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LATE CARBONIFEROUS–NEOGENE GEODYNAMIC EVOLUTION AND PALEOGEOGRAPHY OF THE CIRCUM-CARPATHIAN REGION AND ADJACENT AREAS

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Abstract: Twelve time interval maps were constructed which depict the plate tectonic configuration, paleogeography and general lithofacies. The aim of this paper is to provide the geodynamic evolution and position of the major tectonic elements of the area within the global framework.

The Hercynian orogeny was concluded with the collision of Gondwana and Laurussia, whereas the Tethys Ocean formed the embayment between the Eurasian and Gondwanian branches of Pangea. The Mesozoic rifting events resulted in the origin of the oceanic type basins like Meliata and Pieniny along the northern margin of the Tethys. Separation of Eurasia from Gondwana resulted in the formation of the Alboran-Ligurian-Pieniny Ocean as a part of the Pangean breakup tectonic system. During the Late Jurassic–Early Cretaceous time, the Outer Carpathian rift had developed.

Latest Cretaceous–earliest Paleocene was the time of the closure of the Pieniny Ocean. Adria-Alcapa terranes continued their northward movement during Eocene–Early Miocene time. Their oblique collision with the North European plate led to the development of the accretionary wedge of Outer Carpathians and foreland basin. The formation of the West Carpathian thrusts was completed by the Miocene time. The thrust front was still progressing eastwards in the Eastern Carpathians.

Abstrakt: Dla obszaru wokółkarpackiego skonstruowano 12 map przedstawiających konfigurację płyt litosferycznych, paleogeografię i uproszczony rozkład litofacji w okresie od późnego karbonu po neogen. Przedstawiono ewolucję geodynamiczną tego rejonu na tle ruchu płyt i pozycji głównych elementów tektonicznych w globalnym układzie odniesienia.

Orogeneza hercyńska zakończyła się kolizją Gondwany i Laurusji, a Ocean Tetydy utworzył zatokę pomiędzy dwoma ramionami Tetydy – Gondwaną i Laurazją. W wyniku mezozoicznych ryftów wzdłuż północnej krawędzi Oceanu Tetydy powstało szereg basenów typu oceanicznego takich jak Meliata i basen pieniński. Ocean albo-rańsko-liguryjsko-pieniński powstał w wyniku oddzielenia się Gondwany i Laurazji jako fragment tektonicznego sytemu rozpadu Pangei. W okresie od późnej jury do wczesnej kredy rozwinął się ryft Karpat Zewnętrznych.

Na przełomie kredy i paleocenu nastąpiło zamknięcie basenu pienińskiego pasa skałkowego. W okresie od eocenu do wczesnego miocenu terany Adri-Alkapy i Karpat Wewnętrznych kontynuowały ruch w kierunku północnym, a ich kolizja z płytą euroazjatycką doprowadziła do powstania pryzmy akrecyjnej Karpat Zewnętrznych i basenu przedgórskiego. Przy końcu miocenu środkowego uformowały się ostatecznie nasunięcia Karpat Zachodnich, podczas gdy w Karpatach Wschodnich ruchy te przetrwały do końca pliocenu.

Key words: plate tectonics, paleogeography, Tethys, Mediterranean, Carpathians, Carboniferous, Triassic, Jurassic, Cretaceous, Paleogene, Neogene.

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INTRODUCTION

Twelve time interval maps were constructed which depict the plate tectonic configuration, paleogeography and lithofacies for circum-Carpathian region (Fig. 1) and adjacent areas from the Late Carboniferous through Neogene. These maps were derived from the Jan Golonka's contribution to the Mobil project, which encompassed 32 global Phanerozoic paleoenvironment and lithofacies maps aimed to evaluate petroleum systems in time and space. The original maps were constructed in a 1:25,000,000 scale with a full variety of colors and patterns linked to computer databases. The

