Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	73	37–60	Београд, децембар 2012 Belgrade, December 2012

DOI: 10.2298/GABP1273037K

The Neogene Lakes on the Balkan Land

Nadežda Krstić[1], Ljubinko Savić[2] & Gordana Jovanović[3]

Abstract. Palaeogeographic maps of the lacustrine Miocene and Pliocene have been constructed according to all the known geological data. The Lakes of the Balkan Land, depending on the tectonics, migrated due to causes from the deep subsurface. There are several phases of the Miocene lakes: the lowermost Miocene transiting from marine Oligocene, Lower, Middle, Upper Miocene covering, in patches, the main part of the Land. The Pliocene lakes spread mostly to the north of the Balkan Land and covered only its marginal parts. Other lake-like sediments, in fact freshened parts of the Black Sea Kuialnician (Upper Pliocene), stretched along the middle and southern portions of the Balkan Peninsula (to the south of the Balkan Mt.). Subsequently, the Balkan Peninsula was formed.

Key words: Neogene, south-eastern Europe, lacustrine environments.

Апстракт. Палеогеографске карте језерског миоцена и плиоцена начињена су на основу свих геолошких података сакупљеним до данас. Распоред језера Балканског копна зависио је од тектонике, а мигрирала су сагласно са узроцима насталим дубоко под земљом. Може се разликовати неколико фаза настанка миоценских језера: најнижи миоцен на преласку из морског олигоцена, доњи, средњи и горњи миоцен који су местимично покривали велике делове копна. Плиоценска језера налазила су се углавном на северу од Балканског копна и захватала су његове маргиналне делове. Друга врста седимената, слична језерским, у ствари ослађене биофације делова црноморског кујалника (горњи плиоцен) пружале су се дуж средњег дела Балканског полуострва (јужно од планине Балкан). После тога је било формирано Балканско полуострво.

Кључне речи: неоген, југоисточна Европа, језерска средина.

Introduction

The lacustrine Miocene and Pliocene sediments of the Balkan Peninsula have been known since the late 19th century. Later studies were performed in the first half of the 20th century and culminated during its second half in the preparation of the Basic Geological Map (BGM) 1:100 000 of Yugoslavia (Coll. authors 1968–1995 for Serbia) and all the Balkan and neighbouring countries. The second phase of 1:50 000 mapping included specialist studies of phenomena characteristic for certain areas, resulting in the publication of monographs solving some of problems raised by the BGM. The third phase was important as UNESCO started international cooperation through their IGCP projects, including the Neogene and post-Neogene of the area through the following Projects: 25, 155, and 329 (Coll. authors 1974–1997), as well as through bilateral and multilateral cooperation based on these projects. All these studies enabled the preparation of palaeogeographic maps (Hamor 2001; Krstić *et al.* 2003; Popov *et al.* 2004; *etc*.), including both marine and lacustrine biofacies, as they were often in immediate contact.

Study area

The present-day Balkan Peninsula includes the area to the south of the Sava and the Danube. The Balkan Land, together with its lakes, in certain phases of the Neogene development also spread to areas that are presently included not only in the Lower but also in the Middle Danube Plains.

[1] Djoke Vojvodića 6, 11000 Belgrade, Serbia. E-mail: n_krstic@ptt.rs
[2] Serbian Chamber of Commerce, Resavska 13-15, 11 000 Belgrade, Serbia. E-mail: ljubinko.savic@pks.rs
[3] Museum of Natural History, Njegoševa 51, 11 000 Beograd, Serbia. E-mail: gordana.j@nhmbeo.rs;

The Balkan Land originated from the coalescence of an eastern part, making the edge of stable Europe (Carpatho-Balkanides), and a western island, which in the Upper Cretaceous was a part of Africa (Dinaric Alps). A strait existed between them until the very end of the Oligocene (DE CAPOA & RADOIČIĆ 2002). At the turn of the Palaeogene to the Neogene, the two islands merged into the Balkan Land. The complicated tectonic movements, only occasionally precisely defined (KRSTIĆ *et al.* 1999), matched with appropriate climatic conditions, caused the appearance and diversity of a series of Miocene and Pliocene lakes, positioned in various parts of the Balkan Land (ZAGORČEV 2001, *etc*.). In other words, the shape changes of the Balkan Land were caused by tectonics (PRELEVIĆ *et al.* 2005).

The transgressing and retreating of the mostly epicontinental seas enables a correlation of the lacustrine formations of the Balkan Land with the stratigraphic scale of a World Ocean. Unfortunately, the direction of these connections has still not been unambiguously determined, although the Central Paratethys was during the Miocene connected with the Mediterranean towards the West (RÖGL 1998; HAMOR 2001). However, this view is challenged by the presence of Lower Miocene lacustrine formations on the Adriatic islands Rab and Pag (KOCHANSKY & SLIŠKOVIĆ 1978; KRSTIĆ 2000, BULIĆ & JURIŠIĆ-POLŠAK 2009). During the Pliocene, this connection certainly existed towards the Adriatic (KRSTIĆ 2006) and in the area of the present-day Aegean Sea (KRSTIĆ *et al.* 1999; GEORGIADES-DIKEOULIA *et al.* 2002, *etc*.).

Material and methods

It was possible to study in great detail the sediments of the Neogene lakes at outcrops and in shallow bore holes during studies of the drillings made for coal research, sources of underground water, the preparation of the BG Maps and, additionally, other works (such as the choice of a site for a nuclear power plant), all of which are included in this review. The systematic drillings (of 20 and 200 m in depth) made for the purpose of the BG Mapping were performed in the lowlands, mostly to the north of the Sava and Danube, and the number of such drillings was over 80 per sheet 1:100 000 (a sheet area is 1500 km^2, while the surface of the Balkan Peninsula is about 500 000 km^2).

In addition to ostracodes, which are the most useful as they are very abundant in lacustrine sediments, the results of other palaeontological methods were also employed. In the first place were the autochthonous fossils: well-studied molluscs and sufficiently known diatoms. The presence or absence of Charophyta gyrogonits are important for in-depth enciphering. The allochthonous fossils include mammals, macroflora (leaves and fruits) and palynomorphs; also fish fossilized under thermocline. All the recorded fossils enabled the determination of the biostratigraphic age, as isotope studies were rarely performed.

Fossil position in sediments and their characteristics indicate the properties of a basin and its shape. For this, the sediment type is very important.

Miocene lakes

The origin of the Miocene lakes may be connected with tectonic movements, from the northwards movement of the Adriatic Plate to the curvature of the Carpatho-Balkan Mountain Range. Both these factors caused alternating shifts of dilatations and compressions, which produced depressions (filled with Neogene formations) followed by faulting and overthrusting (KRSTIĆ *et al.* 1988; RADOIČIĆ *et al.* 1989; MIKES *et al.* 2008; *etc*).

Various Early Miocene lakes

Several smaller lakes originated from the closure of the limans situated around the Late Oligocene Strait in the axis of the present Balkan Peninsula. Other such lakes were set against the Aegean Sea. The limans might have been the habitat for marine fishes of the family Mugilidae, which spawned exclusively in the sea (GAUDANT 2002). After the strait became closed due to the appearance of the Balkan Land, the limans became closed lakes, which existed in the place of the limans for a short period of time, which were mostly inhabited by *Botriococcus* algae, and oil shale sediments formed (VASS *et al.* 2006).

Šumadijan Lake

The Šumadijan Lake (Š in Fig. 1) is one of these lakes (KRSTIĆ *et al.* 2003). Unfortunately, it lacked organisms with a calcium carbonate shell, as the lake water had to be acidic due to influence of some volcanic apparatus surrounding the lake from all sides, dated about 23 Ma and less (CVETKOVIC *et al.* 2000). Hence, it is possible that the Lake origin follows the collapse of the magma chamber. The Šumadijan Lake also contains oil shale sediments–a few drillings were made for oil research (KNEŽEVIĆ 1997).

The Buštranje–Poljanica Lake (B in Fig. 1) is the second lake, with a number of layers of oil shale and palynomorphs, which indicate the Oligocene (VASS *et al.* 2006). According to geotectonics, palaeoclimatic indicators and spectrums of palynomorphs, this lake should be of the same age as the Šumadijan Lake.

In Bulgaria, SW of Sofia, the Pernik Coal Mine (P in Fig. 1) has a probable late Oligocene to early Aquitanian age, according to the palynomorphs and some fishes (VATSEV 2004).

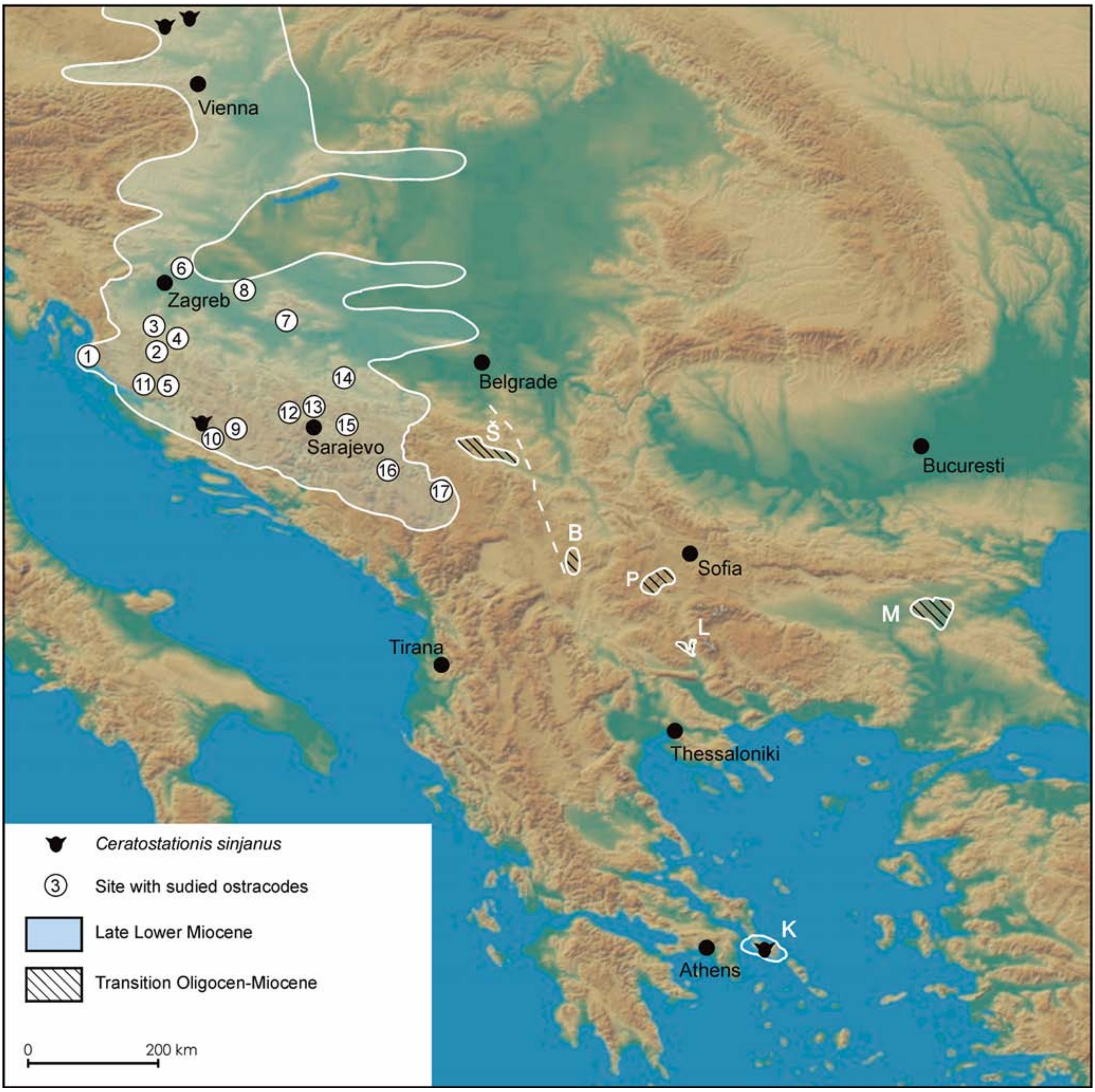

Fig. 1. Approximate distribution of the early Miocene lakes on the Balkan Land. Legend: Oblique lines - water basins existing in the Late Oligocene and the very start of the Miocene: **Š,** Šumadijan Lake; **B,** Buštranje–Poljanica area; **P,** Pernik mine area; **M,** basins of Plovdiv and western Maritsa; **L,** Luleva Fm. of the Brežani area under Pirin Mt. (Juranov *et al*. 1993), **K,** Kymi on Eubea. Horizontal lines – Dinaric system of lakes and its probable extension northwards into Hungary, Austria, Slovakia and beyond. Horned dots – sites with fruits of *Ceratostationis sinjanus*. Empty circles - sites with ostracodes (Sokač & Krstić 1987): **1,** Rab; **2,** Žagar; **3,** Gata; **4,** Cazin; **5,** Dugo Selo; **6,** Medvednica; **7,** Psunj; **8,** Bunjani; **9,** Livanjsko Polje; **10,** Sinj; **11,** Krbava; **12,** Busovača; **13,** Breza; **14,** Korenita; **15,** Romanija; **16,** Pljevlja; **17,** Sjenica.

Also in Bulgaria, the lowlands around the lower reaches of the Maritsa River (M in Fig. 1), with possible connection toward Plovdiv, are of Chattian to Aquitanian age. The Merichleri Limestone Formation includes exclusively marine molluscs of the Chattian. For the next, the Maritsa Formation, Vatsev claimed, “age probably Chattian–Early Miocene... b) member of shale with lower coal bearing unit; age probably Early Miocene”, contains only the fossil fish *Drapalis macrurus*. The ostracodes are drawn only aside the marine column part (Vatsev 2004).

Westwards, in the graben of Brežani under Pirin Mt., the lowermost Miocene, Luleva Formation of Rakitna Village, contain *Paleoleuciscus elegans* Gau-

DANT and remnants of an Anoures (frog), *Paleobatrachus?* (GAUDANT & VATSEV 2003). The genus *Paleoleuciscus* was not known previously to the Miocene. In two formation below appear freshwater molluscs, Oligocene palynomorphs and *Protothymallus pirinensis* GAUDANT, the genus known from the Oligocene and Lower Miocene. The species *P. pirinensis* and the coal below it, may be Rupelian in age, while the GAUDANT species is very similar to *P. elongatus* (KRAMBERGER). The formation between the two, a fluviatile one, contain only badly preserved freshwater gastropods.

Dinaride System of Lakes

In the area of the Dinarides, but also further towards the northwest (KRSTIĆ *et al.* 2003), all the way to Lower Austria, there are well-developed, karst-subtropical types of lakes, in the intramontane depressions. In the winter half of the year, the lakes coalesced. This situation matches the present day example of the Scodra Lake, rising by 6 m during the wet half of the year (KARAMAN & BEETON 1981).

Preserved Neogene sediments were tilted during and, even more, after the sedimentation. The coal beds deepened as a result of faults, mostly along the NE of the valleys. These movements affected the bedrocks by the same amount, *i.e*., by 1500 m, thus forming all the mountains (MILOJEVIĆ 1966).

Two column parts are easy distinguishable; a lower one without congeria and an upper one with halofile organisms, mainly dreissenids. While in the lower column part freshwater genera predominate (KRSTIĆ *et al.* 2009), in the upper one, different aberrant bentic creatures made an endemic biofacies. The source of these highly developed taxons, transported from distant eastern saline lakes, could be China, with several unknown adequate refugiums in between.

The lithology is quite diverse. Marl is the type of sediment with the widest distribution, forming mostly the upper part of the column. At the base, there are some well-sorted, unconsolidated, white chalky layers, indicating shallow lake water as in Kupres (KRSTIĆ *et al.* 2010b) and submersed plants of the *Potamogeton* type. In other places, there are some poorly sorted siliciclastics, indicating fluvial transport as in Maoče Bay (KRSTIĆ *et al.* 2010a). Above the marl, there are sand and conglomerate of prograding deltas filing up the lake basins. At the lower part of the column, there are many layers of coal and thick packages of bentonite, indicating a remote volcanic activity at the time, as there are no autochthonous synchronous igneous rocks (VUJNOVIĆ *et al.* 2000). The main coal seams lie between the lower (freshwater) and the upper (saline) part of the column.

