Geodynamic evolution and paleogeography of the Carpathian-Pannonian region – a global perspective

JAN GOLONKA, NESTOR OSZCZYPKO & ANDRZEJ ŚLACZKA

Jagiellonian University, Institute of Geological Sciences, Oleandry Str. 2a, 30-063 Kraków, Poland.

Abstract: The geodynamic evolution of the Carpathian region reflects the plate tectonic history of the Earth from the Early Cambrian to Late Miocene. In this region the several terranes form the mosaic of tectonic units. The Alpine history of the Carpathians begins with the Mesozoic rifting and formation of the oceanic type basin along the northern margin of the Tethys Ocean and terminated with the Early Miocene continental collision, and Middle/Late Miocene overthrusting upon the North European platform.

Key words: plate tectonic, terranes, rifting, continental collision, Carpathians

The geodynamic evolution of the Carpathian-pannonian region reflects the plate tectonic history of the Earth from the disassembly of Rodinia-Pannotia during the Sauk (Early Cambrian - Middle Ordovician) time, through closure, assembly, reorganization and formation of Pangean supercontinent during the Tippecanoe (Middle Ordovician - Early Devonian), Kaskaskia (Early Devonian - Late Carboniferous) and Lower Absaroka (Late Carboniferous - Late Permian) time, rifting, spreading and disassembly during the Upper Absaroka (Early Triassic - Middle Jurassic) and Zuni (Middle Jurassic - Early Paleogene) time, and new closure during Tejas (Early Paleogene - Neogene) time.

The several terranes form the mosaic of the tectonic units of the present day basement of major plates in the circum-Carpathian region. The terranes' history began with the Cadomian orogeny during the Vendian time. This orogeny caused deformation and magmatic events of terranes from Iberia through Armorica, Bohemian and Malopolska massifs, Carpathians to the Transcaucasus area. Southern Poland (the Małopolska Massif) and other terranes belonged at the Cambrian time to the Gondwana supercontinent and were situated at the high latitudes of the Southern Hemisphere. Rheic Ocean and Tornquist Sea separated the Baltica continent, which included most of Ukraine and northeastern Poland, from Gondwana (Golonka et al., 1994).

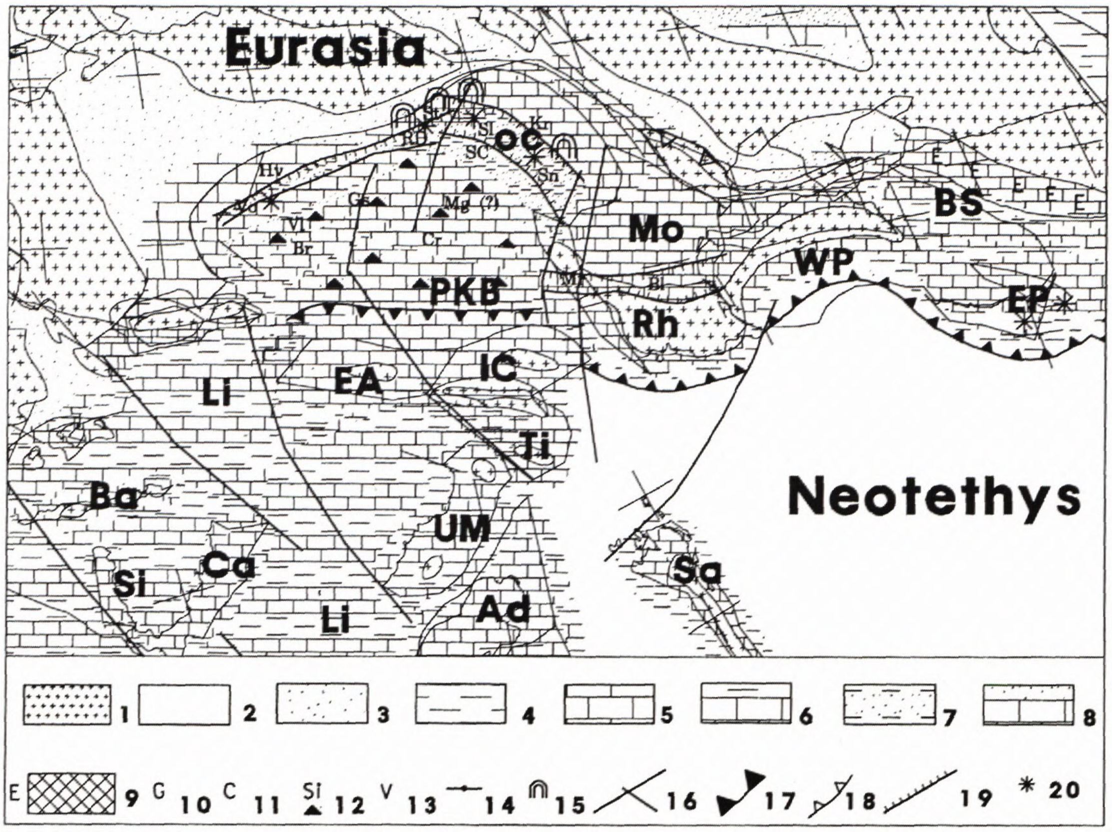
The Early Paleozoic rifting and drifting detached several terranes from Gondwana. These terranes collided with Baltica during the Caledonian orogeny (Late Ordovician Early Devonian) and the early stages of the Hercynian (Variscan) orogeny (Devonian-Early Carboniferous). Baltica at this time became the part of the larger continent Laurussia. During the Carboniferous time the Hercynian orogeny was concluded with the collision of Gondwana and Laurussia. The supercontinent Pangea was formed. The Tethys Ocean formed the embayment between the Eurasian and Gondwanian branches of Pangea. The basement of the major plates was consolidated at that time.

