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Summary

GEOLOGY OF THE MESOZOIC IN THE VICINITY OF BELGRADE

by

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The paper is a detailed study of the geology of Mesozoic formations in the vicinity of Belgrade with an emphasis on the stratigraphic development and tectonics and a reference to the magmatism and tectonics of the area.

Jurassic

The oldest rocks in the vicinity of Belgrade are of Jurassic age and underlie Cretaceous and Tertiary sediments. The Jurassic is represented by (a) pre-Upper Jurassic and (b) Upper Jurassic formations.

The pre-Upper Jurassic formations are represented by serpentines which occur in the base of all other rocks. They are distributed along a

zone extending from the Danube bend via Kumodraž and Leštane, east and southeast of Mount Avala as far as Klenje. On the basis of redeposited material now found in clastic rocks of Jurassic, Lower and Upper Cretaceous age, it can be assumed that serpentine rocks once had a considerably wider distribution.

A correlation of serpentine rocks and the sedimentary formations of Jurassic, Cretaceous and Tertiary age, and study of the composition of Jurassic and Cretaceous clastic rocks leads to the conclusion that the serpentines of the vicinity of Belgrade — wherever overlying the Jurassic, Cretaceous or Tertiary — have a tectonic contact and are of pre-Upper Jurassic age.

Upper Jurassic. — Upper Jurassic formations have a considerable distribution in the valley of the Topčiderska Reka and its tributaries, in the Železnička Reka stream and along the periphery of Makiš. With respect to facies, several of them could be distinguished.

Volcanogenic-sedimentary formation. — The earliest Upper Jurassic sediments along with volcanic rocks constitute the volcanogenic-sedimentary formation. Lithologically the following are recognized: (a) sandstone-chert series and (b) schistose-chert series. In the sandstone-chert series predominate sandstones of a brown or yellow colour, often covered with a manganese substance, and red and grey or green chert associated with shales and clayey schists. The schistose-chert series consists dominantly of black or brown intensively folded and fractured shales and schists containing muglas and lenses of sandstones with rather large concretions of a manganese substance. The schists are associated with cherts and the latter with diabases and spilites.

A detailed study of the volcanogenic-sedimentary formation in the Šumadija zone and the vicinity of Belgrade as its part, led the author to conclude that this formation resulted from intensive fracturing of the Šumadija geosyncline along profound faults coupled with effusion of basic rocks in the time interval Oxfordian — Lower Tithonian.

The facies of *Aptychi* beds. — The strata containing *Aptychi* fossil remains in the vicinity of Belgrade are found in several localities. They are most often represented by marls of a red or reddish, less often of a grey or greyish brown or blue colour; next, by sandy marls, marly sandstones, marly limestones or shales interstratified with diabases, spilites and their tuffs. Form the *Aptychi* beds of the vicinity of Belgrade the following were recovered: *Lamellaptychus beyrichi* (Opp.), *L. beyrichi* (Opp.) var. *fractocosta* Trauth., *L. beyrichi* (Opp.) var. *moravica* Blansch., *Laevaptychus latus* Park., *L. longus* Mey., *Laevaptychus* sp. ind., *Lamellaptychus euglyphus* Opp., *Punctaptychus punctatus* Woltz., *P. punctatus* Woltz. var. *longa* Trauth., along with belemnites, fragments of ammonites, radiolarians and tintinnids. As borne out by the faunal remains, the *Aptychi* beds were formed during the Tithonian. Upwards these strata grade into marls with *Aptychi* of Berriasian age.

Reef limestone facies. — Upper Jurassic reef sediments constitute a separate facies which was deposited on emerged reefs or in shallow offshore parts of the sea. The Upper Jurassic reef sediments consist of grey or white dense or saccharoidal, very compact limestones mostly banked

or massive. Locally they are sandy and brecciated and partly associated with sandstones. The limestones contain a rich fauna consisting of hydrozoans (*Ellipsactinia ellipsoidea* Steinm., *Ell. thyrensis* Can., *Ell. caprense* Stein., *Sphaeractinia diceratina* Steinm., *Sphaeractinia* sp.), corals (*Ripidogyra flabellum* Mich., *Calamospheris flabellum* Rheinv., *Thecosmillia dichotoma* Koby); gastropods (*Nerinea pyrophornis* Gemm., *Cryptoplocus pyramidalis* Münst., *C. picteti* Gemm., *Phaneroptychsis staszycii* Defr.); next, remains of bryozoans, echinoids, less often brachiopods and crinoids. The microfauna is represented by *Clypeina jurassica* Favre, *Coscinoconus* sp. The facies is developed at Vezirsko Brdo, Straževica, along the middle course of the Bela Reka river, in the Ripanj area and at the periphery of Makiš.