All these sediment types alternate at short distances, indicating a very long twisting shoreline of the lacustrine system of the Dinaric Alps (KRSTIĆ *et al.* 2003, text-fig. 3; ČIČIĆ & MILOJEVIĆ 1977; MANDIĆ *et al.* 2009; BULIĆ & JURIŠIĆ-POLŠAK 2009). The marginal areas were covered with characin meadows, and in some remote gulfs, such as Maoče (KRSTIĆ *et al.* 2010a), bentic organisms could show a lower degree of salinity due to freshwater tributaries.

These sediments were disturbed by a number of gravitational faults. The faults are post-sedimentation ones and, in the northern half, they seem to be exclusively situated along the northern edge of the valleys (Pljevlja), while even somewhat reverse faulted towards the south (KRSTIĆ *et al.* 1994). In the southwestern half of the Dinaric System of lakes, the faults are situated along the south-western edges of the valleys, adjusting the nape structures (ILIĆ & NEUBAUER 2005; MIKES *et al.* 2008). The napes were produce by northward movements of the Adriatic plates on both sides of the Adrian (cf. CIPOLLARI *et al.* 1999). The collision zone of the Adriatic and Dinaric segment is caracterized by late-orogenic (Oligocene to Miocene) thick-skinnned compressional uplift (exhumation), related gravity gliding, and still active escape tectonics renching (CORBAR 2009).

There are numerous sites with endemic molluscs (BRUSINA 1897, 1902, *etc*.), but it is difficult to attribute them to a definite part of the column as the exact positions are lacking. The lacustrine molluscs belong to "endemic" forms mostly congerias (KOCHANSKY & SLIŠKOVIĆ 1978 etc). The endemicity level is extremely high (98 %) (HARZHAUSER & MANDIC 2008). These large creatures are known from the Paratethys province, its estuaries, gulfs and similar biotopes (POPOV *et al.* 2004). The gastropods *Clivunella, Orygoceras, Fossarulus,* as well as endemic species from *Prososthenia, Melanopsis, Emmericia*, are often ornamented with ridges and tubercles. However, there is not a single representative of the genus *Viviparus* (BRUSINA 1884), a freshwater to halotolerant genus. At some lacustrine costal sites, there is admixture of terrestrial snails (PRYSJAZHNJUK 2008).

The ostracode fauna was studied only at a smaller number of localities (Fig. 1). Below the coal seams and close to them, the ostracodes are freshwater types; in the marly sediments their shells may be partly or highly absorbed (Štavalj Coal Mine on the Sjenica Plateau). In the silty beds of the higher column parts, the ostracodes are well preserved and represented by elongated aberrant forms of Candoninae, bimucronate representatives of the genus *Amplocypris* and ornamented representatives of the genus *Potamocypris*, while there are several species of Cytherideidae from the genera *Clonocythere* (earlier as *Amnicythere*), *Guangbeinia*, *Sinometacypris* (KRSTIĆ 1987a, b, 2000; YOUTANG *et al.* 2002) – the Chinese forms. The above-listed and some others indicate a salty lacustrine environment.

Charophyta indicate shallow water. They appear abundantly below the coal seams, represented by large gyrogonits, of a genus close to *Harrisichara,* and a great number of small ones belonging to *Chara, Sphaerochara*, *etc*. (KRSTIĆ *et al.* 2009). Above the main coal seam appear large gyrogonits *Nitellopsis merianii*, in some levels "tuberculate", and small ones *Chara molassica notata, Rhabdochara langeri* and others (KRSTIĆ *et al.* 2010a).

Fruit of the water nut *Cerastoderma sinjana* is not abundantly present but was recorded from Austria and Slovakia through Sinj to the area Kymi at the southern part of Eubea in Greece (VELIZTELOS & GREGOR 1990), hence, in a stratigraphic-time sense, it connects these distant regions.

Age. Studying the congeria fauna, KOCHANSKY & SLIŠKOVIĆ (1978) anticipated the Ottnangian age of the Dinaric Alps lakes. The Pag succession as deposited between 17,41 and 16,7 Ma and that it corresponds to the Burdigalian Stage of the Central Paratethys (JIMENEZ-MORENO *et al*. 2009). According to terrestrial snails (PRYSJAZHNJUK *et al.* 2000; PRYSJAZHNJUK 2008), the Sjenica Lake should be regarded as somewhat younger than the mammal Zone MN3b, or Ottnangian–Karpatian. A fossiliferous bed in Sjenica is overlain by a basalt (analcimite) flow, dated 22.95±1.25 (but its prolongation on Koritnik /leucitite/ yielded 9.12±0.35) Ma (CVETKOVIĆ *et al.* 2004) – this indicate late Eggerian (and the second one, a subsequent basaltic outflow on the same fault line in the Upper Miocene equivalent of the MN10 Zone !). In Sinj, recent measurements of the upper column part yielded an age of 17.92±0.18 Ma (LEEUW *et al.*, 2010).

The larger mammals *Antracotherium minus* and *Chalicotherium grande* are known in different places and less indicative are several findings (from BULIĆ & JURIŠIĆ-POLŠAK 2009) of *Gomphotherrium angustidens* and *Prodeinotherium bavaricum,* which give the age of the MN4 Zone (Ottnangian) to these sediments.

Serbian Lake

Lacustrine sediments are widely distributed throughout Serbia (Fig. 2) as they originated by post-collision spreading, not only in the area where the Dinaric and Carpatho-Balkan islands collided, but also deep into both sides. To the east, they are compressed due to the later curvature of the Carpathian Mountain Range (KRSTIĆ *et al.* 1988), while in the Western Island they sank due to post-compressional extension (CVETKOVIĆ & PECSKAY 1999).

The sediments of the Serbian Lake are composed of sand, silt, clayey silt, marl and marlstone, as well as of sandy limestone, rarely lacustrine chalk and different limestone types. This today highly populated hilly area acquires its drinking water mostly from Neogene sands. Coal is present in many of the depressions, but underground exploitation in most mines is no longer economically viable. The areas with marly clays are susceptible to sliding, causing great damage during heavy rains (*e.g.*, in the spring of 2006 and all of 2010).

The sedimentological features were given by OBRADOVIĆ & VASIĆ (2007). The sediments of deep depressions (lacustrine profundal) are of a meromictic character containing the autogenic minerals: sirlesite in Kremna, magnezite in Baljevac on the Ibar River, zeolite in Zlatkop near Vranje and many other sites of similar origin but with a smaller content of them; in shallow lake parts, dolomitic limestone could be present. The lacustrine profundal often bear oil shales, richest in Bela Stena near Valjevo and Subotinac near Aleksinac (VASS *et al.* 2006).

The very large Serbian Lake, dotted with many islands, was for the first time comprehended by CVIJIĆ in 1924 based on the contours of the Mačkat fluviodenundation Plain. The age was defined by STEVANOVIĆ *et al.* (1977b) as Middle Miocene, according to records of the reverse-spiralled Lymnaeide snail *Kosovia* (PAVLOVIĆ, 1903, 1931). The lacustrine basin was recognized as unique by DOLIĆ (1983), according to molluscs in oxygen-rich, shallow parts of the lake. This large lake, which used to stretch throughout Serbia from Belgrade to Macedonia and through SW Bulgaria (OGNJANOVA-RUMENOVA 2000; KRSTIĆ *et al.* 2003) to Serrai in Greece, was named the Serbian Lake by KRSTIĆ & KOMARNICKY (1996). It is not clear whether the small Čukurovo Basin to the SE of Sofia, having plant remnants only (VATSEV 2004), was linked to the Serbian Lake or was only a satellite.

The diatom microflora of the Serbian Lake was studied in the Lubnica near Zaječar, and in the Simitli Basin of SW Bulgaria. *Aulacoseira, Ellerbeckia, Melosira* and *Actinocyclus* developed there during the Middle Miocene time. "This period is marked mainly by the coarsely ornamented forms of *Aulacoseira granulata* and *A. islandica* and different lacustrine *Actinocyclus* species" (OGNJANOVA-RUMENOVA 2000).

Allochtonous, macroflora is represented by forests stretching along the river margins, called riparian or galerian flora. It has its climatic value, but changes in short cycles and depends on the exposure. A large study of Serbian flora by PANTIĆ (1956) was completed by MIHAJLOVIĆ (1978), which placed Serbian sites not far from the Morava Valley, but to the east (Melnica, Rakova Bara, Popovac, Misača), and Slanci near Belgrade into subtropical Helvetian (early Middle Miocene). Palynological analyze of silt from the Ribnica River in Mionica gave again a subtropical climate (VASS *et al.* 2006). Only one site in the Levač County of central Serbia, in village Kaludra, contained macroflora of Lower Miocene age, equivalent to the Upper Ottnangian-Karpatian (MIHAJLOVIĆ 1988).

The sediments with lacustrine ostracodes at the locality Slanci near Belgrade lie concordantly below the marine Middle Badenian (as below the Lower Badenian – ĆORIĆ, *et al.* 2009 – in the northern lying trough). The species *Mediocypris nisseana* was collect-

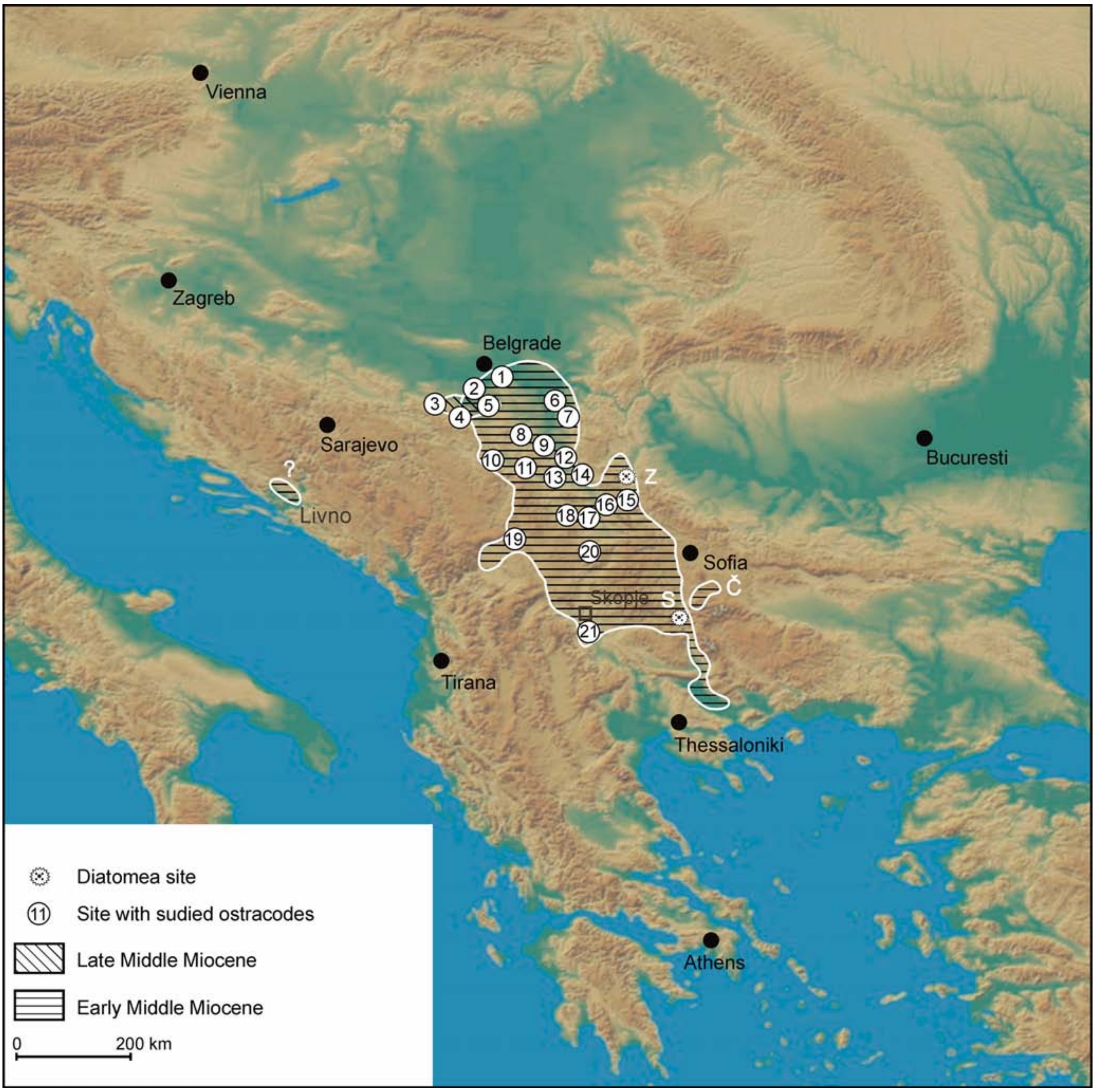

Fig. 2. Approximate spreading of the Middle Miocene lakes on the Balkan Land. Ostracode sites of the Serbian Lake: **1,** Slanci; **2,** Koceljeva; **6,** Petrovac; **7,** Melnica; **8,** Kragujevac-Sabanta; **9,** Levač; **10,** Dragačevo; **11,** Kraljevo – Dragčić; **12,** Paraćin – Mutnica; **13,** Ražanj – Madjari; **14,** Sokobanja – Resnik & others; **15,** Knjaževac – Gradište; **16,** Svrljig; **17,** Niš – Komren; **18,** Mali Jastrebac – Azbresnica; **19,** Metohija-Rudnik; **20,** Vladičin Han; **21,** Skopje – marl pit. Diatomacea sites: **Z,** Zaječar (Lubnica); **S,** Simitli; (OGNJANOVA-RUMENOVA 2000), Higher plants: **Č,** Čukorovo. Early Sarmatian (early Volhinian) Lake of Bukulja, ostracode sites: **3,** Vračević; **4,** Brajkovac; **5,** Jelovik.

ed not only at Slanci and Niš but also at other localities with silty layers (compare KRSTIĆ *et al.* 1988). In the sand and sandy silt of Mutnica near Paraćin and nearby sites, the rich ostracode assemblage contains *Ilyocypris pannonica, Cypridopsis pannonica, Potamocypris bouei*, *Dinarocythere costata*, *etc*. In marly-dolomitic layers all over the central and western parts of the Serbian Lake, the most common ostracode species are 'halofile' "*Reticulatocandona" baljkovacensis* and *Ohridiella sabantae*. At the eastern part of the Serbian Lake, between Carpathian/Balkan ridges, freshwater genera predominate in Žagubica, Lubnica near Zaječar, Čitluk near Sokobanja, *etc*. Rarely they are replaced by halofile ones, like in Melnica from where the endemic genus *Septocypris* (European equivalent of the Chinese genus *Megacypris*) was described (KRSTIĆ 1987a). The second such, remote outcrop of white chalky unconsolidate sediment lies where Žukovska Reka reaches the Timok trench (on the road to the Gradište village): white chalk yealded a candonid from *lampadis* group and in Žagubica (commentary of Selište) another candonid of the *chasei* group both are corroborating unusual water chemistry.

The mollusc macrofauna association differs largely from that of the Dinaride System of lakes, despite some dreissena being successor of their very well known Lower Miocene predecessors. According to KNEŽEVIĆ 1996 and JOVANOVIĆ & KRSTIĆ 2010, these are *Mytilopsis cvitanovici servica*, *M. antecroatica sumadica* and others differing more, such as *M. nisseana, M. dactyloides* descriebed by PAVLOVIĆ 1931. Gastropods are more numerous and very diversified– *Ancylus serbicus*, *A. dimici*, *Planorbis pavlovici*, *Prososthenia serbica* they were described by BRUSINA (1894) and *P. fuchsi*, *Melanopsis petkovici* by PAVLOVIĆ (1903) Later PAVLOVIĆ (1931) presented snails from the Peć Fm.: *Hydrobia santrici*, *Bythinella cvijici*, *Micromelania proni*, *M. metohiana*, *Kosovia praepontica*, *Gyraulus decani*. Some of these species (*Radix cobeltiformis*, *R. levasi*, *Fossarulus praeponticus* and *Marticia macarii*) spreads northwards along the Ibar River (STEVANOVIĆ, 1985) making them Ibar biofacies.