The Mesozoic rifting events resulted in the formation of the oceanic type basins along the northern margin of the Tethys Ocean. The Meliata and Pieniny Klippen Belt Oceans were formed in the western part of the region. Tauric and Greater Caucasus-Caspian Oceans were located east of the Moesian Platform (Kiessling et al., 1999).

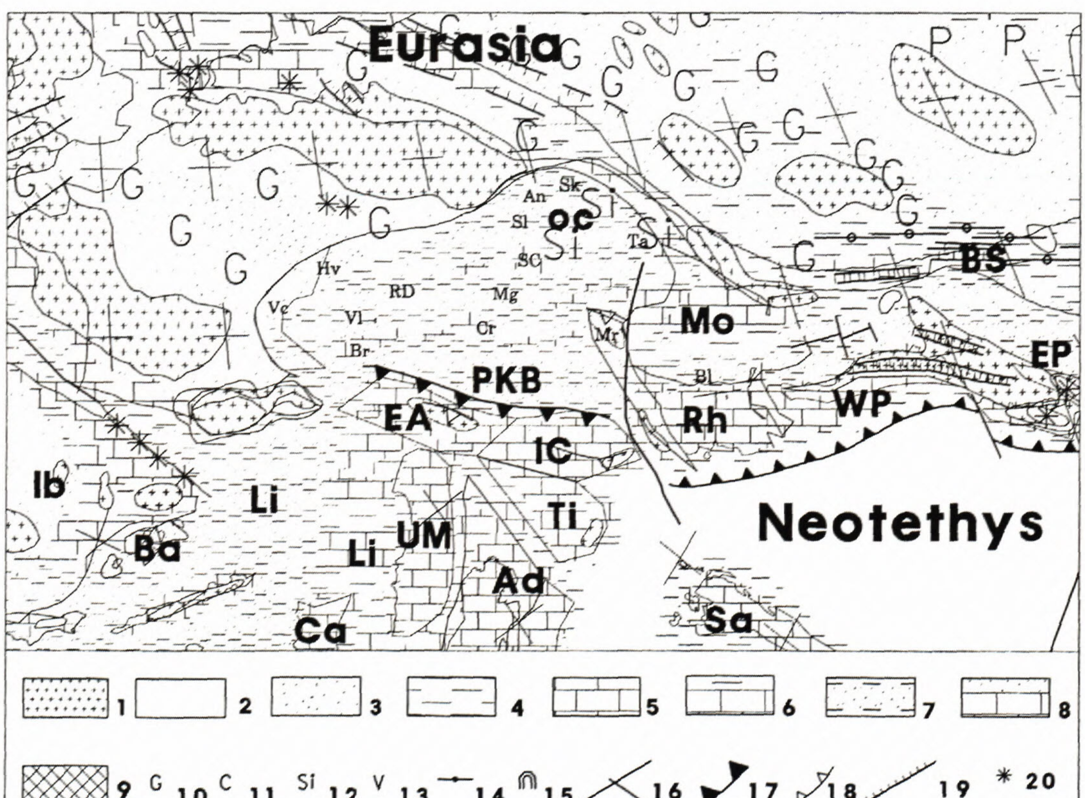
The Central Atlantic was in an advanced drifting stage during Middle – Late Jurassic (Golonka et al, 1996). Rifting continued in the North Sea and in the northern Proto-Atlantic. The progressive breakup of Pangea resulted in a system of spreading axes, transform faults, and rifts, which connected the ocean floor spreading in the Central Atlantic and Ligurian-Piedmont Ocean to the opening of the Pieniny Klippen Belt Basin and to rifting which continued through the Polish-Danish graben to Mid-Norway and the Barents Sea. The Pieniny Klippen Belt Basin was fully opened by the Middle - Late Jurassic time. The Czorsztyn ridge separated this basin from the enigmatic and speculative Magura basin. This ridge may be related to the Briançonnais zone in Alps, while Magura basin may be connected with the opening Valais trough. Tethys was connected with the Polish-Danish graben by transform fault and rift system, which preceded opening of the Outer Carpathian basins. The Żegocina Andesite is a volcanic expression of this early Outer Carpathian rifting (Ślączka et al., 1999).

