation lithofacies, the largest ultramafic massifs of the ophiolitic zone in Bosnia and Herzegovina. The foothills of the diabase-chert complex are formed of clasts of the Palaeozoic and Triassic and carbonates of the middle and upper Triassic and Jurassic. The majority of the olistolites in the shaly-sandstone matrix of the diabase-chert formations also originate from these. The same sedimentary, igneous and metamorphic rocks appear in these regions too. The sediments are usually broken up and in melange. However, in the area of Kladanj, Olovo and Banovići there are profiles where alternations of sandstones, shales and aleurolites can be seen, with lenses of breccia and conglomerates locally, and contacts where Lias limestones with gradual transition are to be found in the diabase-chert formation foothills. Certain microfossils originating from various sites indicate that the sediments of the diabase-chert formation date back to the Dogger–Malm epoch.

– The **upper Jurassic in general (J_3)** is isolated in the areas around Bihać, in Grmeč, in south-western Bosnia and around Gacko. In the Grmeč area it lies transgressively over carbonates of the upper Triassic; at the base are conglomerates and breccias, followed by thick bedded and reef limestones of a thick of 300 to 500 metres. Carbonates of the upper Jurassic have also been isolated south of Sanski Most, south-west of Banja Luka, on Vlašić and between Gacko and Nevesinje. They are represented by elipsactinian limestones, and more rarely by dolomitic limestones and dolomites, with a thick of 300 to 500 metres.

– **Upper Jurassic, Oxfordian–Kimmeridgian ($J_3^{1,2}$)**, is widespread in a large part of the Outer Dinarides. It is composed of dolomites, limestones and dolomitic limestones, while locally, conglomerates, sandstones and marls are encountered. They contain a characteristic fauna that makes it possible to distinguish them from younger strata. Their thick ranges from 100 to 600 metres. Oxfordian-Kimmeridgian strata have been isolated between Olovo and Kladanj in breccia, conglomerate, sandstone and marl facies. They lie transgressively over diabase-chert formations, while over them are elipsactinian reef limestones with gradual transition. The thick of the older group is 200 to 250 metres, and of the massive limestones with elipsactinia around 400 metres.

– **Upper Jurassic, Kimmeridgian–Portlandian ($J_3^{2,3}$)** is markedly present in the composition of the Outer Dinarides, particularly around Bihać, in south-western Bosnia and eastern Herzegovina. Various limestones and dolomites, with the typical fauna of this level, have been studied in greatest detail in Paklina, Ljubuša and Vran mountain, where three levels of carbonate have been identified, with a total thick of 2,800 to 3,000 metres. In eastern Herzegovina, too, between Ulog, Zalom and Gacko, younger strata of Malm evolved from the Kimmeridgian–Portlandian strata, with continual transition. The thick of the upper Jurassic carbonates in this area is about six hundred metres.

JURASSIC–CRETACEOUS (J,K), CRETACEOUS (K) AND CRETACEOUS–PALAEOCENE (K_2,Pc) FLYSCHES

Flysches of the Jurassic–Cretaceous, Cretaceous or Cretaceous–Palaeocene ages have been identified in three areas:

a) **Mala Kladuša – Bosanska Krupa – Grmeč**. Upper Cretaceous–Palaeocene flysches in north-western Bosnia begin at Mala Kladuša and the border with Croatia, and extend outwards with minor breaks as far as

Bosanska Krupa, Krnjeuša and Crni Vrh, where there are several isolated areas of flysch, probably as remnants of a formerly much larger whole.

Between Krnjeuša and Koprivna, Cretaceous-Palaeocene flysch lies discordantly over various Triassic–Jurassic rocks. They are composed of finely stratified marls and marlaceous limestones with interstratifications of fine-grained sandstones and lenses of variously granulated calcarenites and red and grey limestones with chert. The strata have the essential features of flysch, but complete turbidite sequences are rare. Certain fossils indicate that this flysch dates back to the Campanian–Maastrichtian ages and the Palaeocene epoch. The thick of the flysch is from 400 to 600 metres.

In the environs of Bosanska Krupa, Risovac and Krnjeuša, the flysch is primarily composed of carbonates. Part of these strata have been isolated in the upper Cretaceous as a whole (K_2) and part is separated into two groups: a) the older base of the flysch ($^1K_2^3$); b) the younger lower Cretaceous ($^2K_2^3$). In the older group calcarenites dominate, alternating in a sequence of three to fifty metres in thick with thick packages of laminated and stratified marls. The thick of these strata is about four hundred metres.

Cretaceous-Palaeocene flysch has been isolated in the synclinal of Ripač – Velebit and in the synclinal of Grmeč north of Bosanski Petrovac, or west of Ključ.

b) **Banja Luka – Sarajevo – Kalinovik**. Jurassic–Cretaceous and upper Cretaceous flysches are represented in the trench that extends from Banja Luka to Sarajevo and Gacko. In the older group they have been isolated into and noted on the map as three units:

– **Jurassic–Cretaceous flysch in general (J,K)**, composed of calcarenites, marls and clays. They often begin with breccias and conglomerates above which, as well as the components referred to, there are also strata of sandstone and silicified limestones. These strata are well developed between Banja Luka and Teslić, in the upper course of the Vrbanja and Bila, where they are divided into four groups (^{1}J,K to ^{4}J,K) according to the predominant proportion of limestone, marl and sandstone (arenite). Similar strata of flysch have been identified between Sarajevo, Kalinovik and the Neretva in Vojkovići – Kijevo, Tušila, Ljuta, Mokro and other places.

– **Jurassic–Cretaceous flysch, older group (^{1}J,K)**, has been identified in areas south of Sarajevo, around the village of Tušila, as far as Rakitnica and Umoljani, where it overlies older (J,K) sediments with gradual transition. It is composed of marls, calcarenites, sandstones and,

Igneous and metamorphic rocks in these areas fall into two groups: **a) rocks of the spilite-gabbro association; b) rocks of the peridotite-amphibolite association.** Two large ultramafic massifs give this area its chief features: a) the Ozren massif, with a surface area of about 300 sq.km.; b) the Krivaja–Konjuh massif with a surface area of more than 600 sq.km. Large masses of amphibolite (Vijaka, Jaruške, Banovići) and of serpentine appear alongside these massifs.

d) **Sokolac – Višegrad – Vardište.** This area is located in the south-eastern part of Bosnia and Herzegovina. On the basis of the 1:100,000 geological map, on the pages for Vlasenica, Prača, Višegrad, Pljevlja, in several profiles it has been determined that the diabase- chert formation sediments lie concordantly with the Triassic–Jurassic limestones with chert or with the Lias limestones and marls. The base of the sedimentary part of the diabase-chert formation is composed of chert with shales, through which runs an olistostromic mlange. Here and there are also appear packages of quartz sandstones, greywackes, silicified marls and limestones. A microfauna indicating that the diabase-chert formation dates back to the Dogger-Malm epoch has been identified in calcareous rocks from the left bank of the Lim (Hercegovačka Goleša). The thick of sediments of the diabase-chert formation is estimated to range from about one hundred to one thousand metres. Basic rocks, spilites, diabases, dolerites and ophitic gabbro are very widespread. In the Višegrad area they appear over an area of about 300 sq.km. They are greatly disrupted and broken up, as is particularly noticeable in the area between the Drina and the Rzav, but also in other places.

