Geologia Croatica	55/1	83 - 92	4 Figs.			ZAGREB 2002

The South-Western Boundary of Central Paratethys

Davor **PAVELIĆ**

Key words: Neogene, Dinarides, Central Paratethys, Mediterranean.

Abstract

Small Neogene basins within the Dinarides were never invaded by marine transgressions during their evolution. The fresh-water sedimentation, endemic fauna and their position between the Adriatic region and the Pannonian Basin System explain why these basins have not been considered as parts of the Mediterranean or Central Paratethys realm. The correlation of sediments and fauna of these fresh-water basins with the Pannonian Basin System and Adriatic region suggests that Dinaridic fresh-water basins may be considered as a part of the Central Paratethys. This consideration locates the southwestern boundary of Central Paratethys within the High Karst Belt.

1. INTRODUCTION

Paratethys was the intercontinental bioprovince, which began to evolve in the Oligocene due to the counter-clockwise rotation of Africa that caused the closure of the Tethys Ocean. It extended from the western Molasse Basin in Switzerland and the Rhone Basin in France towards Lake Aral in Asia. Paratethys is subdivided into Western Paratethys, Central Paratethys and Eastern Paratethys. The Central Paratethys extended from Bavaria to the Carpathian mountain chain (LASKAREV, 1924; SENEŠ, 1979; STEININGER & RÖGL, 1979, 1984; RÖGL & STEININGER, 1983, 1984; RÖGL, 1998, 1999) (Fig. 1). The nature of the evolution of Central Paratethys and the occurrences of an endemic fauna has necessitated the establishment of local Miocene stages (Fig. 2).

In the geotectonical sense, the largest part of Central Paratethys is represented by the Pannonian Basin System, formed due to continental collision and subduction of the European plate under the African (Apulian) plate (HORVÁTH & ROYDEN, 1981; ROYDEN, 1988; TARI et al., 1992; HORVÁTH, 1995; KOVÁČ et al., 1998). The Pannonian Basin System is surrounded by the Alps and Carpathian mountains, and by the Dinarides which existed as land between the Mediterranean Sea and Pannonian Basin System during its evolution. The southwestern part of the Pannonian Basin System consists of the North Croatian Basin and the Northern Bosnia region (PAVELIĆ, 2001).

The Dinarides represent a mountain complex, which formed during the Tertiary and Quaternary due to tectonic activity, which caused disintegration and uplift of the Mesozoic carbonate platform. In the Tertiary, compressive movements culminated with orogenesis of the Dinarides. Further neotectonic activity caused uplift and transpressive deformations of the older structure. These tectonics strongly controlled the formation of many small Neogene basins within the Dinarides which were characterized by fresh-water sedimentation and an endemic fauna. That tectonic activity has been strongest along the recent eastern Adriatic coast due to the continental collision of the Adriatic microplate and the Dinarides. This collision caused the compression and uplift of blocks which is represented by a mountain chain known as the High Karst Belt, the highest peaks of which reach from 1400-1913 m (BAHUN, 1974; PAPEŠ, 1985; HERAK, 1986, 1991, 1999; ALJINOVIĆ et al., 1987; BLAŠKOVIĆ, 1991, 1998, 1999; HERAK & TOMIĆ, 1995; MARINČIĆ et al., 1977; MATIČEC et al., 1997, 2001; PAMIĆ et al., 1998; DRAGIČEVIĆ et al., 1999; KUK et al., 2000; DRAGIČEVIĆ, 2001).

Several papers deal with the palinspastic reconstruction of Central Paratethys, or some parts of it during it's evolution (STEININGER & RÖGL, 1979, 1984; RÖGL & STEININGER, 1983, 1984; MARINESCU, 1992; KOVAČ et al., 1998, 2001; RÖGL, 1998, 1999; MAGYAR et al., 1999; GULYÁS, 2000; PAVELIĆ, 2001). In some of these articles the southwestern Central Paratethys boundary was constructed in the area of north Bosnia and central Croatia. However, these boundaries were not located in detail, and are, in part, incorrect due to a lack of data from this area, and a language problem. The locations of these boundaries also imply that the Neogene fresh-water basins within the Dinarides do not belong to Central Paratethys, neglecting the view of ANIĆ (1951-1953), who suggested that these basins might be a part of that realm during Sarmatian time. The correlation of Neogene sediments and fauna of fresh-water basins within the Dinarides with

Institute of Geology, HR-10000 Zagreb, Sachsova 2, Croatia;
e-mail: dpavelic@igi.hr

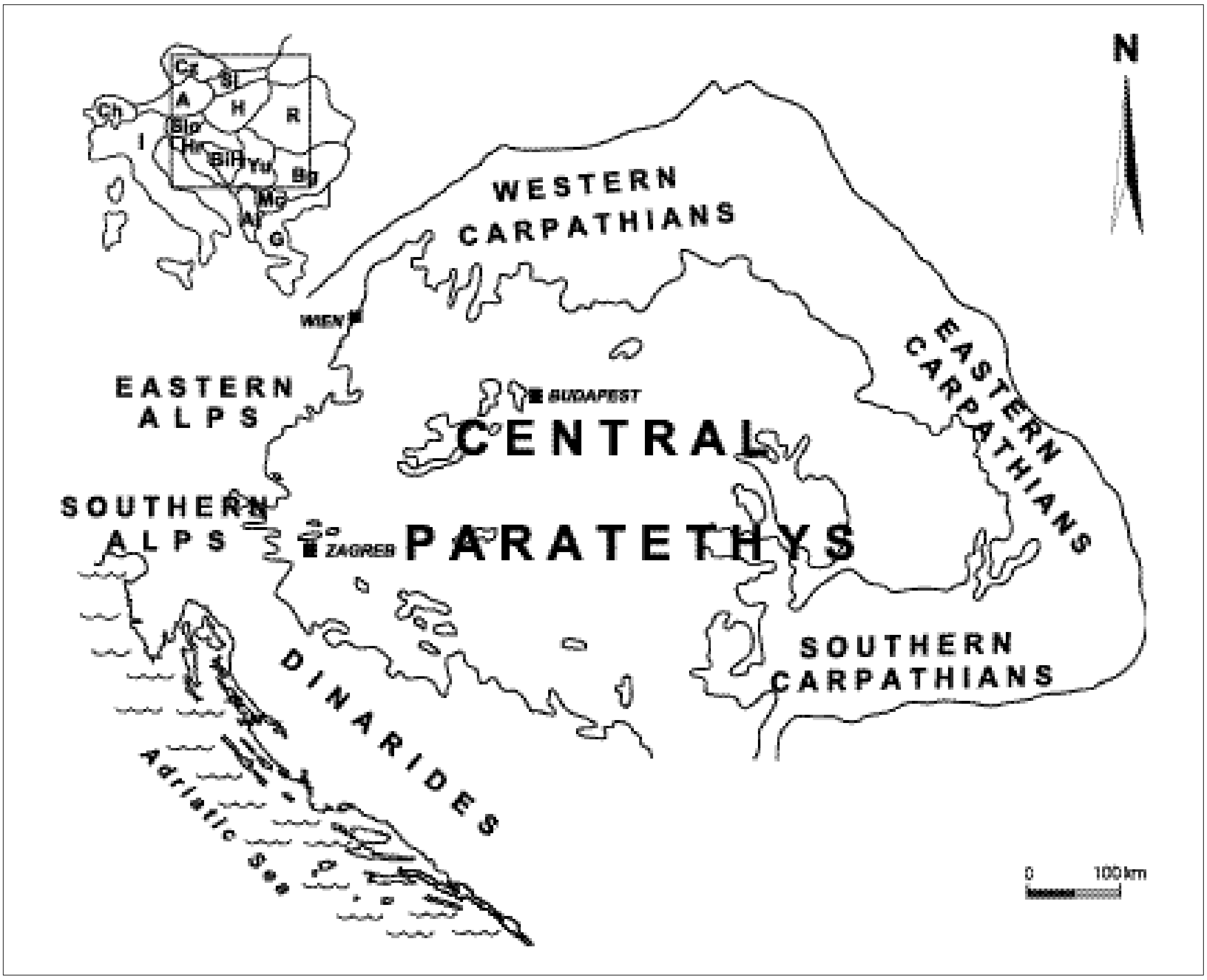

Fig. 1 Location of the Central Paratethys.

the North Croatian Basin and Northern Bosnia region, and with the Adriatic region, supports the suggestion that these fresh-water basins may be considered as a part of Central Paratethys, although there was no marine sedimentation.

