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JURASSIC PALEOGEOGRAPHY OF THE PIENINY AND OUTER CARPATHIAN BASINS

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Abstract. The Jurassic history of the Pieniny/Outer Carpathian basins reflects the evolution of the Circum-Tethyan area, especially its Alpine Tethys part. The Alpine Tethys that is Ligurian, Penninic Oceans and Pieniny/Magura Basin constitute the extension of the Central Atlantic system. The synrift stage lasted in the Pieniny/Magura Basin from late Early Jurassic to Tithonian (the Magura Unit constitutes the southernmost part of the Outer Flysch Carpathians). The Pieniny rift opened during Pliensbachian – Aalenian. The central Atlantic and Alpine Tethys went into a drifting stage during the Middle Jurassic.

The Late Jurassic (Oxfordian-Kimmeridgian) history of the Pieniny/Magura Basin reflects strongest facial differentiation within sedimentary basin where mixed siliceous-carbonate sedimentation took place. Greatest deepening effect is indicated by widespread Oxfordian radiolarites, which occur in the all basinal successions, whereas the shallowest zone is completely devoid of siliceous intercalations at that time (sedimentation from Ammonitico Rosso facies up to coral reef limestone).

The southern part of the North European Platform, north from the Pieniny/Magura realm, started to be rifted during Late Jurassic time and Silesian Basin in the Outer Western Carpathians and Sinaia Basin in the Eastern Carpathians, with black, mainly redeposited marls have been created. The outer sub-basins were differentiated during the latest (Hauterivian-Barremian) phase of basinal development. The connection of Silesian Basin with Sinaia and Southern Carpathian Severin areas suggests the NW-SE direction of the basinal axis while the orientation of the Pieniny Klippen Belt/Magura Basin was SW-NE; so, two Outer Carpathian perpendicular directions are possible within the basins.

Major reorganization happened during the Tithonian-Berriasian time. It was reflected by both paleoceanographical and paleoclimatical changes. The Neo-Cimmerian tectonic events as well as main phase of the Outer Carpathian basins opening is connected with this reorganization.

Riassunto. La storia giurassica dei bacini di Pieniny/Carpatici Esterni riflette l'evoluzione dell'area circum-tetidea, specialmente della sua parte di Tetide alpina. La Tetide alpina, ossia gli Oceani Ligure e Pennidico ed il Bacino di Pieniny/Magura costituisce l'estensione del sistema atlantico centrale. Lo stadio di sin-rift è durato nel Bacino di Pieniny/Magura dal tardo Giurassico inferiore al Titoniano (l'Unità di Magura costituisce la parte più meridionale dei Flysch Carpatici Esterni). Il rift di Pieniny si è aperto durante il Pliensbachiano - Aaleniano. L'Atlantico centrale e la Tetide alpina subirono uno stadio di drifting durante il Giurassico medio.

La storia tardo-giurassica (Oxfordiano-Kimmeridgiano) del Bacino di Pieniny/Magura riflette una più marcata differenziazione di facies all'interno dei bacini sedimentari in cui aveva luogo una deposizione mista siliceo-carbonatica. Un effetto di maggior approfondimento è indicato dalle diffuse radiolariti oxfordiane, che si ritrovano in tutte le successioni bacinali, mentre la zona meno profonda è, in quel periodo, completamente priva di intercalazioni silicee (sedimentazione dalla facies di Ammonitico Rosso fino al calcare di scogliera corallina).

La parte meridionale della Piattaforma Europea Settentrionale, a Nord del reame di Pieniny/Magura, ha cominciato a essere interessata da rifting durante il Giurassico superiore, e sono stati creati il Bacino della Slesia nei Carpazi Esterni occidentali ed il Bacino di Sinaia nei Carpazi Orientali, con marne nere, principalmente rideposìtate. I bacini satellite esterni si sono differenziati durante l'ultima fase di sviluppo bacinale (Hauteriviano-Barremiano). La connessione del bacino della Slesia con Sinaia e con le aree sud-carpatiche di Severin suggerisce la direzione NW-SE dell'asse del bacino, mentre l'orientazione della Catena di Klippen di Pieniny/Bacino di Magura era SW-NE. Quindi nei bacini sono possibili due direzioni Carpatiche Esterne perpendicolari.

Durante il Titoniano-Berriasiano è avvenuta una maggior riorganizzazione, rispecchiata sia da cambiamenti paleoceanografici che paleoclimatici. Gli eventi tettonici Neocimmerici, così come la fase principale dell'apertura dei bacini dei Carpazi Esterni è connessa a questa riorganizzazione.

Introduction

The Outer Carpathian and Pieniny Klippen Belt realm (Fig. 1) are the northernmost part of the Polish Carpathians. Their palinspastic reconstructions attempt to restore the age and past location of basins, their age, their floor or basement, relations to the surrounding crustal elements as well as character of the paleostructural elements separating them. All this goals are still not easy to achieve, many problems have to be solved and many

