tion perpendicular to F_2 axes were formed. Successive rodding lineation L_3 and S_3 mylonitic fabric formed parallel to the zonally reactivated S_2 foliation. Lineation L_3 plunges toward the N or NW at low angles. The concentric D_4 folds range from tens of metres in scale to the centimetre scale of crenulation then forming crenulation lineation L_4. The D_4 axes with L_4 lineations exhibit two maxima – 330/10 and 40/40. Large, NW-plunging D_4 folds visible in outcrops determine the structural architecture of the Krowiarki Range. They are considered to be mesoscopic equivalents of the macroforms described by Don (1964).

On the microscopic scale, the S_1 foliation in mica schists is locally preserved as inclusion trails of the *chl-ctd-ma-q-ilm* assemblage within intertectonic garnet cores. *Ctd-chl-ma* inclusions disappear towards the rim growing simultaneously with the D_2 where the *q-ilm* inclusion trails take curved shape and continue into the external S_2 foliation, which additionally contains the *bi-st-ky* assemblage. The D_2 axial fabric is marked by parallel arrangement of *cc-dol-tr-phl-mu-q* in marbles from the Stronie Śląskie area and *cc-dol-chl-mu-q* in marbles occurring in the Żelazno area. On the thin-section scale, the D_4 structures appear as intensive crenulation, but with no associated new axial-planar foliation.

D_1 and D_2 events took place under progressive conditions of regional metamorphism; in mica schists, they are characterized by normal garnet zoning and prograde mineral assemblages. In the SE part of the Krowiarki Range, the peak mineral assemblage consists of *g(rim)-ky-st-bi-mu-ilm-q*, which forms the S_2 foliation. In mica schists, staurolite disappears to the NW and is missing west of the village of Romanowo. Pressure-temperature calculations carried out by THERMOCALC software (running on the average P-T mode), for the D_2 peak mineral assemblages differ slightly along the Krowiarki Range and show temperatures of 603 ± 21 °C and 548 ± 16 °C for its SE part (Stronie Śląskie) and NW part (Żelazno), respectively, attaining a pressure of about 8 kbar in both cases. The calcite-dolomite thermometry applied to the Stronie Śląskie marbles yielded maximum temperatures of 565 °C for the calcites arranged parallel to the S_2 axial plane foliation and 512 °C for the carbonates constituting the S_3 mylonitic foliation. The maximum temperatures calculated for marbles occurring to the northwest decrease to 430 °C near Żelazno.

Generally subvertical attitude of the S_2 foliation and a relatively high angle at which it intersects the enveloping surface to F_2 folds observed in some outcrops indicates that the ENE–WSW shortening was assisted with an important vertical stress component. On the other hand, the continuous transition between the internal foliation S_1 preserved in the garnet cores to the external S_2 foliation seen in thin sections points to nearly parallel S_1 and S_2 planes. The observed steep inclusion trails within the inter-tectonic garnet cores may be the result of the rotation of garnet porphyroclasts during D_2 movement. Some S_3 shear zones reactivating the S_2 were developed during the uplift and the drop of temperature, invariably indicating top-to-the-N/NW kinematics.

Tectonic features of earlier stages of structural evolution were together reoriented during the last compressional stages, i.e., NW–SE followed by NE–SW shortening. The observed orientation of S_2//S_3 foliation in the Krowiarki Range is mainly due to the rotation about NW-plunging macrofold axes. During progressive metamorphism (D_1–D_2), the NW part of the Krowiarki Range might occupy a higher structural level. This is shown by lower temperatures obtained for the S_2 fabrics in both schists and marbles and northward disappearance of tremolite from marbles and staurolite from mica schists. The light difference in the metamorphic grade, i.e., temperatures, along the Krowiarki Range may have resulted from folding of D_2-established isograds during the D_4 event around the NW-plunging axes of F_4 folds, which corresponds with the slope of macroform axes towards the NW proposed by Don (1964). Accordingly, the results of this study show that the fan-like pattern of the Lądek-Śnieżnik Metamorphic Unit developed by a tectonic event following the regional metamorphic peak.