2. THE NORTH CROATIAN BASIN AND NORTHERN BOSNIA REGION

The evolution of the North Croatian Basin and Northern Bosnia region, as a part of the marginal zone of the Pannonian Basin System was generated by continental rifting processes. The main depressions in this area represent elongated half-grabens formed by tectonic subsidence along the listric faults and strike-slip faults (TARI & PAMIĆ, 1998; LUČIĆ et al., 2001; PAVELIĆ, 2001). Formation of the North Croatian Basin and Northern Bosnia region started in the Ottnangian, with fresh-water deposition. The first phase was characterized by accumulation of coarse-grained breccias and conglomerates, with subordinate sandstones and siltstones. Deposition took place in braided alluvial fans, which were strongly influenced by synsedimentary tectonics (PAVELIĆ & KOVAČIĆ, 1999). In the central part of Mt. Papuk a salina-type lake developed (ŠĆAVNIČAR et al., 1983).

During the second sedimentation phase a hydrologically open fresh-water lake was formed in this area (KOCHANSKY-DEVIDÉ, 1979; PAVELIĆ, 2001; PAVELIĆ et al., 2001), in which silts and sands with sporadic layers of gravel were deposited, together with peats along the lake margins. The lake had an endemic fauna of molluscs and ostracods, such as *Congeria fuchsi*, *Unio* sp., and *Heterocypris* sp. (Fig. 3). Lacustrine deposits contain remnants of mammalian species *Prodeinotherium bavaricum*, *Gomphotherium angustidens* and *Brachypotherium brachypus* (RADOVČIĆ et al., 1998).

During Karpatian time lacustrine conditions were replaced by marine environments due to a minor marine transgression caused either by the opening of a Paratethyan seaway to the Mediterranean as a consequence of the tectonic activity within the Dinarides (STEININGER & RÖGL, 1979; HAMOR & SZENTGYÖRGYI, 1981; RÖGL & STEININGER, 1983, 1984; RÖGL,

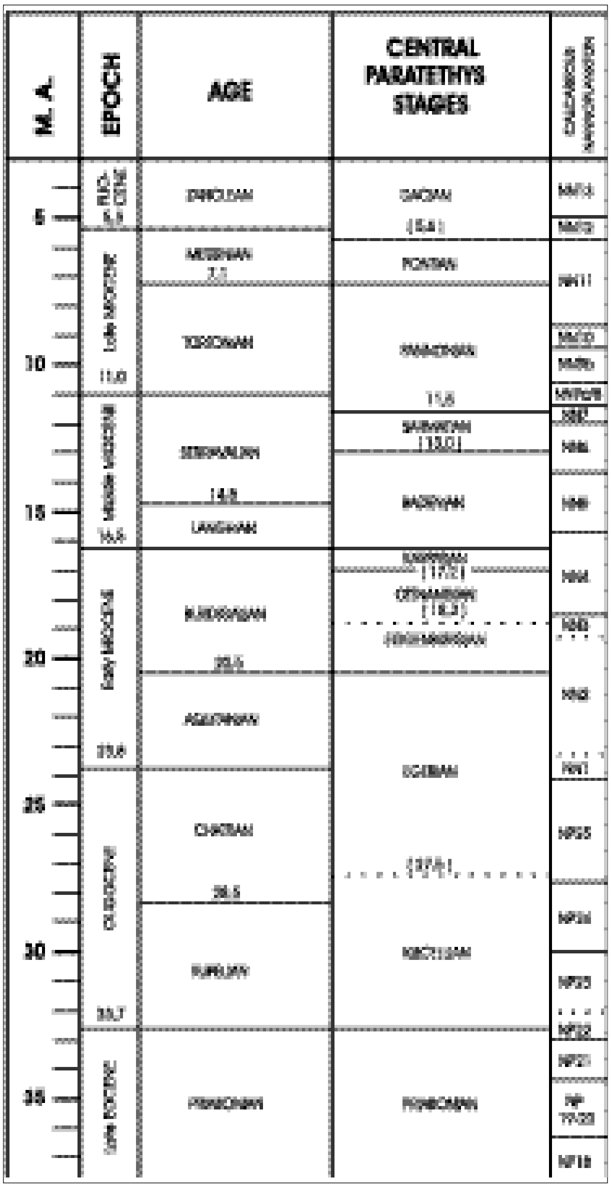

Fig. 2 Chronostratigraphic correlation of the Mediterranean and Central Paratethys Miocene, and calcareous nannoplankton biozonation (after RÖGL, 1996, and BERGGREN et al., 1995).

1998), or eustatic sea level rise (KOVAČ & HUDAČKOVA, 1997; KOVAČ et al., 2001). Deposition was characterized mainly by marls and silts with temporary input of coarse-grained siliciclastics into the basin, and sandy facies in the coastal environments (PAVELIĆ et al., 1998). The marine regime is indicated by foraminiferal and mollusc associations which are presented by *Pappina bononiensis*, *Quinqueloculina triangularis*, *Quinqueloculina akneriana*, *Ammobaculites agglutinans*, *Triloculina scapha*, *Dorothia gibbosa*, *Ammonia beccarii*, *Elphidium macellum* and others (Fig. 3). During Ottnangian and Karpatian time volcanic activity gradually increased, from pyroclastics to trachyandesites (shoshonites) (PAMIĆ et al., 1992/1993; PAVELIĆ, 2001). Marine environments continued into the Badenian.

The Early Badenian was characterized by a sea-level rise well correlated with the global sea-level rise at the beginning of the Middle Miocene (RÖGL & STEININGER, 1983; HAQ et al., 1987; STEININGER et al., 1989; RÖGL, 1996, 1998; KOVAČ & HUDAČKOVA, 1997; PAVELIĆ et al., 1998). Coarse-grained siliciclastic material was transported into shallow marine environments, and also to the relatively deeper marine environments, where marls and gravelly calcarenites were deposited (PAVELIĆ et al., 1998; VELIĆ et al., 2000). Favourable ecological conditions resulted in expansion of shallow- and deep-water benthic and planktonic species, such as *Amphistegina* sp., *Lenticulina cultrata*, *Cibicidoides ungerianus*, *Uvigerina pygmoides*, *Globigerina praebulloides*, *Globigerinoides trilobus* and *Preaorbulina glomerosa* (Fig. 3). Intense volcanism produced sequences a few hundred metres thick in some places. During the Late Badenian, the last Miocene marine transgression flooded this area. It was connected with the broad re-opening of the Indo-pacific seaway (RÖGL & STEININGER, 1983, 1984; STEININGER et al., 1988; RÖGL, 1996, 1998), and coincides with a temporary sea-level rise at 13.4 Ma (HAQ et al., 1987). Sedimentation was similar to that during the Early Badenian. The most important Late Badenian species are *Bolivina dilatata*, *Pappina neudorfensis*, *Ammonia beccarii* and *Spirorutilus carinatus*.