Major plate reorganization happened during the Tithonian time. (fig.1) The Central Atlantic began to propagate to the area between Iberia and the New Foundland shelf (Ziegler, 1988). The Ligurian-Pieniny Ocean reached its maximum width and stopped. The subduction

Slovak Geol. Mag., 6, 2-3(2000), 139–142



E:/paleomnt/jurcre1.dgn Apr. 05, 2000 11:34:11



E:/paleomnt/jurcre3.dgn Apr. 05, 2000 11:35:40

of the Meliata-Halstatt Ocean and the collision of the Tisa block with the Inner Carpathian terranes was concluded at the latest Late Jurassic - earliest Lower Cretaceous time. Subduction jumped to the northern margin of the Inner Carpathian terranes and began to consume the Pieniny Klippen Belt Ocean (Birkenmajer, 1986). The Outer Carpathian (Silesian) basin) had developed with extensional volcanism (Golonka et al., 1999). To the west, this troughs extended into the Valais ocean, which entered into a seafloor spreading phase (Froitzheim et al., 1996), and further into the area between Spain and France and to the Biscay Bay (Stampfli, 1996). Eastward it was prolongated into the Eastern Carpathians in Ukraine and Romania (Ślączka et al, 1999. The Polish-Danish rift turned into aulacogen (Żytko, 1985) with marginal marine, sometimes evaporitic sediments. Carbonate platforms with reefs have developed on the northern margin of Silesian Basin. The Silesian ridge (Książkiewicz, 1977) separated Silesian and Magura basins. The subsidence in the Silesian Basin was accompanied by the extrusion of basic lavas (teschenites in the Western Carpathian and diabase-melaphyre within the Black Flysch of the Eastern Carpathians. The Outer Carpathian basin reached its greatest width during the Hauterivian - Aptian time. With the widening of the basin, several subbasins (troughs) began to show their distinctive features. This subbasins, like Silesian, Sub-Silesian, Skole, Tarcau, were separated by uplifted areas. The general downwarping of the Silesian Basin was probably due to the cooling effect of the underlying lithosphere (Ślączka et al., 1999).

