and Australia. The location of Chinese plates as well as numerous smaller continental blocks that bordered Gondwana is less certain (Golonka, 2000). Some of these plates perhaps rifted off Gondwana and drifted toward Siberia. The Eastern Iapetus was probably located between Gondwana and the plates (see Zonenshain et al., 1990) like Tuva-Mongolian, Tom, Barguzin and central Kazkhstan.

Advanced seafloor spreading occurred during the Cambrian. The width of the Iapetus Ocean reached 5000 km (Kent and Van der Voo, 1990). Subduction zone developed along the margin of Gondwana between Northwestern South America and the Chinese terranes. This subduction caused the onset of rifting of the Avalonian terranes during the Early Ordovician (Golonka et al., 1994).

The continent of Avalonia is traditionally believed to have consisted of northwestern and possibly southern Poland and their foredeep, terranes in northern Germany, the Ardennes of Belgium and northern France, England, Wales, southeastern Ireland, the Avalon Peninsula of eastern Newfoundland, much of Nova Scotia, southern New Brunswick and some coastal parts of New England. The Brunovistulicum terrane, some accreted terranes in the basement of East Carpathians, parts of the Scythian platform, parts of Kazakhstan and Southern Mongolia terrane could have constituted the eastern extension of Avalonia.

A large longitudinal oceanic unit, known as the Rheic Ocean, was formed between Gondwana and Avalonia. The Turkmen (Zonenshain et al., 1990) and Solonker (Sengör and Natalin, 1996) oceans in Asia constitute the eastern parts of this Rheic Ocean.

Sedimentary sequences in the Gobi desert area in Mongolia reflect the plate-tectonic development of Central Asia. A collision between microcontinents (Salairian orogeny) during Late Cambrian–Early Ordovician times in the Mongolia–Tuva area (Zonenshain et al., 1990) marked the onset of the formation of the Amuria (Mongolia) microcontinent. A thick pile was developed on the southern margin of this continent. With convergence of the South Mongolian terrane, these turbidites turned into synorogenic flysch and, later, into the Late Paleozoic shallow-water carbonate sequences. The collision of the North China plate and closure of the Solonker Ocean (Sengör and Natalin,1996) in the Permain concluded the orogenic process.

References

GOLONKA J., 2000. Cambrian-Neogene Plate Tectonic Maps, Wydawnictwa Uniwersytetu Jagiellońskiego, Kraków, 125 pp.

GOLONKA J., ROSS M.I. and SCOTESE C.R., 1994. Phanerozoic paleogeographic and paleoclimatic modeling maps. In: A.F. EMBRY, B. BEAUCHAMP and D.J. GLASS (Editors), Pangea; global environments and resources: Calgary, Canada, *Can. Soc. Petrol. Geol. Memoir*, 17: 1-47.

KENT D.V. and VAN DER VOO R., 1990. Palaeozoic palaeogeography from palaeomagnetism of the Atlantic-bordering continents. In: W.S. MCKERROW and C.R. SCOTESE (Editors), Palaeozoic palaeogeography and biogeography, *Geol. Soc. London Memoir,* 12: 49-56.

SENGÖR A.M.C. and NATALIN B.A., 1996. Paleotectonics of Asia: fragment of a synthesis. In: AN YIN and T.M. HARRISON (Editors), The Tectonic Evolution of Asia. Cambridge University Press, Cambridge, pp. 486-640.

TORSVIK T.H., SMETHURST M.A., MEERT J.G., VAN DER VOO R., MCKERROW W.S., BRASIER M.D., STURT B.A. and WALDERHAUG H.J., 1996. Continental break-up and collision in the Neoproterozoic and Palaeozoic; a tale of Baltica and Laurentia. *Earth-Science Reviews*, 40: 229-258.

ZONENSHAIN L.P., KUZMIN M.L. and NATAPOV L.N., 1990. Geology of the USSR: A Plate-Tectonic Synthesis. In: B.M. PAGE (Editor), Geodynamics Series, 21. American Geophysical Union, Washington, D.C., 242 p.