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The Rheological Parameters Controlling Asymmetrical Cretaceous Extensional Process in the Vepor unit, West Carpathians

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The Vepor unit composed of the pre-Alpine basement and Mesozoic cover sequences is one of the major crustal segments incorporated into the Alpine structure of the Central West Carpathians. The basement mostly consists of high-grade orthogneisses, migmatites and large Variscan calc-alkaline intrusive bodies overlying metasedimentary rocks, mainly micaschists, paragneisses and amphibolites. It is generally accepted that this superposition results from a southward Variscan nappe stacking. Two major Alpine deformational events have been recognized in the Vepor unit, the earlier E-W extension followed by dextral transpressional regime, which resulted from oblique convergence of the Vepor basement and presumed

southern continental segment. In this contribution we discuss kinematic and rheological significance of the early Alpine extensional process.

The first Alpine deformation produces a flat lying fabric connected with the development of vast extensional shear zone marked by an E-W oriented deformation and metamorphic gradients. The highly deformed orthogneisses exhibiting the upper greenschist facies overprint are located in the footwall of highly mylonitized lower greenschist facies rocks of the Permian cover sequences and the undeformed Mesozoic Silica nappe. The intensity of the deformation diminishes towards the west where it becomes confined to an anastomous network of shear zones. Microstructural observations together with changes in chemical composition of analysed minerals have revealed the presence of E-W metamorphic zoning across the studied shear zone. We distinguish two metamorphic-microstructural zones: the lower grade zone 1 in the east and the higher grade zone 2 in the west. The zone 1 is marked by lower content of Fe in the grossular rich garnet, biotite, muscovite and epidote, by the presence of core-mantle microstructure of quartz, quartz fill of K-feldspar fractures and oval shape of albite subgrains. On the other hand, the grossular rich garnet, biotite, muscovite and epidote of the zone 2 contain higher amount of Fe, the presence of older almandine garnet cores was distinguished, the microstructure of quartz lacks original quartz cores, the K-feldspar fractures are filled with albite and the shape of albite subgrains is round. The observed features of both zones correspond to the development under different temperature conditions, which were estimated by using conventional garnet-biotite thermometry (Kleemann and Reinhardt, 1994). The average temperature for the zone 1 corresponds to 420 °C and for the zone 2 to 490 °C, respectively. Quartz grain size measurement in the two zones was applied to estimate the differential paleostresses using quartz piezometry constants of Christie et al. (1980), which yields in average 16.5–22.2 MPa for the zone 1 and 9.1–12.4 MPa for the zone 2. These variations in the stress estimates are interpreted in accordance with the thermometry data as a result of different flow temperature rather than a difference in stress under the condition of constant strain rate. In both zones the strain rate and effective viscosity were calculated. The strain rate reaches similar values for both zones 1 and 2, varying between $2.5–7.9*10^{-14}s^{-1}$. The values of effective viscosities are ranging between $2.79–6.56*10^{20}$ Pas in zone 1 and $1.57–3.6*10^{20}$ Pas in zone 2. These values correspond well with the values of strain rate and effective viscosities assumed for deformation of standard continental crust (Pfiffner and Ramsay, 1982).

The EBSD measurements of crystal preferred orientation of recrystallized quartz and plagioclase grains together with plotting the stress data (piezometric curve) to the deformational mechanisms maps of Etheridge & Wilkie (1979) confirmed microscopically determined operation of dislocation creep mechanism. The dominance of the inferred deformational mechanism, the rheological parameters estimated above and the observed deformational pattern may serve as a basis for rheological model of dislocation creep dominated stretching of quartzo-feldspatic continental crust under the conditions of higher thermal gradient. Basing on structural, petrological and microstructural data we suggest that the quartzo-feldspatic crust of the Vepor unit played dominant mechanical role in controlling the process of asymmetrical extension during the onset of Cretaceous orogeny in the West Carpathians and that the observed deformational pattern of extensional tectonics corresponds to the limited mechanical influence of the lithospheric mantle during the extensional event (Bassi, 1995).

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