tain numerous clasts cut by inherited joints filled by these veins. The organization of inherited joints is very poor (Tokarski and Świerczewska, 2003). However, within the Witów series we have observed only very few veined clasts. It appears that the long sedimentary transport resulted in decomposition of veined clasts and consequent absence of inherited joints. We conclude that the longer the sedimentary transport is, the better organization of clast-scale joints can be visible.

(4) Most of the studied clast-scale joints are orientated subperpendicular to perpendicular to the AB planes of the clasts, notwithstanding orientation of the planes. This suggests that joints form subperpendicular to the existing lithological boundaries, notwithstanding the orientation of the latter.

(5) Within the Witów series, the direction of offset is only exceptionally visible on the metre-scale strike-slip faults that cut sandstone beds, and this handicaps the analysis of the faults. On the other hand, the offset is evident on the faulted clasts.

References

BRUD S. and WOROBIEC G., 2003. Results of investigations of macroscopic plant remains from the Witów series (southern Poland) (in Polish). *Przegląd Geol.*, 51: 392-401.

TOKARSKI A.K. and ŚWIERCZEWSKA A., 2003. Quaternary tectonic activity of the Bystrica overthrust in the Nowy Sącz area (Outer Carpathians, Poland). In: W. ZUCHIEWICZ (Editor), Mater. V Ogólnopolskiej Konferencji "Neotektonika Polski - Neotektonika a morfotektonika: metody badan", Kraków, 26-27.09.2003. Komisja Neotektoniki Kom. Bad. Czwart. PAN, ING UJ, Galicia T. Group, Kraków: Kraków: 67-69.

Devonian Exotics in the Pieniny Klippen Belt Flysch and their Significance for the Plate Paleozoic Plate Tectonic Reconstruction of the West Carpathia

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Introduction

In Poland, Slovakia and the Czech Republic, Carpathian Fold Belt consists of an older unit known as the Inner Central or Central Carpathians and a younger one, known as the Outer West Carpathians the latter being overthrust onto the southern part of the European platform (Golonka and Lewandowski, eds. 2003). The boundary between the overriding Inner Carpathian (Alcapa plate) and the European plate is the Pieniny Klippen Belt. The fit between these plates constitutes one the problems of the Carpathian plate tectonic reconstruction. The most logical assumption would be to produce a reconstruction of the Pieniny Klippen Belt Basin, built of the Mesozoic sedimentary successions basins with the European margin on one side and the Inner Carpathian plate on the other (Golonka and Lewandowski, eds., 2003). The known basement of the Inner Carpathians comprises however variously metamorphosed Precambrian, Lower Paleozoic to Lower Carboniferous rocks (Gawêda et al., 2003) while the Devonian-Lower Carboniferous rocks of the European platform under Outer Carpathian south of Krakow are unmetamorphosed and undeformed (Slaczka, 2001).

The devonian exotics

The new discovery of the unmetamorphosed Devonian limestones in the exotic pebbles in the Pieniny Klippen Belt and Outer Carpathian Flysch (Silesian unit) certainly will help to solve this problem. The Pieniny exotic is represented by micritic boundstone from mainly blue algae with partially recristalized matrix. Most important among the fossils are: *Parathurammina*, *Bisphaera*, *Caligella*, *Earlandia*), calcispheres, ostracods, and multi-chamber forams (e. g. *Tournayellina*, *Palaeospiroplectammina*). They indicate the late Famennian – early Visean, but the lack of diagnostic forms younger than late Famennian and occurrence of the numerous primitive forms point to the late Famennian age.

The Outer Carpathian Flysch exotic was found in the Gródek on Dunajec river. It is a strongly dolomitised mudstone with numerous microfossils such as: algae (*Issinella*, *Kamaena*, *Girvanella*), calcispheres (*Archaesphaera*, *Radiosphaera*), single-chamber forams (*Vicinesphaera*, *Parathurammina*, *Bisphaera*, *Irregularina*), crinoids, echinoids spines, ostracods, brachiopods and vermetid gastropods. This assemblages of fossils indicate lagoonal facies characteristic for the late Devonian strata.

Plate tectonic implications

The Pieniny exotic pebbles were supplied from the so-called Andrusov Ridge, which belonged to the northwestern margin of the Inner Carpathian terrane southeast from the Pieniny Klippen Belt Basin (Birkenmajer et al., 1990, Golonka et al., 2003). This margin was destroyed during the orogenic process or may be is now hidden under the Central Carpathian Paleogene. The Devonian rooks were deposited in the shallow basin in the foreland of the Inner Carpathian Variscides. The Precambrian or lower Paleozoic (Caledonian) continental crust constituted the floor of this basin. This configuration display similarities with the Brunovistulicum (Finger et al., 2000, Kalvoda, 2001, Kalvoda et al., 2003) suggesting that the area belonged to the Avalonian terranes.