Due to the beginning of the isolation of the basin during the Sarmatian, brackish-water environments developed, resulting in deposition of shallow water gravel, biocalcarenites and limestones, and general dominance of fine-grained deposits in the deeper parts of the basin. Typical Sarmatian foraminiferal species are *Elphidium macelum*, *Elphidium josephinum*, *Anomalinoides badenensis* and *Porosononion granosum*. *Ervilia dissita dissita*, *Musculus sarmaticus* and *Cardium vindobonense* belong to the molluscan association.

In the Early Pannonian the environment became "caspi-brackish", locally even fresh, followed by expansion of endemic species of molluscs and ostracods, as a consequence of definite basin isolation (STEININGER et al., 1988). The Pannonian deposits consist of littoral lacustrine limestones, and deep water marls. The Pannonian fossil association contains *Radix croatica*, *Congeria banatica*, *Clivunella* sp. and *Hemicytheria croatica*. In the Pontian a gradual shallowing took place, reflected by increased terrigenous material. The species are also endemic, including *Paradacna okrugici*, *Paradacna abichi*, *Congeria croatica* and *Congeria rhomboidea*.

3. DINARIDIC FRESH-WATER BASINS

The Neogene basins in the Dinarides, i.e. in Bosnia and Herzegovina and in central and southern Croatia, represent depressions generated by tectonics (Figs. 1 and 4). They started to form at the end of the Palaeogene and

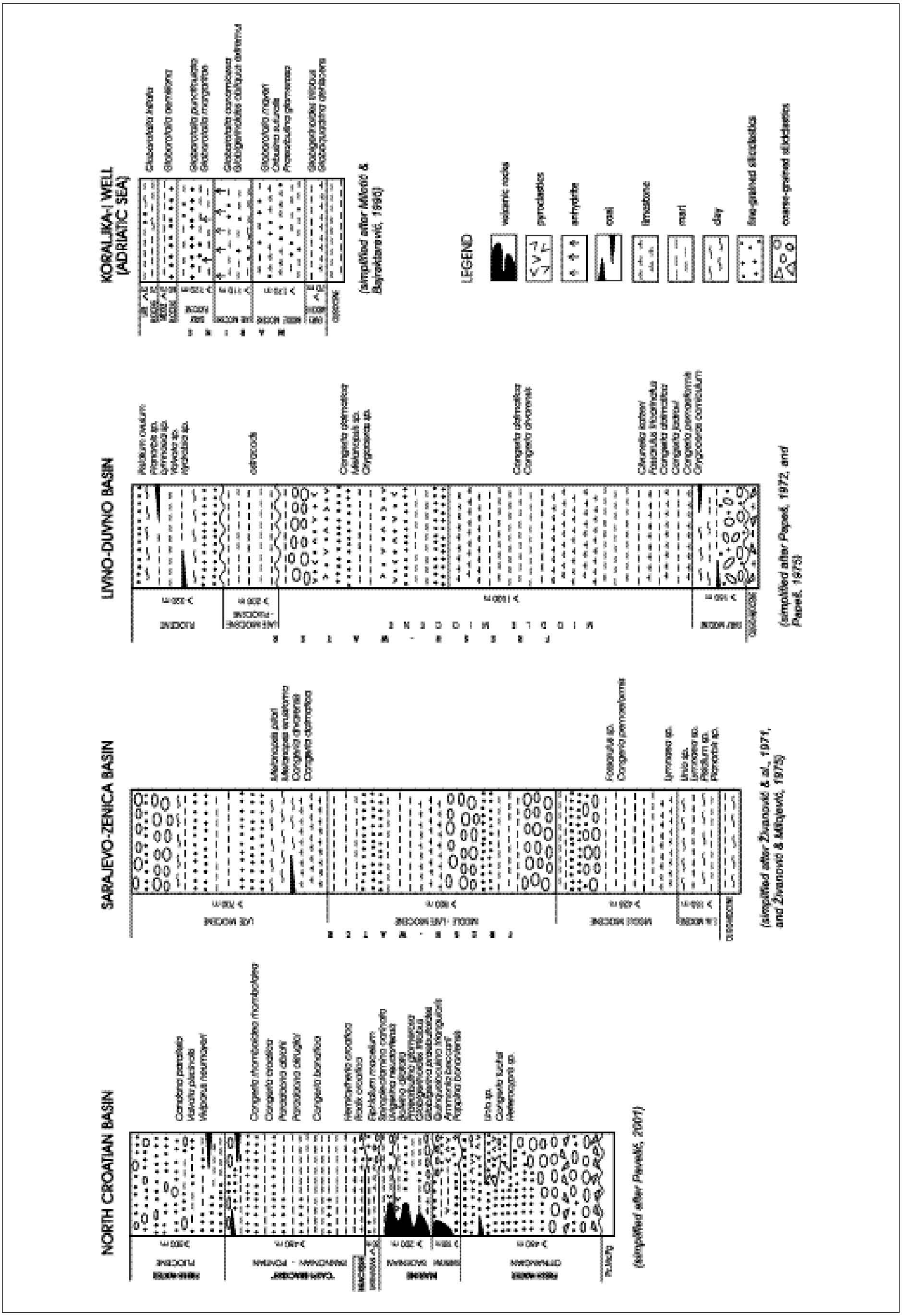

Fig. 3 Geological columns of the North Croatian Basin (Pannonian Basyn System), Sarajevo-Zenica Basin and Livno-Duvno Basin (Dinaridic fresh-water basins), and Koraljka-I Well (Adriatic region).