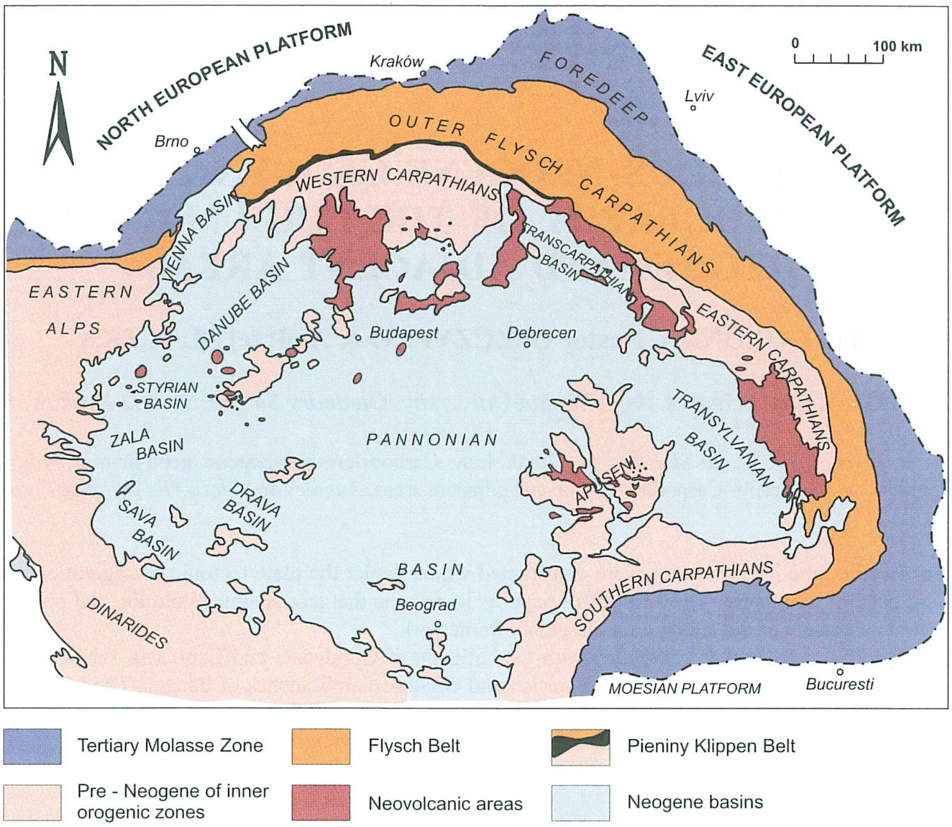

Fig. 1. Tectonic sketch map of the Alpine-Carpathian-Pannonian-Dinaride basin system (after Kováč *et al.*, 1998; simplified)

presented version of circum-Carpathian regional maps was constructed by the authors in 1999–2000 at the Institute of Geological Sciences, Jagiellonian University.

The aim of this paper is to provide the plate tectonic evolution and position of the major crustal elements of the area within the global framework (Fig. 2). Therefore, we restricted the number of plates and terranes modeled, trying to utilize the existing information and degree of certainty. We tried to apply geometric and kinematic principles, using computer technology, to model interrelations between tectonic components of the circum-Carpathian area. This general framework will provide a basis for the future integration of the local tectonics.

MAPPING METHODOLOGY

The maps were constructed using the following defined steps:

1. Construction of the base maps using the plate tectonic model. These maps depict plate boundaries (sutures), plate position at the specific time and outline of present day coastlines.

2. Review of existing global and regional paleogeographic maps.

3. Posting of generalized facies and paleoenvironment database information on base maps.

4. Interpretation and final assembly of computer map files.

The maps were constructed using a plate tectonic model, which describes the relative motions between approximately 300 plates and terranes. This model was constructed using PLATES and PALEOMAP software (see Golonka *et al.*, 1994; Golonka & Gahagan, 1997), 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 (Morgan, 1971; Golonka & Bocharova, 1997). Magnetic data have been used to define paleolatitudinal position of continents and rotation of plates (see e.g., Van der Voo, 1993; Besse & Courtillot, 1991; Krs *et al*, 1996). Ophiolites and deep-water sediments mark paleo-oceans, which were subducted and included into foldbelts.

Information from several general and regional paleogeographic papers were filtered and utilized (e.g., Ronov *et al.*, 1984, 1989; Dercourt *et al.*, 1986, 1993; Robertson, 1998; Sengör & Natalin, 1996; Stampfli *et al.*, 1991; Ziegler, 1988; Zonenshain *et al.*, 1990; Kováč *et al.*, 1993, 1998; Plašienka, 1999). We have also utilized the unpublished maps and databases from the PALEOMAP group (University of Texas at Arlington), PLATES group (University of Texas at Austin), University of Chicago, Institute of Tectonics of Lithospheric Plates in Moscow, Robertson Research in Llandudno, Wales, and the Cambridge Arctic Shelf Programme. The plate and terrane separation was based on the PALEOMAP system (see Scotese & Langford, 1995), with modifications in the Tethys area (Golonka & Gahagan, 1997). The contents of the original maps were supplemented by detailed information concerning paleogeography of the Outer Carpathians basin (Książkiewicz, 1962; Ślączka, 1976; Golonka *et al.*, 1999; Ślączka *et al.*, 1999, Kovač *et al.*, 1998). The calculated paleolatitudes and paleolongitudes were used to generate computer maps in the Microstation design format using the equal area Molweide projection. The glossary with the definition of the plate tectonic is attached at the end of the paper.

MAP DISCUSSION

Late Carboniferous

The map on Fig. 2 depicts Europe and adjacent parts of North America, Africa, arctic and Siberia after the initial assembly of the Pangea supercontinent. The Paleotethys Ocean (Sengör & Natalin, 1996) was situated between northern, Laurussian (North America, Baltica and Siberia) and southern, Gondwanian (Africa, Arabia, Lut and other Iranian terranes) branch of Pangea. The collision between Gondwana and Laurussia (Ziegler, 1989) developed the central Pangean mountain range – Ouachita – Appalachian Mountains in North America (Hatcher *et al.*, 1989), Mauretanides in Africa and Hercynian mountains in Europe (Franke, 1989a, b; Ziegler, 1989).

