Pan-African Modification of the Contact between Middle and Upper Crust in the Western Zone of the Kaoko Belt (NW Namibia)

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Pan-African evolution of the Kaoko belt in NW Namibia is governed by a long period of transpressional deformation active from high- to low-temperature stages of the tectonic history. The Western Zone of the belt is characterized by almost complete exhumation of the Mesoproterozoic orthomigmatites and orthogneisses in its eastern part, whereas the western (coastal) part is built of metasedimentary rocks intruded by Pan-African granitoids ranging in age from ~700 to 550 Ma. Such a lithological and age contrasts suggest that the eastern and western parts of this zone represent different crustal levels reworked during Pan-African orogeny. The present-day boundary between these two units is represented by a large medium- to low-temperature transcurrent shear zone, and geochronological and structural data suggest a complex history of this contact between middle and upper crust.

In the Mesoproterozoic orthomigmatites, an early (D1) stage of structural evolution is characterized by oblique south-eastward thrusting of the basement over the easterly foreland. D1 structures were subsequently reworked by a penetrative D2 fabric as a result of high-temperature sinistral transpression. Despite distinctively different orientation of S_1 and S_2, NW-SE oriented stretching recorded as a strong aggregate lineation remains the same during both deformation events.

The pre-tectonic contact between the easterly Mesoproterozoic basement and coastal metasediments is masked by a large intrusional complex built of ~625 Ma and 550 Ma old granitoid rocks. Overlying metasedimentary complex contains at its base well developed unit characterized by periodic alternation of metamorphosed granitoids and amphibolites. This unit shows high-temperature metamorphism associated with partial melting of amphibolites. In contrast to the Mesoproterozoic orthomigmatites, metamorphic fabric is dipping to the south to southwest and bears strong southward oriented lineation. This lineation is missing in the hangingwall paragneisses and paramigmatites and these metasediments, as well as the granitoid complex show low-temperatrure refolding and development of localized transcurrent shear zones. The stress field of this low-temperature event is compatible with that of D2 in the basment orthomigmatites.

We interpret the southward dippping high-temperature fabric at the base of the metasedimentary complex to be contemporaneous with that in easterly Mesoproterozoic orthomigmatites. As the orientation of principal stretching (recorded as high-temperature lineation) is different in these two units, we suggest that the southward plunging lineation has developed as a result of normal ductile faulting along the boundary between middle and upper crust during active transpression in the basement. Although there are no macroscopic kinematic indicators associated with the development of this fault, an alternative thrusting scenario would not be compatible with sinistral movement observed in the Mesoproterozoic basement. Subsequently, several granitoid intrusions were emplaced along the whole middle-upper crustal boundary at ~550 Ma. Final stage of tectonic evolution of the metasedimentary (coastal) complex is the result of transfer of major transpressional deformation into the granitic complex and overlying paramigmatites and paragneisses during cooling. This process resulted in folding of the metasedimentary complex associated with the development of localized shear zones, the most prominent of which marks the boundary with the easterly Mesoproterozoic basement.

Metamorphic Zonation and Anomalously Hot Geothermal Gradient of the Silesian domain: an Interplay between Devonian Rifting and Carboniferous Collision

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Investigations of metamorphic evolution in the Keprník dome and in the southern part of the Desná dome of the Silesian domain has shown an anomalously hot geothermal gradient compared to the rest of the Moravo-Silesian zone. The variations in T/P ratios along the collisional margin are discussed in terms of heterogeneously developed pre-collisional rifting within the Brunia microcontinent.

The Silesian domain was interpreted as a continental accretionary wedge developed in the marginal part of the Brunia microcontinent due to underthrusting under the Moldanubian/ Lugian domain during Variscan collision (Schulmann and Gayer, 2000). The Silesian domain was tectonically subdivided from the base upward into: 1) para-autochthonous Desná dome and its Devonian cover, 2) lower allochthonous Keprník dome

with its detached Devonian cover of the Branná group, and 3) upper allochthon of the Velké Vrbno unit consisting of high grade gneisses and eclogites. The orogenic evolution was initiated by the Early Devonian rifting resulting in a formation of two large-scale crustal boudins (Desná and Keprník domes) and the overlying syn-rift volcano-sedimentary sequences (Hladil et al., 1987, Chlupáč, 1989, 1994). The two crustal boudins were underthrust beneath the western orogenic root system and educted as a crustal wedge. This event is responsible for the formation of a Barrovian metamorphic zonality as well as the main fabric. The compression switched later into a transpressive regime, which was responsible for the development of post-metamorphic upright folding. This event is contemporaneous with the syntectonic intrusion of the granitic pluton below the lower allochthon and western part of para-autochthon.

Deformation evolution in the studied area is characterized by two main Variscan deformation phases D_2 and D_3 already described by (Schulmann and Gayer, 2000). The D_2 deformation produced a penetrative foliation S_2 and intra-foliation folds F_2 in the metasediments and discrete shear zones in the gneisses. The deformational phase D_3 is characterized by heterogeneously developed upright folds F_3 and steeply dipping cleavage S_3 in the Desná dome and eastern part of the Keprník nappe while D3 led to almost complete transposition of the S2 foliation in the NW dipping flank of the Keprník dome and in Branná envelope.

The mapping of index minerals shows increase of metamorphic grade from the east to the west from chlorite, chloritoid, garnet, staurolite to staurolite-sillimanite zone in the Desná dome, with a very narrow spacing of isograds developed at its western margin. The whole Keprník nappe is situated in the staurolite and staurolite-sillimanite zones with late andalusite. Geometry of the inclusion trails within garnet, staurolite, plagioclase and andalusite porphyroblasts allows correlation of mineral growth with deformational phases. Chloritoid, garnet, staurolite and kyanite grow in the S2 foliation, staurolite is locally overgrowing heterogeneously developed S3 crenulation cleavage and sillimanite is associated with S3 foliation in both domes. Late andalusite is overgrowing the S3 foliation. The succession of observed mineral associations in metapelites in combination with model pseudosections constructed in NCKFMASH system was used to determine prograde metamorphic path and peak P-T conditions in individual zones which were corroborated by average P-T calculations.

Metamorphic field gradient determined for the peak M_2 conditions for all zones between 28 °C/km and 32 °C/km is significantly higher compared to those of southern and central parts of the Moravo-Silesian Zone where the gradient of 16.5–20 °C/km was reported (Konopásek et al., 2002, Štípská and Schulmann, 1995). We explain these major differences by existence of very high initial thermal gradient preceding the thickening of the Silesian domain. The Devonian stretching of the NE part of the Brunia platform was significantly stronger than in the south, which was documented by shallow marine Devonian sedimentation and absence of volcanism in the central part of the Brunia and even an absence of the Devonian sedimentation further to the south. The end of Devonian rifting is characterised by the transition from the Famenian carbonate platform to Lower Carboniferous flysh type sediments at Famenian/ Frasnian boundary. All these data indicate an important change in tectonic regime at about 360 Ma represented by the end of rifting on the whole Brunia continent. Therefore, there was probably very little time lag of 10–20 Ma between the end of rifting characterized by high thermal gradient and onset of collision and burial of the Silesian rocks. It is also evident that the late stages of compression (D_3) of the thickened zone were related to additional heat input from the Žulová pluton. The asymmetrical pattern of metamorphic zones increasing towards west is attributed to more important exhumation of western deeper and rheologically weaker part of thickened zone.

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