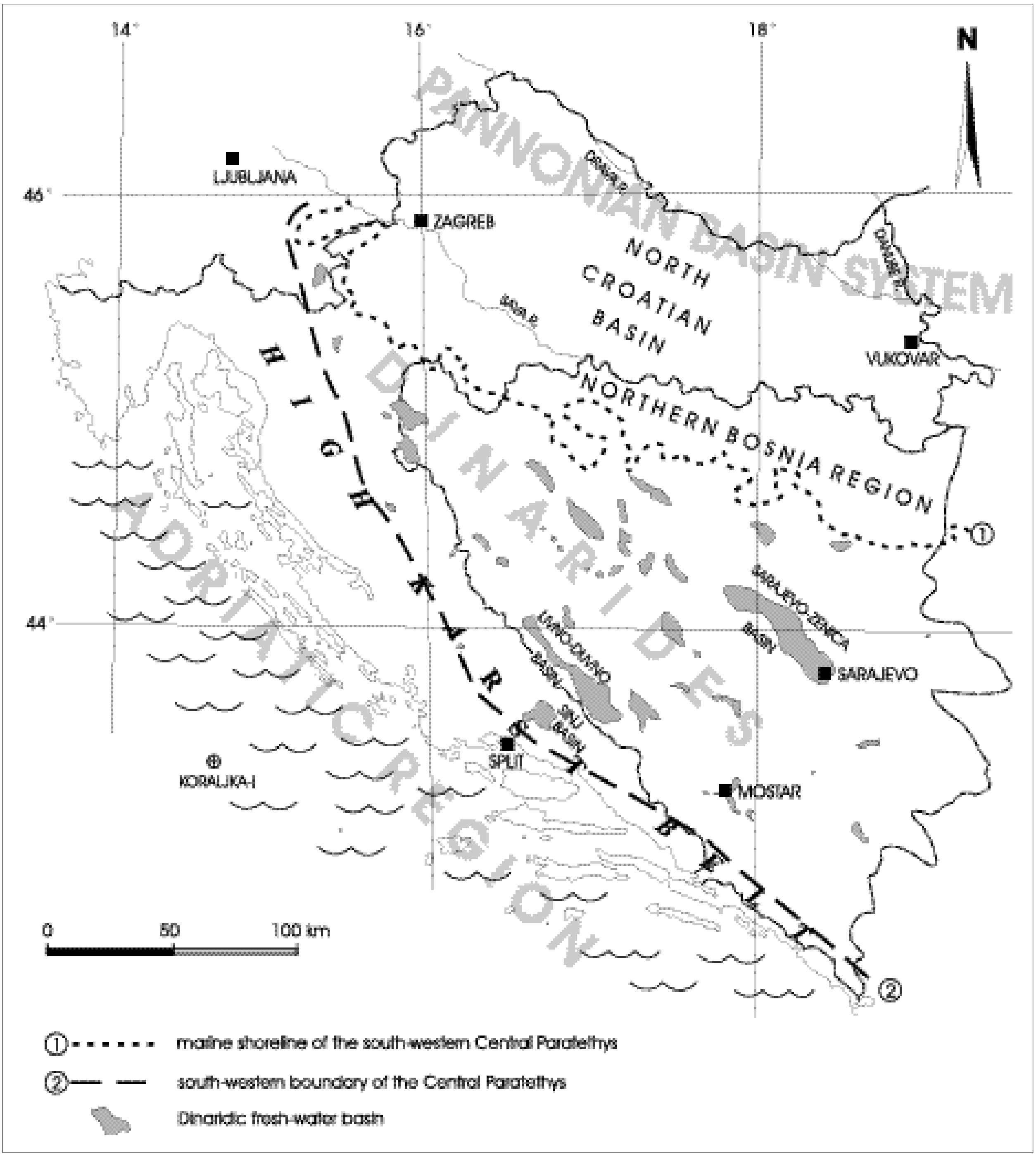

Fig. 4 Approximate locations of the south-western shoreline of the Paratethyan Sea, and the south-western boundary of Central Paratethys.

continued to evolve through the Neogene. The time of onset and the end of evolution of different basins was unequal, as was subsidence which varied from a few hundred to a few thousand metres in the deepest depressions (PAPEŠ, 1985). These basins occur in many areas, with dimensions which range from a few kilometres up to 70 km long and 18 km wide, such as the Sarajevo-Zenica Basin in central Bosnia (Fig. 4). Basins were temporarily connected during their evolution, and occupied much wider areas than at present (JURIŠIĆ-POLŠAK & SLIŠKOVIĆ, 1988). However, the strong neotectonic activity generated by the continental collision of the Adriatic microplate and the Dinarides caused uplifting of the Dinarides to the recent elevations, erosion of the Neogene sediments, and reduction of the dimensions of fresh-water basins (PAPEŠ, 1985; ALJINOVIĆ et al., 1987; BLAŠKOVIĆ, 1991, 1998, 1999; MATIČEC et al., 1997, 2001; PAMIĆ et al., 1998; DRAGIČEVIĆ et al., 1999; KUK et al., 2000; DRAGIČEVIĆ, 2001).

Thicknesses of the Neogene deposits in fresh-water basins vary from a few hundred metres to 1900 m in the Livno-Duvno Basin and 2600 m in the Sarajevo-Zenica Basin (Fig. 4). Siliciclastics dominate but marls and limestones also occur. Some sediments are coal-bearing (Fig. 3).

Neogene basins in this area were of fresh-water. Some sediments are determined as alluvial, lacustrine, or marsh and swamp, but there have been no detailed sedimentological data.

The main geological problem of these basins is the dating of sediments. Basins did not have any connection with the sea during their evolution, and endemic species with no chronostratigraphic value developed. Therefore, the Neogene is subdivided on the basis of local mollusc and ostracod associations, superposition, lithostratigraphic correlation, flora, and occasional mammal occurrences (Fig. 3). However, these stratigraphic interpretations are almost highly speculative, sometimes very confusing, and partly incorrect, and are therefore of little use for detailed correlations with Central Paratethys and Mediterranean stages.

Neogene sediments overlie the pre-Neogene basement or Oligocene deposits, and are characterised by frequent lateral and vertical variations, and different sedimentary thicknesses as a result of the independent local basin evolution. Columns for the Sarajevo-Zenica and Livno-Duvno Basin are shown in Fig. 3.

The following general description of sediments and fossil associations is summarized from several works, without a critical stratigraphic approach (SOKLIĆ, 1957; ČIČIĆ & MILOJEVIĆ, 1977; PAPEŠ, 1975; ŽIVANOVIĆ et al., 1975; MARINČIĆ et al., 1977; JOVANOVIĆ et al., 1978; KOCHANSKY-DEVIDÉ, 1976; KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, 1978; PAMIĆ et al., 1978; POLŠAK et al., 1978; SOKAČ, 1980; JURIŠIĆ-POLŠAK, 1984; RAIĆ et al., 1984; ŽAGAR-SAKAČ & SAKAČ, 1984; JURIŠIĆ-POLŠAK & SLIŠKOVIĆ, 1988; ŠUŠNJARA & SAKAČ, 1988; JURIŠIĆ-POLŠAK et al., 1993; OLUJIĆ, 1999).

The oldest Neogene sediments are dated as the upper part of the Oligo-Miocene. Siliciclastics predominate, the most frequent include conglomerates, sandstones, marls and clays. Characaean limestones and coal beds occur sporadically. A mollusc association contains *Helix rugulosa*, *Helix geniculata*, *Lymnaea socialis*, *Lymnaea dilatata*, *Planorbis* sp. and *Pisidium* sp.

Lower Miocene sediments are more widespread than Oligo-Miocene ones. They consist of clays, limestones, marls, sandstones, conglomerates and coal intercalations. Tuff is found in some basins. Dacite-andesite tuff beds in the Sinj Basin are interpreted as a consequence of volcanic activity in Bosnia (ŠUŠNJARA & ŠĆAVNIČAR, 1974) (Fig. 4). A fossil association is very rich in Lower Miocene sediments. Molluscs are represented by *Congeria pernaeformis*, *Congeria jadrovi*, *Orygoceras corniculum*, *Lymnaea dilatata*, *Lymnaea socialis*, *Sphaerium* sp., *Unio* sp., *Helix* sp., *Bythinella* sp., *Planorbis obtusus* and *Planorbis subcingulatus*. Floral species include *Carpolithes floveatus*, *Glyptostrobus europeus*, *Cinnamomum* sp. and *Ceratophyllum sinjanum*. Mammalian species, such as *Dynotherium bavaricum*, occur.