During Hauterivian-Aptian the Ligurian Ocean entered into its compressional phase (Ricou, 1996). Continued closure of the western part of Neotethys was related to the subduction along the Neotethys margin. This closure was marked by Albian collisional deformation, in the early stage of Trupchun phase in Alps and by the formation of eclogites in Austroalpine units (Froitzheim et al., 1996). . The thrusting and shortening was also noted in the Inner Carpathians (Plašienka & Kováč, 1999). Subduction was active on the southern margin of the Pieniny Klippen Belt Ocean. The compressional event took place in the southeastern part of the Carpathians (Ślączka et al, 1999). Intensive folding, accompanied by the deposition of coarse clastic sediments was completed by the Albian time. The northward movement of the Marmarosh terrane perhaps caused this folding. In the Western Outer Carpathians the uplifting of the intrabasinal ridges manifested this period of compression.

Latest Cretaceous-earliest Paleocene was the time of the closure of the Pieniny Klippen Belt Ocean and the collision of the Inner Carpathians terranes with the Czorsztyn Ridge in the Carpathians (Birkenmajer, 1986; Winkler & Ślączka, 1992). The subduction zone jumped from the southern margin of the Pieniny Klippen Belt Basin to the northern margin of the Czorsztyn ridge and began consume the Magura Basin. The Alcapa block was formed at that time by welding together Eastern Alps, Inner Carpathian, Tisa as well as smaller terranes, like Bükk, Transdanubian or Getic (Plašienka & Kováč, 1999). During Paleogene the subduction consumed most of the Magura Basin. After the Late Oligocene folding, the Magura Nappe thrust northward and covered the remnant of the Silesian ridge and in the more outer part of the Carpathian Basin (Silesian Subsilesian, Skole-Tarcau) flysch sedimentation continued during the Oligocene. The Paratethys Sea developed in Europe and central Asia, ahead of the progressing northwards orogenic belts. Geodynamic evolution of the basins in the Alpine-Carpathian belt led to a transition from flysch to molasse type of sedimentation.

Apulian and Alcapa terranes continued their northward movement colliding with the European plate, until 17 Ma (Oszczypko, 1992, 1999). This collision caused the foreland to propagate North. N to NNW-vergent thrust system of the Eastern Alps was formed. The oblique collision between the North European plate and the overriding Western Carpathian terranes led to the development of the outer accretionary wedge, the built up many flysch nappes and the formation of a foredeep. These nappes were detached from their original basement and thrust over the Paleozoic-Mesozoic deposits of the North European platform. This process was completed during the Early Miocene time slice in the Vienna basin area and then progressed northeastwards. Th formation of the West Carpathian thrusts was completed by the middle Miocene time. The thrust front was still progressing eastwards in the Eastern Carpathians, with a strong element of translation. The thrusting was completed during the Pliocene-Quaternary in the Vrancea Mountains in Romania. The Carpathian foredeep developed as a peripheral foreland basin (Golonka et al. 1999). In Central Europe, the NW-SE trending rift system was perpendicular or diagonal to the thrust front of the Carpathians. Tertiary magmatism was crossing the Carpathians between Moravia and Upper Silesia, on one side, and the Pannonian Basin, on the other. Mantle doming contributed to crustal stretching.

Fig. 1. Paleoenvironment and Lithofacies of the circum-Carpathian area during latest Late Jurassic - earliest Lower Cretaceous (146-136 Ma). 1 - Land non-deposit, 2 - deep ocean basin with little to no sediments (primarily oceanic crust, 3 - sandstone, siltstone, 4 - shale, clay, mudstone, 5 - limestone, 6 - interbeded or mixed sand/shale, 7 - interbeded or mixed carbonate/shale, 8 - interbeded or mixed carbonate/sand, 9 - evaporite 10 - glauconite, 11 - coal, 12 - silica, 13 - volcanics, 14 - organic-rich rock, 15 - reef, 16 - oceanic spreading center and transform faults, 17 - active subduction zone, 18 - thrust fault, 19 - normal fault, 20 - volcano. Abbreviations of oceans and plates names: Ad - Adria (Apulia), An - Andrychov Ridge, Ba - Balearic , Bl - Balkans, Br - Briançonnais, BS - Black Sea, Ca - Calabria-Campania, Cr - Czorsztyn Ridge , Di - Dinarides , EA - Eastern Alps, EP - Eastern Pontides, Gs - Gresten, Hv -Helvetic, Ib - Iberia, IC - Inner Carpathians, Li - Ligurian (Piemont) Ocean, Mg - Magura, Mo - Moesia, Mr - Marmarosh, OC - Outer Carpathians, Pi - Pindos, PKB - Pieniny Klippen Belt, RD - Rheno-Danubian, Rh - Rhodopes, Sa - Sakariya , SC - Silesian Ridge (Cordillera), Sl- Silesian, Si - Sicily, Sk - Skole, Sn - Sinaia, Ta - Tarçau, Ti – Tisa, UM - Umbria-Marche, Vc - Vercors, Vl - Valais, WP - Western Pontides.