The Hercynian orogeny in Europe was a result of collision of several separate blocks with the Laurussia margin (Franke, 1989b; Lewandowski, 1998), followed by the involvement of Gondwana continent. Widespread orogenic deformation occurred across western and central Europe in Iberia, Ligerian terrane, Massif Central, Sardinian–Corsican, Armorican, Harz Mts., Saxothuringian, Bohemian, and Silesia areas (Yilmaz *et al.*, 1996).

The Hercynian convergence in Europe led to large-scale dextral shortening, overthrusting and emplacement of parts of the accretionary complexes. The amount of convergence was modified by large, dextral and sinistral transfer faults. Late Carboniferous events were also marked in the Alps, Carpathians (Dallmeyer *et al.*, 1996; Gawęda *et al.*, 1998) and Rhodopes (Yanev, 1992). Mountains formed on the northern margin of Paleotethys, as results of these events, were connected with the Hercynian orogen in Europe. North-dipping subduction developed along the Paleotethys margin. This subduction was a major force driving Late Paleozoic and Early Mesozoic movement of plates in this area.

The basement of most of the plates, which play important role in the Mesozoic–Cenozoic evolution of the circum-Carpathian area, was formed during the Late Paleozoic collisional events. Moesia, Rhodopes and the Alcapa superterrane (Neubauer *et al.*, 1995), which includes Eastern Alps, Inner Carpathians, Tisa and adjacent terranes, were sutured to the Laurasian arm of Pangea, while Adria and adjacent terranes were situated near the Gondwanian (African) arm. The position of the Bohemian Massif, adjacent to the Carpathian plates, according to paleomagnetic study (Krs *et al.*, 1996) was located near Equator, agrees with the global Pangean model (Van der Voo, 1993; Golonka *et al.*, 1994).

Triassic

Many of the continental collisions, which began in the Carboniferous, reached maturity in the Early Permian. A major part of Pangea was assembled, and the new supercontinent, ringed by subduction zones, moved steadily northwards. The formation of Laurasia reached a main phase, with the suturing of Kazakhstan and Siberia with Laurussia (Nikishin *et al.*, 1996; Zonenshain *et al.*, 1990; Ziegler, 1989). Carboniferous–earliest Permian rifting of the Cimmerian plates (see Sengör & Natalin, 1996; Dercourt *et al.*, 1993; Golonka *et al.*, 1994) from Gondwana turned into drifting during the Permian, marking the inception of the Neotethys Ocean. Rifting and oceanic type of basin opening could also have occurred in the Mediterranean, recorded by the deep-water sediments of Sicily (Catalano *et al.*, 1991; Kozur, 1991), Lago Negro (Marsella *et al.*, 1993) and Crete (Kozur & Krahl, 1987).

The subduction zone along the Paleotethys margin (Fig. 3) caused back-arc rifting in the proto-Black Sea area and along the margins of Scythian-Turan platform (Zonenshain *et al.*, 1990; Kazmin, 1990, 1991). The Tauric basin was formed between the Pontides and the Dobrogea-Crimea segment of the Scythian platform. The opening of the Meliata-Halstatt Ocean, between the Eurasian margin and the Hungarian Tisa block (Kázmer & Kovács, 1989; Kozur, 1991; Plašienka & Kováč, 1999), was geodynamically related to this event (Fig. 3). In the proto-Mediterranean area, rifting and fragmentation of separated blocks continue to progress (Ricou, 1996; Golonka & Gahagan, 1997). In the Eastern Mediterranean area rifting occurred during the Permian and Triassic time (Stampfli *et al.*, 1991; Guiraud & Bellion, 1996), accompanied by Mid-Late Triassic, extensive, alkaline basalt flows evident between Levant and Morocco. The rifting was followed by sea-floor spreading recorded by Triassic Mamonia ophiolites from Cyprus (Robertson & Woodcock, 1979, Robertson, 1998).

Several blocks of the Cimmerian provenance (Sengör & Natalin, 1996) collided with the Eurasian margin in the Triassic–earliest Jurassic Early Cimmerian orogeny. Alborz and South Caspian microcontinent collided with the Scythian platform at an earlier time (Carnian), while the Serbo-Macedonian block collided with the Moesia-Rhodopes (Tari *et al.*, 1997), and the Lut block collided with the Turan platform, at a later (Norian) phase (Zonenshain *et al.*, 1990; Kazmin, 1990).

In the western Tethys area, Late Paleozoic and Triassic rifting and sea-floor spreading resulted in several separated carbonate platforms (Philip *et al.*, 1996; Kiessling *et al.*, 1999). The western part of the Neotethys is known as the Vardar Ocean (e.g., Sengör & Natalin, 1996, 1984; Kázmer & Kovács, 1989). The narrow branch of Neotethys separated the Apulia-Taurus platform from the African continent. The Apulia platform was connected with European marginal platforms. Its northernmost part was possibly separated from the Umbria-Marche region by a rift. The in-