The Middle Miocene sediments show a low degree of diagenesis. During the Middle Miocene marls, limestones, sandstones, clays and conglomerates were deposited. Coal beds occur in some places, pyroclastics too. The most frequent molluscs belong to the genus *Congeria*: *Congeria pernaeformis*, *Congeria jadrovi*, *Congeria dalmatica*, *Congeria drvarensis*, *Congeria bosniaca*, *Congeria bihacensis* etc. Gastropods include *Orygoceras bifrons*, *Planorbis cornu*, *Clivunella katzeri*, *Fossarulus tricarinatus*, *Prososthenia schwartzi*, *Melanopsis geniculata*, *Melanopsis inconstans*, *Melanopsis lanzae*, *Melanopsis euristoma*, *Melanopsis kispatici* and *Melanopsis pilari*. ČIČIĆ & MILOJEVIĆ (1977) mention mammals found in Bosnia and Herzegovina, such as *Mastodon angustidens*, *Mastodon longirostris*, *Dynotherium bavaricum* and *Rinoceras sansaniensis*, but it is now clear that some of these species are of a different Neogene age. In the Sinj Basin (Fig. 4), *Mastodon angustidens* sp. and *Aceratherium* sp.aff. *incisivum* were determined (OLUJIĆ, 1999).

The Upper Miocene and Pliocene deposits are characterized by marls, clays, siltstones, sandstones, conglomerates, limestones and coal beds. A molluscan association consists of *Congeria dalmatica*, *Congeria zoisi*, *Orygoceras dentaliforme*, *Orygoceras cornucopiae*, *Hydrobia* sp., *Valvata* sp., *Lymnaea* sp., *Pisidium ovulum*, *Melanopsis acanthica*, *Melanopsis defensa*, *Prososthenia tournoueri* etc. Some ostracods have been found, such as *Paralimnocythere rostrata*, *Potamocypris* sp. and *Candona* sp.. The youngest Pliocene to Pleistocene newly determined molluscan species are *Odontohydrobia croatica* and *Limnidia likana* (JURIŠIĆ-POLŠAK et al., 1997). The Upper Miocene and Pliocene sediments are overlain by Quaternary deposits.

4. THE ADRIATIC REGION

In a region of the Adriatic, as a part of the Mediterranean, marine deposition was almost continuous from the Paleogene into the Neogene, although transgressive contacts have been registered at some localities. Sediments of Neogene age are almost of marine origin and the occurence of fresh-water sediments which include endemic species, such as on Pag Island (KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, 1978), are very rare. The unconformities between sediments observed in several places belong to different stages, and are consequences of emergence due to local tectonics (TURK, 1971; JENKO & BISTRIČIĆ, 1978; KALAC & BAJRAKTAREVIĆ, 1989; MILETIĆ et al., 1995). The emergence was particularly long-lasting during the Oligocene and Early Miocene, and resulted in the formation of a land corridor for mammalian migration from the Dinarides to Apulia (DE GIULI et al., 1987; J. RADOVČIĆ, pers. comm.)

Generally, carbonates and fine-grained sediments prevail, and the thickness of the Neogene deposits reaches eight hundreds metres (D. MILETIĆ, pers. comm.) which is much less than in the Dinarides, North Croatian Basin and Northern Bosnia region, suggesting minor tectonic controls (Fig. 3). The stratigraphy of the Neogene deposits in the Croatian part of the Adriatic region is based on foraminiferal associations (JENKO & BISTRIČIĆ, 1978; KALAC & BAJRAKTAREVIĆ, 1989; MILETIĆ, 1994; MILETIĆ & BAJRAKTAREVIĆ, 1995; MILETIĆ et al., 1995). A geological column of the Koraljka-I well, which was located in the central Adriatic, is presented in Figs. 3 and 4.

Early Miocene sedimentation is characterized by a dominance of carbonates, i.e. limestones and marls (Fig. 3). A foraminiferal association consists of *Globoquadrina dehiscens*, *Globigerinoides trilobus*, *Gobigerinoides primordius* and *Amphistegina lessonii*. Sedimentation was open marine.

During the Middle Miocene marl sedimentation dominated, but limestones and sandy limestones were also deposited (Fig. 3). In a foraminiferal association *Praeorbulina glomerosa*, *Orbulina suturalis*, *Anomalinoides pompilioides*, *Lenticulina vortex*, *Spiroplectinella carinata*, *Globoquadrina langhiana*, *Orbulina universa*, *Globorotalia praemenardii*, *Globorotalia mayeri* and *Globorotalia menardi* prevail. This association suggests open marine deposition.

In the Late Miocene, sedimentation was similar to that of the Middle Miocene. However, at the end of the Late Miocene evaporites were deposited in shallow lagoons. These deposits may be a result of a sea level fall due to the tectonic generated closure of the Atlantic-Mediterranean gateway. This event is known as the Messinian salinity crisis (RÖGL & STEININGER, 1983). From the foraminiferal association, *Globigerina nepenthes*, *Lenticulina costata*, *Uvigerina rutila*, *Elphidium crispum*, *Elphidium complanatum*, *Globigerinoides extremus*, *Globorotalia conomiozea*, *Globigerinoides bollii* and *Ammonia beccarii* dominate.

Marls, siltstones and sandstones characterize Pliocene sedimentation. Conglomerates are very rare and only occur sporadically. Deposition was open marine. The cause of the sea level rise in the Pliocene was a re-opening of the Atlantic-Mediterranean gateway in the beginning of the Pliocene (RÖGL & STEININGER, 1983). The most important Pliocene foraminiferal species are *Globorotalia margaritae*, *Uvigerina rutila*, *Globorotalia puncticulata*, *Anomalina helicina*, *Globorotalia aemiliana*, *Globorotalia crassaformis*, *Globorotalia inflata* and *Epistomina elegans*.

5. DISCUSSION AND CONCLUSION

The faunal characteristics of species which occur in sediments in the Neogene fresh-water basins within the Dinarides is almost endemic and can not be correlated with a marine fauna in the Adriatic region. However, they show many similarities to endemic species found in deposits of the North Croatian Basin and Northern Bosnia region, i.e. Central Paratethys. The most frequent endemic species which occur both in the North Croatian Basin and Northern Bosnia region, belong to the molluscan genera *Congeria*, *Unio*, *Lymnaea*, *Pisidium*, *Melanopsis*, *Planorbis*, *Valvata and Clivunella*, and the ostracod genus *Candona*.

Sedimentation in the North Croatian Basin and Northern Bosnia region, and in the Dinaridic fresh-water basins also show similarities. Frequent changes of different types of sediments, including siliciclastics, coarse-grained deposits, coal-bearing beds, pyroclastics, emersions as well as mammalian occurrences are characteristic of both areas. The thickness of sediments in the Dinaridic fresh-water basins is also more comparable to the North Croatian Basin and Northern Bosnia region than to the Adriatic region. The strong tectonic control on sedimentation is also similar.

Similarities between the North Croatian Basin and Northern Bosnia region with Dinaridic Neogene basins suggest that these small basins show many faunal and depositional characteristics of Central Paratethys, and may be considered as a part of this realm. This means that the south-western boundary of the Central Paratethys may be constructed within the High Karst Belt, the mountain chain which separated the Mediterranean from Central Paratethys (Fig. 4), similar to ANIĆ's (1951-1953) idea. In this sense, the boundary located in the northern Bosnia and central Croatia represents only the south-western shoreline of the sea or large lake which occupied the largest part of the Central Paratethys (Fig. 4).

Acknowledgements

The review of the manuscript by Z. BAJRAKTAREVIĆ, I. DRAGIČEVIĆ, K. ŠIKIĆ, D. VRSALJKO, M. MIKNIĆ and J. BULIĆ is gratefully acknowledged. I am indebted to R. AVANIĆ, D. MILETIĆ and I. SLIŠKOVIĆ for providing helpful suggestions. This paper profited from journal reviewers F.F. STEININGER (Frankfurt), Z. JURIŠIĆ-POLŠAK (Zagreb) and J. RADOVČIĆ (Zagreb).