Metadolerites of the Vrbno Group and their Origin, the Jeseníky Mts.

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Many occurrences of basic metavolcanic rocks described here as metadolerites (dolerites) lie between Úsov and Malá Morávka in the Jeseníky Mts. Metadolerites occur both as sills and dykes in the sequence of metasediments and metavolcanites of the Vrbno Group as well as in the rocks of the pre-Devonian crystalline complex. Their bodies are mostly elongated NE–SW, X to several X0 metres in thickness and several X0 to X00 metres in length. Metadolerites studied in borehole JR-10 form four bodies with the thickness of core of 4–21 m, with at least one of these bodies being unconformable to the main foliation (Valenta et al., 1987). In this borehole, metadolerites penetrate the lower part of the sedimentary sequence of Dobřečov Group, dated to the Givetian and Frasnian by Hladil (in Cháb et al., 1987).

Metadolerites are dark and light green-grey rocks, usually light-spotted, fine- to medium-grained. In thin sections, they predominantly show ophitic texture and slightly orientated structure. They generally display secondary, i.e. metamorphic, mineral association. Plagioclase (albite) slightly predominates over amphibole (actinolite); titanite, chlorite, epidote, carbonate and opaque mineral were also observed.

In the deformed and retrogressively metamorphosed parts and/or on margins of thicker bodies, the metadolerites pass to greenschists of grey-green to green colour, locally sericite-chlorite schists. Metadolerite bodies in borehole JR-10 are massive in the centre and intensively cleaved on the margins. The rock is green-grey, medium-grained with lepidonematoblastic matrix (chlorite, titanite, clinozoisite, muscovite, albite, carbonate) and with relict porphyroclasts of actinolite.

Metadolerites represent a generally homogeneous group in view of density, magnetic characteristics including magnetic anisotropy (AMS), as well as the distribution of Th and U (Tab. 1). Two different types of metadolerites can be distinguished from the potassium distribution pattern: the first type with 0.56 % K on average, in a usual ratio to Th and U, and the second type with a very low K content.

Parameter	Average ± stand. dev.
Dm	2.963 ± 0.028 g.cm^{-3}
SUSC	630.10^{-6} ± 150.10^{-6} SI
P-coef.	1.040 ± 0.009
Th	1.2 ± 0.5 ppm
U	0.3 ± 0.2 ppm

Tab. 1. Selected petrophysical parameters for metadolerites of the Vrbno Group (Dm – mineralogical density, SUSC – magnetic susceptibility, P-coef. – coefficient of AMS.

The metadolerites have a composition of basalt (TAS diagram). In their trace and rare earth elements geochemistry, they correspond to tholeiitic basalts at a transition between ocean basalts and basalts of intracontinental rifts. Metadolerites from borehole JR-10 fall in the field of island arc basalts in the geotectonic discrimination diagrams (Pearce and Norry, 1979). All other metadolerites of the Vrbno Group plot in the fields of mid-ocean ridge and within-plate basalts (Fig. 1).

The total REE content in the metadolerites is relatively low (20 to 40 times higher than the REE content in chondrites). Normalized contents form flat curves with slightly enriched LREE and lack distinct negative Eu anomalies, indicating pertinence to E-MORB basalts (Fig. 2). Metadolerite samples from borehole JR-10 correspond to N-MORB basalts with a distinct LREE depletion. Metadolerites from the lower part of this borehole differ in their very low contents of Th and immobile elements which might indicate a different type of magma.

The determination of two types of metadolerites supports the idea, proposed by many authors, about the existence of two different stages of basic volcanism in the Vrbno Group.