Among the proboscideans, most findings belong to *Deinotherium giganteum*, *Anancus avernensis* and a transition form from *Gomphotherrium angustidens* to *G. Longirostris* (KRSTIĆ *et al.* 2007). Several localities rich in diverse bones and teeth of micromammals belong to the MN5 Zone (MARKOVIĆ 2008), hence to the Karpatian–Badenian according to STEININGER (1999).

The age of the Serbian Lake sediments are older than the marine Middle Badenian, while laying concordantly below it. Combining macroflora and micromammals with the Borač eruptive complex (CVETKOVIĆ & PECSKAY 1999), late Karpatian–early Badenian was determined, even though the intercalated dacite tuff (near Mionica and in Popovac) was not measured.

In Popovac, the marl quarry consists of feldspar, quartzite and biotite as the main constituents (PEŠIĆ & KOPRIVICA 1996), hence the material is quite good for radiometric age measurement.

Southern margin of the Badenian Sea

Along the River Sava, from Belgrade to Zagreb, the lacustrine formation is overlain mostly by marine Badenian.

Near Belgrade, the Badenian rises slowly from the lacustrine Slanci Formation, starting as brachyhaline sediments, changing fast into fully marine ones (KRSTIĆ 1978). F. RÖGL (personal communication) recognised in them a Middle Badenian relative of *Uvigerina pygmaea*. The marine Lower Badenian drilled to the north of the Danube, in southern Banat, included numerous plankton foraminifers of the Zone *Praeorbulina-Orbulina suturalis* (determination of F. RÖGL, in personal communication). On the Papuk Mt. and near Zagreb, the initial marine sediments “contain the nanoplankton assemblages characterising the NN5 Zone” (ĆORIĆ *et al.* 2009) covering the whole Badenian. The foraminifera assemblage “belongs to the Early Badenian, corresponding with the Lower Lagenide Zone” (*ibid*). Thus, this is a southward transgression, going step by step from one to another trough. In all cases, it was a “sudden but continuous transition from a freshwater lake into a marine environment” (*ibid*) in the whole southern part of the Pannonian Plain.

Two remote bays of the Badenian Sea penetrated into the Balkan Land, along extremely tectonically disturbed areas. One of them, called Timok Bay, penetrated along the Timok strikeslip fault, which was reactivated before the start of the Middle Badenian (KRÄUTNER & KRSTIĆ 2003). The other larger one, Morava Bay, stretched along the contact between the Dinaric and the Carpatho-Balkanic Islands; at the time, the contact was still not sufficiently stabilized, as still is, as its bottom is still subsiding now.

Age. The Badenian comprises the upper part of the MN5, the MN6 and the lower part of the MN7+8 Zones (STEININGER 1999).

Timok Bay

Timok Bay was not at all elongated. In the Middle Badenian, marine facies reached to the town of Zaječar. In the Upper Badenian, some interbeds have a sarmatoid character; hence, it was classified within the “Buglovka Layers” (DŽODŽO-TOMIĆ 1963). However, the Badenian Sea, of Vienna type, mainly comes through SW Romania to the north-western part of Bulgaria.

Mlava Bay

In the small Mlava Bay, near Petrovac, there are several interbeds of freshwater sediments following thin coal seams in the gulf facies most influenced by freshwater. The ostracodes within the coal-bearing level are less numerous than charophyta gyrogonites, indicating transparent shallow water (to a depth of 7 m, approximately). Biofacies, transiting to marine, lie on the edge of the Bay at the Danube (JOVANOVIĆ & TOMIĆ 1997; KRSTIĆ *et al.* 2003).

Morava Bay

The Morava Bay stretched far towards the south, gradually spreading the marine and then the brackish biofacies of the Middle Badenian all the way to Kruševac (STEVANOVIĆ *et al.* 1977; DOLIĆ 1978). New data on fossils from Tavnik (near Kruševac, wrongly attributed to Upper Miocene by KRSTIC *et al.* 2007), such as the new micrommamal species *Miodyromys wesselsi* (dormouse) and other small mammals, must have oriental origin. The environment was a shallow calm pond according to charophyta (gyrogonits of *Nitellopsis merianii*) and higher plants, such as *Trapa* and *Nysa* (depth around 6–7 m), then frogs, tritons, emids and even small species crocodile remnants. Among the molluscs, there are some hydrobioids, unionacea and other pelecipiods and a ceritihid *Terebralia lignitarum* along with a large *Planorbarius.* The last two indicate a swamp and the proximity of coal forming facies. The only high energy indicator is a roughly ornamented *Theodoxus* and the sandy interbeds embedding all these thermophile fossils.

Towards the west, a sign of the Badenian impact was recorded along Bosna River, to Doboj, but no freshwater dilution of the marine Badenian has been recorded to date.

Sarmatian Bukulja Lake

The relatively small Valjevo–Mionica–Belanovica Lake, hidden by the Bukulja Mt. and Blizanjski Visovi, was only sometimes affected by the influence of Paratethys biofacies.

Lying discordantly above the sediments of the Serbian Lake, with a long gap, it was largely drilled for uranium in Jelovik Village, where the Gornji Breg Hill contained some of uranium in coaly interbeds (KRSTIĆ, *et al.* 2011). To the East, the Lake stretches along the Jasenica Valley, westwards through Kačer (STEVANOVIĆ *et al.* 1977a) and into the Mionica–Valjevo Depression (STEVANOVIĆ 1977). The contact with the Serbian Lake sediments in Tabanović should be at a depth of 82 m (JOVANOVIĆ *et al.*, 1994), just above a kind of hardground made of zeolitised tuff, as in the Zmajevac Brook (JOVANOVIĆ & DOLIĆ 1994).

The shallow water part of Jasenica–Kačer contains mainly freshwater lacustrine organisms. Among the molluscs in Jelovik (site 5 in Fig. 2), there are many dreissenids larval valves covering the bedding planes; adult dreissena are restricted to some beds, while *Prososthenia, Hydrobia, Planorbis, Theodoxus* and *Planorbarius* are usually poorly preserved (PRYSJAZHNJUK & RUDJUK 2005, KRSTIĆ *et al.*, 2011). Some of the Jelovik ostracode fauna is similar to that in the Serbian Lake, but there are numerous large *Eucandona* also found in Brajkovac (site 4 in Fig. 2) together with vertebrates, including *Bunolistriodon meidamon, Giraffokeryx punjabiensis, Pseudoeotragus seegrabensis* and micromammals; "there are also some very well preserved bird remains" including eggs, first found long ago (1959) by STEVANOVIĆ.

In the Valjevo–Mionica costal area, at the ancient watering place of Vračević (point 3 in Fig. 2), many micromammals were collected – *Eomyops oppligeri, Keramidomys mohleri, Anomalomys gaudryi, Bysantinia bayraktepensis, Collimys longidens, Eumyorion latior* and *Microdyromys koenigswaldi*–indicating that these sediments belong to the MN7+8 Zone (MARKOVIĆ & PAVIĆ 2004), actually supporting the Sarmatian age that was determined by STEVANOVIĆ. The profundal of this lake was situated between today's villages Radobić and Šušeoka, the sediments of which had a meromictic character. There, thick seams of oil shales (ERCEGOVAC *et al.* 2003; VASS *et al.* 2006) with imprints of fish carcasses (GAUDANT 2002) and other rare fossils (insects – bee, *etc*.) were collected. These sediments contain authigenic minerals, zeolites, searlesite and even shortite and trona, suggesting a salty lacustrine environment (OBRADOVIĆ *et al.* 1997; OBRADOVIĆ & VASIĆ 2007).

Age. Their stratigraphic position between the Serbian Lake sediments delimited by discordance and the transgressively lying Middle Volhinian (Lower Sarmatian) place them into the lowermost Sarmatian. Many micromammals from Vračević indicate that these sediments belong to the MN 7+8 Zone (MARKOVIĆ 2003; MARKOVIĆ & PAVIĆ 2004), actually supporting the Sarmatian age determined by STEVANOVIĆ.

In the late Volhinian and afterwards, the northern part of the Valjevo–Mionica Depression was periodically flooded by Paratethys water. In a structural borehole in Tabanović (above and eastwards of Radobićka Bela Stena) containing freshwater meiofauna (riverine *Potamocypris* mostly), there are some interbeds with Sarmatian molluscs (JOVANOVIĆ & DOLIĆ 1994) and one meter of the Pannonian on the very top.

Upper Miocene lakes

The Paratethys became fully separated from the Mediterranean and the World Ocean at the beginning of the Upper Miocene (PAPP *et al.* 1974), after the brackish Sarmatian phase of the late Middle Miocene, as some kind of remote gulf sediments.

Transitional lagoons

On the north-western edge of the Middle Danube Plain, there are two small ostracode sites of Upper Miocene age. One is the lowland of Turiec (PIPIK 2001) and the other a lagoon near Graz (GROSS 2005). The Turiec site contains the endemic mollusc *Kosovia stromphostomopsis* and a nanogastropod, possibly *Lithoglyphus nannus*, (collection of the late Miloš Rakuš). Another Turiec sample of the Martin site (PIPIK 2001, GROSS *et al*. 2009) contains sarmatoid fossils (GOZHYK, personal communication). Both the Gratkorn near Graz and the Turiec indicate a faunal succession near the Middle/Late Miocene transition.

The Maeothian in the Lower Danube Plain, the equivalent of the Upper Pannonian of Middle Danubian one, was influenced by sea water in its lower half, with a venerid *Dosinia maeotica*. The upper half has nearly lacustrine fauna; together with ostracodes some Unionacea *Teyserrinaia* and *Anodonta* occur (see: GOZHYK 2006), as many different gastropods sometimes in great accumulations (*Lithoglyphus nannus*).

Caspibrackisch sea- lakes

The specific (Caspian-like) type of sediments of the Paratethys sea-lakes overlaps the northern parts of the Balkan Land from the Middle and Lower Danube plains southwards (Fig. 3, upper case). Large books on the Pannonian (PAPP *et al.* 1985) and the Pontian (eds. STEVANOVIĆ *et al.* 1989) present the geology, palaeogeography, lithology and their fossil content of both huge lakes. Therefore, no details are given in the schematic sketch in Fig. 3. The evolution of the basin was studied by ROYDEN & HORVATH (1988).

Pannonian Sea-Lake

The Pannonian Sea-Lake is restricted to the Middle Danube Plain filled by deltaic sediments from the north-west (KORPÁS-HODI *et al.* 1992, *etc*.). The paleogeographic evolution of Lake Pannon within the Pannonian basin is reconstruced with eight maps, ranging from Middle Miocene to the Early Pliocene. The maps are based on the distribution of selected biozones and specific fossils, and on sedimentological and seismic information (MAGYAR 1999). Outside it, only in the Besarabian (Middle Sarmatian) of Moldavia (Black Sea Basin) are there a few levels with Pannonian fauna (PAPP *et al.* 1985, *etc*.). According to STEININGER (1999), the Pannonian started already in the late Astaracian, the MN7+8 Zone and finished before the upper third of the MN12 Zone.

The Upper Pannonian equivalent in the Dacian Plain is the Maeotian. The Maeotian penetrated the Lower Danube Plain as a deep highly freshened marine gulf.

Pontian Sea-Lake

The caspibrackish Pontian Lake was the largest one ever on the Earth. It overlaps the Balkan Land not only from the North but also from the South, less from the East and the least from the West.

In the Serrai (Strimon) Valley, the Pontian lies over beds of the Turolian (the supposed continental Maeotian of STEVANOVIĆ 1964).

The Pontian and the Maeotian also appear in the west, as their ostracodes were recorded in the Periadriatic Depression (PAD) of Albania (PRILO & HASANAJ 2002).

The Lower Pontian is present in the vicinity of Athens, on the island Aegina.

A contact of the caspibrackish Pontian of the northern Aegean (the Katherina, Halkidiki and Strimon Depression) and the Central Macedonian Lake is not sufficiently clear. It is possible that there were some mountain ridges with very narrow and often closed straits or a threshold of subdued eustatic or tectonic twisting. In a meridional trench covering the Pelagonia-Florina-Ptolemais-Servia Valleys, the Late Miocene was proved below the Pliocene.

The time span of the Pontian was not large. According to STEININGER (1999), it started before the upper third of the MN12 Zone and lasted until the end of the MN13 Zone. The absolute age values are not mentioned here, as their data are not coherent in different publications. According to CHUMAKOV (1993), based on fission track analyses, the Pontian started at 7.00 Ma and ended, in the Black Sea area, *ca*. 5.5 Ma ago, but in Caspian one, it lasted longer until 5.19±0.89 Ma.

Central Macedonian Lake

Between the Paratethys and the Mediterranean, there were several Upper Miocene salty lakes (Fig. 3). The largest among them was the Central Macedonian Lake (DUMURDŽANOV 1997).

The Central Macedonian Lake stretches from the city of Vranje southwards to Athens. Its width is difficult to calculate: lacustrine sediments crop out at Bureli in Albania and in the opposite direction, through Bulgarian Srednegorie, with gaps, reach Elhovo (VATSEV 2004; KRSTIĆ *et al.* 2008). Its column consists of a lower coarse-grained part and an upper fine-grained one.

The sediments of the lower part of the Central Macedonian Lake are exhibited in the uplifting region. They are often badly sorted due to a high erosion rate. None of the autochthonous bentic fossils were found but an accumulations of vertebrate bones were widely spread and sometimes very numerous. In the Axios Valley, lacustrine (?) sediments of the Turolian (lying below the Pontian), contain bones of Hominoidea (DE BONIS *et al.* 1986; KOUFOS & DE BONIS 2004).

In the upper column part, the sediments of the Central Macedonian Lake contain diatomitic beds. The diatom assemblage consists of coarsely ornamented benthic forms of genus *Aulacoseira,* in the Vranje and Prespa Basins. Similar rough species *Aulacoseira (A. granulata, A. ambigua)* are dominant in SW Bulgaria in the diatomaceous sediments of Gotse Delchev, Satovcha, Kostenets and Elhovo Ba-

Fig. 3. The Upper Miocene Lakes: in the North, in the Paratethys realm, these are the Pannonian and Pontian, in the middle of the Balkan land, it is the Central Macedonian Lake. The whole array of basins of the Pelagonia–Florina–Ptolemais–Servia hosted a kind of freshened Late Pontian. Diatomite sites according TEMNISKOVA-TOPALOVA & OGNJANOVA-RUMENOVA 1997, OGNJANOVA-RUMENOVA 2006: **E,** Elhovo, **GD,** Gotse Delchev, **Ko,** Kolubara, **Ks,** Kostenets, **M,** Mariovo, **Pr,** Prespa, **Pt,**Ptolemaida, **Sa,** Satovcha, **Sr,** Srednegorie, **Vr,** Vranje. Lacustrine mollusc sites: **B**, Bureli (Unionidae); **Pt,** Ptolemaida (*Theodoxus*); **S,** Strimon depression; **K,** Katherina. Ostracode sites containing also molluscs of the upper part of the Central Macedonian Lake sediments: **1,** Veternik; **2,** fortress of Skopje. Main sites of mammal bones: **A,** Axios, **K,** Kalimanci; **P,** Pikermi; **V,** Veles.

sins. Their age was determined after the identical microflora recorded in the Upper Pontian sediments of the Serbian coal mine Kolubara (OGNJANOVA-RUMENOVA & KRSTIĆ 2007). In Kostenets, they contain some extinct species which can be considered key fossils for the Pontian. In the Satovcha Basin of SW Bulgaria, the Upper Miocene diatom microflora contains “the Miocene index-species *Eunotia japonica* and *Fragilaria miocenica*” (OGNJANOVA-RUMENOVA 2003). The Late Miocene indicates to eutrophic freshwater lakes, only slightly alkaline, under moderate temperatures (TEMNISKOVA & OGNJANOVA 1997).