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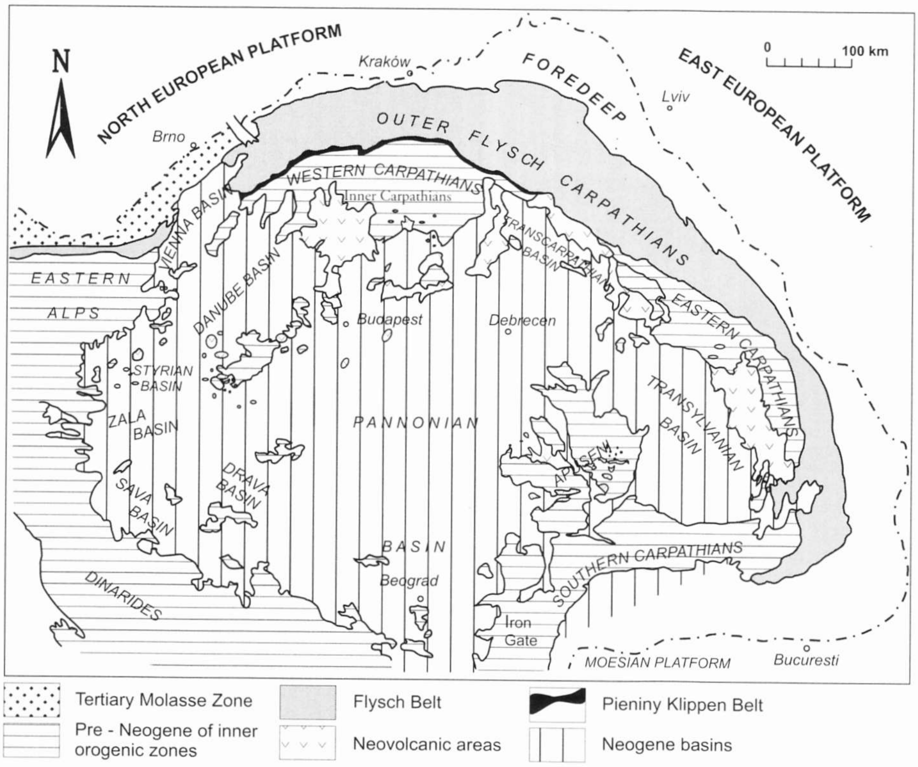

Fig. 1 - Tectonic sketch map of the Alpine-Carpathian-Pannonian-Dinaride basin system (after Kováč et al. 1998, simplified).

pitfalls have to be avoided. This paper discusses some problems related mainly to the Jurassic stage of the Carpathian realm development. This was the age of basins opening (Fig. 2). The basin closure is another issue with an additional set of problems.

Four time interval maps were constructed which depict the Jurassic–earliest Cretaceous plate tectonic configuration, paleogeography and lithofacies of the circum-Carpathian realm (Figs. 3-6). The aim of this paper is to provide an outline of the plate tectonic evolution paleogeography and position of the major crustal elements of the area within the global framework. Therefore, the authors restricted the number of plates and terranes modeled, trying to utilize the existing information and degree of certainty. The authors has tried to apply geometric and kinematic principles, using computer technology, to model interrelations between tectonic components along the Eurasian margin and in the surrounding areas. The maps were constructed using a plate tectonic model, which was constructed using PLATES and PALEOMAP software (see Golonka 2000; Golonka et al. 2000; Golonka & Krobicki 2001), which integrate computer graphics and data management technology with a highly structured and quantitative description of tectonic relationships. The heart of this program is the rotation file, which is constantly updated, as new paleomagnetic data become available. Hot-spot volcanics serve as reference points for the calculation of paleolongitudes (Golonka & Bocharova 2000).

Outline of geology

The Northern Carpathians are subdivided into an older range known as the Inner Carpathians and the younger ones, known as the Outer or Flysch Carpathians (Fig. 1). At the boundary of these two ranges the Pieniny Klippen Belt (PKB) is situated. The Outer Carpathians are built up of a stack of nappes and thrust-sheets changing along the Carpathians built mainly of flysch. All the Outer Carpathians nappes are overthrusting onto the European platform covered by Miocene deposits of the Carpathian Foredeep. These nappes have allochthonous character, and originated in basins situated outside their present location. The Magura Unit form the innermost part of Outer Flysch Carpathian Belt. The Magura subbasin deposits were incorporated into the Outer Flysch Carpathian Belt as well as into the Pieniny Klippen Belt during the Cenozoic orogenic process (Birkenmajer 1986; Golonka et al. 2000).

The Outer (Flysch) Carpathians are composed of flysch sequences ranging in age from Jurassic to Early Miocene (Ślączka 1996). These deposits were folded and overthrust during the Miocene time (Alpine orogeny), forming north-verging nappes detached from their original basement (Ślączka 1996). The Pieniny Klippen Belt is composed of several successions of mainly deep and shallow-water limestones, covering a time span from the Early Jurassic to Late Cretaceous. This strongly tectonized structure is a terrain of about 600 km long and 1-20 km