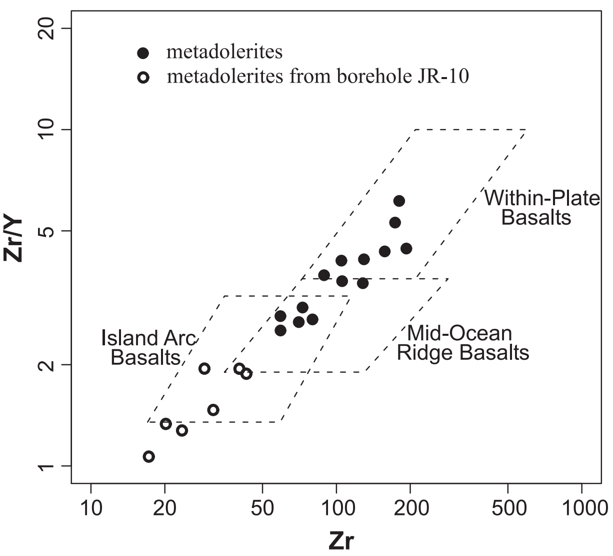

Fig. 1. Metadolerites of the Vrbno Group in the discrimination diagram for basalts (Pearce and Norry, 1979)

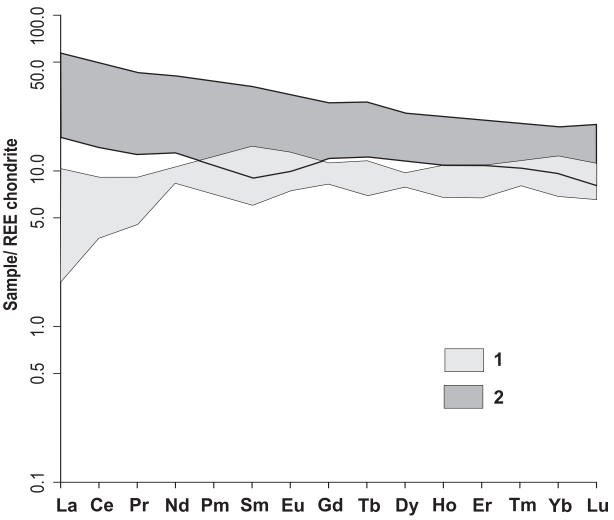

Fig. 2. Metadolerites in the diagram of the REE normalized by Boynton (1984). 1 – metadolerites from borehole JR-10, 2 – metadolerites of the Vrbno Group.

Acknowledgements

This research was supported by the Grant Agency of the Czech Republic, grant project No. 205/01/0331.

References

BOYNTON W.V., 1984. Cosmochemistry of the rare earth elements: meteorite studies. In: P. HENDERSON (Editor), Rare Earth Element Geochemistry. Elsevier, Amsterdam, pp. 63-114.

CHÁB J. et al., 1987. Komplexní vyhodnocení vrtu GPO – Jarda (JR) 10. In: VALENTA et al. (Editor), Janovice-RUDA, závěrečná zpráva z vyhledávacího průzkumu Pb, Zn, Ag rud. – Unpublished report, GP n.p. Ostrava, Geofond P 060604.

PEARCE J.A. and NORRY M.J., 1979. Petrogenetic implications of Ti, Zr, Y, and Nb variations in volcanic rocks. – *Contrib. Mineral. Petrol.*, 69: 33-47.

VALENTA J. et al., 1987. Janovice-RUDA, závěrečná zpráva z vyhledávacího průzkumu Pb, Zn, Ag rud. – Unpublished report, GP, n.p. Ostrava, Geofond P 060604.