In the basin of the Crni Rzav river and in the Varda area, ultramafites appear over an area of more than 120 sq.km. In this ophiolitic complex, starting from the basement, the following elements have been isolated: techtonic peridolites of Varda and harzburgites of Zlatibor; cumulative (igneous) peridotites, chiefly dunite with a little pyroxene, with a thick of about 800 metres; cumulative gabbro, with a thick of 600 to 700 metres; diabases, dolerites and ophitic gabbros, with a thick of about 500 metres; massive and pillow-like basaltic lavas, with a thick of 300 to 500 metres. There are also large masses of amphibolite and amphibolitic schists and serpentinite in this area.

In conclusion to this overview of the diabase-chert formation in the Dinarides of Bosnia and Herzegovina, the following also may be noted:

– the diabase-chert formation is basically a sedimentary product, of which the essential characteristics are determined by the fact that it is the

product of the seabed, in which powerful submarine activity took place, with the compression of parts of the oceanic crust, which were later obducted to terrain close to the current position of the ophiolite massifs;

– the diabase-chert formation arose in the Dogger and Malm epochs ($J_{2,3}$);

– the thick of the the diabase-chert formation ranges from about 600 to 1,500 metres, with exceptionally large variations in the context of the Dinarides of Bosnia and Herzegovina.

For all that, issues of the genesis, age, complex, thick and so on will long remain at the head of research and scientific priorities, particularly in the Tesli region, in the KrivajaKonjuh massif, the Viegrad region and parts of the zone with typical development of the diabase-chert formation.

Lower and middle Jurassic ($J_{1,2}$). In the Lias–Dogger, carbonate facies have been isolated that it has not yet been possible to classify. They appear in all parts of the Dinarides of Bosnia and Herzegovina, with the qualification that they are more widespread in the Visoki Krš zone and in the headwaters part of the Pliva, in Romanija, and around Foča and Gacko. They are most commonly composed of stratified and thick bedded limestones, with locally greater proportions of dolomites (the Sana river basin) and with interstratifications of marl, sandstones and silicified limestones. The thick of the carbonates of the Lias–Dogger is greatest in south-western Bosnia, 300 to 500 metres, and in Cincar, 800 metres, while elsewhere it ranges from 80 to 250 metres.

The **middle Jurassic (J_2)** has been isolated in the Visoki Krš zone, around Bihać, Drvar, Kupres, and in the Mostar and Trebinje region. The basic lithofacies of the Dogger are limestones, stratified, massive, fine-grained, oolitic and pisolitic, grey to dark-grey in colour. Their thick is up to 400 metres.

Middle and upper Jurassic ($J_{2,3}$) have been isolated in the Bihać area (Gata, Ljutoč), in Grmeč and in Srnetica. Around Crkvino and Gata the terrain is composed of dolomites, and in Grmeč and Srnetica of stratified and massive limestones, up to 500 metres thick, with microfossils characteristic of the Dogger and older Malm epochs. In Grmeč the seawaters retreated at the end of the Malm epoch and bauxite was formed.

The **upper Jurassic (J_3)** is at its greatest extent in the zone of the Outer Dinarides, where three lithostratigraphic members are distinguished:

– The **upper Jurassic in general (J_3)** is isolated in the areas around Bihać, in Grmeč, in south-western Bosnia and around Gacko. In the Grmeč area it lies transgressively over carbonates of the upper Triassic; at the base are conglomerates and breccias, followed by thick bedded and reef limestones of a thick of 300 to 500 metres. Carbonates of the upper Jurassic have also been isolated south of Sanski Most, south-west of Banja Luka, on Vlašić and between Gacko and Nevesinje. They are represented by elipsactinian limestones, and more rarely by dolomitic limestones and dolomites, with a thick of 300 to 500 metres.

– **Upper Jurassic, Oxfordian–Kimmeridgian ($J_3^{1,2}$)**, is widespread in a large part of the Outer Dinarides. It is composed of dolomites, limestones and dolomitic limestones, while locally, conglomerates, sandstones and marls are encountered. They contain a characteristic fauna that makes it possible to distinguish them from younger strata. Their thick ranges from 100 to 600 metres. Oxfordian-Kimmeridgian strata have been isolated between Olovo and Kladanj in breccia, conglomerate, sandstone and marl facies. They lie transgressively over diabase-chert formations, while over them are elipsactinian reef limestones with gradual transition. The thick of the older group is 200 to 250 metres, and of the massive limestones with elipsactinia around 400 metres.

– **Upper Jurassic, Kimmeridgian–Portlandian ($J_3^{2,3}$)** is markedly present in the composition of the Outer Dinarides, particularly around Bihać, in south-western Bosnia and eastern Herzegovina. Various limestones and dolomites, with the typical fauna of this level, have been studied in greatest detail in Paklina, Ljubuša and Vran mountain, where three levels of carbonate have been identified, with a total thick of 2,800 to 3,000 metres. In eastern Herzegovina, too, between Ulog, Zalom and Gacko, younger strata of Malm evolved from the Kimmeridgian–Portlandian strata, with continual transition. The thick of the upper Jurassic carbonates in this area is about six hundred metres.

JURASSIC–CRETACEOUS (J,K), CRETACEOUS (K) AND CRETACEOUS–PALAEOCENE (K_2,Pc) FLYSCHES

Flysches of the Jurassic–Cretaceous, Cretaceous or Cretaceous–Palaeocene ages have been identified in three areas:

a) **Mala Kladuša – Bosanska Krupa – Grmeč**. Upper Cretaceous–Palaeocene flysches in north-western Bosnia begin at Mala Kladuša and the border with Croatia, and extend outwards with minor breaks as far as

Bosanska Krupa, Krnjeuša and Crni Vrh, where there are several isolated areas of flysch, probably as remnants of a formerly much larger whole.

Between Krnjeuša and Koprivna, Cretaceous-Palaeocene flysch lies discordantly over various Triassic–Jurassic rocks. They are composed of finely stratified marls and marlaceous limestones with interstratifications of fine-grained sandstones and lenses of variously granulated calcarenites and red and grey limestones with chert. The strata have the essential features of flysch, but complete turbidite sequences are rare. Certain fossils indicate that this flysch dates back to the Campanian–Maastrichtian ages and the Palaeocene epoch. The thick of the flysch is from 400 to 600 metres.

In the environs of Bosanska Krupa, Risovac and Krnjeuša, the flysch is primarily composed of carbonates. Part of these strata have been isolated in the upper Cretaceous as a whole (K_2) and part is separated into two groups: a) the older base of the flysch ($^1K_2^3$); b) the younger lower Cretaceous ($^2K_2^3$). In the older group calcarenites dominate, alternating in a sequence of three to fifty metres in thick with thick packages of laminated and stratified marls. The thick of these strata is about four hundred metres.

Cretaceous-Palaeocene flysch has been isolated in the synclinal of Ripač – Velebit and in the synclinal of Grmeč north of Bosanski Petrovac, or west of Ključ.

b) **Banja Luka – Sarajevo – Kalinovik**. Jurassic–Cretaceous and upper Cretaceous flysches are represented in the trench that extends from Banja Luka to Sarajevo and Gacko. In the older group they have been isolated into and noted on the map as three units:

– **Jurassic–Cretaceous flysch in general (J,K)**, composed of calcarenites, marls and clays. They often begin with breccias and conglomerates above which, as well as the components referred to, there are also strata of sandstone and silicified limestones. These strata are well developed between Banja Luka and Teslić, in the upper course of the Vrbanja and Bila, where they are divided into four groups (^{1}J,K to ^{4}J,K) according to the predominant proportion of limestone, marl and sandstone (arenite). Similar strata of flysch have been identified between Sarajevo, Kalinovik and the Neretva in Vojkovići – Kijevo, Tušila, Ljuta, Mokro and other places.