Slovak Geol. Mag., 6, 2-3(2000), 139–142

References

Birkenmajer, K. 1986: Stages of structural evolution of the Pieniny Klippen Belt, Carpathians: Studia Geologica Polonica, 88: 7-32.

Golonka, J. 1999: Geodynamic Evolution of the South Caspian Basin, AAPG, Bulletin, 83: 1315.

Golonka, J., Ross, M.I. & Scotese, C.R. 1994: Phanerozoic paleogeographic and paleoclimatic modeling map. In: Embry, A. F. Beauchamp, B., Glass, D. J., (eds.), Pangea; global environments and resources. Canadian Society of Petroleum Geologists Memoir, 17: 1-47.

Golonka, J., Edrich, M.E., Ford D.W., Pauken, R.B., Bocharova, N.Y. & Scotese, C.R. 1996: Jurassic Paleogeographic Maps of the World, *in* M. Morales, ed., The Continental Jurassic: Museum of Northern Arizona Bulletin, 60: 1-5.

Golonka, J., Oszczypko, N. & Ślączka, A. 1999: Geodynamic Evolution of the Carpathian Foredeep Basin – a Global Perspective. Biul. Państwowego Instytutu Geologicznego, 387: 100-101.

Kiessling, W., Flügel, E. & Golonka, J. 1999: Paleo Reef Maps: Evaluation of comprehensive database of Phanerozoic Reefs. AAPG Bulletin, 83: 1552-1587.

Książkiewicz, M. 1977: Tectonics of the Carpathians, *in* W. Pożaryski, Ed. Geology of Poland. Vol. IV: Tectonics: Wydawnictwa Geologiczne, Warsaw, Poland, pp. 476-604.

Oszczypko, N. 1998: The Western Carpathian Foredeep – Development of the Foreland Basin in Front of the Accretionary Wedge and its Burial History (Poland): Geologica Carpathica, 49: 415-431.

Plašienka, A. & Kováč, M. 1999: How to Loop Carpathians – an Attempt to Reconstruct Meso-Cenozoic Palinspastic History of the Carpathian Orocline, Geologica Carpathica, 50: 163-165.

Ricou, L.E. 1996: The Plate Tectonic History of the Past Tethys Ocean, in Nairn, A. E. M., Ricou, L.E., Vrielynck, B. & Dercourt, J. eds.: The Oceans Basins and Margin, Vol. 8 The Tethys Ocean. Plenum Press. New York and London. pp.3-70.

Ślączka, A., Oszczypko, N., Malata, E. & Cieszkowski, M. 1999: An Early History of the Outer Carpathian Basin. Geologica Carpathica, 50: 170 – 172.

Stampfli, G.M. 1996: The Intra-Alpine terrain; a Paleotethyan remnant in the Alpine Variscides, *in* Schmid, S.M., Frey, M., Froitzheim, N., Heilbronner, R. & Stuenitz, H. (eds.): Alpine geology; proceedings of the second workshop: 2nd workshop on Alpine geology: Eclogae Geologicae Helvetiae, 89: 13-42.

Winkler, W. & Ślączka, A. 1992: Sediment dispersal and provenance in the Silesian, Dukla and Magura flysch nappes (Outer Carpathians, Poland): Geologische Rundschau, 81: 371-382.

Ziegler, P.A. 1988: Evolution of the Arctic-North Atlantic and the Western Tethys. American Association of Petroleum Geologists Memoir, v. 43,p. 1-198.

Żytko, K. 1985: Some problems of a geodynamic model of the Northern Carpathians: Kwartalnik Geologiczny, v. 29, p. 85-108.