Burial and Exhumation of Eclogites in Continental Accretionary Wedge: An Indentation Model of Eclogite Formation in Variscan Collisional Zone

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Numerous eclogite boudins surrounded by tonalitic gneisses, metavolcanics and metapelites form a unit separating a Neoproterozoic foreland from the Variscan orogenic root at the NE margin of the Bohemian Massif. Eclogites record peak conditions of 15 kbar and 700 °C (indicating burial to 55 km) and near-isothermal exhumation to 40 km, whereas the enclosing metapelites show an almost complete P-T loop with peak pressure conditions at 11 kbar and 640 °C. These different paths suggest differential burial and exhumation of rocks with tectonic amalgamation at mid-crustal levels. Structural features show viscous pure shear-dominated deformation of gneiss-eclogite blocks at deep crustal levels and essentially non-coaxial partitioned deformation of these blocks and their volcano-sedimentary matrix at shallower levels. Based on U/Pb zircon ages (561–633 Ma, 2000 Ma), calc-alkaline intrusive rocks associated with the eclogites are interpreted as a part of the lower crust of the Neoproterozoic Brunian continent. The eclogite protolith ages, field geothermal gradients and geological structures are compared with coherent eclogite-bearing crustal units of the subducted Saxothuringian lithosphere and thickened Variscan (Moldanubian) orogenic root. Based on this comparison, a new model suggests the development of HP rocks at the tip of Brunian lithospheric indentor which penetrated a weak orogenic root in the west with Cambro-Ordovician protolith ages. Subsequent exhumation of HP blocks enclosed in a weak metasedimentary matrix was controlled by ongoing indentation and is similar to that of block-matrix flow in sedimentary or serpentinite wedges. The block-matrix relationship is a characteristic feature of the eclogite micaschist wedge along the entire eastern margin of the Variscan collisional front.

Structural and Metamorphic Record of Thickening and Exhumation of the Moldanubian Lower Crust (NE Moldanubian Domain, Bohemian Massif)

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We document a succession of tectonic events associated with burial and exhumation of the lower crustal rocks at the NE margin of the Moldanubian domain (Bohemian massif) by combining new structural, petrological and geochronological data from plutonic and metamorphic rocks exposed along NE margin of the lower crustal Strážek Complex. This unit has been thrust over middle crustal Svratka Complex during tectonic processes associated with Moldanubian orogenic root formation.

Structural study of granulites, surrounding gneisses and migmatites has demonstrated the presence of an early sub-vertical, mostly N-S trending fabric (S_1) reworked by flat shear zones or newly developed penetrative foliation (S_2). S_2 fabric is generally dipping to the SSE to SW under moderate angles, and becomes progressively steeper towards the contact with the underlying Svratka Complex. Well developed L_2 stretching lineation is mostly subhorizontal or slightly plunging to the S. Durbachitic intrusion emplaced along the boundary between the Strážek and Svratka complexes show strong subsolidus deformation along the western edge of the main durbachite body parallel with the S_2 foliation in surrounding migmatites. On the other hand, only non-deformed magmatic fabrics were observed in the eastern part of the body but aligned xenocrysts of K-feldspar define magmatic foliation which is also parallel with the S_2 foliation of country rocks. Steep igneous fabric is locally developed in small sill-like bodies intruding mechanically resistant granulites with vertical D_1 anisotropy. The character and timing of the intrusion can also be deduced from the magnetic foliations and lineations, which are comparable to the D_2 structures developed in the surrounding rocks.

Steep S_1 foliation in granulites is associated with high-pressure (16–18 kbar at 750–800 °C) mineral assemblage and is interpreted to represent an early fabric developed during or shortly after the period of maximum thickening of the Moldanubian orogenic root. This event has been dated at ~340 Ma on two samples from the granulite body withihn the Strážek Complex (Kröner, unpublished data). D_2 fabric in granulites and surrounding gneisses is associated with low-pressure mineral assemblages (3–4 kbar at 650–720 °C) and interpreted to reflect exhumation and thrusting of the lower crustal Strážek Complex over the middle crustal Svratka Complex. Concordant D_2 fabrics in granulites and surrounding gneisses with magmatic fabric developed in the durbachite body suggest the emplacement of durbachites during D_2, e.g. during thrusting of the lower over the middle crust. The age of durbachite intrusion has been dated at ~323 Ma (Kröner, unpublished data). The above presented data allow to construct an exhumation path suggesting an exhumation rate of ~3 mm/year. Ar/Ar cooling ages in the footwall Svratka Complex (325–332 Ma; Fritz et al., 1996) suggest very rapid cooling of the whole area after termination of exhumation process.

