Three hypotheses can be formulated to explain the origin of regional low–pressure, high–temperature metamorphism. They are summarized as follows: (1) Vertical "telescoping" of thick crust by tectonically driven extension. (2) Fast, adiabatic uplift without associated crustal deformation. (3) Advective heat transfer from the deep crust or from the Earth's mantle by fluids or magmas on a regional scale.

Analysis of the crustal deformation and kinematics associated with metamorphism, and reconstruction of changes in pressure and temperature, and the rates of the changes are the techniques used here to test these hypotheses.

Structural analysis of the Moldanubian in the studied area reveals at least three phases of ductile deformation associated with the peak of low–pressure metamorphism and partial anatexis. Its structures overprint older fold and foliation fabrics of two deformation phases of unknown age. The first of the three deformations produced large strains, a steep foliation and stretching lineation and a reverse (top–to–SW) sense of shear. Deformation geometry is plane strain to slightly oblate, and indicative of NE–SW directed crustal shortening and subvertical stretching. Strain geometry also shows that finite vertical stretching is moderate, thus despite large deformations the net effect of the deformation on crustal thickness was not very large. The second phase produced up to ten–km–sized, tight folds with steep axes and unknown facing. Folding kinematics is unclear, but this deformation certainly produced further NE–SW directed horizontal contraction. The youngest phase is expressed in NE–SW trending folds with steeply dipping axes and axial planes, supporting NW–SE directed coaxial contraction. It is evident from the data that none of the three deformation phases resulted in vertical shortening and horizontal extension.

Peak temperatures during low–pressure metamorphism have most likely exceeded 750 °C, and may locally have been higher than 800 °C. Garnets with chemically homogeneous cores, assuming former growth zoning during metamorphism indicate time periods for the thermal event between less than one million years (Ma) and 29 Ma, depending on sampling locations and assumptions about the maximum temperatures of metamorphism. "Geospeedometry" applied to disequilibrium compositions in garnets acquired and preserved during cooling point to extremely rapid temperature drops after the metamorphic climax. Minimal cooling rates are found to be 70 °C/Ma, but locally cooling rates as high as 600 °C/Ma are inferred from garnet zonations in metapelitic gneisses. Geothermometric analysis of garnet–biotite and garnet–cordierite pairs reveal "freezing" of diffusive exchange of elements at temperatures between 550 °C and 700 °C. The pressure–temperature evolution observed and its kinetics are incompatible with models based on conductive heat transfer in a collisional mountain belt.

The only hypothesis that can at present explain all observed phenomena in the Moldanubian gneisses of eastern Bavaria is that of large scale advective heat transfer by fluids or magmas. Fast and almost isobaric heating and cooling in a regime of moderate crustal thickening define a tectonic regime of "regional contact metamorphism", and the large spread of equilibration and cooling rates may simply portray different distances from moving heat sources. The nature of the external heat source remains enigmatic, but the observed high peak metamorphic temperatures point to intrusion of mafic igneous rocks into the deep crust, or upwelling of hot mantle material beneath the Moldanubian Moho.

EARLY–HERCYNIAN OROGENIC PROCESSES MIRRORED BY LOWER TO MIDDLE DEVONIAN SANDSTONE COMPONENTS OF THE EASTERN RHEINISCHES SCHIEFERGEBIRGE AND ITS BIOSTRATIGRAPHIC CONTROL

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Components of siliciclastic sediments in the Rhenohercynian Basin near Marburg reflect the plate tectonic evolution of their source rock area if we follow their variation through time and space. Continuous change in composition due to long term geological processes like isostatic uplift contrasts with discontinuous changes during orogenic processes like strike slip movements or nappe transport cutting through different strata of the source region. Synorogenic volcanic and plutonic rocks form clear – cut detrital fingerprints too. To date the coming and going of different source areas biostratigraphic methods were used. Palynomorphs and conodonts provide a detailed zonation of the Paleozoic units. Resedimented acritarchs furthermore enable us to date the sediments in the source region. Source rock analysis by the aid of light minerals quantitatively uses the complete petrofabric and petrologic information stored in the clasts of sandstones and conglomerates. Genetic conclusions were drawn from the Hercynian debris back through the tectono – metamorphic history and down to the origin of the source rocks. Two areas of different parent rocks must be distinguished during the Lower Devonian. First the continental shelf of the Old Red landmass provided clastic detritus of proximal sandstone facies to the NW and distal shale facies to the SE. Sediments show a relatively uniform composition in the distal Rhenish facies.