The benthic macrofossils of lacustrine upper part of the column were found around Skopje and Bureli. The mollusc fauna is represented mainly by Unionidae, both in Skopje and Bureli, together with *Melanopsis affinis* (KUMATI *et al.* 1997). At Veternik, to the north from Skopje, one lens included a few well-preserved mollusc shells: *Theodoxus doricus*, *T.* cf. *neumayri*, decorated with ribs and tubercles, and *Aphanothilus* as well as several ornamented species of *Prososthenia* (DUMURDŽANOV & KRSTIĆ 1999).

Ostracodes are very abundant and diverse in the silt below the Skopje Fortress. There from, a new genus *Macedocandona* with reverse valves (RV larger and overlaps LV), yielded a species flock containing four taxa. This new genus shows similarity to the Chinese *Potamocyprella*. There are also other taxa, unknown yet, maybe also oriental. Aberrant ostracodes lived next to the less numerous halotolerant *Fabaeformiscandona*, *Cypria*, *Cypridopsis* and *Plesiocypridopsis.* One marine *Callistocythere* (*Clonocythere?*) representative was, probably, brought from the Mediterranean area (KRSTIĆ & GUAN 2000). These ostracodes have peculiar features and could only be compared with some taxa from the Chinese Eocene and Oligocene stages.

Age. The mammals of the Veles and other sites in the Central Macedonian Lake belong to the Pikermian fauna, *i.e*., to the Turolian. The closeness of the Pontian at the Strimon Valley and Katherina, but also on Aegina, near Athens, where Pikermy itself is situated, indicates that they are superimposed. The conditions that caused mass dying of mammals during the Turolian are probably the repeated droughts which occurred during the MN11 Zone. The palynomorphs of the upper part of the Central Macedonian Lake, at Bitola in Pelagonia, indicate a climate change into a humid warm-temperate one (IVANOV 2002) by the end of the Miocene.

Eordeian Trench

A different evolution proceeded in a meridional trench covering the Pelagonia–Florina–Ptolemais––Servia Depressions. For one of them, CVIJIĆ (1911) used the ancient name Eordeian. Here, this name is applied to the whole trench.

There, only youngest Miocene sediments are present; most of the sediment fill belongs to the Pliocene.

The coal-bearing outcrops are made of the Komnina Formation, belonging to the Late Miocene (BORNOVAS & RONDOGIANNI-TSIMBAOU 1983; PAVLIDES & MOUNTRAKIS 1987). According to orbital signatures, it mostly matches the Pontian age. In the Lava Section, this is from 6.9 to 6.2 Ma (STEENBRINK *et al.* 2000). The 6 m of the Ptolemaida Section, above coal (observed during the Pindosexcursion of the 10th Intern. Congress, Geol. Soc. Greèce, 2004) consists of diatomite-containing, mostly, broken Unionidae, in its lower part and above them, alternate greater or smaller amounts of snails of different sizes (*Theodoxus macedonicus*, *Valvata piscinalis*, *Lymnaea stagnalis*). Two *Neglecandona* sp. juv. valves come out from a shell of *T. macedonicus*, together with a finest ochre red limonitic sandy fill. All this indicate redeposition in water of low energy, diminishing upwards.

Attique

Several localities with aberrant lacustrine molluscs of Attika were shown by KÜHN (1963) and PAPP (1979). Kühn determined museum material according the papers of Brusina on the Dinarides. Later Papp corrected the checklist having his own collection. The gastropod species are highly endemic: *Theodoxus atticus*, *Th. morulus*, *Th. milessii*, *Melanostteira milessii*, *Melanopsis (Canthidomus) longa*, *M. (C.) oroposi*, *M. (C.) freydbergi.*

The Athens area is now heavily urbanized and fossils have not been collected recently. An important finding there was during the digging for a swimming pool at the Pirgos Vasilissis site, also known for molluscs. There were found different mammals, along with *Graecopithecus* (DE BONIS *et al.* 1986): *Mastodon pentelici, Dicerorhinus orientalis, Hipparion mediterraneum, Tragoceras amalheus, Gasella gaudryi, Helladitherium divernoi* and *Giraffa attica*. The age is late Miocene, like the famous Pikermia mammal site, lying in the close vicinity of Athens.

The paleogeography of the marine and continental Miocene of Greece was reconstructed by GUERNET (1978).

Pliocene lakes

The Pliocene lakes (Fig. 4) developed through different mechanism of origin. The two lakes forming the northern boundaries of the Balkan Land belonged to the area of the Paratethys. These are the Paludinian and Dacian–Romanian lakes. Their sediments are connected to and gradually grow out of previously laid formations of the caspibrackish Pontian Lake, as the Paratethys area continued to subside during the Pliocene.

From the east, the Balkan Land was flooded by waters of the Black Sea and from the south by water of the Levantine Aquatorium. The subsidence was due to the obduction of Asia Minor over the Balkans, causing detachment of a "thin skin" (KRSTIĆ *et al.* 1999). The "thin skin" even reached the centre of the present-day Balkan Peninsula, being there combined with strong crustal extension (MAROVIĆ *et al.* 1999). CVIJIĆ (1911) named the southern aquatorium the Aegean Lake.

Fig. 4. Approximate spreading of the two types of Upper Pliocene lakes on the Balkan Peninsula: horizontal lines – the nearly freshwater Paludinian and the Dacian – Romanian Lakes; vertical lines – the slightly salty Aegean Lake being in connection with the oblique lines – Kuialnician Sea – Lake in the East (in the Black Sea realm). Diatomite sites (Sofia, Palakaria, Karlovo, Pilep, Bitola, Servia) according OGNJANOVA-RUMENOVA (2006) and JENKO & GJUSELKOVSKI (1957–1958 for Prilep). **1,** Moslavina, Kutina ZP-8, ZP-9; **2,** Slavonia, Strizivojna V-4; **3,** Posavina, Prevlaka OS-1; **4,** Erdut P-2; **5,** Baranja Hill P-10 (all from SOKAČ, 1978); **6,** Bajmok Sb-5, Sb-6, Sb-7; **7,** Čoka K-11 and others; **8,** Mol K-59 and others; **9,** Crnja Ž-11 and others; **10,** Lazarevo JT-1 and others; **11,** Gložanj G-3 and others; **12,** Srbobran SRB-2; **13,** Mačva: Crna Bara and Pričinović; **14,** brickyard at Krivci; **15,** Ugrinovci KG-33 and Zemun B-12.13 (from KRSTIĆ, 2006); **16,** Baraolt; **17,** Silistra; **18,** Mazgoš – Stanjinci, **19,** Metohija; **20,** Joanina; **21,** Eubea; **22,** Megara; **23,** northern Peloponnesus; **24,** Megalopolis; **25,** Sparta; **26,** Kos (starting with No 16 - by different authors).

Paludinian Lake

The Paludinian Beds obtained their name from a synonym of the gastropod genus *Viviparus*. The Paludinian Lake of the Middle Danube lowland was probably the deepest, among the Pliocene lakes of the Balkans, lasting for the longest period. At the boundary, "caspibrackish sediments alternate with limnic ones on the border between the 'Pontian' and the 'Paludinian Beds', therefore making the border diachronous" (STEVANOVIĆ *et al.* 1989).

The Early Pliocene of northern Europe had mostly an arid and regressive character, especially during its latter half. At that time, all the lakes in southeastern Europe decreased in size, and their interconnections were occasionally interrupted (KRSTIĆ 2006).

Molluscs appeared in shallow water, along the coast or on the shore. The Paludinian molluscs cited by KNEŽEVIĆ (PAPAIANOPOL *et al.* 2003) are distributed according to *Viviparidae* stratigraphy. In the Lower Paludinian, along with the smooth key species *V. neumayri*, ornamented Unionidae appear as *Rytia bielzi, Cuneopsidea partschi* and many *Melanopsis* species. In the Middle Paludinian, the key fossil is *Viviparus bifarcinatus* followed by other ribbed, smooth and ornamented unionids, a few *Melanopsis* species and different extinct gastropod taxa. The Upper Paludinian is marked by the key species *V. dezmanianus* and other knotted, but also some smooth viviparids along with different *Unionacea* and some extinct *Theodoxus, Hydrobia* and *Valvata* as several species of *Melanopsis*. To the Pliocene belong *Viviparus boeckhi* Beds still having ornamented Unionidae: *Potomida sturi, P. wilchelmi, Wenziella, Rugunio* as the first *Unio* cf. *pictorum*, then *Pisidium rugosum, Hydrobia syrmica*, *etc*. Some recent species, such as *Dreissena polymorpha*, *Fagotia esperi, Theodoxus transversalis* and many others are known since the Middle Paludinian.

The ostracode meiofauna, as well as planktonic microflora, was evenly distributed by wetland birds, which carried it over large distances. The numerous records of ostracodes enable a quite precise recognition of the arid phases which were present with variable intensity and quantity, depending on the particular basin. For the Middle Danube Plain, the key fossils are *Cypris subglobosa mandelstami*, *Zonocypris membranae*, *Stenocypris* cf. *boileki*, *Cyprideis torosa*, and various taxa of Limnocytheridae (KRSTIĆ 2006). Representatives of Leptocytheridae are rare (SOKAČ & KRSTIĆ 1987).

The Upper Paludinian Beds have a transgressive character. The lakes increased in size and in the Upper Pliocene, they were widely connected with each other (KRSTIĆ, *et al.* 2005). Only once did evaporation prevail, indicated by *Scordiscia*, making distinctive subzone in the lower part of the Upper Paludinian Beds.

The most important species of ostracodes in the Upper Paludinian Beds is *Ilyocypris malezi*. Most of the other taxa are known from extant biotopes, but the Paludinian Lake contains exclusively halotolerant forms, probably those that also thrived in alkaline environments. Subspecies of recent species are common (only a few of them were occasionally described, therefore most are indicated by "cf."). These subspecies lasted until the Mindel / Riss interglacial (300–100 KAa): *Ilyocypris* cf. *monstrifica*, *Cyclocypris* cf. *serena*, *C.* cf. *impressopunctata*, *Laevicypris laevis ducatensis*, *Trajancypris* cf. *laevis*, as well as the species *Ilyocypris sokacae.* The subspecies *Scottia browniana kubanica* and *Ilyocypris getica crnjanskii* became the main species below the Pliocene–Pleistocene boundary. Both subspecies of the species *Scottia browniana*, indicate an environment of high water energy, while they are abundant in more or less sandy sediments (KRSTIĆ 2006).

In the Dinaric realm, Viviparids and large mammals are known from the Vinodol–Ilirska Bistrica graben. An erosional remnant in a supposed Pliocene lake strait, on the way to Adrian, in Srb, along with Hydrobiids just a single *Erpetocypris* was recorded (JURIŠIĆ-POLŠAK *et al.* 1997). In Istria, STACHE (1889) collected also *Viviparus* snails.

A curiosum is that Pliocene ostracode communities of the same type as in the Pannonian Lake appear as far as Thüringia (KRSTIĆ 2006).

Dacian–Romanian Lake

The Dacian–Romanian Lake lies on the Platform Moesian, covering mostly the Romanian plain and only small part crosses the Danube towards the south covering a little of Bulgarian territory.

At the Miocene–Pliocene transition, the Paratethys water retreated and connection between the Pannonian and Dacian Basins "was reduced to a system of channels and straits" (ENCIU 2007). Its water chemistry changed and in the Dacian Basin, along with different Lymnocardiidae (*Pachidacna*, *Dacicardium*, *Pseudocatillus*, *Stylodacna*), the "first species of *Psilunio (Psilunio)*, *Jaskoa* and numerous gastropods of paludal facies (*Valvata, Planorbis*)" appear. "The internal change of lithology, architecture of sedimentary rhythms and thickness depended on the slow tectonic movement of the Moesian" Plate. The Early Pliocene was named Dacian, the late Romanian; they continue one after other making a single Dacian–Romanian Lake.

In volume, Dacian (MARINESCU & PAPAIANOPOL 1995) in a description of the Getian substage Lake was figured as large and spread over the whole of the southern plain of Romania, ending in the south at Lom in Bulgaria. Bivalvia Lymnocardiids are diverse and numerous, giving the name *Pachidacna* – Beds to Getian, but there are enough *Dreissena polymorpha*, *Viviparus rumanus* and other molluscs in it. Thick coal beds spread over western and northern part of the Dacian Basin.

During the late Dacian, the Paskovian substage, the Lake shrank considerably, retreating from the west and north, where the coal areas were situated; now coal appears in the middle of this smaller Lake, but also in its NE portion were there was nearly none regression, as opposed to the southwards ingression in the middle and eastern Lake portions. The main fossils are Lymnocardiidae: *Limnodacna*, *Pseudocatillus*, *Horiodacna*, *Dacicardium*, *Prosodacnomya* and some gastropods, such as, *Lithoglyphus*. Among the ostracodes in Bulgaria, halophilous species prevail, such as *Cyprideis torosa*, *Paracyprinotus salinus* and the extinct *Zonocypris membranae*, also the halotolerant: *Pseudocandona compressa*, *Laevicypris laevis* and *Neglecandona*. In the Roþitori borehole, *Romanocastor filipescui* was determined to the MN14 Zone belong Bereþti site rich in micromammals and Ciupreceni with large mammals.

The Upper Pliocene, Romanian spread its aquatorium even larger than it was at the beginning of the Pliocene. The Romanian stage of Moesian Plate was delimited towards the Black Sea, the Kuialnician biofacies, by a threshold laying to the south of the Buzau River. It was not a barrier while the two sea-lakes communicated over it (PAPAIANOPOL *et al.* 2003). This could be used to explain Pliocene remnants in Baraolt-Brasov intramontane depression containing aberrant ostracodes, molluscs and mammals.

The Romanian has its tripartite biostratigraphic subdivision supported on molluscs: while Lymnocardiidae vanished, Unionacea flourished. The Lower Romanian contains smooth unionids accompanied by *Viviparus bifarcinatus*, *Jaskoa sturdze*, *Psilunio sibinensis* and *Melanopsis rumana*. The Middle Romanian is rich in ornamented unionidae, corroborating a higher temperature when $CaCO_3$ intake was faster; it is possible to distinguish three contemporaneous zones: a) *Rugunio lenticularis*, *Rytia slavonica*; b). *Pristinunio davilai* with *Viviparus stricturatus* and c) *Bulimus vukotinovici* with *Canthidomus lanceolata*. In the Upper Romanian, climatic variations are observed according to lacustrine, palustrine and terrestrial facies, the zone with *Ebersiniana milcovensis* and subzone *Unio kujalnicensis*. In the Romanian stage are present: *Ilyocypris angulata*, *I. lanceolata*, *Zonocypris membranae*, *Berocypris*, *Kowalevskiella*, *Scordiscia jiriceki* (taxonomy corrected according to KRSTIĆ 2006) and others. Mammals are recorded in two areas of the Romanian Plain: the ten outcrops at the slope of Carpathians along the Olt and neighbouring rivers belong to the Gilbert and early Gauss (4.3–3.1 Ma) and Slatina 1, 2, 3, as the Tetoiu to the Matuyama (2.6–1.9 and 1.75 Ma) (PAPAIANOPOL *et al*. 2003).

The mentioned Baraolt–Brasov Depression could be a remote bay of the Black Sea. Kuialnician penetration into the Carpathian Mountains and having higher salinity (due to evaporation and the narrow strait), *Paradacna abichi*, *Lymnocardium zagrabiense* and even *Budmania,* being there in a refugium, were therefore determined (MARINESCU & PAPAIANOPOL 1995). From the Baraolt Basin in the Carpathians, the first recorded species was *"Candona" kinkelini*. Eight ostracode taxa are identical for both Baraolt and Metohija (in southern Serbia), and one of them is shown on the drawing–*Carpathocandona bataniica* (from Metohija). The last belongs to the most distinctive find at Baraolt–a species flock of bimucronate Candoninae, there together with *Cyprideis jekeliusi* and a few Leptocytheridae species of the Pontian type (PAPAIANOPOL *et al*. 2003). In Baraolt-Brašov, one mammal-bearing column started at 3.7 and ended at 3.5 Ma; the remaining three columns started at 3.5 and ended at 3.1 Ma, hence they belong completely to the Early Gauss, in other words, to the middle and the first one partially to the Lower Romanian.