Brachiopod limestone facies. — Straževica limestone. — A brachiopod limestone facies occurring at Straževica, from which its name has been derived, is particularly well developed. Lithologically, these are banked, or less often, stratified bluish or dark blue dense limestones. Thickness of the bank ranges from 30 to 60 cm. In the upper parts of the series these limestones are sandy, dense, granular or brecciated, locally stratified and of a dark blue colour. Stratified limestones grade laterally into banked limestones. These most often contain a brachiopod fauna on account of which they are referred to as brachiopod limestones. The following species are most frequent: *Rhynchonella proeminensis* Yin., *Rh. dilatata* Roll., *Rh. hohenegeri* Suess., *Terebratula insignis* Schub., *T. gallieneri* d'Orb., *T. ventricosa* Ziett., *T.* cf. *ornitocephala* Sow., *T. immanis* Zeuschn., *T. moravica*, *T. gratianopolitensis* Pict., *T. formosa* Suess., *T. buckmani* Mor., *T. bouei* Zeuschn., *T.* cf. *carpathica* Zitt., *Pygope diphia* (F. Col.); next, nerineas (*Nerinea conoidea* Pict.), fragments of Trichites, Opis, Lima, Pecten; occasional corals, crinoids, belemnites being represented by *Belemnites zeuschneri* Opp., and other. Of the microfossils *Clypeina jurassica* Favre and some other were recowered.

Brachiopod limestones were deposited during the Kimmeridgian and Tithonian and partly represent lateral equivalents of the upper part of the volcanogenic-sedimentary formation, the *Aptychi* beds and reef sediments.

Facies of crinoid sediments. — This facies consists of grey or whitish, brown and yellow dull-looking sandstones associated with coarse-grained sandstones and conglomerates. Sandstones most often contain well preserved crinoid stems whose structure can be distinctly observed.

Facies of brachiopod marls. — This facies is built up of grey tabular and stratified marls intercalated with marly limestones containing brachiopods *Terebratulla moravica* Glock., *T. zietteni* Mösch., *T. humaerensis* Gemm., *T. pseudolagenalis* Mösch., *T. formosa* Suess., *T. gratianopolitensis* Pict.; next, gastropods *Nerinella punctata* Volz., *Pleurotomaria* sp., echinoids, etc.

Lower Cretaceous. — The Lower Cretaceous occurs in the city area: at Topčidersko Brdo, Banovo Brdo, Košutnjak, Dedinje, and extends southward across the Topčiderska Reka towards Kosmaj mountain.

All the stages of the Lower Cretaceous developed in various facies have been recognized.

Berriasian. — This stage consists of calcarenites, brecciated limestones, sandy calcarenites and sandstones with carbonatic chert containing microfossils *Tinthinopsella carpathica* Murg. and Fil., *Stenosemelopsis hispanica*, cross sections of belemnites, ammonties and *Aptychi*. Berriasian sediments also occur closely associated with Valanginian and Neocomian sediments from which they were not separated.

Berriasian—Valanginian. — These stages of the shallow water development encompass marly-clayey rocks with an association of brachiopods, clams, echinoids, viz., *Lima (Plagiostoma) vigneulensis* Pict. et Camp., *L. (P.) carteroniana* d'Orb., *L. (Acestes) longa* Roem., *Pecten (Camtonectes) arzierensis* de Lor., *Ostrea* sp., *Arca* sp., *Terebratulla gratianoplotensis* Pict., *T. moutoniana* d'Orb., *T. moravica* Glock., *T. praelonga* Sow., *T.* cf. *saueri* Pict., *Zeilleria* cf. *egena* Bayle., *Pygope triangularis* Lam., *Terebratulla sueuri* Pict., *T. aubersonensis* Pict., *T. collinaria* d'Orb., *T. viteli* Pict., *Pseudodiadema tetragamma* Des., *Leocidaris solviensis* (Coth.), *Acropletis aequituberculatus* Ag., *Pseudocidaris spinosa* Lor.