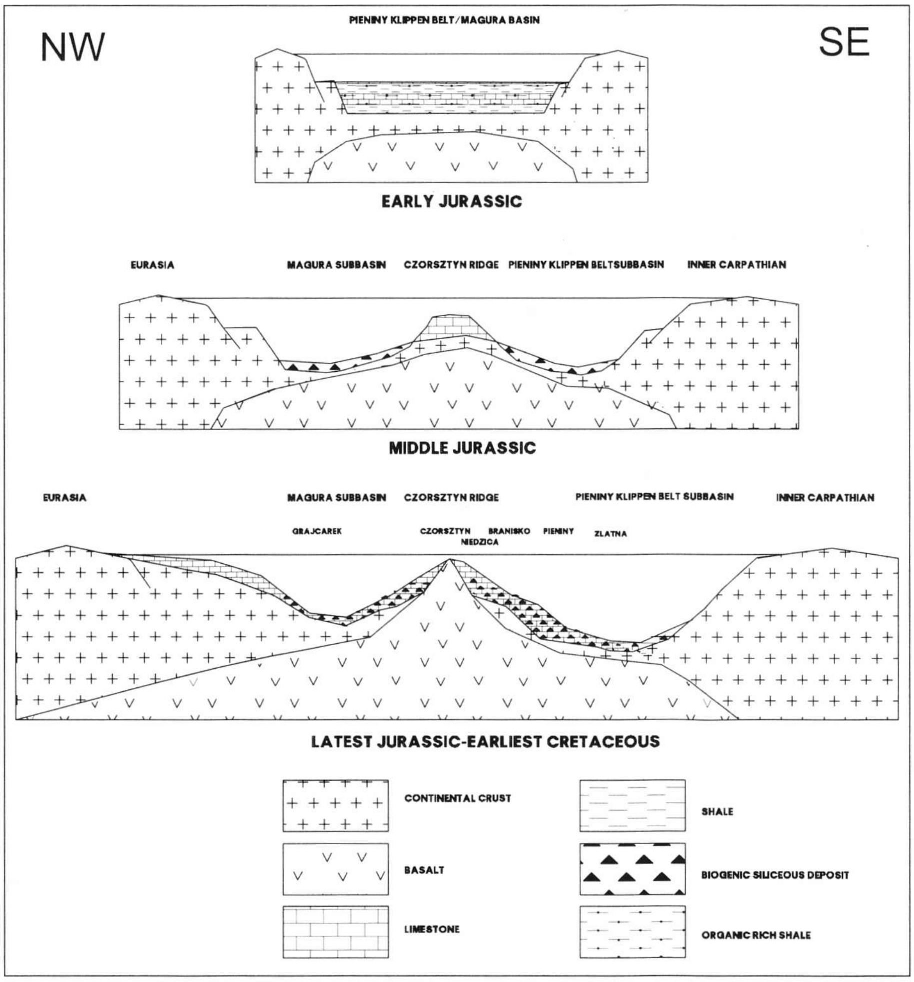

Fig. 2 - Highly schematic (not to scale) profiles showing the evolution of the Pieniny Klippen Belt/ Magura Basin during the Jurassic-earliest Cretaceous time.

wide, which stretches from Vienna to the West, to Romania to the East (Fig. 1). The PKB is separated from the present-day Outer Carpathians by the Miocene subvertical strike-slip fault (Birkenmajer 1986).

During the Jurassic and Early Cretaceous within the Pieniny Klippen Belt/Magura Basin the submarine Czorsztyn Ridge and sourrounding zones ("pelagic swell" – Mišík 1994) were an elongated structure with domination of pelagic type of sedimentation. The orientation of the Pieniny Klippen Belt/Magura Basin was SW-NE (see discussion in Golonka & Krobicki 2001). This basin was divided into the northwestern and southeastern subbasins by the Czorsztyn Ridge (Fig. 2). The deepest part of the southeastern (Pieniny Klippen Belt) subbasin is documented by extremely deep water Jurassic-Early Cretaceous deposits (pelagic limestones and radiolarites) of Złatna Unit (Golonka & Sikora 1981; Golonka & Krobicki 2002) later described also as Ultra-Pieniny Succession (Birkenmajer 1988; Birkenmajer et al. 1990) or Vahicum (e.g. Plašienka 1999). The transitional slope sequences between deepest basinal units and ridge units are known as Pieniny, Branisko (Kysuca), and Niedzica successions (Fig. 2). The strongly condensed Jurassic-Early Cretaceous pelagic cherty limestones (Maiolica type facies) and radiolarites were also deposited in northwestern (Magura) subbasin. This extremely deep-water basinal zone of the southern Magura Subbasin is known as Magura Succession (equivalent of tectonic Grajcarek Unit, sensu Birkenmajer 1970, 1986) or Hulina Unit (Golonka & Sikora 1981; Golonka et al. 2000, 2003; Golonka & Krobicki 2002). The paleogeographic extent of the Magura Subbasin remains somewhat enigmatic and speculative. Also speculative is existence of oceanic crust below the whole Magura basin. The presumable transitional slope sequence is known from some outcrops located north of the Czorsztyn Ridge (such as Zawiasy and Stare Bystre in Poland) (Golonka & Krobicki 2002). Ridge sequences as well as transitional slope sequences are also called Oravicum (e.g. Plašienka 1999). Generaly, the Pieniny Klippen Belt/Magura Basin history is tripartite (i-iii) – from the (i) oxygen-reduced dark/black terrigenous deposits of the Early-early Middle Jurassic age (Fleckenkalk/ Fleckenmergel facies) trough (ii) Middle Jurassic-earliest Cretaceous crionoidal, nodular (of the Ammonitico Rosso type) or cherty (of the Maiolica = Biancone type) limestones and radiolarites up to the (iii) Late