Aegean Lake

The ancient Aegean Lake covered the southern Balkan Peninsula, Aegean Sea and parts of Asia Minor. Its water chemistry was similar to seawater but much diluted, while it comes from the Black Sea Kuialnician biofacies. It is fossil-bearing from Kosovo and Metohija to the Peloponnesus. At the same time, the southern part of the Balkan Peninsula communicated with the Mediterranean Sea. This can be observed in a column of Megara near Athens, where *Melanopsis* layers and *Cardium* layers alternate (GEORGIADES-DIKEOULIA *et al.* 2002).

The largest area with fossiliferous Pliocene sediments lies approximately in the middle of the Balkan Peninsula. It is Kosovo and Metohija where mollusc fauna (mostly congerias and *Viviparus*) in places litters the sediment (PAVLOVIC, 1903). The ostracode fauna of the area is rich and diverse-three groups of ostracodes are distinguishable (KRSTIĆ *et al.* 1988). The species which are the same as recent freshwater ones are: *Fabaeformiscandona krstici*, *Cypria karamani*, *C. sketi*, *Paralimnocythere ohridensis*, *P. geogevitschi*, with some others, such as *Candona candida pliocenica,* which are related to them. On the other hand, there are species of the Kuialnician type, such as *Graviacypris*, *Zalaniella*, *Ohridiella*, *Reticulocandona* as the very rare *Amnicythere* and *Cyprideis*; also extinct species *Ilyocypris malezi*, *Scottia browniana kubanica*. Bimucronate Candoninae belongs to an intermediary group.

West of Sofia, at the very border of the state of Serbia, the erosion remnants of Pliocene sediments are present at the open coal pits in Mazgoš and Stanjinci. In Mazgoš (Serbian mine), the halophilous ostracodes *Paracyprinotus salinus* and *Neglecandona angulata decimai* were recorded together with halotolerant ones, such as *Peudocandona compressa* and others. The mollusc fauna present in Mazgoš includes the ubiquitous pond species *Planorbarius corneus* and *Galba palustris* as well as a slightly smaller and *Planorbarius*–shaped, African snail (JOVANOVIĆ *et al.* 2005). This intramontane area was slightly influenced by Kuialnician water, in the same manner as Metohija.

Towards the south, sediments of the same Upper Pliocene age with numerous fossil ostracodes and molluscs, such as *Viviparus brusinai*, are recorded in the basins of Joanina (GUERNET *et al.* 1977), also at northern Eubea (MOSTAFAWI 1994), in the open pit of Megara near Athens (GEORGIADES-DIKEOULIA *et al.* 2002), on the north of Peloponnesus (MOSTAFAWI 1994), as well as the central part of Peloponnesus at Sparta (GUERNET 1979; KRSTIĆ & VELITZELOS 2002) having the same community in Megalopolis (LÜTTIG & MARINOS 1962).

There are similar interesting associations away from the Balkan Peninsula mainland on the island Kos (GUERNET *et al.* 1976; MOSTAFAWI 1988). All this means that Paratethys water during the Upper Pliocene poured into the nearly dry Mediterranean depression, yet recorded only close to Barcelona (GILLET 1965) and curiously in the upper Ebro Basin (RODRIGUEZ-LAZARO & MARTIN-RUBIO 2005).

Implications

For the precise determination of the biostratigraphic placement of lake fossils, the ostracode communities have to be used for various purposes. The ecology and distribution of certain species, clear enough in the younger levels, indicate the evolution of climate. The correlation with other similar or different palaeobiological units enables an understanding of the evolution of the Balkan lakes in Neogene time and space. These conclusions mirror the geodynamic evolution–the distribution of equivalent time sediments indicates the tectonic mechanism that preceded them. The obtained data are actually proof for the existing tectonic models (CIPOLLARI *et al.* 1999; MIKES *et al.* 2008). However, certain explanations are still lacking.

The transition from the latest Oligocene limans into early Miocene lakes is connected to compressive closing of the strait between the Western (Dinaric) and the Eastern (Carpatho-Balkanic) Islands. The origin of the water basins also assumes transcurrent movements along the straits in the direction North–South, with perpendicular faulting at their sides, causing the appearance of depressions in the West–East direction.

The origin mechanism of Dinaride System of Lakes slowly becomes apparent, aside it spreading across the Middle Danube Plain until behind the Alps. The explanation by De CAPOA and RADOIČIĆ (2002) is that tectogenesis of the External Dinarides "actually occurred during the Early Late Miocene", so the early extensional movements could commence in the mid Lower Miocene, while the faulting occurred later. A detailed study of palaeostress in the Central Dinarides "indicates, a NE–SW contraction, as well as a subordinate NW–SE extension, which is related to the early Miocene shortening of the Dinaric orogenic wedge" (ILIĆ & NEUBAUER 2005). These pressures caused isoclinal folds of the Dinarides along the Adriatic, where de CAPOA & RADOIČIĆ (2002) recorded a continuity of sediments from the Eocene to the Seravalian. Whether the Eubean Kymi site (VELITZELOS & GREGOR 1990) is a part of this folding is difficult to say. The last research prolonged the marine Miocene northwards until Istria (Triesete–Kopar and Pazin Basin) all along the Outer Dinaride (MIKES *et al.* 2008) "Upper Oligocene palynomorphs, nanofossils and larger foraminifera in the Pićan flysh" (Istria) "have been dated herein to be not older than the Late Burdigalian" according to nanofossils which "tolerate reduced salinity". For the islands Rab and Pag (BULIĆ & JURIŠIĆ-POLŠAK 2009), with their freshwater ostracode genera and congerian fauna, the conclusion should be the same, namely, there was a large lacustrine aquatorium of the Ottnangian Stage.

The Chinese biota had to travel a long way to the Dinaride Lake, from one refugium to another, carried by birds, in order to appear in south-eastern Europe in the Lower Miocene. Some such refugiums are presented on the Palaeogeographic Maps of SE Europe–SW Asia (POPOV *et al.* 2004). A large Dneper–Donets Basin, from Donets High over Kiev and into Poland contains congeria fauna in its gulfs and estuaries of already freshened sea.

For the Middle Danube Area, HAMOR (2001) declared that "the marginal sediments of the Ottnangian transgression are the 'Oncophora-bearing sandstones'" and that it was "detected in the NN3 Zone, the 'Rzehakia layers' ... in the Vienna Basin", in northern Hungary and in Czech Moravia. HAMOR drew quite narrow river valleys on his map of the Lower Miocene (Upper Eggerian–Eggenburgian–Ottnangian), where fluvial channel line facies and fluvial floodplain facies separated. According to the distribution of the lacustrine pre-Badenian in the Serbian part of the Middle Danube Plain (COLL. AUTH. 1968–1995), the equivalent sediments are widely distributed but preserved only as remnants of erosion processes.

For the Serbian Lake, there is a hypothesis of post-collision spreading (CVETKOVIĆ *et al.* 2000, 2004) and later compression (PRELEVIĆ *et al.* 2005), explaining the great elongation of this "narrow" lake. However, the original width of the lake was much larger than shown in Fig. 2. Its eastern half is compressed between the many stripes of the Carpatho-Balkanides and often deeply buried Neogene (KRSTIĆ *et al.* 1988). The time of these movements approximately corresponds to the boundary between the Lower and Middle Miocene, but it cannot be precisely determined as the coal-bearing "lower Badenian" part of the lacustrine sediments is folded and faulted, while the upper part remained almost horizontal. In the Serbian Lake, the depth zones are already recognizable: the almost unconsolidated lake chalk with "*Candona"* cf. *similil-ampadis* at Knjaževac, compressed between the gabro massif of Zaglavak at the East and Mesozoic rocks in the West; the right transcurrent Timok dislocation transversely cuts through Jurassic limestone and an over - laying succession of lower Cretaceous stratigraphic units (KRSTIĆ *et al.* 1970; KRÄUTNER & KRSTIĆ 2003).

The spacious valleys of the mid-southern Balkan (including the Pelagonia–to Servia trench–PAVLIDES & MOUNTRAKIS, 1987; STEENBRINK 2001), where the Upper Miocene continental and lacustrine sediments were laid, could be connected with the collapse of the present-day Aegean Sea (MAROVIĆ *et al.* 1999). This extension follows the closing of the Middle Miocene Serbian Lake in the North, due to a compression of the actual bending of the Carpathian-Balkan Arc.

Upper Miocene sediments have their widest distribution in Macedonia and a somewhat smaller area along the southern flank of the Balkan Mt. and nearly the whole of southern Bulgaria (OGNJANOVA-RUMENOVA 2001, 2003, 2007). Towards the west, the Bureli surroundings in the middle of Albania (KUMATI *et al.* 1997) could be an extremely freshened distal part of an Adriatic bay containing Unionacea. A small erosion remnant, rich in ornamented *Theodoxus*, is situated in the town of Athens (KÜHN 1963; PAPP 1979).

The Pliocene tectonics is quite different, being connected with the obduction of Asia Minor over the Balkan Land. The obduction caused the detachment of a "thin skin" layer over a wide area from Sofia and Metohija southwards, with very visible bow-shaped boundaries near Skopje (COLL. AUTH., 1968–1995). The obduction reflexes might be found all the way to Čačak and Rtanj (KRSTIĆ, 2006), and towards the west to the Adriatic Coast in Albania, as well as in its Peshkopi Trench (KRSTIĆ *et al.* 1999). The Montenegro–Adriatic fault caused great earthquakes.

Due to such a great impact of tectonics on the present distribution of the Neogene lacustrine sediments, a palaeogeographc reconstruction is difficult. Each individual lake or any of its parts would have to be studied in greater detail–that would be one of palaeolimnology important tasks. The problem is an insufficient number of observation points and an even smaller number of detailed studies of fossil associations in the Miocene part of the Balkan Peninsula Neogene. The number of samples from the Pliocene is already considerably larger, especially in the Middle Danube Plain, and their fauna is similar enough to the extant one that a palaeogeographic map could be constructed (KRSTIĆ 2006). For the Pliocene spreading all over southern Europe and SW Asia, a reconstruction was performed (KRSTIĆ *et al.* 2005).

The chemistry of the lacustrine water could be deduced based on a number of "endemics"-the aberrant taxa-and the ornamentations on their shells. There is a surprising diversity in the ornamentation of ostracode genera that in freshwater environments are either smooth or only insignificantly punctuated, such as the various systematic categories of Candoninae, except *Pseudocandona.* The genus *Potamocypris* has tubercles or spines, some Limnocytheridae taxa (the one transported from China and Russia) may be heavily ornamented with ridges and tubercles along with a denticulate hinge, *etc*. The chemistry of the water sometimes caused reversion of the shells, when the left ostracode valve acquires the characteristics of the right one and *vice versa*. *Theodoxus* ornamentation was also noticed. Even the lack of ostracodes and other organisms that bear a calcium carbonate shell can indicate the acidity of the lake water. This characteristic is due to intensive volcanic action in the Šumadijan Lake.

The energy of the water is represented through the presence or absence of certain groups. In addition to the gastropods *Fagotia, Theodoxus* and *Lithoglyphus,* ostracodes may also be reophilous, for example *Scottia browniana*.

Changes in climatic belts cause the presence or absence of certain ostracode species. While in the Pannonian Plain, the Pliocene taxon *Scottia browniana kubanica* is very abundant and at Metohija, it is rarely represented but still recorded, it is completely missing in Peloponnesus and southwards. The representatives of the species *Ilyocypris malezi* are smaller in the Aegean than in the Paludinian Lake, probably due to the warmer climate in the southern areas.

A climate reconstruction is possible for the late Pliocene and for the lacustrine Pleistocene. By the end of the Pliocene, colder winters are recorded while in the same sample may be found both–summer and winter generations of a particular species (cold winters and warm summers)–hence, a climatic cooling may be directly recorded. In the older lacustrine sediments, reconstruction of the climate is more or less connected with the reconstruction of the water chemistry, when it is affected by the climate. Thus, warm temperatures cause an increase in evaporation and, therefore, also a diminishing of the tributaries. Both increased the mineralization of the water. However, it is more complicated–when a lake decreases in size, due to aridity, it looses not only its influx but also its outflow, hence the balance in the water chemistry is affected.

Ostracode meiofossils are the best support for studies of lacustrine sediments as they are much more abundant than molluscs, they are also autochthonous benthic organisms and since studies of diatoms, dinoflagelata and endemic calcareous nanoplankton, which were often transported still alive, are less significant.

The main means of meiofauna and microflora unification, when the environment is appropriate, is dissemination by birds. Old ideas of their evolution in restricted geographic region were born due to the slow evolution of the environment chemistry in the Paratethys and similar areas. Understanding that bird transport was the main agent of ostracode dissemination providing the meiofauna of the Central Macedonian Lake (KRSTIĆ & GUAN 2000) explains why the ostracodes have no similarity with those of the neighbouring Paratethys parts but with the Kainozoic lacustrine ostracodes of China. The same comprehension was a little later placed for the microflora–diatoms and dinoflagelata (personal communication by OGNJANOVA–RUMENOVA) and afterwards for larval stages of gastropods, maybe all molluscs (personal communication by Bandel, Hamburg). It is not known how many ancient refugia existed between China and southeastern Europe. Some of them, since Lower Miocene, contain congerian and other fauna, still insufficiently correlated between themselves. The recent molluscs and ostracodes of western and central Europe are identical in every of lake and pond due to the circulation of wild geese. However, there are different recent species in the southeastern part, especially on the Balkans, due to the different climate and bird migration, which come from SW Siberia and have their feather change on the Caspian. In general, today and in the past, bird migration had the same direction, from east toward west, due to the rotation of the Earth. Hence, the appearance of the community from Chinese early Eocene is the same as in the early Pliocene of the Middle Danube Lowland; the same species *Ilyocypris angulata* Sars lives today in the H'nka Lake near Vladivostok with its subspecies found in the Middle Paludinian Beds (KRSTIĆ 2006) and so on.

Meiofauna indirectly provide data on ancient water chemistry, even by their absence due to lake water acidity. When the obtained proxies are combined with studies of palynomorphs and macroflora, there is a possibility for conclusions about the climate in the whole Neogene past. Matched with sedimentological and other geological studies, they provide data for palaeogeography and tectonics, which can protects us from geological hazards.

Conclusions

The time of the appearance and the distribution of lacustrine basins on the Balkan Peninsula were caused by numerous processes at the boundary of the asthenosphere and the lithosphere, combined with movements of tectonic plates.

The water of the Šumadijan Lake used to have high acidity, judging by the absence of autochthonous carbonate fossils. It may be assumed that the lake was formed by the collapse of a magma chamber, from which the numerous magmatic bodies have already erupted, including the massifs of Borač and Kotlenik.

The Dinaric system of lakes was formed by pulsating indentation of Adriatic plates towards the north. The Dinaric mountain system was formed by underthrusting and uplifting, leading to greater elevation of younger sediments and the altitudinal difference of about 2000 m between the same levels, for example Livanjsko Polje and the freshwater biofacies of Kupres. The measured absolute age of the younger Neogene of Sinj, deposited in mineralized water inhabited by dreissena, is 17.92 ± 0.18 Ma.

The Serbian Lake originated by the postcollision spreading of western and eastern Balkan Islands. At the East, the nape of the Carpatho-Balkanides has covered the older Lake, coal-bearing sediments with Mesozoic and other older sediments in the meridional direction. In the younger subhorizontal part, there are coarse-grained coastal limestones with *Kosovia* and fine-grained siliciclastic rocks rich in benthos fauna in lentic areas. The fauna shows a slight indication of mineralization. The profundal in the deeper parts of the Lake is highly mineralized with well-preserved remains of fish. According to the diatomic association, it may be concluded that the Lake stretched southwards to the Simitli Valley in SW Bulgaria.