Avalonia was probably sutured to Baltica by the end of the Ordovician or in the Early Silurian during the the early Caledonian orogeny (Golonka and Lewandowski, eds. 2003). Granitoids of the Eastern Carpathian terranes in Romania, according to Panã et al. (2002), are of Early to Middle Ordovician age and represent the same early Caledonian event. Between Gondwana and Avalonia, a large longitudinal oceanic unit, known as the Rheic Ocean (Golonka and Lewandowski, eds. 2003), was formed. After the collision of Avalonia with Baltica, a southward dipping subduction developed along the new margin of Gondwana. This subduction triggered detachment of a new group of Armorican terranes, which included Armorica, Saxoturingia, Central German (Harz), Moldanubian (Czechia), Helvetic, Penninic, Austroalpine, Inner Carpathian, Pannonian, Serbo-Macedonian, Rhodopes and Pontides. At the same time, after the complete closure of the Iapetus Ocean, the continents of Baltica, Avalonia, and Laurentia formed the continent of Laurussia (Ziegler, 1989). The Armoric terranes began to arrive at the Laurussia margin during Devonian time. Collisional activities were detected in the Alpine-Carpathain area (Dallmeyer et al., 1996, Rakús et al., 1998). The oldest deformation and metamorphic event in the Western Tatra Mts. in the Carpathians took place around 400–380 Ma (Gaweda et al., 2003). The Variscan orogeny in Europe was a result of the collision of several separate blocks with the Laurussian margin, followed by the Gondwana-Laurussia collision (Golonka & Lewandowski, 2003). The basement of most of the plates, which played an important role in the Mesozoic-Cenozoic evolution of the circum-Carpathian area, was formed during the Late Paleozoic collisional event. The older, Cadomian and Caledonian basement elements experienced Variscan tectonothermal overprint (Golonka et al., 2003). During the Mesozoic rifting events this basement was separted forming North European and Inner Carpathian plates.

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References

BIRKENMAJER K., 1986. Stages of structural evolution of the Pieniny Klippen Belt, Carpathians. *Studia Geol. Pol.*, 88: 7-32.

BIRKENMAJER K., KOZUR H. and MOCK R,1990. Exotic Triassic pelagic limestone pebbles from the Pieniny Klippen Belt of Poland: a further evidence for Early Mesozoic rifting in West Carpathians. *Ann. Soc. Geol.Pol.*, 60:. 3–44.

DALLMEYER R. D., NEUBAUER F. HANDLER R ., FRITZ H., MUELLER W., PANA D. and. PUTIS M., 1996. Tectonothermal evolution of the internal Alps and Carpathians; evidence from 40Ar/39Ar mineral and whole-rock data. In: S. M. SCHMID, M. FREY, N. FROITZHEIM, R. HEILBRONNER, and H. STUENITZ (Editors), Alpine geology; proceedings of the second workshop. 2nd workshop on Alpine geology. *Ecl. Geol. Helv.*, 89:203–227.

FINGER F., HANZL P., PIN C., VON QYADT A. and STEYER H., 2000. The Brunovistulicum: Avalonian Precambrian sequence at the eastern end of the Central European Variscides. In: W. FRANKE, W. HAAK, V. ONCKEN, and D. TANNER (Editors), Orogenic Processes: Quantification and Modelling in the Variscan Belt: Geological Society, London, Special publication 179, pp. 103–112.

GAWEDA, A., LEFELD, J. MICHALIK M. and UCHMAN A., 2003. Inner Carpthians: Tatra Mountains. In: J. GOLONKA and M. LEWANDOWSKI (Editors), Geology, geophysics, geothermics and deep structure of the West Carpathians and their basement. Publications of the Institute of Geophysics Polish Academy of Sciences. Monographic Volume 28 (363), Warszawa, Poland, pp. 57-63.

GOLONKA J, 2002, Plate-tectonic maps of the Phanerozoic. In: W. KIESSLING, E. FLÜGEL, an J. GOLONKA (Editors), Phanerozoic reef patterns. SEPM (Society for Sedimentary Geology) Special Publication 72, Tulsa, pp. 21–75.

GOLONKA J. and LEWANDOWSKI M. (Editors), 2003. Geology, geophysics, geothermics and deep structure of the West Carpathians and their basement. Publications of the Institute of Geophysics Polish Academy of Sciences. Monographic Volume, Warszawa, Poland

GOLONKA J., KROBICKI M., OSZCZYPKO N., SLACZKA A. and SLOMKA T., 2003. Geodynamic evolution and palaeogeography of the Polish Carpathians and adjacent areas during Neo-Cimmerian and preceding events (latest Triassic – earliest Cretaceous). In: T. McCANN and A. SAINTOT (Editors), Tracing tectonic deformation using the sedimentary record. Geological Society, London, Special Publication 208, pp 138–158.

KALVODA J., 2001. Upper Devonian-Lower Carboniferous foraminiferal paleobiogeography and Perigondwana tarranes at the Baltica-Gondwana Interface. *Geol. Carp.*, 52, 205–215.

KALVODA J., LEICHMANN J., BÁBEK O. and MELICHAR R., 2003. Brunovistulian terrane (Central Europe) and Istanbul zone (NW Turkey): Late Proterozoic and Paleozoic tectonostratigraphic development and paleogeography. *Geol. Carp.*, 54, 139-152.

PANA D., BALINTONI I., HEAMAN L. and CREASER R., 2002. The U-Pb and Sm-Nd dating of the main lithotectonic assemblages of the Outer Eastern Carpathians, Romania. *Geol. Carp.*, 53: 177–180.

RAKÚS M., POTFAJ M, and VOZÁROVÁ A., 1998. Basic paleogeographic and paleotectonic units of the Western Carpathians, In: M. RAKÚS, ed., Geodynamic development of the Western Carpathians: Geological Survey of Slovac Republic, Bratislava, pp. 15–26.

SLACZKA A., 2003. Deep structure below the Carpathian overthrust SW from Kraków. In: J. GOLONKA and M. LEWANDOWSKI (Editors), Geology, geophysics, geothermics and deep structure of the West Carpathians and their basement. Publications of the Institute of Geophysics Polish Academy of Sciences. Monographic Volume 28 (363), Warszawa, Poland pp. 177-179.

ZIEGLER P.A., 1989. Evolution of Laurussia. Kluwer Academic Publishers, Dordrecht, Netherlands.