– **Jurassic–Cretaceous flysch, older group (^{1}J,K)**, has been identified in areas south of Sarajevo, around the village of Tušila, as far as Rakitnica and Umoljani, where it overlies older (J,K) sediments with gradual transition. It is composed of marls, calcarenites, sandstones and,

locally, breccias and shales. The stratum has the typical features of flysch. They are very close-packed, and of a thick of up to 800 metres.

– **Jurassic–Cretaceous flysch, younger group (^{2}J,K)**, is noted in the north-eastern and eastern parts of the trough, as well as at certain points south of Sarajevo. In this terrain there are occasional outcrops of strata from the older group, and the horizontalization is drawn-out. In the lower parts of the group there are calcarenites, and in the upper parts sandy, marlaceous and breccioid limestones, calcarenites, and interstratifications and lenses of chert, shales, sandstones and conglomerates. On the evidence of the foraminiferae identified here, these sediments date back to the Tithonian–Valanginian ages, the Neocomian epoch. The deposit has all the major features of flysch, but the composition of the sequences differs from profile to profile. This flysch has yet to be studied as a geological whole, with its rim of course, which highlights the differences in treatment to date. The flysch in this part of the trough is highly grooved and faulted. Its thick is from 900 to 1,200 metres.

Cretaceous flysches (K_2 and K_2^3) have been isolated around Banja Luka ($^1K_2$ – carbonaceous flysch and $^2K_2$ – marls and calcarenites), and in the region of Kotor Varoš to Jajce, where the flysch has megasequences of micrite and calcarenite and lesser proportions of breccio-conglomerates of sandstone and marls. Similar deposits form the terrain around Skender Vakuf, Vagan, Bešpelj and Bočac, and particularly on the northern slopes of Ranča and Vlašić mountain. On the basis of their position in the geologic column, and their lithological and sedimentological features, five groups are distinguished: $^1K_2$, the arenite-rudite group (Demića river), probably transgressive on the younger part of J,K flysch; $^2K_2$ – the carbonate-marlaceous group with olistostroms of clasts (Demića river and the upper course of the Vrbanja); $^3K_2$, the carbonate marlaceous-rudite group, with well-marked features of turbidite sedimentation (the upper course of the Vrbanja and Ugar, the Ilomska river); $^4K_2$, the calci-rudite group (Koričani, the Ilomska river); $^5K_2$, the marlaceous group, with lesser proportions of intramicrite and arenite.

In addition to the globotruncana characteristic of the Turonian–Senonian, the flysches of this area are composed of an abundance of Maastrichtian forms and of those that also suggest the Palaeocene. The total thickness of the upper Cretaceous flysches in the area between Banja Luka, Jajce and Kotor Varoš is estimated at around 2,500 metres. The upper Cretaceous flysches from the rim of the Sarajevo–Zenica basin show a similar evolution and sedimentological characteristics. They too have marked features of turbidite sedimentation and contain Turonian-Senonian fossils. No parallelization has been carried out, however, with the flysch from the northwestern part of this belt, which is indispensable for a fuller knowledge of them.

c) **Rakitnica – Avtovac – Volujak**. A belt of upper Cretaceous flysch extends from the south-western slopes of Visočica mountain to the border with Montenegro, about 58 km. long and from two to sixteen kilometres wide. This flysch complex is known as the Durmitor flysch. Five lithofacial groups have been distinguished in it, which can be traced from the north-west to the south-east: $^1K_2$ – calcareous breccias, conglomerates and limestones (Kunjak potok, Nadanići); $^2K_2$ calcareous breccias and limestones (Klinje, Mušnica); $^3K_2$ limestones with chert, limestones, marls, calcarenites (Morine, Lebršnik). This group already shows, in its upper levels, fossils that suggest it dates to the Maastrichtian-Palaeocene; $^4K_2$ – sandy, marlaceous sediments, with features typical of flysch (watershed of the Neretva and Sutjeska); $^5K_2$ – facies of breccia and breccioid limestones (Lebršnik) with some sandy and marlaceous limestone and chert. The total thickness of the Durmitor flysch in this area is about 1,250 metres.

On the north-eastern slopes of Crvanj mountain two groups are distinguished in the upper Cretaceous flysch: $^1K_2$ – calcareous breccia, breccioid and marlaceous limestones with interbedded and lenses of chert, calcarenites and marls. The thick of the package is about 500 metres; $^2K_2$ – breccioid limestones, marlaceous stratified and laminar limestones, calcarenites, and marls and limestones in the final part. They contain Turonian–Senonian foraminiferae.

Discontinuities in the belt of flysch and sub-flysch deposits of the upper Cretaceous in the area between Grmeč and Kozara, and in particular south of Sarajevo and in the region of Visočica mountain, arose in the Oligocene, as a result of the action of the orogenic shifts of the Pyrenean stage and of Neogene and in particular of Pliocene movements. Many features, and in particular the successively superimposed structures from Vojkovići to Hrčavka and Brod on the Drina, indicate that Triassic carbonates have overridden the upper Cretaceous over a large area, which should be the subject of serious research in future studies of this terrain.

Upper Cretaceous flysch of the Inner Dinarides

In much of northern Bosnia flysch of the upper Cretaceous is to be found. It has thus far been identified and isolated on all the mountains of

this region: Kozara, Prosara, Motajica, Vučjak, Trebovac and Majevica. There is a well-founded view that at the end of the Cretaceous period and in the Palaeocene epoch, at the time of the Laramide orogeny, a continuity of sedimentation took place in these areas which continued throughout the entire Eocene and up to the middle Oligocene.

In the Krnin region, on Kozara mountain, the terrain is formed of upper Cretaceous marls, shales and pelagic limestones, and near Lisina of Maastrichtian flysch, some 300 metres thick, composed of greywacke, sandstones and pelagic silty rocks;

On the mountains of Prosara and Motajica, Cretaceous–Palaeogene flysch has survived as a mantle over a granite corpus – stocks. In this mantle a more strongly metamorphized element is distinguished in contact with the granites, which gradually merges into the Cretaceous–Palaeogene flysch of which the southern parts of these mountains are composed. This strongly suggests that the granites of northern Bosnia date back to the upper Miocene and Oligocene epochs and that they arose some thirty to forty million years ago.

On Vučjak, Trebovac and Majevica, a Cretaceous–Palaeocene, in fact Maastrichtian–Palaeogene flysch complex with a thick of as much as 2,000 metres or more composes a large part of the terrain. There is an indubitable continuity of sedimentation from the Senonian to the Palaeocene. The flysch is clastic for the most part. The compositional sequence is formed of micaceous sandstones, shales, marls, lenses of limestones and, more rarely, conglomerates. A significant part of the older deposits of the Eocene is in fact Palaeocene and Senonian, and in this regard major changes can be noted.

CRETACEOUS (K)

First to be represented are Cretaceous flysches, while this area is primarily composed of carbonate deposits created on the littoral, the shelf and the high-seas pelagic areas of Tethys.

