Drilling site Groß-Umstadt - Heubach – New results to the metamorphic and geodynamic evolution of the Northern Böllstein Odenwald, Hessen

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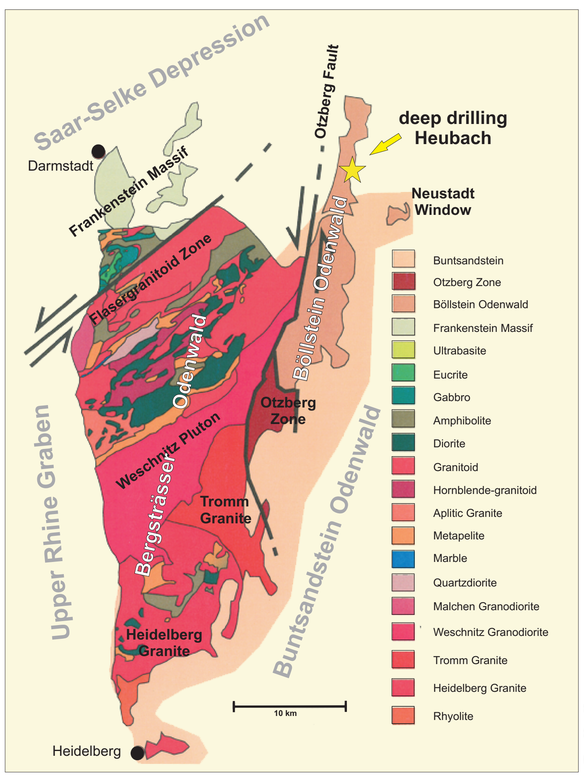
Introduction

In a pilot study for testing the feasibility of deep geothermal application in the crystalline basement of the Odenwald a borehole was drilled to a depth of 775 m. This drilling provides new information on the structure and composition of the basement, and gives access to unique rock material for detailed investigation of the metamorphic and geodynamic evolution of this part of the basement.

Geological setting

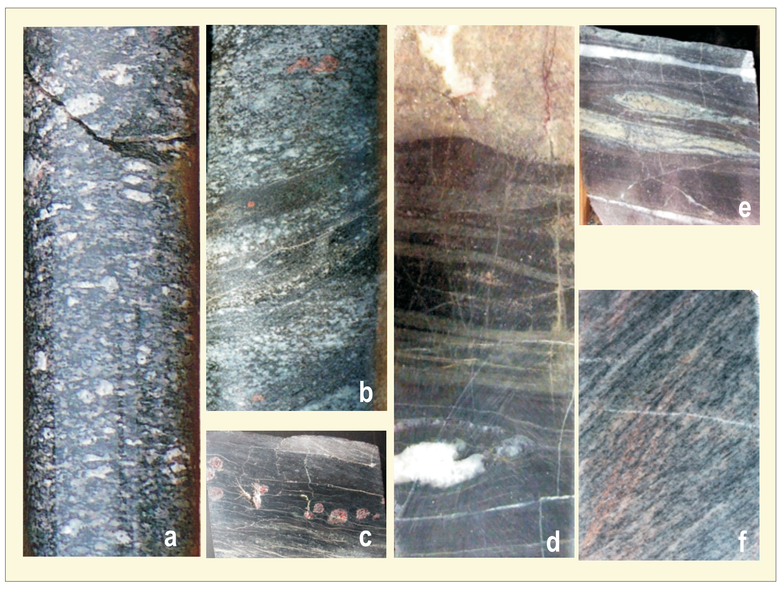
The drilling site at Heubach/Groß-Umstadt is located in the northern Böllstein Odenwald, which is a part of the Mid-German Crystalline Rise. The Otzberg fault zone separates the Böllstein from the Bergsträsser Odenwald to the west, whose structural, chemical, magmatic and metamorphic history is different (STEIN, 2001). The Böllstein Odenwald, is a metamorphic complex forming a large NNE-SSW striking anticline cored by granitoid gneisses. These are surrounded by a metamorphosed volcano-sedimentary unit, a relic of a pre-Variscan accretionary prism.



Geological map of the Crystalline Odenwald (after: STEIN, 2001)

Petrology

The borehole samples comprise mainly biotite and hornblende gneisses, some of which are garnet-bearing. Minor rock types are amphibolites, mica-schists, meta-carbonates, quartzite and migmatites.