The marine Badenian later gradually penetrated from the North into the Serbian Lake, and the furthest attained area was in the Morava Bay: the Middle Badenian, of Sarmatoid biofacies, reached the town of Kruševac. The other bays were shorter and shallower: at the Mlava Bay, the meiofauna close to the coal was of the freshwater type - with abundant characean gyrogonites. The marine Middle-Badenian fauna penetrated to Doboj down the River Bosna Valley. The Viennese type of Badenian reached Bulgaria and eastern Serbia through Romania, along the River Olt .

Generally speaking, the northern boundary of the Serbian Lake sediments, predisposed by faults in the W–E direction, moved slowly southwards. Therefore, in southern Banat, the Papuk belt, the marine Lower Badenian continuously ascended from the lacustrine pre-Badenian. The belt passing through Belgrade included the Middle Badenian only, while to the south from Bukulja and in Valjevo–Mionica Depression, the lacustrine-riverine Lower Volinian with *Potamocypris* was concordantly covered with brackish *Mactra* limestone of the Middle Volinian.

The deep gulfs at the northern and western edge of the Pannonian Plain were inhabited by endemic fauna. The one close to Graz was determined as Sarmatian (due to vertebrate bones), while the other in Hungary is the equivalent of freshened Badenian and includes Black Sea biofacies.

The two Upper Miocene lacustrine phases, the "Pannonian Sea" and its much greater Pontian descendant, have entered over the Balkan Land to the south to only a small extent. However, the Pontian part also approached the Balkan Land from the South, *via* the Aegean, and from the West in the Periadriatic Depression of Albania.

The Aegean collapse reached northward to Vranje. It was widespread in central Macedonia and SW Bulgaria. The Central Macedonian Lake was a tectonically mobile area; hence, the older coarse clastic sediments with mammalian remains (Veles, Kalimanci, *etc.*) were preserved over a wider area than the younger fine-grained lacustrine sediments with endemic macro and meiofauna and rich microflora. The Central Macedonian Lake was bordered by a threshold from the Pontian of the Aegean Lake in the South. In Greèce, besides the Eordean Rift, there are numerous valleys stretching from Athens southwards and across the sea to Rhodes and the Anatolian Xanthos Rift.

The Pliocene lakes from the North entered the Southern areas along the coasts of the Balkan Land. These are the Paludinian and the Dacian–Romanian Lakes. In the Middle Danube Valley, the gradual decrease in salinity influenced the formation of ornaments in species of the genus *Viviparus* and numerous taxa of Unionacea. In the ostracodes, there are some almost exclusively halotolerant species, with the exception of rare layers with halophiles. In the Lower Danube Valley, a great regression is observed during the Dacian stage, as well as the transgression during the Romanian stage.

The Kujalnitian of the Black Sea reached to the Buzãu River; hence, the Brašov-Baraolt Depression in the Carpathians was narrowly connected to the Black Sea, having more saline biofacies. To the south from Stara Planina, the waters of the Black Sea flooded the SE part of the Balkan Land, as a consequence of the obduction of Asia Minor over the Balkans.

In the southern parts of Greece, the lacustrine Pliocene was alternating with marine biofacies in short intervals. This was the area of contact between the water bodies of the Paratethys and the Mediterranean.

The occasional records of Pliocene formations with *Viviparus* and meiofauna, reaching westwards into Spain and northwards into Thuringia, pose a question about the uniformity of the lacustrine biotopes of the Late Pliocene and the transport of smaller organisms (including mollusc larvae) inside the plumage of migratory birds.

This concludes the present-day knowledge on the origin, development and disappearance of the Miocene and Pliocene lakes on the Balkan Land.

Acknowledgements

All authors are thankful to all their colleagues for providing many of the papers dealing with this important topic. The two reviewers, STJEPAN ĆORIĆ (Vienna) and PLATON TCHOUMATCHENCO (Sofia) are thanked for their useful comments.

References

BORNOVAS, J. & RONDOGIANNI-TSIMBAOU, TH. 1983. Geological map of Greece 1:500 000. *In*: PAPAVASSILOU, K. (ed.), Institute of Geological Mining Exploration, Division & General Geology.

BRUSINA, S. 1884. Neritodonta Dalmatiens und Slavoniens, nebst allerlei Malakologischen Bemerkungen. *Jahrbücher der Deutschen Malakozoologischen Geselschaft*, 1: 5–120.

BRUSINA, S. 1894**.** Fragmente der serbischen tertiäre Malacologie 8. *Geološki anali Balkanskoga poluostrva*, 5 (1): 193–199 (in Serbian).

BRUSINA, S. 1897. Materiaux pour la faune malacologique neogene de la Dalmatie, de la Croatie et de la Slavonie avec les especes de la Bosnie, de l'Herzegovinae et de la Serbie. *Djela Jugoslavenske akademije znanosti i umjetnosti*, 18: 1–43.

BRUSINA, S. 1902. Iconographia Molluscorum fossilium in telure Tertiaria Hungariae, Croatiae, Slavoniae, Dalmatiae, Bosniae, Herzegovinae, Serbiae et Bulgariae inventorum. Operis per alteris, Atlas: 10 pls, Zagreb.

BULIĆ, J.& JURIŠIĆ-POLŠAK, Z. 2009. Macropalaeontology and stratigraphy of lacustrine Miocene deposit et Crnika beach an the Island of Pag (Croatia). *Geologica Croatica,* 62 (3): 135–155.

CIPOLLARI, P., COSENTINO, D. & GLIOZZI, E. 1999. Extension and compression-related basins in central Italy during the Messinian Lago-Mare event. *Tectonophysics,* 315: 163–185.

COLL. AUTH. 1968–1995. Basic geological map of SFR Yugoslavia 1:100 000: Sheets and Explanatory booklets 216. *In*: DIMITRIJEVIĆ, M. et al. (eds.), *Federal geologocal survey*, Beograd.

COLL. AUTH. 1974–1997. Geological correlation, International geological correlation programme IGCP. Geoscience in the service of society. *In* Martisson, A. (ed.). UNESCO, Paris.

CORBAR,T. 2009: Orogenic evolution of the External Dinarides in the NE Adriatic region: a model constrained by tectonostratigraphy of Upper Cretaceous to Paleogene carbonates. *Earth-Sciences Reviews,* 96: 296–312.

CVETKOVIC, V. & PECSKAY, Z. 1999. The Early Miocene eruptive complex of Bora (Central Serbia): Volcanic facies and evolution over time*. Geologica Carpathica*, 50: 91–93.

CVETKOVIC, V., PRELEVIĆ, D. & PECSKAY, Z. 2000. Lamprophyric rocks of the Miocene eruptive complex (Central Serbia, Yugoslavia). *Acta geologica Hungarica,* 43 (1): 25–41.

CVETKOVIC, V., PRELEVIĆ, D., DOWNES, H., JOVANOVIĆ, M., VASELLI, O. & PECSKAY, Z. 2004. Origin and geodynamic significance of Tertiary postcollisional basaltic magmatism in Serbia (Central Balkan Peninsula). *Lithos*, 73: 161–186.

CVIJIĆ J., 1911. L'ancien lac Égéen. *Annales Geographie*, 20: 233–259.

CVIJIC, J., 1924. Morphologie terrestre. State Printing House of the Kingdom of Serbs, Croats and Slovenes, 1: 586 pp, Belgrade (in Serbian).

ČIČIĆ, S., & MILOJEVIĆ, R. 1977. Terestričko-limničke naslage tercijara u Bosni i Hercegovini. Geologija Bosne i Hercegovine. *In* Čičić (ed.), 3. Kenozojske periode, 67–118, Geoinženjering, Sarajevo.

CHUMAKOV, I.S. 1993. Radiometric scale for the late Cenozoic Paratethys. *Priroda,* 12: 68–75 (in Russian).

ĆORIĆ, S., PAVELIĆ, D., RÖGL, F., MANDIĆ, O., VRABAC, S., AVANIĆ, R., JERKOVIĆ, L. & VRANJKOVIĆ, A. 2009. Revised initial datum for the initial marine flooding of North Croatian basin (Pannonian Basin System, Central Paratethys). *Geologica Croatica*, 62 (1): 31–43.

DE CAPOA, P. & RADOIČIĆ, R. 2002. Geological implications of biostratigraphic studies in the external and internal domains of the Central-Southern Dinarides. *Memorie della Società Geologica Italiana*, 57 (1): 185–191.

DE BONIS, L., BOUVRAN, G., KOUFOS, G. & MELENTES, J. 1986. Succession and dating of the late Miocene primates of Macedonia. *In*: ELSE, G.J. & LEE, C.P. (eds.), Primate evolution. Cambridge University, Press, Cambridge, 107–114.

DOLIĆ, D. 1978. New data about the marine and brackish Miocene from Paraćin Pomoravlje, Serbia. *Bulletin de l' Académie serbe des sciences et des arts,* 306*, Classe des sciences mathématiques et naturelles*, *Sciences naturelles*, 43: 13–26.

DOLIĆ, D. 1983. Miocene freshwater molluscs from the Kačer-Jasenica basin. *Compte Rendue des Séances de la Société Serbe Géologie*, pour 1982: 123–127 (in Serbian, English summary).

DUMURDŽANOV, N. 1997. Lacustrine Neogene and Pleistocene in Macedonia. Proceedings Field Meetings IGCP 329, *Special publications Geoinstitute*, 21: 31–36.

DUMURDŽANOV, N. & KRSTIĆ, N. 1999. The Skopje Neogene basin in the Republic of Macedonia. *Geologica Macedonica*, 13: 47–56.

DŽODŽO-TOMIĆ, R. 1963. Microfauna of Buglovian horizont from Timočka krajina with the special regard to its stratigrafical position. *Vesnik Geozavoda*, A, 21: 11–132 (in Serbian, English summary).

ENCIU, P. 2007. Pliocenul si cuaternarul din verstul bazinul Dacic, stratigrafie si evoluție paleogeografică. Editura Academiei Române, 149: 1–228.

ERCEGOVAC, M., GRGUROVIĆ, D., BAJĆ, S. & VITOROVIĆ, D. 2003. Oil shales in Serbia: geological and chemical-technological investigations, actual problems of exploration and fisibility studies. *In*: VUJIĆ, S. (ed.), *Mineral and material complex of Serbia and Montenegro on the crossing of two millenniums*, 368–378 (in Serbian, English summary).

GAUDANT, J. 2002. The Miocene non-marine fish-fauna of Central Europe: a review. *Bulletin de l' Académie serbe des sciences et des arts,* 25, *Classe des sciences mathématiques et naturelles*, *Sciences naturelles*, 125 (41): 65–74.

GAUDANT, J. & VATSEV, M. 2003. Deux nouvelles ichtyofaunes lacvustres dans l'Oligo-Miocène du graben de Brežani (Bulgarie du Sud-Ouest). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen,* 230 (1): 25–47.

GEORGIADES-DIKEOULIA, E., KRSTIĆ, N. & KOSKERIDOU, E. 2002. Faunal correlation between the Pliocene of Central Greece (Lokride, Megara) and Southern Serbia (Metohia, Kosovo). *Bulletin de l' Académie serbe des sciences et des arts*, 125, *Classe des sciences mathématiques et naturelles*, *Sciences naturelles*, 41: 97–119.

GILLET, S. 1965. Los Limnocardidos del Plioceno de Papiol (Barcelona), *Memoir y Communicatione*, 1 (2): 3–82.

GOZHYK, P. 2006. Freshwater molluskcs of the late Kainozoicum in southern Europe, Superfamily Unionacea, 247 pp. National academy of sciences of Ukraine, Kiev (in Russian).

GROSS, M. 2005. What about Upper Miocene ostracodes from the Styrian basin? *In*: RUNDIĆ, LJ., JOVANOVIĆ, G. & SIMIĆ, V. (eds.), First International Workshop Neogene of Central and Southeastern Europe, Serbian, Geological Society Abstracts: 14–15, Fruška Gora.

GROSS, M., BÖHME, M. & PRIETO, J. 2009. Gratkorn–A new late Middle Miocene vertebrate fauna from Styria (Late Sarmatian, Austria). Geophysical Research Abstracts, 11, EGU General Assembly 2009, 11: EGU2009-7091.

GUERNET, C. 1978. L'evolution paléogéographique et tectonique de la Grèce au miocène: Un essai de synthèse. *Revue de Geographie Physique et de Géologie Dynamique*, 2 (20): 95–108.

GUERNET, C. 1979. Les ostracodes de Levantin de Sparte (Péloponnèse, Grèce): Intérêt stratigraphique et paléoécologie. *Revue de Micropaléontologie*, 22 (1): 29–36.

GUERNET, C., KERAUDREN B. & SAUVAGE, J. 1976. La série „Levantine" du Cap Phocas (Île de Kos, Dodécanèse, Greèce): Stratigraphie, palynologie et paleoecologie. *Revue de Micropaléontologie,* 19 (2): 61–76.

GUERNET, C., SAUVAGE, J. & SOULIE-MARSCHE, I. 1977. Le Levantin de Joanina (Epire, Greece): Observation stratigraphiques et paleontologiques. *Geobios*, 10 (2): 297–309.

HAMOR, G. 2001. Miocene paleogeography of the Carpathian basin-Explanatory notes to the Miocene paleogeographic maps of the Carpathian Basin, 71 pp. Geological Institute of Hungary, Budapest.

HARZHAUSER , M., & MANDIC, O. 2008. Neogene lake systems of Central and South-Eastern Europe: Faunal diversity, gradients and interrelations. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 260: 417–434.

ILIĆ, A. & NEUBAUER, F. 2005. Tertiary to recent oblique convergence and vrenching of the Central Dinarides: constrain from paleostress study. *Tectonophysics*, 410 (1–4): 465–484.

IVANOV, D. 2002. Late Neogene flora and vegetation from the Bitola basin (FYR of Macedonia) based on palynological data. *Acta Universitatis Carolinae, Geologica*, 46 (4): 65–74.

JENKO, K & GJUZELKOVSKI, D. 1957-1958. Kiselgursaette zwischen der Dorfe Manasti Bešište (Mariovo). *Trudove Geozavod Macedonia*.6, 211-225.

JIMENEZ-MORENO, G., DE LEEUW, A., MANDIC, O., HARZHAUSER, M., PAVELIĆ, D., KRIJGSMAN, W., & VRANJKOVIĆ, A. 2009: Integrated stratigraphy of the early Miocene lacustrine in the Dinaride deposits of Pag Island (SW Croatia): palaeovegetation and environmental changes in the Dinaride Lake System. Palaeogeography, Palaeoclimatology, Palaeocology, 280 (1–2): 193–206.

JURANOV, S. IVANOV, M.,YOLKICHEV, N., KOZHUCHAROV, D., NIKOLOV, T., POPOV, N., ROUSKOVA, N., SAPUNOV, I., TENCHOB, Y., TRONKOV, D., CHEMBERSKI, N. & TSCHOUMACHENKO, P. 1993. Glossary of the formal lithostratigraphic units in Bulgaria (1882–1992). 399 pp. Bulgarian Academy of Sciences (in Bulgarian).

JOVANOVIĆ, G. 1992. Paleoecological and taphonomic analyses of a fossiliferous red in badenian sediments of Žuti Breg near Golubac, Eastern Serbia. *Geološki anali Balkanskoga poluostrva,* 55 (2):309–219.

JOVANOVIĆ, G., TOMIĆ Z., 1997: Paleoecological and mineralogical methods in living conditions reconstruction in Badenian age at Golubac (Eastern Serbia). *Geološki anali Balkanskoga poluostrva,* 61 (2): 371–392.

JOVANOVIĆ, O. & DOLIĆ, D. 1994. Novi nalazi sarmata u okolini Tabanovića (Valjevsko-Mionički basen). *Vesnik Geozavoda*, A, 46: 183–192.

JOVANOVIĆ, G. & KRSTIĆ, N. 2010. Mekušci i ostrakode srednjemiocenskog Srpskog jezera. 15 Kongres geologa Srbije, Zbornik radova, 77–81.