Lower Cretaceous (K_1) is developed in all three zones of the Dinarides. These deposits are best preserved in the Outer Dinarides, followed by the north-western parts of the Central and locally in the Inner Dinarides; as a rule the lower Cretaceous deposits are distinguished into three groups:

– K_1 – limestones, dolomites, breccias and dolomitic limestones,

– $^1K_1$ – limestones, marlaceous limestones, dolomites, breccias, oolitic limestones with sandstone intrusions,

– $^2K_1$ – limestones, dolomites, calcareous breccias, oolitic limestones, marlaceous and sandy limestones, marls.

The **lower Cretaceous as a whole ($^1K_1$)** has been identified in large areas around Bihać, in south-western Bosnia (Staretina, Vitorog, Dinara), in eastern Herzegovina (Gacko, Trebinje), in the Stupčanica river basin, between Olovo and Han Pijesak and in the Drinjača river basin. In the Grmeč area, lower Cretaceous deposits are discordant on limestones and dolomites of the Malm, and in the Stupčanica river basin on the rocks of diabase-chert formation. There are marked differences in the evolution of the lower Cretaceous in these areas, particularly when they are discordant on an older base. The thick of sediments of the lower Cretaceous ranges from 400 to 700 metres.

The **older lower Cretaceous ($^1K_1$)** covers the Neocomian for the most part (Valanginian – Barremian – Hauterivian). These chiefly carbonate sediments appear in the same areas as undifferentiated lower Cretaceous. They are concordant on limestones with clipeinas with gradual transition. Their thick ranges from 200 to 700 metres. In the Central Dinarides, on Vlašić and around Jajce, older lower Cretaceous is discordant on the Triassic and Jurassic. It is represented by basal breccias and conglomerates, over which there follow stratified and thick bedded limestones. The thick of these sediments in the structural-facial unit of Vitorog – Hrbljina is more than seven hundred metres.

New lower Cretaceous ($^1K_2$). This group covers the period from the Barremian to the older Albian stages. It plays a marked role in the development of the terrain in Grmeč and its surroundings, and in south-western Bosnia (Klekovača, Dinara, Paklina), around Mostar and Nevesinje. Its lithofacial evolution is uniform. Carbonates of this level have also been identified in the areas between Sanski Most and Banja Luka, where laminar limestones with small clusters and lenses of dolomites are predominant. Their thick ranges from 200 to 700 metres.

Albian–Cenomanian ($K_{1,2}$). Transitional deposits between the lower and upper Cretaceous are represented by limestones, breccias, marls and calcarenites. These deposits form the greater part of Grme, south-western Bosnia, parts of the Central Dinarides between Sanski Most, Jajce and Kupres, and also appear on the south-western rim of Popovo Polje. This complex, composed primarily of carbonate deposits, covers the younger

Albian and older Cenomanian. Sedimentation took place in relatively stable conditions, so that similar facies were laid down, with a microfauna that has not allowed for differentiation. The thick of the Albian–Cenomanian carbonates varies from 200 to 550 metres.

Upper Cretaceous (K_2). In much of the Dinarides of Bosnia and Herzegovina there was a continual process of marine sedimentation during the upper Cretaceous, too. The older upper Cretaceous was a period of relative quiet in the dynamics of the earth's crust, and it was chiefly carbonate deposits that were laid down. In the Turonian and Senonian a trench formed in which the flysches already described were laid down, and in the area of Visoki Krš and parts of the Outer and Inner Dinarides there was marine carbonate sedimentation. Carbonate deposits of the undifferentiated upper Cretaceous have a very important place in the geological composition of Bosnia and Herzegovina. As will be seen, they have been fairly extensively studied and classified.

The **upper Cretaceous as a whole (K_2)** covers a very small area. These deposits have been isolated in the area of Duvno (Brdo) and in Paklina, from Šujica to Ljubuša, where they overlie older limestone breccias and conglomerates, and are succeeded by marls, and by marlaceous and organogenic limestones. The thick of the series is 320 metres. Upper Cretaceous limestones with rudistids have been isolated in the composition of the wider Mostar area (Čabulja, Velež). Limestones of the upper Cretaceous, with lesser proportions of calcarenites, chert and conglomerates, are to be found in the valleysides of the river Bosnia, from Maglaj to Doboj, and near Gračanica, at the start of the Tinja crag and on the left bank of the Spreča. These sediments most likely date back to the Turonian-Senonian, but as of now there are no elements available to classify them more precisely. Their roof contains unbroken reef limestones of the Palaeocene. The thick of these sediments is from 100 to 250 metres.

Cenomanian (K_2^1). The oldest lower Cretaceous on the 1:300,000 map is identified solely in Leotar, north-west of Trebinje. However, limestones and dolomites of this stratum are referred to near Trubar and Osječnica, west of Drvar, and between Duvno and Ljubuški, in the wider Mostar region (Čabulja, Čvrsnica, Prenj), Nevesinje and Gacko. As a rule they form part of transition deposits ($K_{1,2}$ and $K_2^{1,2}$).

Cenomanian–Turonian ($K_2^{1,2}$) has been isolated in almost every part of the Outer Dinarides zone. The deposits of this stratum are more widespread between Bihać and Drvar. The dominant facies are diverse limestones, and rarely intrabasin breccias. Near Trubar they are at base bituminous breccias, bauxite clays and quartz sandstones, which indicates a local ground stage. The thick of the Cenomanian–Turonian of this area is 400 to 700 metres. In south-western Bosnia, limestones with chronodonts are predominant (Vaganj, Tušnica, Kamenica, Cincar etc.). The thick of these limestones is 250 metres in Staretina, 460 metres in Cincar, 800 in Dinara, and about 400 metres around Ljubuški. On the southern slopes of Velež and the edge of Popovo Polje limestones with chonrodonts and rudistids also predominate, with a thick of 300 to 400 metres.

Reef limestones of the Cenomanian–Turonian are to be found in Janj, Vitorog and the Dnoluka mountain, where their thick is about 400 metres, and in the Stupčanica river basin, the Kladanj, Milići and Han Pijesak area. In these terrains a continuity of sedimentation has been identified, for limestones and breccioid limestones of the Cenoman–Turonian ($^1K_2$), with a thick of 500 metres, overlie the Barremian–Albian.

Between Kladanj, Vlasenica and Višegrad the upper Cretaceous is differentiated into three groups: $^1K_2$ – conglomerates, sandstones, shales and, more rarely, chert and various limestones. At the base of this heterogeneous series, between Milići and Bijela Voda, are large deposits of bauxite, and near Vardište and Mokra Gora there are nickle-bearing oolitic iron ores. In the Višegrad area stratified and thick bedded limestones and marls (300 metres) overlie this series, followed by reef massive limestones (200 metres), with thick bedded and stratified biomicrites and marlaceous micrites. These deposits have not been classified, but are differentiated into two groups: $^1K_2$ Cenomanian–Turonian, and $^2K_2$ Turonian–Senonian. The evolution around Kladanj in the bauxite-bearing zone, where the sediments of the first group have a thick of 350 to 600 metres, is similar.

Turonian (K_2^2). In the Central Dinarides zone sediments of this stage have been isolated in areas from Vitorog to Trebinje. They are formed of various limestones and, to a lesser extent, of dolomites. The characteristic evolution of these deposits is in the mountains west of Mostar, and on the south-western slopes of Velež and from Nevesinje to Meka Gruda, where they are differentiated into two groups. The thick of the Turonian in Visoki Krš ranges from 250 to 400 metres. Turonian has not been isolated in the Central Dinarides but has markedly developed in the Inner Dinarides, particularly on Ravna Romanija, in the Drinjača river basin and in the upper course of the Spreča, where it is differentiated into two groups ($^1K_2$ and $^2K_2$). Here too, carbonate facies predominate. The thick of the older group is about 300 metres and of the young about 200 metres.