6. REFERENCES

ALJINOVIĆ, B., PRELOGOVIĆ, E. & SKOKO, D. (1987): Novi podaci o dubinskoj geološkoj građi i seizmotektonski aktivnim zonama u Jugoslaviji.- Geol. vjesnik, 40, 255-263.

ANIĆ, D. (1951-1953): Starost naslaga sa smeđim ugljenom u Bosni, Hercegovini i Dalmaciji.- Geol. vjesnik, 5-7, 73-110.

BAHUN, S. (1974): Tektogeneza Velebita i postanak Jelar-naslaga.- Geol. vjesnik, 27, 35-51.

BERGGREN, W.A., KENT, D.V., SWISHER, C.C. III & AUBRY, M.-P. (1995): A revised Cenozoic geochronology and chronostratigraphy.- In: BERGGREN, W.A., KENT, D.V., AUBRY, M.-P. & HARDENBOL, J. (eds.): Geochronology, Time Scales and Global Stratigraphic Correlations. Spec. Publ. Soc. Econ. Pal. Min., 54, 129-212.

BLAŠKOVIĆ, I. (1991): Raspored uzdužnih, reversnih i normalnih rasjeda i konstrukcija oblika i dubina ploha podvlačenja.- Geol. vjesnik, 44, 247-256.

BLAŠKOVIĆ, I. (1998): The two stages of structural formation of the coastal belt of the External Dinarides.- Geol. Croatica, 51/1, 75-89.

BLAŠKOVIĆ, I. (1999): Tectonics of part of the Vinodol Valley within the model of the continental crust subduction.- Geol. Croatica, 52/2, 153-189.

ČIČIĆ, S. & MILOJEVIĆ, R. (1977): Terestrično-limničke naslage tercijara u Bosni i Hercegovini.- In: ČIČIĆ, S. & PAMIĆ, J. (eds.): Geologija Bosne i Hercegovine. Knjiga III. Kenozojske periode. Geoinženjering, Sarajevo, 67-106.

DE GIULI, C., MASINI, F. & VALLERI, G. (1987): Paleogeographic evolution of the Adriatic area since Oligocene to Pleistocene.- Riv. It. Paleont. Strat., 93, 109-126, Milano.

DRAGIČEVIĆ, I. (2001): Poslijeplatformni razvitak na Dinarskoj karbonatnoj platformi.- In: DRAGIČEVIĆ, I. & VELIĆ, I. (eds.): 1. znanstveni skup "Karbonatna platforma ili karbonatne platforme Dinarida", Knjiga saž., RGNF, PMF, Inst. za geol. istraž & HGD, 89-90, Zagreb.

DRAGIČEVIĆ, I., PRELOGOVIĆ, E., KUK, V. & BULJAN, R. (1999): Recent tectonic activity in the Imotsko Polje area.- Geol. Croatica, 52/2, 191-196.

GULYÁS, S. (2001): The paleogeography of Lake Pannon during deposition of the Congeria rhomboidea beds.- Geol. Croatica, 54/1, 15-26.

HÁMOR, G. & SZENTGYÖRGYI, K. (1981): Outlines of geological structure and evolution of the Miocene.- Excursion guide of molasse formations in Hungary. Hung. Geol. Inst. Publ., 42-55, Budapest.

HERAK, M. (1986): A new concept of geotectonics of the Dinarides.- Acta geol., 16/1, 1-42, Zagreb.

HERAK, M. (1991): Dinaridi. Mobilistički osvrt na genezu i strukturu.- Acta geol., 21/2, 35-117, Zagreb.

HERAK, M. (1999): Tectonic interrelation of the Dinarides and the Southern Alps.- Geol. Croatica, 52/1, 83-98.

HERAK, M. & TOMIĆ, V. (1995): Continental subduction tectonics in the High Karst Dinarides of Western Croatia.- Geol. Croatica, 48/2, 161-166.

HORVÁTH, F. (1995): Phases of compression during the evolution of the Pannonian Basin and its bearing on hydrocarbon exploration.- Mar. Petrol. Geol., 12, 837-844.

HORVATH, F. & ROYDEN, L.H. (1981): Mechanism for the formation of the Intra-Carpathian Basins: A Rewiev.- Earth Sci. Rev., 3-4, 307-316.

HAQ, B.U., HARDENBOL, J. & VAIL, P.R. (1987): Chronology of fluctuating sea levels since the Triassic (250 Myr ago to present).- Science, 235, 1156-1167.

JENKO, K. & BISTRIČIĆ, A. (1978): Doprinos poznavanju biostratigrafskih odnosa mlađeg paleogena, neogena i kvartara Dugootočkog bazena.- 9. kongr. geol. Jugosl., Zbornik radova, 25-39, Sarajevo.

JOVANOVIĆ, R., MOJIČEVIĆ, M., TOKIĆ, S. & ROKIĆ, Lj. (1978): Osnovna geološka karta SFRJ 1:100.000, Tumač za list Sarajevo, K34-1 (Basic geological map of SFRJ 1:100.000, Explanatory notes for the Sarajevo sheet).- Zav. za inž. geol. i hidrogeol. Građ. fakult., Sarajevo, Inst. za geol. istraž., Sarajevo, Sav. geol. zavod, Beograd, 52 p.

JURIŠIĆ-POLŠAK, Z. (1984): Novi fosarulusi u slatkovodnom neogenu Dalmacije (južna Hrvatska).- Rad Jugosl. akad. znan. umjetn., 411, 197-208, Zagreb.

JURIŠIĆ-POLŠAK, Z., KRIZMANIĆ, K. & HAJEK-TADESSE, V. (1993): Freshwater Miocene of Krbavsko Polje in Lika (Croatia).- Geol. Croatica, 46/2, 213-228.

JURIŠIĆ-POLŠAK, Z., SAKAČ, K. & POJE, M. (1997): New Pliopleistocene gastropods from Lika, Croatia.- Nat. Croatica, 6, 91-111, Zagreb.

JURIŠIĆ-POLŠAK, Z. & SLIŠKOVIĆ, T. (1988): Slatkovodni gastropodi neogenskih naslaga jugozapadne Bosne.- Zbor. ref. nauč. skupa "Minerali, stijene, izumrli i živi svijet BiH", 167-174, Zem. muz. Bos. Herceg., Sarajevo.

KALAC, K. & BAJRAKTAREVIĆ, Z. (1989): Biostratigrafska istraživanja naslaga pliocena i pleistocena podmorja sjevernog Jadrana.- Geol. vjesnik, 42, 33-48.

KOCHANSKY-DEVIDÉ, V. (1976): O slatkovodnim mekušcima srednjeg miocena Hrvatske, Bosne i Hercegovine.- 8. jugosl. geol. kong., 2, 125-130, Ljubljana.

KOCHANSKY-DEVIDÉ, V. (1979): Srednjomiocenske kongerijske naslage Požeške gore.- Geol. vjesnik, 31, 69-72.

KOCHANSKY-DEVIDÉ, V. & SLIŠKOVIĆ, T. (1978): Miocenske kongerije Hrvatske, Bosne i Hercegovine.- Palaeont. Jugosl., 19, 1-98, Zagreb.

KOVÁČ, M. & HUDÁČKOVÁ, N. (1997): Changes of paleoenvironment as a result of interaction of tectonic events with sea level changes in the northeastern margin of Vienna Basin.- Zbl. Geol. Paläont. Teil I, 5/6, 457-469, Stuttgart.

