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Neotectonic structural development of the Polish segment of the Outer Carpathians: an overview of structural, geomorphological, break-out and palaeomagnetic data

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Different pieces of structural evidence imply that during the Late Neogene times structural development of the Polish segment of the Outer Carpathians was controlled by normal faulting. This interpretation is corroborated by geomorphic data indicative of *en block* uplift in the western part of the belt. However, there is no unequivocal evidence to decide whether the faulting was due to successive phases of alternating N-S and E-W extension or owing to one or more phases of heteroaxial extension. Moreover, the geomorphic data from the medial and eastern parts of the belt suggest the occurrence of compressional stress regime during Pliocene times. It follows that during the Late Neogene the stress arrangement could have been differentiated depending on time and the position in the belt.

The data available for Quaternary times show an apparent contradiction. On one hand, different pieces of geomorphic evidence imply compressional stress arrangement, with σ_1 oriented roughly perpendicular to the belt. This interpretation is compatible with the present-day orientation of the S_{Hmax} inferred from the breakout analysis and from focal solutions of the Krynica earthquakes. On the other hand, Quaternary normal faulting within the intramontane basins and in localised narrow zones of frontal parts of nappes and larger slices points to extensional stress arrangement. This contradiction can be explained by a concept of normal faulting restricted to the gradually steepening frontal parts of nappes and large slices, whose shortening has been induced by the Recent relaxation of remnant horizontal stresses, accumulated during the Neogene thrusting. These processes were probably not uniform, as shown by differentiated rates of erosional dissection of Quaternary straths in individual geomorphic units within different Quaternary stages. Another, although not contradictory explanation, lies in the general isostatic post-orogenic uplift, being overprinted by coeval relaxation of remnant horizotal motions within the flysch cover.

We conclude that the Quaternary stress pattern within the Polish segment of the Outer Carpathians has been differentiated depending on depth, position in the belt, and time.

Ophiolites of the Main Vardar basin: the Ophiolitic complex of Ždraljica (Central Serbia) as an example

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The ophiolitic complex of Ždraljica (OCŽ), covering an area of about 30 km^2, is situated in Central Serbia, around 150 km^2 south of Belgrade. It was emplaced during the Middle Jurassic closure of the Main Vardar Ocean. At present, it belongs to the eastern branch of the Vardar Zone Composite Terrane – VZCT (Karamata et al., 1994), directly juxtaposed to the Serbo-Macedonian Massif.

The Ždraljica ophiolitic complex is predominantly built of a NMORB-affinity rock assemblage composed of basalts (as pillow-lavas, coherent lava flows and primary and redeposited hyaloclastites), diabases (represented by individual dykes or dyke swarms as well as occurrences of massive diabases or ophitic gabbros), gabbros (massive and cumulitic), serpentinized peridotites and rare plagiogranites. This assemblage is intruded by dioritoids and granitoids of VA-affinity.

The tholeiitic basalt-diabase-gabbro complex of Ždraljica originated by melting of a depleted mantle source of

NMORB characteristics (Pearce, 1983). The HFSE contents and ratios in these rocks are close to average NMORB (e.g. Zr/Y around 2.3 and Ti/Y around 245 in comparison to the recommended values for NMORB of 2.5 and 240, respectively, Saunders & Tarney, 1984), whereas certain scattering of LILE is due to secondary alteration and/or metamorphic processes. The most primitive rocks have around 150 ppm and 560 ppm of Ni and Cr, respectively, with #Mg around 0.6. Given the rather constant ratios of trace elements of slightly different incompatibility (Y/Nb, Zr/Nb, etc.), it seems probably that differing in the degree of partial melting has probably no important role in magma evolution. On the basis of partial melting modelling the most primitive samples of the OCŽ could be obtained by modal batch melting of 25-30 % of a MORB-like mantle source. Parental magma was primarily modified by processes of fractional crystallization. It is indicated by both petrographical and geochemical evidence e.g. glomeroporphyritic texture in mafic and cumulitic texture in ultramafic rocks and the presence of olivine gabbros in close relation with serpentinized peridotites, as well as by compatible behavior of Al_2O_3, CaO, Sr, Cr and Ni. Plagioclase and clinopyroxene ± olivine likely represented the most important fractionation phases. Magnetite was essentially absent from the fractionation assemblage in keeping with clear tholeiitic trend of differentiation of these rocks. According to available data, the origin of plagiogranites could be explained by liquid immiscibility rather than by an advanced fractionation, but for confirming the assumption new data are necessary.

In the OCŽ occur calc-alkaline igneous rocks of VA-affinity, represented by quartzdiorites, quartzmoncodiorites, granites and granodiorites. These rocks show similar values of HFSE as the first group (NMORB, i.e. plagiogranites), but they appear to be richer in LILE. Their clear VA-character is further interpreted as corresponding to precollisional granitoids (Harris et al., 1986). This assumption gives a new point of view for interpretation of geological setting of the whole complex, because the occurrences of the VA-rocks imply that an intraoceanic subduction might have operated, suggesting the existence of an immature island arc, during the development (evolution) of the eastern branch of the VZCT. So, there is a possibility that the OCŽ could represent relicts of the oceanic crust/immature volcanic-arc related to a back-arc basin development.

The emplacement age of the OCŽ is inferred by the presence of late Upper Jurassic sediments within the overstep sequence. Available K/Ar radiometric ages of basaltic rocks reveal younger ages (post-emplacement events). However, a radiometric age determination on hornblende from a VA-affinity quartzdiorite gave 168.4±6.7 Ma. If the precollisional character of these rocks is correctly defined, it could be taken as the youngest age of the oceanic crust of the OCŽ.

Key words: Ophiolitic complex, Ždraljica, MORB-affinity, VA-affinity, depleted source, fractional crystallization

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Short review of Paleozoic units of the Dinarides and the northwestern part of the Vardar zone

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Five blocks/terranes built up of Paleozoic rocks are exposed in the Dinarides and the Northwestern part of the Vardar zone (Figure). These blocks/terranes originated at different parts of the Tethys margin, they had different evolution, and they were added/docked to the (pre-Upper Permian) Dinaridic block or were included into the present geologic framework at different time.

THE CENTRAL BOSNIAN MOUNTAINS BLOCK/ TERRANE (CBMT). The oldest members are Early Paleozoic (probably also Uppermost Proterozoic) schists, with rare quartzites originating from psammitic and pelitic protolithes. They were deformed and metamorphosed before the end of the Silurian. The Uppermost Silurian metapsammites and phyllites are followed by a thick sequence of dolomites and limestones (Devonian and partly Tournaisian). Over them were deposited shales and sandstones of undetermined age. In all these formations occur lenses and sills of rhyolites (of undetermined, Devonian