JOVANOVIĆ, O., GRGUREVIĆ, D. & ZUPANČIĆ, N. 1994. The Neogene sediments in Valjevo–Mionica basin. *Vesnik Geozavoda*, A/B, 46: 207–226 (in Serbia, English abstract).

JOVANOVIĆ, G., KRSTIĆ, N., KOVALENKO, V. & PRYSJAZHNJUK, V. 2005. Paleoecology of Pliocene lake a Mazgoš (Estern Serbia). *In*: RUNDIĆ, LJ., JOVANOVIĆ, G. & SIMIĆ, V. (eds.), First International Workshop Neogene of Central and Southeastern Europe, Serbian, Geological Society Abstracts: 22-23, Fruška Gora.

JURIŠIĆ-POLŠAK, Z., SAKAČ, K., POJE, M. 1997. New Pliopleistocene gastropods from Lika, Croatia. *Natura Croatie*, 6 (1): 91–111.

KARAMAN, G. & BEETON, A. 1981. The biota and limnology of Lake Skadar. *In*: KARAMAN, G. & BEETON, A. (eds.) Monitoring programe for the protection of Lake Skadar (pp. 425–428); BEETON, A. & KARAMAN, G. General summary (429–436), (443–449). Univerzitet "Veljko Vlahović", Institut za Biološko-medecinska istraživanja SRCG, Biološki Zavod Titograd, Smithsonian Institut Washington, D.C.,-Center for greate Lakes Study University of Wisconsin: 468 pp. Titograd.

KNEŽEVIĆ, S. 1996. Neogene of Levač. Neogene of Central Serbia. Neogene of Paratethys. *In*: N. KRSTIĆ (ed.), IGCP project 329, Special publication of Geoinstitute, 19: 23–27, Beograd.

KNEŽEVIĆ, S. 1997. The Kruševac Tertiary basin. Neogene of Paratethys. Proceedings of the Field Meetings in Serbia of IGCP project 329. *In*: MIHAJLOVIĆ, Đ. & KRSTIĆ, N. (eds.), Special publication Geonstitute, 21: 99–106, Beograd.

KOCHANSKY, V. & SLIŠKOVIC, T. 1978. Miocenske kongerije Hrvatske, Bosne i Hercegovine. *Paleontologia Jugoslavica*, 19: 1–98.

KORPÁS-HÓDI, M., POGÁCSÁS, G. & SIMON, E. 1992. Paleogeographic outlines of the Pannonian s. l. of the southern Danube-Tisza Interfluve. *Acta geologica Hungarica*, 35 (2): 145−163.

KOUFOS, G. D. & DE BONIS, L. 2004. The late Miocene hominoids Ouranopithecus and Graecopithecus. Implications about their relationship and taxonomy. In: 5th International Symposium of Eastern Mediterranean Geology, abstract, pp. 322–325, Thessaloniki.

KRÄUTNER, H.G. & KRSTIĆ, B. 2003. *Geological map of the Carpatho-Balkanides between Mehadia, Oravita, Niš and Sofia,* Scale (1: 300 000). Geoinstitute, Belgrade.

KRSTIĆ, N. 1978. Ostrakodi u miocenu Beogradskog dunavskog ključa. *Zbornik radova IX kongresa geologa Jugoslavije*: 117–125, Sarajevo.

KRSTIĆ, N. 1987a. Three new ostracode genera from lacustrine Miocene. *Bulletin de l' Académie serbe des sciences et des arts*, 92, *Classe des sciences mathématiques et naturelles*, *Sciences naturelles,* 27: 129–140.

KRSTIĆ, N. 1987b. Ostrakodi iz neogena Rabitlja i Otilovića, Plevlja (Montenegro). SANU, Odeljenje prirodnih nauka, Zbornik radova posvećen akademiku Z. Bešiću, 1: 75–94, Titograd.

KRSTIĆ, N. 2000. Some ostracodes from the Dinaric Alps Neogene and its paleoecology. *In*: KARAMATA, S. & JANKOVIĆ, S. (eds.), *Geology and metalogeny of the Dinarides and the Vardar Zone*, 207–217. Academy of Sciences and Arts of the Republic of Srpska, Banja Luka–Serbian Sarajevo.

KRSTIĆ, N. 2006. Pliocene ostracodes of the Paludinian Beds in Pannonian Plain, serbian part. *Natural History Museum*, *Special issue,* 1, 383 pp, Belgrade.

KRSTIĆ, N. & BOSSIO, A. 1992. Some new ostracode species from Upper Maeotian. Proceedings of Geoinstitute, 26: 175–199 (in Serbian, English summary).

KRSTIĆ, N. & KOMARNICKI, S. 1996. Maximal spreading of the Serbian Lake (possible of the Lower Badenian age). *In*: BABUŠKA, V. (ed.), Symposium Neogene stratigraphy and paleontology of Kerch and Taman Peninsulas. IGCP project 329 & 343, 18–19. Moscow–Krasnodar–Anapa.

KRSTIĆ, N. & GUAN, S. 2000. A proposal for the systematics of the subfamily *Candoninae* (Ostracodes) with the description of *Macedocandona* new genus. *Geologica Macedonica*, 14: 25–48.

KRSTIĆ, N. & VELITZELOS, E. 2002. Lacustrine Pliocene of Scoura near Sparti (Peloponesos) and its ostracodes. *Bulletin de l' Académie serbe des sciences et des arts*, 125*, Classe des sciences mathématiques et naturelles*, *Sciences naturelles*, 43: 169–197.

KRSTIĆ, N. & KEYSER, D. 2010. Two new endemic bimucronate Candoninae-genera from the Upper Pliocene of Metohia (Ostracoda, Crustacea). *Bulletin de l' Académie serbe des sciences et des arts*, 140*, Classe des sciences mathématiques et naturelles*, *Sciences naturelles*, 46: 105–129.

KRSTIĆ, N., SIKOŠEK, B. & KRSTIĆ, N. 1988. The Neogene tectonics of the Yugoslav Carpathian–Balkanides. Proceedings of Geoinstitute, 22: 77–85 (in Serbian, Engilsh summary).

KRSTIĆ, N., KNEŽEVIĆ, S. & PAVIĆ, S. 2007. Fauna of a large early Middle Miocene lake of Serbia. *Joannea*,*Geologie und Paleontologie*, 9: 51–54.

Krstić, N., Jovanović, G., & Savić, Lj. 2010b. The Freshwater Ostracodes and Accompanied Gastropodes of Kupres in the Lower Dinaric Lake System (Ottnangian) at an Altitude of 1,150 m. Molasse Group Meeting 2010, Program & Abstracts, 27 pp., München.

Krstić, N., Jovanović, G., Savić, LJ. & Bodor, E. 2003. Lower Miocene lakes of the Balkan Land. *Acta Geologica Hungarica*, 46 (3): 291–299.

Krstić, N., Semenenko, V., Velitzelos, E. & Safak, U. 2005. Lacustrine Upper Pliocene in the Southern and Middle Europe. *Bulletin de l' Académie serbe des sciences et des arts*, 130*, Classe des sciences mathematiques et naturelles*, *Sciences naturelles*, 43: 107–121.

Krstić, N., Dumurdžanov, N., Ognjanova-Rumenova, N. & Marković, Z. 2008. Central Macedonian Lake with its satelite basins. Proceedings of First geological congres of Republic of Macedonia, *Special publication of Geologica Macedonica,* 2: 57–62.

Krstić, N., Žic, J., Savić, Lj., & Soulie-Marsche, I. 2010a. Importance of the Charophyta for the Dinaride Tectonic structure explanation–stratigraphy and paleogeography. Proceedings of 15th Congres of Geologists of Serbia, 115–119. Belgrade.

Krstić, N., Jovanović, G., Ilić, B. & Kovalenko, V. 2011. Miocene fossils from Jelovik at the foothills of Bukulja mountain. *Comptes Rendus des* séances *de la société Serbe de géologie pour l'année* 2008, 23-53. (in Serbian).

Krstić, N., Olujić, J., Đajić, S., Milutinović-Đorđević, D. & Tanasković, LJ., 2009. Fossils from the drill hole GS-1 near Gacko, Republic of Srpska. *Bulletin of Natural history Museum*, 2: 35–61.

Krstić, B., Kalenić, M., Divljan, M., Maslarević, Lj., Đorđević, M. & Antonijević, I. 1970. Sheet for Knjaževac K-34 -21 and Belogradčik K 34-22: 1-7. *In*: Dimitrijević, M., Karamata, S., Sikošek, B.& Veselinović, D. (eds.), Explanatory booklet of the Basic Geological Map of the SFR Jugoslavia, 1: 100 000. Federal geological survay, Beograd.

Krstić, N., Krsmanović, R., Čađenović, D., Mirković, M, Pulejković, D., Dodiković, S. & Potkonjak, B. 1994. Condition of accumulations and the age of the coal and cement marl in the Potrlice deposit–Pljevlja. *Radovi Geoinstituta*, 29: 105–120 (in Serbian, English summary).

Krstić, N., Dumurdžanov, N., Bratuljević, N., Milićević, V., Simić, M., Radovanović, S. & Aleksić, I. 1999. Pliocene tectonics of southern Serbia and adjoining regions. *Bulletin de l'Académie serbe des sciences et des arts*, 119, *Classe des sciences mathématiques et naturelles*, *Sciences naturelles,* 39: 99–121.

Kühn, O. 1963. Das Süßwassermiozän von Attica. *Praktika Akademiai Atinion*, 38: 370–400.

Kumati, L., Myftar, S. & Gjani, E. 1997. The geological setting of lacustrine-marine basins in eastern Albania and their origin. Proceedings of Field meeting of IGCP project 329, Special publication Geoinstitute, 21: 107–118, Beograd.

Leeuw de, A., Mandić, O., Vranjković, A., Pavelić, D., Harzhauser, M., Krijgsman, W. & Kuiper, F.K. 2010. Chronology and integrated stratigraphy of Miocene Sinj Basin (Dinaride lake System, Croatia). *Palaeogeography, Palaeoclimatology, Palaeoecology,* 292: 155–167.

Lourens, L. J., Hilgen, F. J., Laskar, J., Shackleton, N. J. & Wilson, D. 2004. The Neogene Period. *In*: Gradstein, F. M., Ogg, J.G. & Smith, A.G. (eds.), *A Geologic Time Scale 2004*, 409–440. Cambridge University Press, Cambridge.

Lüttig, G. & Mrinos, G. 1962. Zur Geologie der neuen griechische Braunkohle-Lagre-stäte von Megalopolis. *Braunkohle*, 14 (6): 222–231.

Magyar, I., Geary, H.D. Müller, P. 1999. Paleogeographic evolution of the Late Miocene Lake Pannon in Central Europe. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 147, 151–167.

Mandić, O., Pavelić, D., Harzhauser, M., Zupanić, J., Reischenbacher, D., Sachsenhofer, R.F., Tadej, N. & Vranjković, A. 2009. Depositional history of the Miocene Lake Sinj (Dinaride Lake System, Croatia): a long-lived hard-water like in a pullapart tectonic setting. *Journal of Paleolimnology*, 41: 431–452.

Marinescu, F., & Papaianopol, I. 1995. Chronostratigraphie und Neostratotypen, Neogen der Zentrale Paratethys, 9, Dacien. 530 pp.Editura Academiei Române, Bucuresti.

Marković, Z. 2003. The Miocene small mammals from Serbia–a review. *In:* Reumer, J.W.F. & Wessels, W. (eds.), Distribution and migration of Tertiary mammals in Eurasia, a volume in honour of Hans de Bruijn, *Deinsea*, 10: 393–398.

Marković, Z. 2008. Miocenski glodari (Rodentia) Srbije. Unpublisched Thesis, 152 pp. The Faculty of Mining and Geology, Unuversity of Belgrade.

Marković, Z. & Pavić, S. 2004. The correlation of the Miocene mammal fauna from Serbia with the adjascent region Miocene faunas. and Poster. The 10th International Congress of Geological Society Greece, Abstract, p. 499, Thessaloniki.

Marović M., Krstić N., Stanić S., Cvetković V. & Petrović, M. 1999. The evolution of Neogene sedimentation provincies of central Balkan Peninsula (Evolucija neogenih sedimentacionih prostora centralnih delova Balkanskog poluostrva). *Bulletin of Geoinstitute*, 36: 25–94.

Mihajlović, Đ. 1978. Fossil flora from Slanci near Belgrade. *Bulletin Museum histoire naturelle*, A, 33: 199–207.

Mihajlović, Đ. 1988. Miocene flora from the Levač basin, Kaludra village. Compte Rendu des Séances de la Société serbe de Geologie pour l'années 1985-1986, *Zapisnici Srpskog Geološkog Društva*: 143–149 (in Serbian, English summary).

Mikes, T.M, Baldi-Bekem, M., Kazmerm, M., Dunklm, I. & von Eynattenm, H. 2008. Calcareous nannofossil age constrains on Miocene flysh sedimentation in the Outher Dinarides (Slovenia, Croatia, Bosnia-Herzegovina and Montenegro). *In*: Siegesmund, S., Fügenschih, B. & Froitzheim, N. (eds.), Tectonic Aspects of the Alpine-

Dinaride-Carpathian System, Geological Society Special Publlication, 298: 335–363, London.

MILOJEVIĆ, R. 1966. Uticaj mladotercijarnih tektonskih pokreta na opšti geološki sklop Bosansko-Hercegovačkih Dinarida. *Geološki glasnik,* 11: 9–32 (in Serbian, German summary).

MOSTAFAWI, N. 1988. Süßwasser-Ostracoden aus dem Plio-Pleistozän der Insel Kos (Griechenland). *Meyniana*, 40: 178–193, Kiel.

MOSTAFAWI, N. 1994. Ostracoden aus dem Ober Pliozän und Ober Pleistozän des N-Peloponnes. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 194 (1): 95–114.

OBRADOVIĆ, J. & VASIĆ, N. 2007. *Neogene lacustrine basins of Serbia*. Serbian academy sciences et arts, Monographs 662, Department of Mathematics, Physics and Geo Sciences, 3, 310 pp, Beograd (in Serbian, English summary).

OBRADOVIĆ, J., DJURDJEVIĆ-COLSON, J. & VASIĆ, N. 1997. Phytogenic lacustrine sedimentation–oil shales in Neogene from Serbia, Yugoslavia. *Journal of Paleolimnology,* 18: 351–364.

OGNJANOVA-RUMENOVA, N. 2000. Lacustrine diatom flora from Neogene basins on the Balkan Peninsula: Preliminary Biostratigraphical data. *In*: WITKOWSKI, A. & SIEMINSKA, J. (eds.), *The origin and early evolution of diatoms: Fossil, Molecular and Biostratigraphical Approaches*, 137–143. Polish Academy of Sciences, Cracow.

OGNJANOVA-RUMENOVA, N. 2001: Neogene diatom assemblages from lacustrine sediments of F.Y.R.O.M. (Macedonia) and their distribution in correlative formations of south-western Bulgaria. *In*: ECONOMOU-AMILLI, A. (ed.), 16th International Diatom Symposium 2000: 423–432, University of Athens, Athens & Aegean Islands.

OGNJANOVA-RUMENOVA, N. 2003. On micropaleontology and paleoecology of Miocene non-marine diatoms from Sivik Formation, Satovcha basin, Southwestern Bulgaria. *Phytologia Balcanica,* 9 (2): 207–220.

OGNJANOVA-RUMENOVA, N. 2006. Some aspects and problems concerning diatom biochronology for the Neogene in the region of the Balkan Peninsula. *In*: WITKOWSKI, A. (ed.), 18th International Diatom Symposium: 337–345, Bristol.

OGNJANOVA-RUMENOVA & KRSTIĆ, N. 2007. Neogene diatom assemblages from lacustrine sediments of Serbia and their distribution in the correlative formations in South-West Bulgaria and Republic of Macedonia. *In*: KUSBER, H-W. & JAHN, R. (eds.), *Proceeding of 1st Central- European Diatom Meeting* 2007: 121–124, Berlin.

PANTIĆ, N. 1956. Biostratigrafija tercijarne flore Srbije. *Geološki anali Balkanskoga Poluostrva,* 24: 199–322.