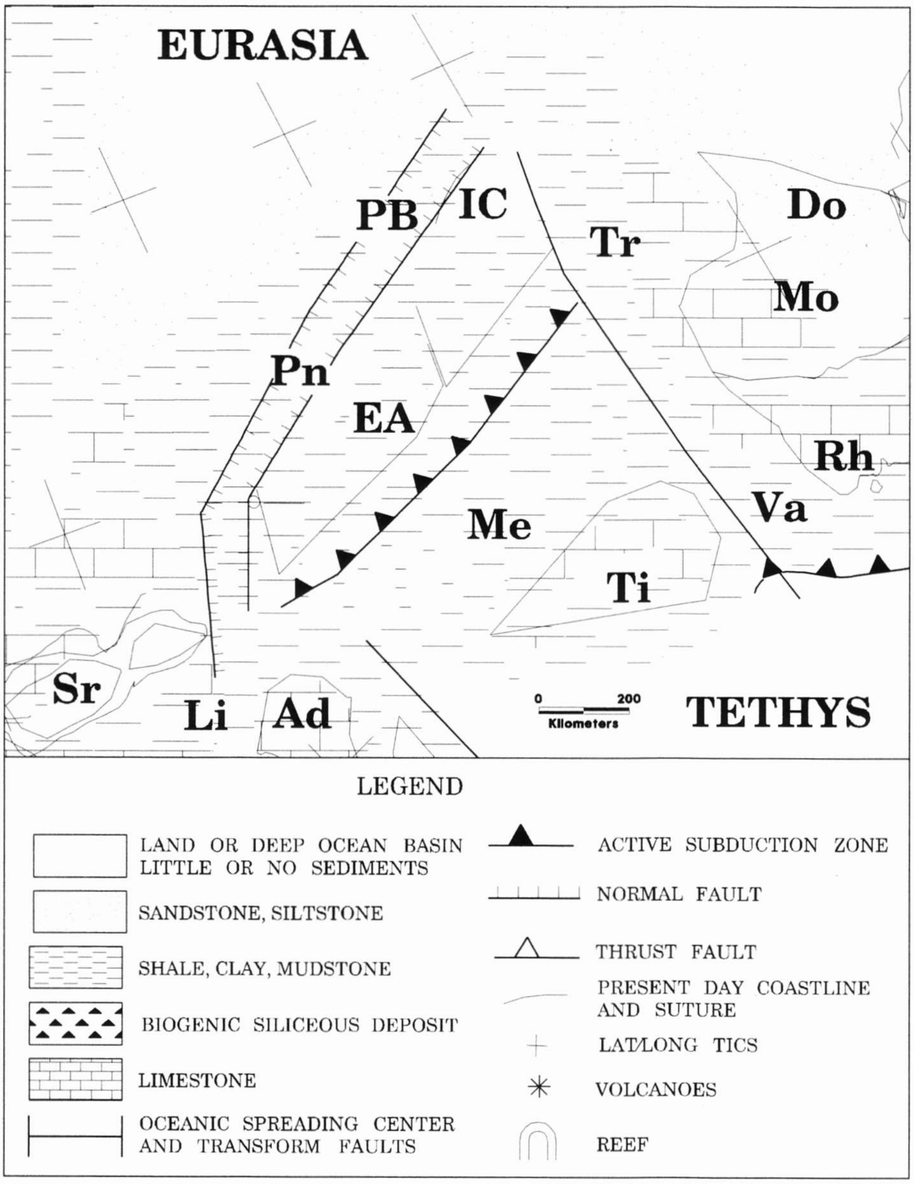

Fig. 3 - Paleogeography of the circum-Carpathian area during Early Jurassic; plates position at 195 Ma (after Golonka et al. 2003, modified). Abbreviations of oceans and plates names: Ad – Adria (Apulia), Do – Dobrogea, EA – Eastern Alps, IC – Inner Carpathians, Li – Ligurian rift (site of future Ligurian Ocean), Me – Meliata/Halstatt Ocean, Mo – Moesia plate, PB – Pieniny Klippen Belt rift (site of future Pieniny Klippen Belt /Magura Basin), Pn – Penninic rift (site of future Penninic Ocean), Rh – Rhodopes, Sr – Sardinia, Ti – Tisa plate, Tr – Transilvanian Ocean, Va – Vardar Ocean.

Cretaceous pelagic marls (i.a. Scaglia Rossa = Couches Rouge = Capas Rojas; Bąk 2000) facies and/or flysch/flyschoidal series (i.a. Birkenmajer 1986; Mišík 1994; Aubrecht et al. 1997).

On the other hand within Northern Outer Carpathians, traditionally (e.g. Ślączka & Kaminski 1998) the following sedimentary basins have been distinguished from south to north: the Magura Subbasin, the Dukla and Fore-Magura set of basins, the Silesian Basin, the Sub-Silesian Ridge and the Skole Basin. The main part of Magura flysch sequences is of Late Cretaceous-Paleogene age. However, there is also widely accepted possibility of the much earlier, Early-Middle Jurassic origin of the Magura Subbasin (see e.g. Birkenmajer 1986; Dercourt et al. 1993, Golonka et al. 2000). It appears that Magura Subbasin shared its history with the Pieniny Klippen Basin during the Jurassic time.