Controls on Delta Plain Sandstone Geometries and their Implication for Reservoir Exploration in Middle Jurassic Successions: Saltwick Formation, Yorkshire Ness Formation, North Sea

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Delta plain sandstones form hydrocarbon reservoirs in several North Sea oil and gas fields, most prominently in Brent Group reservoirs. These sandstones have restricted lateral extent and are encased in mudstones and siltstones (Mjøs and Prestholm, 1993). It is generally difficult to correlate these sandstones and determinate their geometries even if the well separation is less than 1 km (Livera, 1989). Hence studies of analogous data focused on facies variations and sandstone geometries may help to reduce the uncertainty in the geological reservoir descriptions of the North Sea fields, where the delta plain reservoir sandstones are not detectable on seismic profiles at reservoir depths (Mjøs and Prestholm, 1993). This research aims to apply sedimentary facies and architectural outcrop analysis of the Middle Jurassic Ravenscar Group of the Yorkshire delta to the analogous Middle Jurassic Brent Group of the Brent delta. Despite deposited 700 km apart, the Yorkshire delta and the Brent delta both record the sudden progradation of delta systems over the shallow muddy environment and their subsequent abandonment (Johnson, 1994). The Aalenian Saltwick Formation of the Ravenscar Group (Yorkshire delta) has been studied at the outrops on the N.E. England coast within the area between Whitby and Hayburn Wyke. The Ness Formation of the Brent Group (Brent delta) has been studied in cores of wells of the Strathspey Field and Brent Field in Northern North Sea.

The Saltwick Formation is composed of 10 sedimentary facies – coal (C1), claystone (Cl1), root-penetrated siltstone (Sl1), very fine to fine-grained sandstone sheets (Fs1), very fine to fine-grained sandstone channels (Fs2), medium-grained sandstone channels with lateral accretion surfaces (Ms1), medium-coarse-grained sandstone channels with sporadic bioturbation (MCs1), medium-coarse-grained sandstone channels (MCs2), coarse-grained sandstone channels with siltstone interbeds (Cs1) and conglomerate (Cg1). These facies except Fs1 and Cg1 were observed also within the Ness Formation. Facies of siltstone containing bioturbation (Sl2), very fine to fine-grained sandstone channels containing bioturbation (Fs3) and fine-grained hummocky cross stratified sandstone (Fs4) occur only within the Ness Formation. Marine influence indicators, which are common within the Ness Formation, are rare within the Saltwick Formation and occur predominantly at the Hayburn Wyke.

Sandstone facies can be divided into four groups:

1) Crevasse splay sandstones, which consist of facies Fs1 with sheet-like geometry and width/thickness ratios higher than 50.

2) Distributary channel sandstones cut into delta plain, which consist of facies Fs2, Ms1, MCs2 and Cs1 with channel geometries and width/thickness ratios of three categories – up to 10 at Whitby West Cliff, between 10 and 35 in the area from High Whitby to Pursglove Stye Batts and higher than 35 at High Whitby. Measurements at Whitby West Cliff, where are channels exposed also in longitudal cross sections, e.g. parallel with palaeoflow direction, show width/thickness ratios up to 50.

3) Inlet channel sandstones, which consist of facies Fs3.

4) Wave dominated lagoonal shoreface sandstones, which consist of facies Fs4.

Vertical and lateral relationships between individual channels were studied. Two different depositional geometries were observed. Channels are vertically stacked at Whitby West Cliff, Ravenscar and High Whitby. The High Whitby sandstone body has a width of 465 m and a thickness of 15 m. It has a complex architecture including vertically stacked channels and lateral accretion surfaces and erodes deeply into sheet crevasse splay sandstones and overbank fine deposits. On the opposite side, isolated lenticular channels encased in overbank fine deposits were found at the Whitby East Cliff.

The vertically stacked channel geometry could be explained as controlled by relatively high subsidence along the hanging wall of the adjacent faults. (the Whitby Fault at Whitby West Cliff see Alexander and Gawthorpe, 1993, and the Peak Fault see Mjøs and Prestholm, 1993). This explanation is not applicable to the High Whitby stacked channels because no fault is present there. The High Whitby stacked channels could be interpreted as an incised valley infill. Its base can be interpreted as a sequence boundary reflecting relative sea level fall and delta progradation. The implication for the Ness Formation is that although well interconnected stacked channel sandstone reservoir units that bear significant hydrocarbon volumes often occur within the Ness Formation, outcrop analogues show combination of controls on deposition of stacked channel sandstones and high variability in their lateral extent. Thus the prediction of Ness Formation chan-