Valanginian-Hauterivian-Lower Barremian (cephalopod sediments). — Cephalopod sediments of the earlier Lower Cretaceous of the vicinity of Belgrade were deposited in the deepest parts of the sea and are represented by marly-clayey rocks such as grey, bluish, reddish or yellow marls, blue marly shales, sandy or clayey marls, marly fine-grained sandstones intercalated with marly limestone. From these sediments a rich fauna consisting of ammonites, belemnites and *Aptychi* was recovered. (See p. 41—43).

Neocomian flysch. — During the Neocomian (Berriasian, Valanginian and Hauterivian) there was also a flysch basin, close to the present city site, in which flysch sediments were deposited. The Neocomian flysch is made up of sandstones, siltstones, marls, shales and clayey shales with layers of calcarenite. This flysch is characterized by an alternation of two of its members: sandstone and shale or sandstone and marl. Its sedimentology was studied in detail by J. Obradović (1967). Neocomian flysch also contains spilitic rocks as products of submarine effusions. This flysch was found to contain *Calpionella alpina* Lor., *Clypeina jurassica* Favre., *Conicospirilleina bassiliensis* Moh., *Thaumatoporella parvovesiculifera* (Rein.), and also *Tintinopsella carpathica* Murg. and Fil., *Stenosemelopsis hispanica* in its upper parts. Calcarenites contain echinoid spines (Cidaris), mollusks (Ostrea), crinoid stems and ammonites (*Applites* sp.). A rich microfloral assemblage was also recovered from this flysch (See p. 48—49).

Barremian and Aptian. — These formations are widely distributed and represented by a zoogenic-reef development (a) and flysch development (b).

Reef and sub-reef development (Urgonian facies) occurs over a wide area (Košutnjak, Banovo Brdo, Dedinje, etc.). Two facies have been recognized: (i) sandstone-conglomeratic and (ii) limestone facies.

(i) The sandstone-conglomeratic facies contains a rich gastropod fauna with *Nerinea (Dyosoptixis) coquandi* d'Orb., *N. (D.) coquandi* d'Orb. var. *sigunovi* Petk., *Nerinea vogti* de Mort., *N. vogti* de Mort., var. *archimedi* d'Orb., *Nerinea gigantea* d'Hombre-Fir.; next, ammonites: *Phylloceras tethis* d'Orb., *Ph. ponticuli* Rous., *Desmoceras ponticum* Kar., *D. ligatum* d'Orb., *Holcodiscus caillandi* d'Orb., *H. perezi* d'Orb., *Hoplites arnoldi* Pict. et Camp., *H. catuloi* Par., *Crioceratites angulicostatus* d'Orb., followed by orbitolinas *Orbitolina conoidea discoidea* Gras.

(ii) The limestone facies consists of banked and massive limestones containing a rich faunal assemblage of orbitolinas *(Orbitolina conoidea discoidea* Gras., pachyodonts Requienia, Toucasias, corals, brachiopods, etc.

Barremian and Aptian flysch of the vicinity of Belgrade is considerably developed in the zone Rušanj—Ripanj and in that of Barajevo. It is represented by fine-grained and coarse-grained marly, less often schistose standstones, marls, siltstones and clayey slate containing lenses of sandy limestone from which orbitolinas *(Orbitolina conoidea discoidea* Gras.), pachyodonts, brachiopods, corals and other were recovered.

The Aptian in the neritic facies consists of yellow and brown sandstones and calcarenites containing a rich fauna of lamellibranches, gastropods, corals (See p. 55—56).

The Albian occurs at several localities. Its lower and middle parts are built up of clastic rocks: conglomerates, ferruginous sandstones, glauconitic sandstones with an oolitic iron ore, while the upper part consists of sandy marls and marly sandstones. From the sediments of this stage a rich fauna comprising ammonites, belemnites, clams, brachiopods and other has been recovered, thus providing material on the basis of which all Albian horizons have been recognized.