Map discussion

Early Jurassic

The synrift stage lasted in the Pieniny/Magura Basin from late Early Jurassic to Tithonian (Aubrecht et al. 1997). The earliest stage of the basin history is enigmatic and documented only by pebbles in the Cretaceous-Tertiary flysch. These pebbles indicate the possibility of an existence of an enigmatic embayment of the Vardar-Transilvanian Ocean (see Fig. 3 – Va-Tr) which separated the Tisa (Bihor-Apuseni) (Ti) block from the Moesian (Mo)-Eastern European Platform (Săndulescu 1988). The pelagic Triassic limestones in the exotic pebbles in the Pieniny Klippen Belt (Birkenmajer et al. 1990) and the Outer Carpathian Flysch (Magura Unit, see Soták 1986) could have originated in this embayment. The embayment position and its relation to the other parts of Te-

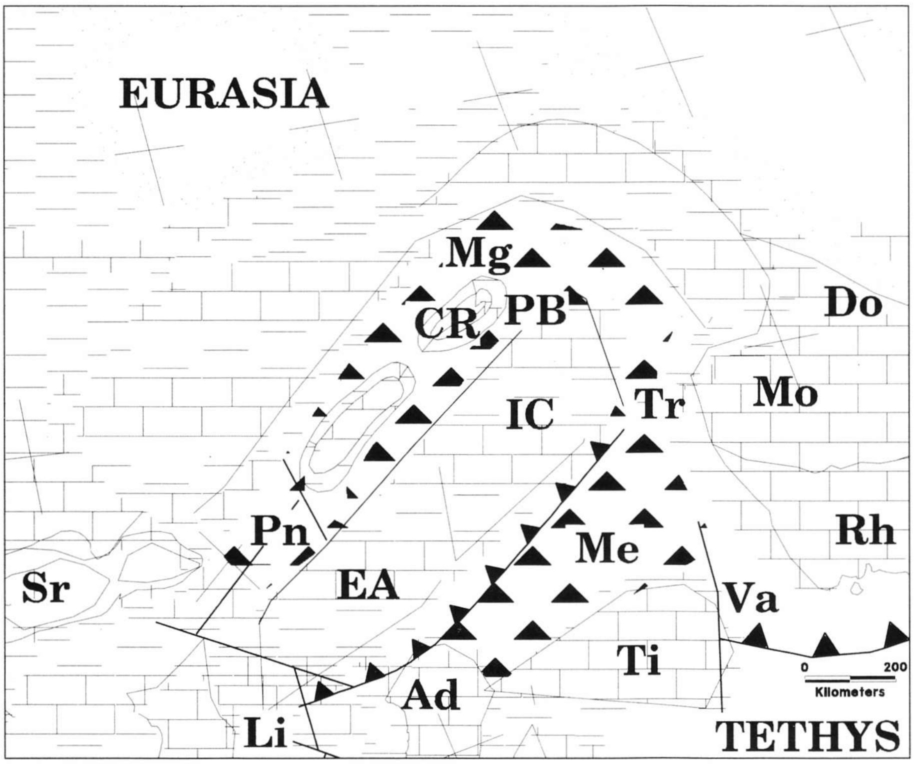

Fig. 4 - Paleogeography of the circum-Carpathian area during Middle Jurassic; plates position at 166 Ma (after Golonka et al. 2003, modified). Abbreviations of oceans and plates names: Ad – Adria (Apulia), CR – Czorsztyn Ridge, Do – Dobrogea, EA – Eastern Alps, IC – Inner Carpathians, Li – Ligurian Ocean, Me – Meliata/Halstatt Ocean, Mg – Magura Subbasin, Mo – Moesia plate, PB – Pieniny Klippen Belt Subbasin, Pn – Penninic Ocean, Rh – Rhodopes, Sr – Sardinia, Ti – Tisa plate, Tr – Transilvanian Ocean, Va – Vardar Ocean. For explanation of lithological symbols – see Fig. 3.

thys, Vardar Ocean (Va), Meliata-Halstatt Ocean (Me), Dobrogea (Do) rift remain quite speculative. The Pieniny rift (PB) opened during Pliensbachian – Aalenian time (Fig. 3) forming a part of the global system related to the opening of the Alpine Tethys. The Alpine Tethys, that is Ligurian (Figs 3, 4 – Li), Penninic Oceans (Pn) and Pieniny/Magura Basin (Figs 3, 4 – PB, Mg) constitute the extension of the Central Atlantic system (Golonka 2000). Stampfli (2001) recently postulated single Penninic Ocean (Pn) separating Apulia (Adria) (Ad) and Eastern Alps blocks (EA) from Eurasia. We proposed similar model for the Pieniny/Magura Basin (PB/Mg) in the Carpathians. The basins' opening is related to the closure of the Meliata Ocean (Me). The restricted environment prevailed in this newly formed basin.

The oldest Jurassic rocks (Hettangian/Sinemurian in age) of the Pieniny Klippen Belt are more or less completely preserved (mainly due to tectonic movement and reduction) only in the Slovakian and Ukrainian part of the region. They consist of different type of Gresten-like dark/black facies both clastic and limestone sediments. Still younger Toarcian-Lower Bajocian *Bositra* ("*Posidonia*") black shales with spherosiderites (Skrzypny Shale Fm.), as well as dark marls and spotty limestones of widespread Tethyan Fleckenkalk/Fleckenmergel facies (of the Krempachy Marl Fm., Harcygrund Shale Fm. and Podzamcze Limestone Fm. – see Birkenmajer 1977) indicate the oxygen-depleted conditions (Birkenmajer 1986; Tyszka 1994, 2001).