Turonian–Senonian ($K_2^{2,3}$). Transition Turonian–Senonian deposits have been isolated in parts of the Outer Dinarides from Drvar, via Mostar, Čapljina and Stolac, to Trebinje. In Lunjevača and Klekovača rudistid limestones with a thick of 600 to 700 metres predominate; in south-western Bosnia three types of facies are differentiated: a) white microcrystalline limestones, about 450 metres thick (edge of Livanjsko Polje); b) breccias, marls, limestones and calcarenites (Dinara, Tušnica), about 300 metres thick; c) rudistid limestones (Dinara, Vinica, Slivno). Limestones with chronodonts and rudistids, which are widespread around Posušje, in Čabulja, Prenj, Velež and towards the south-east as far as Meka Gruda and Trebinje. The thick of the rudistid limestone is 300 to 700 metres.

Transition deposits of the Turonian-Senonian also belong to these deposits from the Višegrad area ($^2K_2$), of which the biointramicrudites, micrites and marls, preserved at the bottom of the Bjeli Rrzav synclinal, with a thick of about 200 metres, are of particular interest.

The **Senonian (K_2^3)** composes significant parts of the terrain in Bosnia and Herzegovina. Around Bihać rudistid limestones with a thick of 600 to 800 metres (Turija, Ripač) belong to the Senonian; stratified and thick bedded limestones with rudistids, with a thick of 200 to 400 metres, have been discovered in the areas around Drvar and Tičevo; in the synclinal of Čardak Livade a hiatus between the Cenomanian–Turonian and the Senonian has been identified; on the mountains of Paklina and Ljubuša, the Senonian is composed of breccioid limestones and breccias, and in Herzegovina, on both sides of the Neretva, rudistid limestones with a thick of 200 to 300 metres are represented in the Senonian.

Sediments of the Senonian appear, with interruptions, from Klisura Tinja to close to Zvornik. The terrain in the area of Straža and Greda on the Majevica ridge is composed of breccias, conglomerates with interstratifications of limestone in the lower part, and alternating series of sandstones, marls, conglomerates and, in lesser proportions, micrites, with the features of flysch, in the upper part. From Priboj and Snježnica to Kozluk, over a length of about 18 km, there are thick bedded, often breccioid and massive reef limestones of the Senonian. The fauna thus far identified indicates that the entire Senonian layer is represented by these limestones.

On the eastern slopes of Majevica, between Sapna, Kalesija and Glumina, over a surface area of about 100 sq.km., the terrain is composed of conglomerates, sandstones, marls and limestones. According to the identified fauna these deposits date chiefly from the Senonian, with extensions into the Turonian and Palaeocene. They also appear as the lateral facial equivalent of the calcareous carbonates from the Drinjača river basin and around Kozluk.

CRETACEOUS – PALAEOGENE (K_2, Pg)

Transition Cretaceous–Palaeogene deposits, represented by sandstones, calcarenites and marls, are referred to from the south-eastern rim of the Gacko basin, around Kula Fazlagića and Stepen. They lie discordantly over Mesozoic carbonates, on a base of Palaeocene–Eocene flysch. Their thick is around twenty metres. Given their small surface area, they are not shown on the 1:300,000 map.

CAINOZOIC ERA

Various rocks of the Cainozoic are to be found throughout Bosnia and Herzegovina, forming 22% of the country's territory. Research and mapping to date has established the presence of all stratigraphic members from the Palaeocene to the Holocene.

PALAEOGENE (PG)

The **Palaeogene (Pg)** has been isolated in small areas in the Glavatičevo region, and in inverted synclinals near Borovčići, Gornja Bijenja and Kruševljani. Foraminiferae have been identified from the limestone-marlaceous series of Borovčići that indicate the Palaeocene–Eocene origin of these sediments. The thick of the unclassified Palaeogenic series is 80 to 100 metres.

The **Palaeocene (Pc)** has been isolated as an independent member only to the south-west of Vitorog, in the nucleus of the synclinal of Čardak Livada. The Palaeocene is composed of breccias, conglomerates, marls and calci-rudites in a mutually rhythmic alternation. The series has the features of flysch deposits; it contains Palaeocene microfossils; its thick is around 400 metres.

The **Palaeocene–Eocene (Pc,E)**. Transition deposits between the Palaeocene and the Eocene form large areas of the terrain from Grmeč to Popovo Polje. They have been isolated and described under the name of Liburnian strata. They are represented by stratified limestones of dark-grey to black in colour. They lie discordantly over rudistid limestones. A hiatus is indicated by thin deposits of bauxite. They appear in belts of up to two

kilometres wide. They have the features of brackish deposits; their thick ranges from 80 to 150 metres.

In the Inner Dinarides, around Teslić and between Doboj and Srebrenik, there are large isolated masses of various limestones of a thick of 100 to 150 metres. The lower range is composed generally of massive white limestones with a microfauna of the older Palaeocene, and in the upper ranges limestone breccias and stratified marlaceous limestones appear. The microfauna has been identified as of the earlier and later Palaeocene and the lower Eocene, appearing in facies of massive and thick bedded limestones.

In the northern part of Majevica, clastic deposits of the Palaeocene and lower Eocene with flysch features have been isolated.* The clastic deposits are composed of shales (3/4), sandstones and marls. They contain a rich foraminiferous fauna, which is reliable evidence of their dating back to the Palaoecene–Lower Eocene epoch. Their thick is from 700 to 1,500 metres.

The core of Motajica mountain is composed of a granitic stock, which has been identified by isotopic studies as dating from the Cretaceous-Palaeogene period. It is not impossible, however, that the granite is significantly younger, from the Oligocene, which is prominent in an overview of the lower Cretaceous. There are veins of granite porphyry, pegmatite, aplite and quartz rocks on Motajica, and on Prosara there are decimetric veins of granite and, very occasionally, of sienitic and dioritic rocks.

Lower and middle Eocene ($E_{1,2}$). In south-western Bosnia (Dinara, Lip mountain), this member is in a facies of alveoliticnummulitic limestone, which are continuous in the Liburnian strata. It is the same in western and eastern Herzegovina. However, to the north and north-east of Livno there is carbonate flysch in this stratigraphic range, with rhythms in the range of two to twenty metres. The thick of the alveolitic-nummulitic limestone is 200 to 250 metres, and of the flysch around 400 metres.

In the lower and middle Eocene sediments of flysch have been isolated, composed of rhythms formed by strata of sandstones of arkose and sub-arkose type, aleurolite and, more rarely, conglomerates and limestones. They have been discovered over an area of about 300 sq.km, between the Una and Kozara. They contain a microflora and fauna characteristic of the upper Palaeocene to lower and middle Eocene, which indicates that they have not been sufficiently differentiated. Their thick is from 800 to 1,000 metres.

In the Outer Dinarides the **middle Eocene (E_2)** is evidenced only around Bihać, but given the small area concerned it could not be shown on the map. In the Inner Dinarides, on the north flank of Majevica mountain, flyschoid sandstones, marls and limestones with a thick of 80 to 120 metres have been identified in this member, with above them marls, shales and sandstones with lenses of limestone and thin strata of coal, with a thick of about 200 metres. The coalbearing level contains a rich fauna of crustaceans and snails of the middle Eocene. The lower-lying limestones, according to the above-mentioned findings, are clearly early Palaeocene and lower Eocene.