Upper Cretaceous. — These sediments have the widest distribution in the area studied.

The Cenomanian is represented by a facies of limestones (a) and a facies of marls and marly sandstones (b). The limestone facies comprises grey or bluish sandy limestones with an echinoid fauna *(Holaster subglobosus* Ag., *H. nodulosus* Goldf., *Discoidea cylindrica* Ag., *Echinoconus rhotomagense* d'Orb., *Codiopsis doma* Ag., *Pyrina desmoulinsi* d'Ach., *Orthopsis ganulosus* Cott.); next, brachiopods *(Terebratula dutempleana* d'Orb., *T. biplicata* Sow., *T. tornacensis roemeri* d'Erch., *T. depressa cyrta* Wall., *T. subrotunda* Sow., *T. subrotunda subundata* Stol., *Rhynchonella contorta* d'Orb.) in addition to clams *(Polyconites operculatus* Rouv., *Ostrea* sp., etc.).

From the facies of marls and marly sandstones, ammonites and a rich flora were recovered (See p. 84).

The Turonian stage consists of the lower part of inoceramic foraminiferal marls containing *Inoceramus labiatus* Scholth, *In. linqua* Goldf., ammonites such as *Baculites* cf. *gracilis* Sol., *Tragodesmoceras clypeale* Schlüt and *Turrilites* sp. as well as a rich association of globotruncanids.

The Coniacian-Santonian consists in its upper part of marls containing inocerams and foraminifers. A rich association of foraminifers has been observed (See p. 86). These marls grade laterally and vertically into Upper Cretaceous flysch.

The Upper Cretaceous flysch of the vicinity of Belgrade has a very wide distribution. It has been divided into (a) the Avala flysch, (b) the Barajevo flysch, and (c) the Ostružnica flysch. A detailed study of the Upper Cretaceous flysch can be found in the paper »Stratigrafija krednog fliša u okolini Beograda« (Stratigraphy of the Upper Cretaceous Flysch in the Vicinity of Belgrade) by the present author published in Geološki anali Balkanskog poluostrva, knj. XXXVII, fasc. 1.

The Maestrichtian is built up of sandstones, shales, marls and conglomerates in addition to limestones containing a rich clam and gastropod fauna (See p. 99).

The Danian and Paleogene. — The youngest Mesozoic sediments in the area studied are represented by a conglomeratic-sandstone series transgressively and unconformably overlying the youngest sedimentary members of the Upper Cretaceous. The series belongs in the Danian and Paleogene.

Magmatic activity. — Igneous rocks such as diabases and spilites, andesites and their pyroclastics are found in the vicinity of Belgrade The basic rocks were poured out in several phases. The first phase is associated with the ophiolites of the pre-Upper Jurassic period; the second phase with the late Cymrian orogenic movement (Upper Jurassic); the third occurred in the Neocomian, while the fourth one is associated with the earlier Upper Cretaceous. The andesitic volcanic activity started in the Upper Cretaceous and continued in the Tertiary.

Tectonic movements. — Tectonically, the area studied is very complex. Facial diversity of the Upper Jurassic and Cretaceous, an intensive magmatic activity, alternation of sediments and facies of different age over a comparatively small area, contact between older and younger sediments, inverse occurrence of individual stratigraphic members — all point to a complicated tectonic structure of the vicinity of Belgrade.

This area is characterized by primary and secondary tectonic lines. Tectonic structures have a NNW-SSE as well as an E-W strike. The paper contains descriptions of the Ripanj overthrust as the most prominent tectonic unit, various tectonic outliers, the Petrov Grob-Devojački Grob and the Rušanj overthrusts; next, descriptions of numerous faults such as the Ripanj fault, the Rušanj fault, the Ripanj system of faulting, the tectonic structures of Straževica and Košutnjak. The description of folding structures includes the Žarkovo syncline, the syncline and anticline of Košutnjak, the Barajevo anticline, the Barajevo fold and the Avala anticline.

The evolution of tectonic movements was considered in connection with the following orogenic phases: the Old Cymrian, the Young Cymrian, the Austrian, the Mediterranean, the Sub-Hercynian and the Laramian orogenic phases.

Geotectonically, the vicinity of Belgrade is part of the Šumadija zone.