Middle Jurasssic

The central Atlantic (Withjack et al. 1998) and Alpine Tethys went into a drifting stage during the Middle Jurassic. The oldest oceanic crust in the Ligurian-Piemont Ocean was dated as late as the Middle Jurassic in the southern Apennines and in the Western Alps (see Ricou 1996 and literature cited therein). Bill et al. (2001) date the onset of oceanic spreading of the Alpine Tethys by isotopic methods as Bajocian. According to Winkler & Ślączka (1994) the Pieniny data fit well with the supposed opening of the Ligurian-Penninic Ocean (Li-Pn). One of the most rapidly change of sedimentation/paleoenvironments within this basin took place between Early and Late Bajocian when well-oxygenated multicoloured crinoidal limestones replaced dark and black sedimentation of Early-early Middle Jurassic period. However, sedimentation of still younger (since latest Bajocian) red nodular Ammonitico Rosso-type limestones was effect of Meso-Cimmerian vertical movements which subsided Czorsztyn Ridge (Figs 4-6 – CR) and produced tectonically differentiated blocks as well as accompanied by the formation of neptunian dykes and scarp-breccias (e.g. Birkenmajer 1986; Aubrecht et al. 1997; Wierzbowski et al. 1999; Aubrecht 2001; Aubrecht & Túnyi 2001). The Bajocian emergence of the Czorsztyn Ridge (CR) within the Pieniny/Magura Basin (PB/Mg) was connected with the postrift phase of the basin evolution (Golonka et al. 2003). In the same time in the axial, basinal sequences first episode of radiolarite sedimentation took place

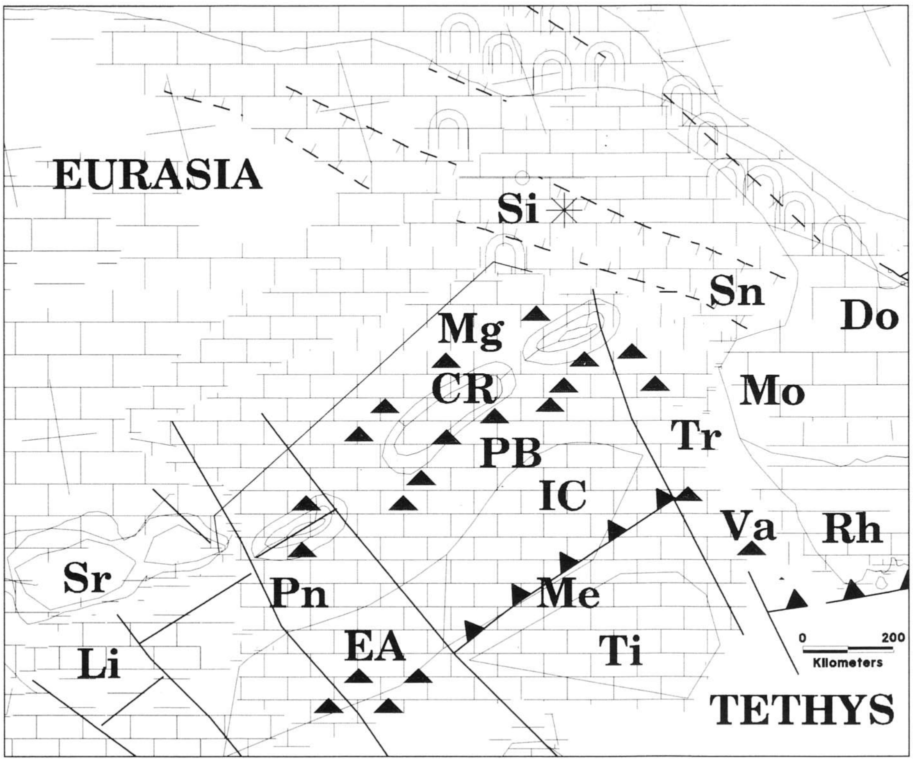

Fig. 5 - Paleogeography of the circum-Carpathian area during Late Jurassic; plates position at 152 Ma (after Golonka et al. 2003, modified). Abbreviations of oceans and plates names: CR – Czorsztyn Ridge, Do – Dobrogea, EA – Eastern Alps, IC – Inner Carpathians, Li – Ligurian Ocean, Me – Melaiata/Halstatt Ocean, Mg – Magura Subbasin, Mo – Moesia plate, PB – Pieniny Klippen Belt Subbasin, Pn – Penninic Ocean, Rh – Rhodopes, Si – Silesian Basin, Sn – Sinaia Basin, Sr – Sardinia, Ti – Tisa plate, Tr – Transilvanian Ocean, Va – Vardar Ocean. For explanation of lithological symbols – see Fig. 3.

(Birkenmajer 1977, 1986; Mišík 1999), which marked great facial differentation between deepest successions and shallow (ridge) ones (Fig. 4).

Late Jurassic

The Late Jurassic (Oxfordian-Kimmeridgian) history of the PKB reflects strongest facial differentiation within sedimentary basin (Fig. 4) where mixed siliceous-carbonate sedimentation took place. Greatest deepening effect is indicated by widespread Oxfordian radiolarites which occur in the all basinal successions, whereas the shallowest zone (Czorsztyn Succession) is completely devoid of siliceous intercalations at that time (sedimentation from Ammonitico Rosso facies up to coral reef limestones). The change of oceanic circulation in northernmost Tethyan Realm during Oxfordian is probably responsible for such distribution of facies. It very well corresponds with microfacial sequence within Ammonitico Rosso-type limestones as well, with domination of: filament (*Bositra* filaments) (Middle Jurassic) - *Globuligerina* ("*Protoglobigerina*") (Oxfordian) - *Saccocoma* (Kimmeridgian) microfacies, where boom of planktic *Globuligerina* forams was simultaneously with maximum development of radiolarites (Wierzbowski et al. 1999). Similar sequence is known in several European Alpine regions (e.g. Betic Cordillera, Southern Alps, Karavanke, Ionian Zone). On the other hand, extremally shallow water coral reef facies occur locally in the Slovakian part of the PKB (Mišík 1979; Aubrecht et al. 1997) or even oolitic limestones as infilling neptunian dykes of enigmatic age (presumable Late Jurassic – Oxfordian?) (Aubrecht et al. 1998).