Middle and upper Eocene ($E_{2,3}$). In western Herzegovina two groups of sediments have been isolated in this member: $^1E_{2,3}$ – marls, conglomerates, sandstones, clays, breccioid limestones, clays and limestones, alternating with other features of typical flysch. They are laid down discordantly over Liburnian strata and alveolitic-nummulitic limestones, and are in the roofs of all the larger deposits of bauxite. In addition to Posušje and Široki Brijeg, similar flysch deposits are represented around Bivolje Brdo, Stolac, Nevesinje and Gacko; $^2E_{2,3}$ – marls, sandstones, conglomerates, breccioid limestones, shales and limestones; this group has evolved around Posušje, Tribistovo and Konjevac in western Herzegovina. These deposits, too, have been laid down discordantly over alveolitic-nummulitic limestones and bauxite. They are probably synchronous with the older parts of the flysch from the preceding member. Their thick is up to 200 metres, and that of the flysch ($^1E_{2,3}$) ranges from 100 to 600 metres.

On Trebovac and Majevica mountains, a thick complex (800 to 1,500 metres) of middle and upper Eocene has been identified, composed of stratified and thick bedded sandstones, marls and shales, with lenses of conglomerates and, more rarely, of limestones. According to the foraminiferae identified from the Derventa area and the molluscs of the older part, these deposits were laid down in the middle and upper Eocene. However, spores and pollen from eastern Majevica (Jasenica) indicate the upper Eocene and lower Oligocene, which is more logical, and calls for serious study over a wider area in northern Bosnia.

* R. Radoičić (1992) identified a rich algal microflora and foraminiferae from the limestones of Kamenjak on the northeastern part of Majevica, which had been previously differentiated into a different "horizon" (E_2). This is evidence that these deposits date back to the Palaeocene–Thanetian period. This is a very significant finding, since it could radically alter the image of the "Eocene" deposits of Majevica and of northern Bosnia as a whole.

Eocene-Oligocene (E, Ol). In this member the main components that have been isolated are conglomerates, calcarenites and marls, typically evolved on Promina mountain, from which they have their name. They appear over a large area in Herzegovina, from Livno (Tušnica) to Posušje, Stolac, Nevesinje and Gacko. They have been laid down discordantly over various members of the upper Cretaceous and Palaeogene, as typical molassoid sediment. Thus far no fossils have been identified that could determine the age of these deposits. Most authorities are of the opinion that they were laid down in the upper Eocene and lower Oligocene. The thick of the Promina deposits is 200 to 600 metres (Nevesinje); 900 metres (Tihaljina); 1,300 metres (Livno).

Oligocene (Ol). North of Duvno, between Šujica and Mokronoge, clastic deposits have been identified in the Oligocene, discordant on Palaeogene structures. The deposit is formed of limestone conglomerates, with lesser proportions of breccias, sandstones and calcarenites. No fossils have been found, and their relationship with the older Miocene deposits with coal is not clear either. Their thick is around 450 metres.

In the central area of Majevica, between Gornja Tuzla and Priboj, the Oligocene includes a series about 700 metres thick of marls, shales, aleurolites, laminar sandstones with ripple-marks, and thick bedded sandstones. In the lower part of the series there are also thin strata of coal. No fauna has been found, so that the age of these sediments remains to be further studied.

Oligomiocene (Ol, M). This horizon includes basal clastites, discovered on the north-eastern rim of the Sarajevo–Zenica basin. This is the so-called first polyfacial complex in which there is also a Košćanski coal stratum. The classical local evolution of these deposits is Kapa hill near Breza.

NEOGENIC (Ng)

The **Neogenic (Ng)** has been identified throughout Bosnia and Herzegovina. It is classified into lacustrine, lacustrinelagoonal and marine facies of the **Miocene** and **Pliocene**.

MIOCENE (M)

Lacustrine facies of the **Miocene (M)** are differentiated on the 1:300,000 geological map of Bosnia and Herzegovina into five stratigraphic units, which is in conformity with the current knowledge of stratigraphic relations in this part of the Dinarides.

Lower Miocene (M_1). Lower Miocene limnic sediments have been isolated in the Lopare, Ugljevik and Tuzla basins. They are separated into three zones: the floor, the coal and the roof. The floor zone is composed of conglomerates, breccias, sandy clays and marls; in the coal zone, in addition to coal, there are interstratifications of clays and marls; and in the roof deposits of marls predominate. Mammalian findings indicate that the coal stratum in Ugljevik dates back to the Chattian–Aquitainian (Egerian) period. The thick of the limnic deposits in these basins ranges from 100 to 500 metres.

Lower and middle Miocene ($M_{1,2}$). In this stratigraphic range, lacustrine, lacustrine-lagoonal and vulcanogenic facies were created, and are presented in that order.

In the zone of the Outer Dinarides there are a large number of depressions or basins in which fresh-water lacustrine coal-bearing deposits were formed: the Drvar, Livno, Duvno, Mostar and many other, lesser basins. They are best differentiated in the Livno and Duvno basins, where the thick of lower and middle Miocene sediments is around 1,400 metres. In the other basins the thick ranges from about 200 to 750 metres.

In the Central Dinarides the most important are the Sana-Kamengrad basin, the Sarajevo–Zenica basin, the Banja Luka, the Kotor Varoš, the Konjic and the Miljevina basins. The classical evolution of these deposits is in the second polyfacial complex of the Sarajevo–Zenica basin. Each basin has its own specific lithofacial evolutionary features, while roof deposits were created throughout the Miocene.

In the Inner Dinarides, similarly, there are a large number of limnic basins, of which the most important are the Lješljan, the Prnjavor, the Teslić, the Banovići, the Đurevik, the Seona, the Žepče–Novi Šeher, the Rogatica and a large number of smaller basins. The most complete evolution of the limnic series is in the Banovići basin, with a thick of about 700 metres. In the majority of basins three zones developed: the floor, the coal-bearing and the roof, with major differences in regard to thick and degree of coal-bearing.

Lacustrine-lagoonal facies ($M_{1,2}$) have been isolated between Tuzla and Gornja Tuzla and in the Lopare–Priboj basin. These are sediments of the banded series, which are differentiated into two groups: $^1M_{1,2}$ – the red

series, composed of red conglomerates, variously coloured sandstones and aleurolites, tuffs, shales, marls and gypsum. These sediments lie concordantly over the Egerian (Ol_3, M_1^1) deposits, with gradual transition; $^2M_{1,2}$ – the banded series or salt formation of Tuzla in which, in addition to marls, tuffites, micrites, dolomicrites and shales, in the area between Gornja Tuzla (Tetima), Tuzla (Tušanj) and Lipnica there are deposits of rock-salt. In the roof of the banded series there are laminar limestones and chlir. The total thick of both groups of lacustrine-lagoonal deposits ranges from 700 to 1,200 metres.

Igneous rocks. The lower Miocene was a period of great volcanic activity in northern Bosnia and beyond. Tuffs are found in large quantities in the Livno basin, and in the areas of Medna–Baraći, in Lješljani, around Prnjavor, Ugljevik, Zvornik and Srebrenica. They are most commonly found in complexes of lacustrine and lacustrine-lagoonal deposits or in the stratum of Baden sediments (Sapna, Kozluk). This vulcanism produced dacites, andesites, tuffs and other pyroclastites which are to be found over an area of about 100 sq.km in the Srebrenica area, and also in the Maglaj, Teslić and Doboj region.

