Geophysical Research Abstracts
Vol. 13, EGU2011-3049, 2011
EGU General Assembly 2011

Alteration of a subvolcanic rock from the Rhenish Massif - complete or partial equilibration at very-low grade metamorphism?

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The Variscan Rhenish Massif in central Europe is dominated by clastic sediments, which are traditionally related to anchi-metamorphism. Occasionally, volcanic rocks are intercalated in the sedimentary sequence as a little stock of rhyodacitic to dacitic composition in the Ardennes close to the boundary between Belgium and Germany (locality "La Helle"; see Dejonghe, 2003). The La Helle rock shows a porphyric subvolcanic texture but metamorphic minerals like prehnite and epidote also occur. Thus, this rock was assigned to low grade metamorphism (Schreyer and Abraham, 1978). The present investigation should explore if the La Helle rock experienced a slight overprint only or if a true equilibrium mineral-assemblage was established over a wider range. For this purpose, the chemical compositions of the minerals in the La Helle rock were studied in detail with the electron microprobe and a PT-pseudosection was constructed using the PERPLE_X software package (Connolly, 2005) as demonstrated by Massonne (2010) for rocks altered at very-low grade metamorphic conditions. The thermodynamic calculations with PERPLE_X were undertaken in the system Na-Ca-K-Fe-Mg-Al-Si-Ti-C-O-H for the pressure-temperature range 0.5-6.5 kbar and 150-350°C.

In the pseudosection calculated for very high Fe^{2+}/Fe^{3+} ratios a narrow PT-field, ranging between 2.7 and 3.3 kbar and 250 and 270°C, emerged, where the observed mineral assemblage chlorite-phengite-pumpellyite-prehnite-titanite-plagioclase-K-feldspar-plagioclase-quartz-calcite coexists. In addition, the observed phengite Si content of 3.30 pfu is compatible with this PT-field but rather points to its lower pressure range. The same is true concerning the calculated and analyzed composition of pumpellyite with X_{Mg} around 0.74. Thus, the obtained results suggest that equilibrium conditions were reached at very-low grade metamorphism. The additional occurrence of epidote in the above mineral assemblage is a function of the Fe^{2+}/Fe^{3+} ratio. In the absence of Fe^{3+}, clinozoisite appears in the calculated PT-pseudosection at 300°C, but some Fe^{3+} lowers this temperature significantly. The lowest temperature for the appearance of biotite in the pseudosection is 310°C, but accessory brown biotite, surrounded by chlorite, in the La Helle rock is interpreted to be a rare magmatic relic.

The reason for the formation of the equilibrium assemblage is dehydration that occurred when the rock was transformed from zeolite-facies conditions to those of the prehnite-pumpellyite facies. In the calculations, this transformation, including the breakdown of stilpnomelane, causes the release of about 1 wt% H_2O at temperatures close to 250°C and pressures between 1.5 and 3.5 kbar. The presence of a hydrous fluid phase should have enhanced metamorphic equilibration within a wider range probably within the entire subvolcanic stock at La Helle.

This example demonstrates that the (sub)volcanic rocks of the Rhenish Massif bear a good chance to reliably estimate PT-conditions, based on extensive metamorphic equilibration, whereas the corresponding clastic sediments with the ordinary assemblage phengite (classically termed illite) + chlorite are hardly capable to contribute to a precise evaluation of PT-conditions. The determined PT-conditions of 2.9 kbar and 250°C, probably the peak conditions for the studied meta-rhyodacite, reflect a burial of about 11 km and a geotherm of 23°C/km. These characteristics are compatible with our present knowledge on the rocks of the Ardennes. The location of the metamorphosed subvolcanic stock is related to a near-base position in a thick sedimentary pile, which was additionally thickened by compression leading to duplex-forming thin-skinned thrusts.

References:

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