The southern part of the North European Platform, north from the Pieniny/Magura realm (PB/Mg) started to be rifted and Silesian Basin (Figs. 5, 6 – Si) in the Western Carpathians (W-E direction) and Sinaia Basin (Sn) in the eastern Carpathians, with black, mainly redeposited marls (?Kimmeridgian-Tithonian) have been created (Pescatore & Ślączka 1984). The other Sub-Basins were differentiated during the latest (Hauterivian–Barremian) phase of basinal development. The connection of Silesian Basin (Si) with Sinaia (Sn) and Southern Carpathian Severin areas (Fig. 6 – Sv) (Săndulescu 1988) suggests the NW-SE direction of the basinal axis; so, two Outer Carpathian perpendicular directions are possible within the basins.

Latest Jurasssic – Early Cretaceous

Major plate reorganization happened during the Tithonian time (Fig. 6). The Central Atlantic began to expand into the area between Iberia and the New Foundland shelf (Ziegler 1988). The Ligurian-Penninic Ocean (Li-Pn) reached its maximum width and the oceanic spreading stopped. The subduction of the Meliata/Halstatt Ocean (Fig. 5 – Me) and the collision of the Tisa-Pelsonian block (Ti) with the Inner Carpathian terranes (IC) was concluded at the end of Jurassic (Golonka et al. 2000). The Tethyan plate reorganization resulted in extensive gravitational fault movement. Several tectonic horsts and grabens were

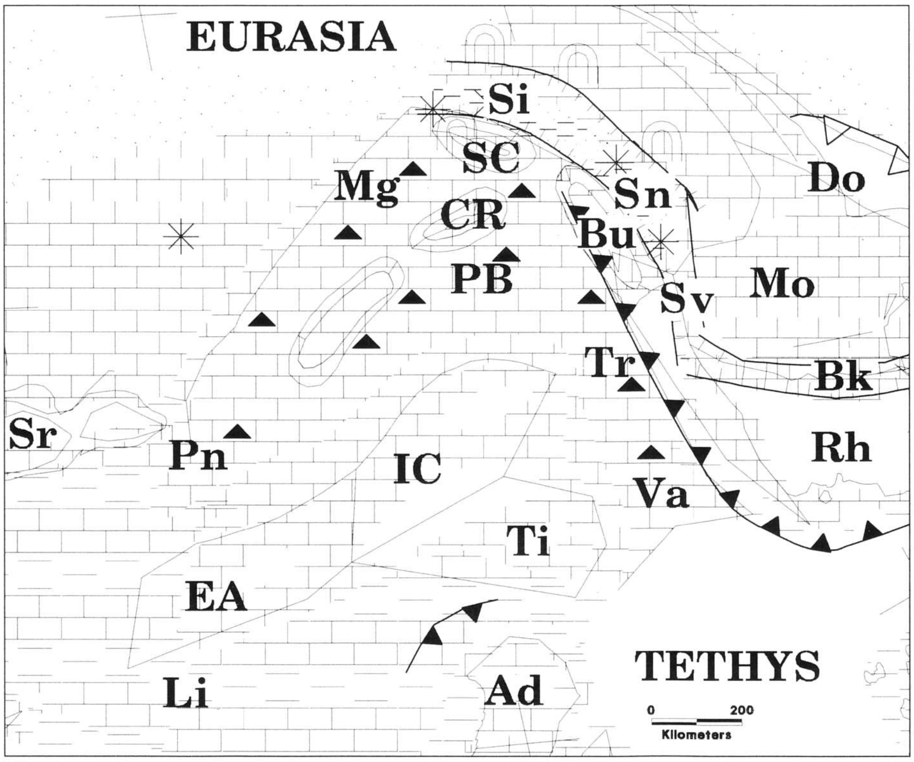

Fig. 6 - Paleogeography of the circum-Carpathian area during latest Late Jurassic – earliest Early Cretaceous; plates position at 140 Ma (after Golonka et al. 2003, modified). Abbreviations of oceans and plates names: Ad – Adria (Apulia), Bk – Balkan rift, Bu – Bucovinian-Getic terrane, CR – Czorsztyn Ridge, Do – Dobrogea, EA – Eastern Alps, IC – Inner Carpathians, Li – Ligurian Ocean, Mg – Magura Subbasin, Mo – Moesia plate, PB – Pieniny Klippen Belt Subbasin, Pn – Penninic Ocean, Rh – Rhodopes, SC – Silesian Ridge (Cordillera), Si – Silesian Basin, Sn – Sinaia Basin, Sr – Sardinia, Sv – Severin Basin, Ti – Tisa plate, Tr – Transilvanian Ocean, Va – Vardar Ocean. For explanation of lithological symbols – see Fig. 3.

formed, rejuvenating some older, Eo- and Meso-Cimmerian faults (Birkenmajer 1986; Krobicki 1996). Such features resulted from the intensive Neo-Cimmerian tectonic movements which affected the intrabasinal Czorsztyn pelagic swell and are documented by facies diversification, hardgrounds and condensed beds with ferromanganese-rich crusts and/or nodules, sedimentary-stratigraphic hiatuses, sedimentary breccias, neptunian dykes and/or fauna redeposition (for example famous ammonite coquinas of the so-called "Rogoźnik beds" – sensu Arkell 1956, see also Kutek & Wierzbowski 1986). These processes were caused by formation and destruction of submarine tectonic horsts attributed mainly to the Neo-Cimmerian period of tectonic activity in the Carpathians (Birkenmajer 1958, 1986; Michalík & Reháková 1995; Krobicki 1996; Krobicki & Słomka 1999; Golonka et al. 2003). Additionally, these movements gave rise to the appearance of a shallow submarine swell which separated the basin into different zones with their own water circulation patterns, probably upwelling type (Golonka & Krobicki 2001).