The **middle and upper Miocene ($M_{2,3}$)** are markedly developed in several coal basins: the Livno, Duvno and Glamoč basins, where the horizon of white marls, some 400 metres deep, belongs to these periods; the Sarajevo–Zenica basin where conglomerates of the Lašva series with a thick of around 800 metres were laid down during this period; stalagmitic limestones in the Miljevina basin belong to this level; three coal-bearing zones of the Sana–Kamengrad basin with a thick of 1,020 metres; limnic sediments of the Gacko basin differentiated into nine lithofacial zones with a total thick of up to 1,000 metres, with the reservation that the most recent deposits are probably Pliocene. The lacustrine deposits of the Bihać–Cazin and of smaller basins in the upper course of the Pliva (Medna, Baraći, Šipovo, Vrbljani), the middle and upper part of the deposits of the Mostar basin, and of several small basins in this area – Grabova Draga, Gradnići, Hodovo, Stolac and Nevesinje – also date from the middle and upper Miocene.

Upper Miocene (M_3). In this level two groups are differentiated in the Sarajevo–Zenica basin: $^1M_3$ – marls, clays, aleurolites, argillaceous sandstones and limestones ("počulički" Congerian limestones) with a thick of about 400 metres; $^2M_3$ – orlački conglomerates, with a thick of 100 to 200 metres. So far no other deposits dating from the upper Miocene have been specifically isolated in the lacustrine basins of Bosnia and Herzegovina.

Marine facies of the Miocene are represented in the Baden (M_2^2), Sarmatian (M_3^1) and Pannonian (M_3^2). Baden sediments are represented throughout northern Bosnia, from Bosanska Kostajnica to Zvornik and Tuzla. They are characterized by great facial diversity (chlir marls, conglomerates, sandstones, marls, thick bedded and reef limestones) and their wealth of macro and microfauna, which makes it possible to zone these deposits in many areas. The Sarmatian is characterized by a reduction in salinity, which was caused by the deposition of marls, clays and limestones with fauna characteristic of brackish waters. The Pannonian strata were created in gulfs between the already markedly raised mountains of northern Bosnia. Argillaceous-sandy sediments, sandstones, quartz sandstones, white marls, clays, marlaceous and bioclastic limestones were laid down. The Pannonian sediments contain a rich fauna with Caspian-brackish features. It has been very well studied and classified, particularly in the Tuzla and Prnjavor basins. The thick of the Pannonian sediments is 100 to 200 metres, of the Sarmatian 150 to 300 metres, and of the Baden 150 to 400 metres.

PLIOCENE (Pl)

Lacustrine and marine deposits have been identified from the Pliocene. In the Livno basin, in the area of Prologa and elebia, lignite-bearing sediments and the motley series from their roof probably belong to the lower Pliocene. The thick of these two groups ($^1Pl_1$ and $^2Pl_1$) of the most recent lacustrine deposits is some 250 metres.

Marine facies of the **Pontian (Pl_1)** are widespread on the northern margin of the Prijedor basin, around Puharska, Kozarac and Ivanjska. An important place is taken in the Pontian of this terrain by china clays ($^1Pl_1$), quartz sands ($^2Pl_1$) and ferrous sandstones ($^3Pl_1$). The maximum thick of these deposits is around 300 metres.

Pontian sediments are widespread to the north and northwest of Prnjavor, and in the lignite basi of Stanari and the entire Podgorina of Majevica as far as Šepak on the Drina. In the Pontian of the Brčko Posavina the predominant facies are argillaceous-marlaceous, and in Semberija sandy-sandstone facies predominate. The classical local evolution of the Pontian of northern Bosnia is Kadar hill on the right bank of the Sava, below Vučjak. In the Tinja rift, which linked the Parathetys with the gulf in the present-day Tuzla basin, marls and marlaceous clays were deposited, facies

of rather deeper water. In the extensive gulf that stretched between Doboj and Tuzla in the Spreča fracture zone, Pontian deposits have been preserved over an area of more than 900 sq.km. Here the Pontian deposits, with a thick of around 1,000 metres, were laid down in four rhythms: clay, lignite, quartz sand; the first and second rhythms contain fauna characteristic of the Portaferian, while the more recent rhythms and roof deposits of the Portaferian are poorer in fauna.

Plio-Quaternary (Pl,Q). Sediments of the Plio-Quaternary are very widespread in northern Bosnia. They have been isolated in the Prijedor basin, in the wider area of Dubica, in the Brod and Brčko Posavina and in Semberija. They were laid down in shallow, ancient depressions, and then in the broad valleys and deltas of major rivers. In the Prijedor basin, two types of Pl,Q facies have been isolated: a) variously coloured china clays (Rizvanovići, Hambarine); b) depression material on the slopes of the surrounding mountains. The thick of these deposits is from a few to two hundred metres. From Bosanska Dubica via the Brod Posavina to Semberija and the Drina, Plio-Quaternary sediments are usually represented by sand and gravel, which, cemented by sand, give rise to local conglomerate thick beds and reefs, and also by gravels, aleurolites and yellowish clays with Fe and Mn concretions, as well as a series of deposits of different colours in the Quaternary of Sprečko polje, which are represented in the lower part by argillaceous-sandy, and in the upper part by sandy-gravelly sediments. The thick of the Pl,Q deposits is up to about 100 metres, except in the older depression between B. Brod and Bčko (Vitanovići) and in Sprečko polje, where drilling has established that their thick ranges from 126 to 500 metres.

QUATERNARY (Q)

Various sediments of the Quaternary have been isolated throughout Bosnia and Herzegovina. They are represented by aquatic, slope and glacial deposits.

The aquatic sediments are composed of fluvial limnic and pond sediments. These subaquatic sediments form alluvial plains on the right bank of the Sava, and in the valleys of the rivers Una, Vrbas, Bosna, Drina, Neretva and Trebišnjica, and appear as the most recent sediments in the Bihać, Prijedor, Spreča, Sarajevo and other depressions. River formations are to be found on several terraced levels, particularly upstream from their mouths. The thick of these deposits ranges from five to 100 metres.

Deposits of the slope genetic group comprise a large number of facies from the group of alluvial, deluvial, eluvial, proluvial, slope-aquatic and transition facies. These facies are most widespread in the hilly and mountainous regions of the terrain, particularly in the areas composed of clastic and argillaceous-marlaceous deposits. The moraine and periglacial sediments that are widespread on the high mountains of south-western, central and south-eastern Bosnia and Herzegovina belong to the glacial deposits. In addition to sediments, there are also present various glacial features: cirques, undulations and traces of the movement of glaciers striations. Limno-glacial sediments in the region of Zelengora, Vrbnica and Boračko lake, as well as glacio-fluvial deposits, arisen from the overlaying of moraine material, are also found on the north-eastern slopes of Zelengora.

THE TECHTONICS OF BOSNIA AND HERZEGOVINA

The Dinarides are a major geotechtonic unit in the southern branch of the Alps. They run north-west/south-east, from the Karawanken to Prokletije, between the periadriatic and the Pe dislocation zone. The territory of Bosnia and Herzegovline lies in the central part of the Dinarides, and is characterized in effect by the same techtonic style and geological evolution. An analysis of all the structural-facial parameters in the overall geotechtonic structure of the terrain of Bosnia and Herzegovina has identified three zones: the zone of the Outer Dinarides, most of which belongs to the Visoki Krš overthrust; the zone of the Central Dinarides which corresponds to the belt of Palaeozoic schists, Mesozoic limestones and flysches; the zone of the Inner Dinarides which covers a part of this techtonic unit that is separate in the overall structure of the Dinarides.