The Western Carpathians – 200 Ma Record of Continuing Convergence

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The Meso-Cenozoic Western Carpathians (WC) represent a long-living, expanding orogen, which nucleated as a restricted Meliatic accretionary wedge at the Triassic/Jurassic boundary and developed into a broad and complex orogenic system by the Late Tertiary. In the meantime, the orogenic front propagated continuously, though episodically, from the Meliatic suture to both sides of the asymmetric, double-vergent Carpathian orogen. However, the narrower retrowedge (Internal WC) was inactivated soon after the Meliatic collision in the latest Jurassic, whereas the prowedge widened considerably during the Cretaceous (Central WC) and Tertiary (External WC). The WC units preserve very rich material (sedimentary, metamorphic, magmatic) and structural rock records of various tectonic processes, which all indicate a foreland-ward progradation during the orogenic wedge growth. This contribution summarizes record data on these rock and their paleotectonic interpretation, in order to define time–space constraints to any geodynamic models of the Alpine evolution of the WC.

The Mesozoic oceanic rifting was preceded by significant distensional tectonic events during the Permian and Early Triassic, suggested by rift-related red-bed basins and associated magmatism in several WC zones. The site of the future Meliata oceanic rift was marked by strong Scythian subsidence and shallow marine terrigenous sedimentation. These features indicate that the terminal Variscan event – orogenic collapse and lithospheric attenuation – could have been genetically related to the early Alpine rifting in the southern WC zones, which ultimately led to the Late Anisian opening of the Meliata Ocean.

The Jurassic was the time of extensive rifting of the northern, European passive margin of Tethys, which finally led to a disintegration of the European shelf crust into numerous elevated and subsiding domains, some of which were presumably floored by newly formed oceanic crust. The Liassic uniform stretching of the epi-Variscan continental lithosphere formed several broad, rapidly subsiding intracontinental basins separated by narrower highs. Subduction of the Meliatic oceanic lithosphere commenced at the same time. These processes were probably related to a change in the movement kinematics of large plates – SE drift of Africa and Adria relative to Europe during opening of Central Atlantic. The Western Carpathian orogenic wedge started to nucleate by accretion of material derived from the subducted Meliatic lithosphere to the upper plate toe. The superimposed Dogger rifting phase initiated asymmetric extension, which ultimately led to the breakup of the Vahic (South Penninic) Ocean. The Neocomian distension phase marks further foreland-ward migration of rifting and records opening of the Magura Ocean.

The oldest Alpine structural association related to the Middle – Late Jurassic compressional event in the WC is fixed by a blueschist mineral assemblage in the Meliatic Bôrka Nappe, indicating an incipient collision after the closure of the Meliatic Ocean. Subsequently, the collisional retrowedge originated by shortening and obduction of the Szarvaskő back-arc basin crust, which was thrust over the distal Bükkian hinterland.

In the Early Cretaceous, orogenic shortening returned to the prowedge and its immense growth and northward progradation took place in several phases. The wedge advanced by episodic frontal and basal accretion of lower plate units attenuated by preceding rifting events. Only the upper crustal slivers were amalgamated with the orogenic wedge in the form of thick-skinned and thin-skinned thrust sheets, while the lower crust and the lithospheric mantle were consumed by subcrustal subduction. Collapse events within the wedge are marked by the emplacement of extensive Fatric and Hronic cover nappe systems over the Tatric substratum.

Starting from the Senonian, the Western Carpathian orogenic wedge prograded by an indentation-subduction mode, related to the conversion in drift kinematics of large plates in the western Tethyan realm, particularly the commencement of convergence between the Africa–Adria and Europe. Advancement of the Adriatic indenter brought about shortening and modification of the central, thermally softened parts of the original collisional wedge and triggered transpressional exhumation of the Veporic metamorphic dome. In higher structural levels, this exhumation was achieved by an orogen-parallel, extensional unroofing. At the same time, shortening relocated to the northern Tatric edge, below which the Vahic oceanic crust was consumed. In the latest Cretaceous – earliest Paleogene, units of the Oravic ribbon continent, presently constituting a substantial part of the Pieniny Klippen Belt, were accreted at the wedge toe. Then, the orogenic front reached the Magura Ocean, which was consumed during the Paleogene and Early Miocene.

During the Early Tertiary, the collapse (foundation of the Central Carpathian Paleogene Basin) and shortening pe-