The more northern Outer Carpathian rift had developed in Late Jurassic with the sedimentation of pre-flysch black, mainly redeposited marls (?Kimmeridgian-Tithonian). This Western Carpathian, so-called Silesian Basin (Si), probably extended in the Eastern Carpathian (Sinaia (Sn) or „black flysch") as well as to the Southern Carpathian Severin zone (Sv) (Săndulescu & Visarion 2000). The black sediments mark the beginning of an euxinic cycle of the Outer Carpathian basin that lasted until Albian. The rapid supply of shallow water clastic material to the basin could be an effect of the strong tectonoeustatic sea-level fluctuations known from that time. The marls pass gradually upwards into calcareous turbidites (Cieszyn limestones, see Słomka 1986) which created several submarine fans. The remnants of carbonate platforms with coral reefs (Štramberk-type limestones) along the margin of Silesian Basin and around intraoceanic cordillera (Silesian) (Fig. 6 – SC) and now known only from exotic material occurring within Upper Cretaceous/Paleogene flysch deposits of the Outer Carpathians, were results of the fragmentation of the European platform in this area. The Silesian Ridge (cordillera) (SC) separated the Silesian Basin (on the north) (Si) and Pieniny/Magura Basin (on the south) (PB-Mg) (Książkiewicz 1960; Golonka et al. 2000). The eastward-northeastward subduction along the Silesian Ridge (SC) and Bucovinian-Getic Terrane (Bu) was perpendicular or oblique to the general trend of the Czorsztyn Ridge (CR) and the margin of the Inner Carpathian (IC)-Eastern Alps (EA) terrane. The Jurassic blueschists metamorphic rocks found as pebbles (exotics) in the Albian flysch in the Pieniny-Magura Basin (PB-Mg) (e.g. Faryad 1997) indicate existence of such a subduction.

The Outer Carpathian rift had developed with the beginning of calcareous flysch sedimentation. The remnants of carbonate platforms (Olszewska & Wieczorek 2001) with reefs (Štramberk) along the margin of Silesian Basin (Si) were results of the fragmentation of the European platform in this area. The subsidence in the Silesian

Basin (Si) was accompanied by the extrusion of basic lava (teschenites) in the Western Carpathian and diabase-melaphyre within the „black flysch" of the Eastern Carpathians (Golonka et al. 2000; Lucińska-Anczkiewicz et al. 2002). The spreading stage in the Silesian Basin (Si) was accompanied by the main phase of intrusion of teschenites, which occurred in the Western Carpathians during Hauterivian-Barremian time (Lucińska-Anczkiewicz et al. 2002). The extension of the Silesian-Sinaia Basin (Si-Sn) is marked by the beginning of the sedimentation in the Skole-Tarcău area.

The Jurassic separation of Bucovinian-Getic microplate (Bu) from European plate is perhaps related to the origin of the Silesian Ridge (Fig. 6 – SC). The direct connection is obscured however by the remnants of the Transilvanian Ocean (Tr) in the area of the eastern end of the Pieniny Klippen Basin (PB). These remnants are known from the Iňačovce-Krichevo unit in Eastern Slovakia and Ukraine (Soták et al. 2000, 2002). In this area existed a junction of the different basinal units: Pieniny/Magura Ocean (PB/Mg), Transilvanian Ocean (Tr) and Outer Carpathian Basin. The eastward subduction of Bucovinian-Getic terranes is connected with the northward subduction under Rhodopes-Moesia plate mentioned above. The displacement within Transilvanian Ocean (Tr) which is began in Barremian is perhaps also related to this subduction.

The Outer Carpathian basin reached its greatest width during the post-Jurassic time. With the widening of the basin, several subbasins (troughs) began to show their distinctive features. These subbasins, like Silesian, Sub-Silesian, Skole, Dukla, Tarcău, were locally separated by uplifted areas, e.g. Andrychów zone (Olszewska & Wieczorek 2001). The general downwarping of the Silesian Basin was probably due to the cooling effect of the underlying lithosphere. The sedimentation of calcareous sediments pass upwards gradually into black shales with turbiditic sequences.

Conclusions

The Jurassic history of the Pieniny/Outer Carpathian basins reflects the evolution of the Circo-Tethyan area, especially its Alpine Tethys part. The major differentiation of lithofacies took place during synrift phase of the basins opening of the Pieniny/Magura Basin. Major reorganization happend during the Tithonian-Berriasian time. It was reflected by both paleoceanographical and paleoclimatical changes (Golonka & Krobicki 2001). The Neo-Cimmerian tectonic events as well as main phase of the Outer Carpathian basins opening is connected with this reorganization.

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