This geotechtonic regionalization in the Dinarides of Bosnia and Herzegovina is determined, primarily, by two overthrust structures: a) the Visoki Krš and Durmitor overthrust. The head of the overthrust of Visoki Krš forms the boundary between the Outer and Central Dinarides, and the Durmitor overthrust forms the boundary between the Central and the Inner Dinarides. These are geological boundaries, for the most part approximately located and, as can clearly be seen on the 1:300,000 geological map, in many places intersected and shifted by transversal and diagonal breaks, of which the following are particularly marked: the Una geofracture, the Vrbas dislocation, the Ključ – Kupres rift, the Sarajevo geofracture and others. The Outer Dinarides are almost entirely composed of carbonate facies. In the inner zone they are folded, overthrust and broken, as a result of which

the thick of the sedimentary complex is as much as ten kilometres in places. There is a large number of lesser overthrusts, with a compression index of three to five.

In the Central Dinarides, too, all the rock complexes are greatly folded, broken, severed and shifted. In the southeastern zone, in the context of the Durmitor and other overthrusts, huge masses of Palaeozoic clastites and Mesozoic limestones were shifted and slid over the Jurassic–Cretaceous and Cretaceous–Palaeogenic flysches; in the north-west the Triassic carbonates of the Bosanska Krajina, together with the Palaeozoic of Petrova and Zrinka Gora, slid over the Cretaceous–Palaeocenic flysch; SFU Koprivna – Sanica at Grmeč, Sana–Una Palaeozoic to the southern part of SFU Grmeč. From Banja Luka to Sarajevo in the Central Dinarides zone are still larger quantities of thrusts and several major geofractures: part of the Sarajevo geofracture, the Busovac dislocation in the zone of the Sarajevo-Zenica basin, part of the Vrbas dislocation, the Kozara dislocation, the Teslić – K. Varoš – Prijedor fissure and others. These dislocations, as well as other effects, have led to the exposure of the Palaeozoic of Central Bosnia, and to the creation and evolution of major palaeodepressions on the Gornji Vakuf – Bugojno – Donji Vakuf and Sarajevo – Travnik – Jajce lines.

The zone of the Inner Dinarides occupies the northeastern part of Bosnia and Herzegovina. Here there is an entire belt of diabase-chert formation with ophiolite massifs, as well as the Cretaceous Palaeogenic flysches of northern Bosnia, granite stocks and younger Neogenic lacustrine, lacustrine-lagoonal and marine formations. Its south-western boundary is denoted by the entire overthrust of diabase-chert formation on the Jurassic–Cretaceous flysches of the Central Dinarides and by the southern Kozara dislocation, and the north-eastern and eastern boundaries are on the zone of the Sava trench and the Drina fissure. The inner part of this zone is greatly furrowed, faulted and shifting, which is particularly marked around the large ophiolite massifs, in contacts between the Palaeozoic clastites and Triassic carbonates, and of the diabase-chert formations and Cretaceous–Palaeogenic flysch. Among the major fractures, particularly marked are the Spreča fracture (Zvornik – Doboj), the Northern Bosnian fracture (Janja – Gradačac – Modriča), the Drina geofracture, the southern Kozara fracture and many diagonal dislocations (Lukavac, Tinja and so on).

The complexity of the techtonic structure of the Dinarides in Bosnia and Herzegovina also shows a large number of structural-facial units, identified on the pages of the Basic geological map 1:100,000: the Outer Dinarides 30, the Central Dinarides 31, the Inner Dinarides 11. Within the

context of individual structural-facial units more than two hundred structures of lower order have been identified: folds, thrusts, blocks and faults. This indicates the exceptional complexity of the techtonic system of the Dinarides in the territory of Bosnia and Herzegovina, which is merely outlined in this brief review.

GEOLOGICAL-TECHTONIC EVOLUTION

Over a long time period from the Silurian to the Quaternary, the region to which the Dinarides of Bosnia and Herzegovina belong was primarily beneath the waters of Tethys. During the Silurian period, some 425 million years ago, that part of Tethys was located between the Gondwana and Laurasia (North American) continents, while at the beginning of the Triassic it was surrounded by the megacontinent of Pangaea, formed at the end of the Palaeozoic (some 250 million years ago). From the Silurian to the upper Permian, a period of some 200 million years, two orogenetic cycles took place, the Caledonian and the Herzian, while the orogenesis of the Alps lasted from the beginning of the Triassic.

Data on the processes of sedimentation and vulcanism, the type of sediments and fossils, indicates that the oldest sediments are Silurian, or perhaps Ordovician. Changes to the disposition of the land and the sea during the Silurian and early Devonian belong to the Taconic and Erian stages*, and the break in sedimentation probably to the Breton stage, about 320 million years ago, when the Caledonian orogenesis was complete, which has left marked traces in Northern America (the Appalachian mountain chain was formed as well as the mountain ranges of Scotland, Scandinavia and so on).

The movements and effects of the Herzian orogenesis have left recognizable traces in carbonate deposits. In the lower Carboniferous, techtonic movements gave rise to heavy erosion of older sediments, the deposition of culm flysch and clastites, of which the present-day thick is around 1,000 metres. Local interruptions and powerful vulcanism, which produced intrusions and synsedimentary masses of diabases, spilites, rhyolites and quartz-keratophyres, characterize the end of the lower and middle Carboniferous (the Sudetan stage). These movements brought about the end of sedimentation and led to the terrestrial stage, which lasted until the upper

* All these changes were caused by the movement and collision of the continents. The concept of orogenic stages, here and later, gave rise to changes in the more precise temporal term, particularly in the case of smaller areas and microplates.

Permian. During the upper Carboniferous, lower and middle Permian (about 60 million years ago), rock complexes of the Silurian, Devonian and older Carboniferous periods were lifted, folded and greatly eroded. In the Palaeozoic of central and eastern Bosnian, traces of structures running north-east/south-west have been preserved, which are the produce of the Herzian orogenesis, Asturian stage, the movements of which led to these changes.

A new stage of sedimentation in this part of Tethys began in the upper Permian, about 250 million years ago. This coincides with the formation of the supercontinent Pangea. The Alpine orogenic cycle has been taking place ever since, right up to the present era, within the context of Tethys and the dynamic of the earth's crust linked to the movement of the African plate towards the north, its collision with Eurasia and sliding beneath the European continent. Much information is given in the more extensive text about the evolution and characteristics of sedimentation and vulcanism, the creation of the continental and oceanic crust, changes in the disposition of land and sea in these areas. They show that all the essential changes manifested in this part of the Dinarides are linked to the global movements characteristic of the Mediterranean maritime belt and the Southern branch of the Alps as a whole. This is wholly logical, since this terrain was part of Tethys, that is of the Mediterrean belt in which ever since the Ordovician, and in particular since the Triassic, there has been a marine regime, accompanied by stages of magmatism and volcanic activity, the disappearance of old and the creation of new sedimentary regions, through the processes of collision, subduction and so on. Traces of these movements and processes have been preserved on the terrain of Bosnia and Herzegovina, which have been to a large extent discovered and elucidated in the course of the geological studies and research undertaken to date.

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