KOVÁČ, M., NAGYMAROSY, A., HOLCOVÁ, K., HUDÁČKOVA, N. & ZLINSKÁ, A. (2001): Paleogeography, paleoecology, and eustacy: Miocene 3rd order cycles of relative sea-level changes in the Western Carpathian - North Pannonian basins.- Acta Geol. Hung., 44, 1-45.

KOVAČ, M., NAGYMAROSY, A., OSZCZYPKO, N., CSONTOS, L., SLACZKA, A., MARUNTEANU, M., MATENCO, L. & MÁRTON, E. (1998): Palinspastic reconstruction of the Carpathian-Pannonian region during the Miocene.- In: RAKUS, M. (ed.): Geodynamic development of the Western Carpathians. Mineralia Slov. Monograph., 189-217, Bratislava.

KUK, V., PRELOGOVIĆ, E. & DRAGIČEVIĆ, I. (2000): Seismotectonically active zones in the Dinarides.- Geol. Croatica, 53/2, 295-303.

LASKAREV, V. (1924): Sur les equivalents du Sarmatien superieur en Serbie.- In: VUJEVIĆ, P. (ed.): Receuil de traveaux offert á M. Jovan Cvijic par ses amis et collaborateurs. Drž. štamp., 73-85, Beograd.

LUČIĆ, D., SAFTIĆ, B., KRIZMANIĆ, K., PRELOGOVIĆ, E., BRITVIĆ, V., MESIĆ, I. & TADEJ, J. (2001): The Neogene evolution and hydrocarbon potential of the Pannonian Basin in Croatia.- Mar. Petrol. Geol., 18, 133-147.

MAGYAR, I., GEARY, D.H. & MÜLLER, P. (1999): Paleogeographic evolution of the Late Miocene Lake Pannon in Central Europe.- Palaeogeogr., Palaeoclim., Palaeoecol., 147, 151-167.

MARINČIĆ, S., KOROLIJA, B., MAMUŽIĆ, P., MAGAŠ, N., MAJCEN, Ž., BRKIĆ, M. & BENČEK, Đ. (1977): Osnovna geološka karta SFRJ 1:100.000, Tumač za list Omiš, K33-22 (Basic geological map of SFRJ 1:100.000, Explanatory notes for the Omiš sheet).- Inst. za geol. istraž., Zagreb, 51 p.

MARINESCU, F. (1992): Les bioprovinces de la Paratéthys et leurs relations.- Paleontologia i Evolució, 24-25, 445-453, Sabadell.

MATIČEC, D., VLAHOVIĆ, I., FUČEK, L., OŠTRIĆ, N. & VELIĆ, I. (1997): Stratigraphy and tectonic relationships along the Senj-Ogulin profile (Velika Kapela Mt., Croatia).- Geol. Croatica, 50/2, 261-268.

MATIČEC, D., VLAHOVIĆ, I., TIŠLJAR, J. & VELIĆ, I. (2001): Sinsedimentacijska tektonika na Jadranskoj karbonatnoj platformi.- In: DRAGIČEVIĆ, I. & VELIĆ, I. (eds.): 1. znanstveni skup. Karbonatna platforma ili karbonatne platforme Dinarida.- Knjiga saž., RGNF, PMF, Inst. za geol. istraž & HGD, 46-50, Zagreb.

MILETIĆ, D. (1994): Foraminifere neogena istražnih bušotina u podmorju srednjeg Jadrana.- Unpubl. M.Sc. Thesis, University of Zagreb, 62 p.

MILETIĆ, D. & BARBIĆ, Z., SLAVKOVIĆ, R. & HERNITZ-KUČENJAK, M. (1995): Rezultati biostratigrafskih i petrografskih analiza sedimenata bušotine Ines-1 (sjeverni Jadran, Hrvatska).- In: VLAHOVIĆ, I., VELIĆ, I. & ŠPARICA, M. (eds.): 1. hrvatski geološki kongres. Zbornik radova, 2, 383-386, Inst. za geol. istraž. & Hrv. geol. druš., Zagreb.

MILETIĆ, D. & BAJRAKTAREVIĆ, Z. (1995): Biostratigrafska korelacija neogenskih sedimenata Jadrana u bušotinama Koraljka-1, Ksenija-1 i Ksenija-3.- In: VLAHOVIĆ, I., VELIĆ, I. & ŠPARICA, M. (eds): 1. hrvatski geološki kongres. Zbornik radova, 2, 379-382, Inst. za geol. istraž. & Hrv. geol. druš., Zagreb.

OLUJIĆ, J. (1999): O razvojnim nizovima nekoliko melanopsida i prozostenida iz sarmatskih naslaga okolice Sinja (Dalmacija, Hrvatska) (Über die Ahnenreihen einiger Melanopsiden und Prososthenieden aus Melanopsis lanzae - Schichten der Sinjaner Neogenformation aus der Sarmatischen Stufe (Sinj, Dalmatien, Croatien)).- In: POLŠAK-JURIŠIĆ, Z. (ed.). Hrvatski prirodoslovni muzej, Zagreb, Provincijalat Franjevačke provincije presvetog Otkupiteja, Sinj, 135 p.

PAMIĆ, J., BELAK, M. & SLOVENEC, D. (1992/1993): Donjomiocenski trahiandeziti (šošoniti) Krndije u Slavoniji (sjeverna Hrvatska).- Rad HAZU, 463, 27-47, Zagreb.

PAMIĆ, J., GUŠIĆ, I. & JELASKA, V. (1998): Geodynamic evolution of the Central Dinarides.- Tectonophysics, 297, 251-268.

PAMIĆ, J., PAMIĆ, O., OLUJIĆ, J., MILOJEVIĆ, D. VELJKOVIĆ, D. & KAPELER, I. (1978): Osnovna geološka karta SFRJ 1:100.000, Tumač za list Vareš, L34-133 (Basic geological map of SFRJ 1:100.000, Explanatory notes for the Vareš sheet).- Inst. za geol. istraž. Sarajevo (1970), Sav. geol. zavod Beograd, 68 p.

PAPEŠ, J. (1972): Osnovna geološka karta SFRJ 1:100.000, list Livno K33-11 (Basic geological map of SFRJ 1:100.000, Livno sheet).- Inst. za geol. istraž. Sarajevo, Sav. geol. zavod Beograd.

PAPEŠ, J. (1975): Osnovna geološka karta SFRJ 1:100.000, Tumač za list Livno, K33-11 (Basic geological map of SFRJ 1:100.000, Explanatory notes for the Livno sheet).- Inst. za geol. istraž., Sarajevo (1967), Sav. geol. zavod Beograd, 64 p.

PAPEŠ, J. (1985): Geologija jugozapadne Bosne.- Geol. glasnik, Pos. izd., 9, 197 p., Geoinž., Sarajevo, Inst. za geol., Sarajevo.

PAVELIĆ, D. (2001): Tectonostratigraphic model for the North Croatian and North Bosnian sector of the Miocene Pannonian Basin System.- Basin Research, 13, 359-376.

PAVELIĆ, D., AVANIĆ, R., BAKRAČ, K. & VRSALJKO, D. (2001): Early Miocene braided river and lacustrine sedimentation in the Kalnik Mountain Area (Pannonian Basin System, NW Croatia).- Geol. Carpathica, 52, 375-386.