Secondly a sedimentary mélange was formed by olistostromes including olistoliths, conglomerates and sandstones intercalated between and mixed with Old Red derived shales. Components of the olistostromes clearly show a Barrandian origin. Source rocks were sandstones of all kinds of grain size, Silurian and Devonian limestones, basic volcanics and highly differentiated sills with ultramafic, mafic and granophyric layers. Normal faulting released gravity slides with sedimentary structures indicating transport from the east. These petrological and tectonic observations from the synorogenic sediments prove an extensional regime of early rifting in their source region. Since no other plutonic or metamorphic clasts occur, no Mid–German Crystalline Rise did supply sediments during the Lower Devonian from the south.

VARISCAN DEFORMATION PHASES IN SOUTHERN SPITSBERGEN

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Frequent sedimentary breaks associated with erosional unconformities and coarse–clastic character of many Carboniferous and Permian deposits in Spitsbergen are the evidence of tectonic instability, following destruction of Caledonian Foldbelt at transition to platform conditions. Three major unconformities related to Variscan deformation phases are recognizable in southern Spitsbergen: (1) the Devonian/Carboniferous unconformity; (2) the Early/Middle Carboniferous unconformity, and (3) the Early/Late Permian unconformity. None of these phases resulted in large–scale folding and thrusting, the tectonic deformation being the effect of strike–slip transpression and/or block faulting.

(1) The Devonian/Carboniferous unconformity is expressed as a long hiatus, from Middle Devonian through lowermost Carboniferous, confined to the southern termination of the Devonian Graben. Continental deposits of the Adriabukta Formation (Upper Tournaisian–Upper Visean, Birkenmajer & Turnau, 1962) begin with a thin conglomerate resting directly upon the Marietoppen Formation (Siegenian–Emsian, Old Red Sandstone Facies, Birkenmajer, 1964). An angular unconformity probably existed between these two units, but was subsequently obliterated by mid–Carboniferous and Tertiary folding. The Devonian/Carboniferous unconformity and hiatus relate to Late Devonian (post-Late Givetian – pre–Early Tournaisian) Svalbardian diastrophism (Vogt, 1928). In south Spitsbergen, it affected mainly the eastern flank of the Devonian Graben (a southward prolongation of the Balliolbreen strike–slip fault, Harland et al., 1974) which was upthrown and subjected to deep erosion that exposed Proterozoic basement of the removed Devonian clastics (Birkenmajer, 1981).

(2) The Early/Middle Carboniferous unconformity was a result of strong folding, associated with slight metamorphism, of Lower Carboniferous clastics (Adriabukta Formation) together with their Devonian and pre–Devonian basement rocks, and as westward thrusting of the eastern flank of the Devonian Graben (i.e. the Adriabukta Formation and its Proterozoic basement rocks) over the autochthonous rocks in the graben. This deformation, called the Adriabukta phase (Birkenmajer, 1975), correlates with the Erzgebirge phase of Variscan orogeny (Birkenmajer, 1964). It could be an effect of compression/transpression resulting from strike–slip displacement along the eastern flank of the Devonian Graben in Spitsbergen. Erosion and deep weathering of the folded Adriabukta Formation followed suite. It resulted in development of red–stained regolithic zone that cuts through steeply dipping rocks of the latter formation, already prior to deposition of Mid–Carboniferous coarse clastics (red beds) of the Hyrnefjellet Formation (Birkenmajer, 1964, 1984a).

(3) The Early/Late Permian unconformity, related to the Saalic phase of block–faulting and uplift (Birkenmajer, 1964) is expressed as a low–angle regional unconformity between the Treskelodden Formation (continental to shallow–marine, mixed deposits, Upper Carboniferous to Sakmarian) and