PAPAIANOPOL, I., MATRINESCU, F., KRSTIĆ, N. & MACALEȚ, R. 2003. Chronostratigraphie und Neostratotypen, Pt. 2, Romaniaen, 527 pp. Editura Academiei Române, Bucuresti.

PAPP, A. 1979. Zur Kenntnis neogener Süßwasserfaunen in Attika (Griechenland). *Annales geologiques pays Hellenique*, 29: 664–678.

PAPP, A., MARINESQU, F. & SENEŠ, J. 1974. Chronostratigraphie und Neostratotypen. *In*: SENEŠ, (ed.). Miozän der Zentralen Paratethys 4, M5, Sarmatien.-Veda, Bratislava, 707 pp.

PAPP, A., JAMBOR., Á. & STEININGER, F.F. 1985. M6-Pannonien (Slavonien und Serbien). Chronostratigraphie und Neostratotypen. Miozän der Zentralen Paratethys 7, 636 pp.

PAVLIDES, S.B. & MOUNTRAKIS, D.M. 1987. Extensional tectonics of northwestern Macedonia, Greece, since the late Miocene. *Journal Structural Geology*, 9: 385–389.

PAVLOVIĆ, P. 1903. Zwei neue Arten aus Zvezdan und Madjare. *Geološki anali Balkanskoga poluostrva*, 6 (1): 324–325, Beograd.

PAVLOVIĆ, P. 1931. O fosilnoj fauni mekušaca iz Skopske kotline. *Glasnik Skopskog naučnog društva,* 9, Odeljenje prirodnih nauka, 3: 1–28.

PEŠIĆ, D. & KOPRIVICA, D. 1996. Dacite tuff of Popovac. Special publication of Geoinstute, Neogene of Paratethys, 19: 1–47, Beograd.

PIPIK, R. 2001. Les ostracodes d'un lac ancien et ses paléobiotope au miocène supérieur: le Basin de Turiec (Slovaquie). Thèse. Unpublisched, Université Claud Bernard, 337 pp., Lyon.

POPOV, S.V., RÖGL, F., ROZANOV, A. Y., STEININGER, F.R., SHCHERBA, I. G. & KOVAČ, M. (eds.) 2004. Lithological-Paleogeographic Maps of Paratethys. 10 Maps Late Eocene to Pliocene. *Courier Forschungsinstitut Senkenberg*, 250: 1–46.

PRELEVIĆ, D., FOLEY, S. F., ROMER, R. L., CVETKOVIĆ, V. & DOWNES, H. 2005. Tertiary ultrapostassic volcanism in Serbia: constrains on petrogenese and mantle source characteristics. *Journal of Petrology,* 46 (7): 1445–1487.

PRILO, S. & HASANAJ, L. 2002. Biostratigraphy and paleoenvironments of the late Messinian sediments of the Dures-Lushnja area, Albania. *Bulletin de l' Académie serbe des sciences et des arts,* 125, *Classe des sciences mathématiques et naturelles*, *Sciences naturelles*, 41: 89–96.

PRYSJAZHNJUK, V. 2008. Terrestrial and freshwater molluscs of Trijebine, Sjenica (Southwester Serbia). *Bulletin de l' Academie serbe des science et des arts*, 138, *Classe des sciences mathématiques et naturelles, Sciences naturelles*, 44: 85–109.

PRYSJAZHNJUK, V.A. & RUDJUK, V.V. 2005. Buliminidae i Planorbidae (Mollusca, Pulmonata) iz mestonahozhdenia Vračević. *In*: GOZHYK, P. (ed.), *Biostratigrafichni kriterii rozčlenuvania ta korelacii vikladiv fanerozoiu Ukraini*, 9 pp. Institute of Geological Sciences National Academy of Sciences of the Ukraine, Kiev.

PRYSJAZHNJUK, V., KOVALENKO, V. & KRSTIC, N. 2000. On the terrestrial and freshwater mollusks from Neogene of Western Serbia. *In*: KARAMATA, S. & JANKOVIĆ, S. (eds.), *Geology and metalogeny of the Dinarides and the Vardar Zone*: 219–224. Academy of Sciences and Arts of the Republic of Srpska, Banja Luka–Serbian Sarajevo.

RADOIČIĆ, R., DE CAPOA, P. & D'AEGENTIO, B. 1989. Late rather than early Tertiary deformations of External Dinarides, stratigraphic evidence from Montenegro. *Rendiconto Accademia Scienze Fisicche Mathematiche*, 4, 56: 41–59.

RODRIGUEZ-LAZARO, J. & MARTIN-RUBIO, M. 2005. Pliocene Ilyocyprididae (Ostracoda) from the Ebro Basin (N. Spain). *Revue de Micropaleontology*, 48: 37–49.

RÖGL, F. 1998. Paleogeographic considerations for Mediterranean and Paratethys seaways (Oligocene to Miocene). *Annalen Naturhistorisches Museum Wien*, 99 (A): 279–310.

ROYDEN, L. H. & HORVATH, F. 1988. The Pannonian basin-a study in basin evolution. *American Association of Petroleum Geologist, Memoire*, 45: 1–394 .

SOKAČ, A. 1978. Pleistocene ostracode fauna of Pannonian basin in Croatia. *Paleontologia Jugoslavica*, 20: 1–51.

SOKAČ, À. & KRSTIĆ, N. 1987 Ostracode fauna of some non-marine Neogene basin in Yougoslavia. *Geološki Vjesnik*, 40: 45–52.

STACHE, G. 1889. Die liburnische Stufe und deren Grenzhorizonte. *Abhandlungen Geologischen Reichsanstalt*, 13: 1–170.

STEENBRINK, J. 2001. Orbital signatures in lacustrine sediments: The late Neogene intramontane Florina-Ptolemais-Servia Basin, northeastern Greèce. *Geologica Ultraiectina*, 205: 1–167.

STEENBRINK, J., VAN VUGT, N., KLOOSTERBOER-VAN HOEVE, M. L. & HILGEN, F. J. 2000. Refinement of the Messinian APTS from sedimentary cycle patterns in lacustrine Lava section (Servia Basin, NW Greèce). *Earth and Planetary Sciences Letters*, 181: 161–173.

STEININGER, F. F. 1999. Chronostratigraphy, geochronology and Biochronology of the Miocene "European Land Mammal Mega-Zones" (ELMMZ) and the Miocene "Mammal- Zones (MN-Zones)". *In*: ROSSNER, G. & HEISSING, K. (eds.), *The Miocene Land Mammals of Europe*: 9–24. Pfeil, München.

STEVANOVIĆ, P. 1959. Fossile Eier in den Miozänen Schichten von Brajkovac nahe Ljig im nördlichen Serbien. *Geološki anali Balkanskoga poluostrva*, 26: 153–162 (in Serbian, German summary).

STEVANOVIĆ, P. 1964. Contribution à la connaisance de l'étage Pontien de Grèce avec une remarque spécial sur le Pontien de la Mèr Noire. Instituto Lucas Mallada de Investigaciones Geologicas. Cursillos y Conferencias del Instituto Lucas Mallada, 9, Madrid.

STEVANOVIĆ, P. 1977. Pocerina, Posavo-Tamnava, Kolubarski basen. *I:* PETKOVIĆ, K. (ed.) *Geologija Srbije, Stratigrafija, Kenozoik 2(3)*, 225–243. Zavod za regionalnu geologiju i paleontologiju Rudarsko geološkog fakulteta, Univerzitet u Beogradu, Beograd (in Serbian).

STEVANOVIĆ, P., PAVLOVIĆ, M. & EREMIJA, M. 1977a. Kačersko-Jasenički basen. *In:* PETKOVIĆ, K. (ed.) *Geologija Srbije, Kenozoik 2(3)*, 189–192. Zavod za regionalnu geologiju i paleontologiju Rudarsko geološkog fakulteta, Univerzitet u Beogradu, Beograd (in Serbian).

STEVANOVIĆ, P., PAVLOVIĆ, M. & EREMIJA, M. 1977b. Stratigraphische Lage der Kosovia-Horizontes im Süßwasserneogen Serbiens (Šumadija und Morava Gebiet). *Comptes Rendus des séances de la société Serbe de géologie pour l'année* 1975–1976: 77-81 (in Serbian, German summary).

STEVANOVIĆ, P. 1985. Malakologische und stratigraphische Fragmente aus dem Baljevac am Ibar Neogenbecken. *In*: Neue Beiträge zur Palaeontologie und Stratigraphie aus dem Neogen Jugoslawiens. *Comptes Rendus des* séances *de la société Serbe de géologie pour l'année* 1984: 185–197 (in Serbian, German summary).

STEVANOVIC, P., NEVESSKAYA, L. A., MARINESCU, F., SOKAC, A., JÁMBOR, A. 1989. Chronostratigraphie und Neostratotypen: Neogen der Westlichen ("Zentrale") Paratethys VIII, Pliozän Pl1. Pontien. *In*. MALEZ, M. STEVANOVIĆ, P. (eds.), JAZU & SANU, Zagreb-Beograd. 952 pp.

TEMNISKOVA-TOPALOVA, D. & OGNJANOVA-RUMENOVA, N. 1997: Description, comparison and biostratigraphy of the nonmarine Neogene diatom floras from southern Bulgaria. *Geologica Balcanica*, 27 (1–2): 57–81.

VATSEV, M. 2004. Oligocene and Neogene stratigraphic cycles of the Sredna Gora trough zone (Central Bulgaria*). Bulletin de l'Académie serbe des sciences et des arts,*128, *Classe des sciences mathématiques et naturelles, Sciences naturelles*, 42: 47–75.

VASS, D., KRSTIĆ, N., MILIČKA, J., KOVAČOVA-SLAMKOVA, M., OBRADOVIĆ, J. & GRGUREVIĆ, D. 2006. Organic matter and fossil content in Serbian oil shales: Comparison with oil shales of Central Europe. *Slovac Geologic Magazine*, 12 (2): 147–158.

VELITZELOS, E. & GREGOR, I., J. 1990. Some aspects of Neogene floral history in Greèce. *Review of Palaeobotany and Palynology*, 62 (3–4): 291–307.

VUJNOVIĆ, L., KRSTIĆ, N., OLUJIĆ, J., JEČMENICA, Z., MIJATOVIĆ, V. & TOKIĆ, S. 2000. Lacustrine Neogene of the Dinaric Alps. *In*: KARAMATA, S. & JANKOVIĆ, S. (eds.), *Geology and metalogeny of the Dinarides and the Vardar Zone*: 197–206. Academy of Sciences and Arts of the Republic of Srpska, Banja Luka–Serbian Sarajevo.

ZAGORČEV, I. 2001. Introduction to the geology of SW Bulgaria. *Geologica Balkanica*, 31 (1–2): 3–52.

YANEVA, M., OGNJANOVA-RUMENOVA, N. & NIKOLOV, G. 2002. Palaeoecological development of Gotse Delchev basin, SW Bulgaria, during the Neogene. *Development and State of Environment, Proceedings of Internatuional Scientific Conference in Memory of Prof. Dimitar Jaranov*: 36–47 (in Bulgarian). Varna .

YOUTANG, H., YUNXIAN, G., & DEQIONG, CH. 2002. Superfamilies Cypridacea and Darwinulidacea. Fossil Ostracoda of China 1, Nanjing Institute of Geology and Palaeontology, Academia Sinica, 1090 pp. (in Chinese, English summary).

Резиме

Неогена језера на Балканском копну

Време настанка и распоред језерских басена на Балканском полуострву последица су кретања тектонских плоча и других процеса који су се дешавали на граници астеносфере и литосфере.

Вода Шумадијског језера је била доста кисела јер у њему нису нађени аутохтони карбонатни фосили. Може се претпоставити да је језеро настало урушавањем магматске коморе из које су се већ избила бројна магматска тела, укључујући масиве Борач и Котленик.

Динаридски систем језера је продукт пулсационе индентације Јадранских плоча ка северу. Динаридски планински систем је настао подвлачењем, што је изазивало постепено издизање млађих седимената и висинску разлику од око две хиљаде метара између истих слојева, као на пример између Ливањског поља и слатководних биофација Купреса. Апсолутна старост млађег „конгеријског" дела Сињског неогена, таложеног у минерализованој води, износи 17,92 ± 0,18 Ma.

Пространо Српско језеро настало је услед постколизионог одбијања западног и источног Балканског острва. У његовом источном делу, повијањем Карпато-Балканида дошло је до покривања старијих седимената са мезозојским и другим старијим седиментима меридионалног правца. У млађем субхоризонталном делу могу се разликовати приобалске кречњачке творевине са *Kosovia* и ситнозрни силицикластити богатих бентоском фауном са малим индикацијама минерализације. Профундал дубљих делова језера високо је минерализован са добро сачуваним остацима риба. На основу дијатомеја може се закључити да се према југу језеро пружало до Симитли потолине у ЈЗ Бугарској.

Морски баден је касније са севера продро у Српско језеро, најдаље у Моравском заливу; средњи баден, у сарматоидној биофацији се простире се код Крушевца. Други заливи су били краћи и плићи: у Млавском заливу је меиофауна слатководног типа, а гирогонити харацеа су бројни. Морска средњобаденска фауна је продрла дуж реке Босне до Добоја, а у Бугарску и источну Србију је бечки тип бадена стигао преко Румуније, дуж реке Олт.

Уопште посматрано северна граница седимената Српског језера, приближно правца З–И полако се померала према југу, па у појасу јужни Банат–Папук морски доњи баден постепено је израстао из језерског пребадена. У појасу који пролази кроз Београд заступљен је само средњи баден, а јужно од Букуље и у Ваљевско-мионичкој потолини језерско-речни доњи волин са *Potamocypris* и конкордантно је прекривен бракичним кречњаком средњег волина са *Mactra*.

На северном и западном ободу Панонске низије дубоки заливи су били настањени ендемичном фауном. Нека је одређена као сармат (кости кичмењака), друге су у Мађарској еквиваленти бадена и садрже црноморске биофације.

Две горњомиоценске језерске фазе Паратетиса – "Панонско море" и његов много пространији понтијски наследник – само малим делом залазе према југу на простор Балканског копна.

Егејски колапс је достигао на север до Врања. Дејство колапса се осећало у простору средње Македоније као и ЈЗ Бугарске. Централно Македонско језеро је било тектонски мобилни простор, отуда старији грубокластични талози са остацима сисара (Велес, Калиманци и др.) захватају шире подручје него млађи финозрни језерски талози са ендемичном макро и меиофауном и богатом микрофлором. Централно Македонско језеро је на југу делимично одвојено од понта Егејског језера на југу. Осим Еордејског рова захвата још и бројне потолине, а простире се јужно од Атине и преко мора до Родоса и анадолског Ксантос грабена.

Плиоценска језера на северу незнатно залазе ка југу дуж обала Балканског копна. То су Палудинско и Дакијско-романијско језеро. У средњедунавској низији постепено снижење слaности воде одразило се на скулптуру врста рода *Viviparus* и бројност таксона Unionacea. Остракоде су заступљене скоро само халотолерантним врстама, мада има и ретких слојева са халофилима. У низији доњег Дунава јасно се препознају исушивања настала током дакијског ката као и водом богати романијски кат.

Унутар Карпата, депресија Брашов–Бараолт била је повезана са црноморским кујалником што је допирао до реке Бузау. Слична веза је постојала и јужно од Старе Планине јер су воде Црног мора преплавиле ЈИ део Балканског копна као последица обдукције Мале Азије на Балкан.

На југу Грчке, језерски плиоцен се у кратким интервалима наизменично смењује са морским биофацијама. То је био простор контакта вода Паратетиса и Медитерана. Местимични налази плиоценских творевина са *Viviparus* и меиофауном, према западу до Шпаније и према северу до Тирингије, отварају питања истоветности језерских биотопа касног плиоцена и транспорта ситнијих организама (укључујући ларве мекушаца) у перју птица селица.

Овај закључак представља досадашње познавање настанка, развоја и нестанка миоценских и плиоценских језера на Балканском копну.