PAVELIĆ, D., MIKNIĆ, M. & SARKOTIĆ ŠLAT, M. (1998): Early to Middle Miocene facies succession in lacustrine and marine environments on the southwestern margin of the Pannonian basin system.- Geol. Carpathica, 49, 433-443.

PAVELIĆ, D. & KOVAČIĆ, M. (1999): Lower Miocene alluvial deposits of the Požeška Mt. (Pannonian Basin, Northern Croatia): cycles, megacycles and tectonic implications.- Geol. Croatica, 52/1, 67-76.

POLŠAK, A., ŠPARICA, M., CRNKO, J. & JURIŠA, M. (1978): Osnovna geološka karta SFRJ 1:100.000, Tumač za list Bihać, L33-116 (Basic geological map of SFRJ 1:100.000, Explanatory notes for the Bihać sheet).- Inst. za geol. istraž., Zagreb, 52 p.

RADOVČIĆ, J., MAJIĆ, D. & JURIŠIĆ-POLŠAK, Z. (1998): Miocenski praslonovi i nosorozi iz Moslavačkog gorja.- Zbornik Moslavine, 4, 5-11, Muzej Moslavine, Kutina.

RAIĆ, V., PAPEŠ, J., SIKIRICA, V. & MAGAŠ, N. (1984): Osnovna geološka karta SFRJ 1:100.000, Tumač za list Sinj, K33-10 (Basic geological map of SFRJ 1:100.000, Explanatory notes for the Bihać sheet).- Geoinž., Inst. za geol. Sarajevo, Geol. zav. Zagreb (1982), Sav. geol. zavod Beograd, 52 p.

RÖGL, F. (1996): Stratigraphic correlation of the Paratethys Oligocene and Miocene.- Mitt. Ges. Bergbaustud. Österr., 41, 65-73.

RÖGL, F. (1998): Paleogeographic considerations for Mediterranean and Paratethys seaways (Oligocene to Miocene).- Ann. Naturhist. Mus. Wien, 99A, 279-310, Wien.

RÖGL, F. (1999): Mediterranean and Paratethys. Facts and hypotheses of an Oligocene to Miocene paleogeography (short overview).- Geol. Carpathica, 50, 339-349.

RÖGL, F. & STEININGER, F.-F. (1983): Vom Zerfall der Tethys zu Mediterran und Paratethys. Die Neogene Palaeogeographie und Palinspastik des zirkum-mediterranen Raumes.- Ann. Naturhist. Mus. Wien, 85, 135-163, Wien.

RÖGL, F. & STEININGER, F.-F. (1984). Neogene Paratethys, Mediterranean and Indo-pacific seaways.- In: BRENCHLEY, P. (ed.): Fossils and Climate. 171-200, J. Wiley & Sons, London.

ROYDEN, L.H. (1988): Late Cenozoic Tectonics of the Pannonian Basin System.- In: ROYDEN, L.H. & HORVÁTH, F. (eds.): The Pannonian Basin. A study in Basin Evolution. Am. Assoc. Petrol. Geol. Mem., 45, 27-48.

SENEŠ, J. (1979): Correlation du Neogene de la Tethys et de la Paratethys - Base de la reconstitution de la geodynamique de la region de la Mediterranee.- Geol. Zborn. - Geol. Carpathica, 30, 309-319.

SOKAČ, A. (1980): Miocenski ostrakodi Sinjskog polja.- Geol. vjesnik, 31, 95-99.

SOKLIĆ, I. (1957): Kenozoik Bosne i Hercegovine.- 2. kongres geologa SFRJ, 64-72, Sarajevo.

STEININGER, F.F., RÖGL, F., HOCHULI, P. & MÜLLER, C. (1989): Lignite deposition and marine cycles. The Austrian Tertiary lignite deposits - A case history.- Aus den Sitz. Österr. Akad. Wiss. Mathem.-naturw. Kl., Abt. I, Bd., 5-10 Heft, Springer-Verlag, Wien, New York, 308-332.

STEININGER, F.F., MÜLLER, C. & RÖGL, F. (1988): Correlation of Central Paratethys, Eastern Paratethys, and Mediterranean Neogene Stages.- In: ROYDEN, L.H. & HORVATH, F. (eds.): The Pannonian Basin. A study in Basin Evolution. Am. Assoc. Petrol. Geol. Mem., 45, 79-87.

STEININGER, F. & RÖGL, F. (1979): The Paratethys history - a contribution towards the Neogene dynamics of the Alpine Orogene (an abstract).- Ann. Géol. Pays Hellén., Tome hors serie, fasc. III, 1153-1165, Athens.

STEININGER, F. & RÖGL, F. (1984): Paleogeography and palinspastic reconstruction of the Neogene of the Mediterranean and Paratethys.- In: DIXON, J.E & ROBERTSON, A.H.F. (eds.): The geological evolution of the eastern Mediterranean. Geol. Society, Blackwell, Oxford, 659-668.

ŠĆAVNIČAR, S., KRKALO, E., ŠĆAVNIČAR, B., HALLE, R. & TIBLJAŠ, D. (1983): Naslage s analcimom u Poljanskoj.- Rad Jugosl. akad. znan. umjetn., 404, 137-169, Zagreb.

ŠUŠNJARA, A. & SAKAČ, K. (1988): Miocenski slatkovodni sedimenti područja Sinja u srednjoj Dalmaciji.- Geol. vjesnik, 41, 51-74.

ŠUŠNJARA, A. & ŠĆAVNIČAR, B. (1974): Tufovi u neogenskim naslagama srednje Dalmacije (južna Hrvatska).- Geol. vjesnik, 27, 239-253.

TARI, G., HORVÁTH, F. & RUMPLER, J. (1992): Styles of extension in the Pannonian Basin.- Tectonophysics, 208, 203-219.

TARI, V. & PAMIĆ, J. (1998): Geodynamic evolution of the northern Dinarides and the southern part of the Pannonian Basin.- Tectonophysics, 297, 269-281.

TURK, M. (1971): Građa tercijarnog bazena u sjeveroistočnom dijelu Jadranskog mora.- Nafta, 22, 275-282, Zagreb.

VELIĆ, J., TIŠLJAR, J., DRAGIČEVIĆ, I. & BLAŠKOVIĆ, I. (2000): Shoreline cross-bedded biocalcarenites (Middle Miocene) in the Podvrško-Šnjegavić area, Mt. Psunj, and their petroleum significance (Požega subdepression - eastern Croatia).- Geol. Croatica, 53/2, 281-293.

ŽIVANOVIĆ, M. & MILOJEVIĆ, R. (1971): Osnovna geološka karta SFRJ 1:100.000, list Zenica, L33-144 (Basic geological map of SFRJ 1:100.000, Zenica sheet).- Inst. za geol. istraž. Sarajevo, Sav. geol. zavod Beograd, .

ŽIVANOVIĆ, M., SOFILJ, J. & MILOJEVIĆ, R. (1971): Osnovna geološka karta SFRJ 1:100.000, Tumač za list Zenica, L33-144 (Basic geological map of SFRJ 1:100.000, Explanatory notes for the Zenica sheet).- Inst. za geol. istraž. Sarajevo (1967), Sav. geol. zavod Beograd, 60 p.

ŽAGAR-SAKAČ, A. & SAKAČ, K. (1984): Nalazišta unionacejske faune neogenskih (miocenskih) naslaga Dalmacije (južna Hrvatska).- Rad Jugosl. akad. znan. umjetn., 411, 209-230, Zagreb.

Manuscript received February 21, 2002.

Revised manuscript accepted May 20, 2002.