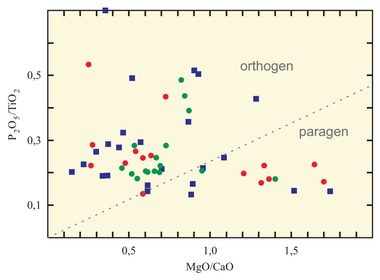


Core samples of the Heubach drilling
a = hornblende - biotite gneiss (from 42 m depth)
b = garnet-bearing biotite gneiss with mylonite zones (82 m)
c = mylonite zone with garnet porphyroblasts (88 m)
d = garnet-bearing biotite gneiss with layers of quartzites (613 m)
e = garnet-bearing biotite gneiss with layers of quartzites (617 m)
f = biotite gneiss, migmatitic (772 m)

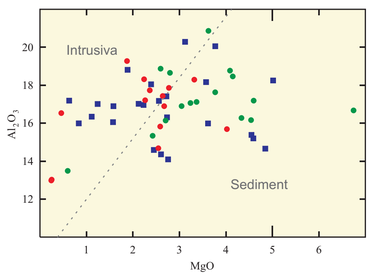
The core samples are characterized by metamorphic layering, a pervasive schistosity and augengneiss textures in places. Locally, the rocks show evidence of partial melting. Strain is heterogeneously distributed and concentrated in mylonitic zones.

Geochemistry

Major element chemical analyses of 74 rock samples show variations of SiO_2 from 53-78%. Geochemical discrimination of the samples into orthogneisses or paragneisses is not unequivocal.

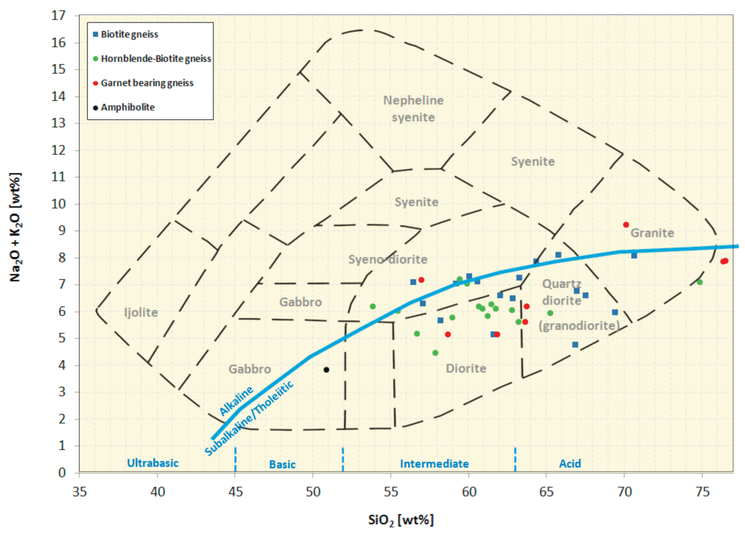


Classification scheme (WERNER, 1987): green = Hornblende gneisses, blue = biotite gneisses, red = garnet bearing gneisses



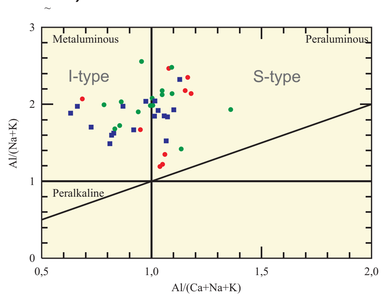
Classification scheme (THELIN, 1983): green = Hornblende gneisses, blue = biotite gneisses, red = garnet bearing gneisses

After petrological investigations at least 43 rock samples are orthogneisses. The composition of the horn-blende gneisses indicates dioritic protoliths. The garnet-bearing gneisses derived from granites, granodiorites, or diorites. The biotite gneisses are primarily of granodioritic and dioritic composition. The amphibolite is interpreted as a metamorphosed basaltic sill.

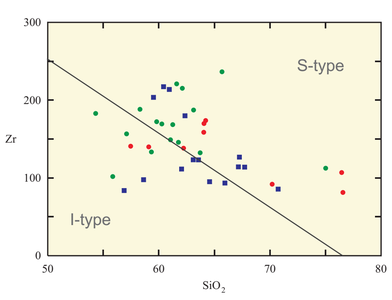


TAS-Diagram (COX et al.,1979; modified WILSON, 1989)

The gneisses from Heubach have a metaluminous as well as peraluminous character with a molar ratio of $Al_2O_3/(Na_2O+K_2O) > 1$. I-type as well as S-type gneisses occur. This is in contrast to the exclusive occurrence of I-type granitoids of the Bergsträsser Odenwald (STEIN, 2001).

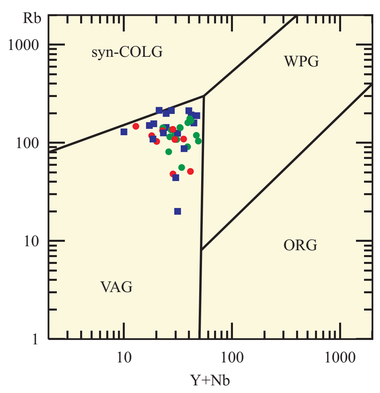


Classification scheme (SHAND, 1978): green = Hornblende gneisses, blue = biotite gneisses, red = garnet bearing gneisses



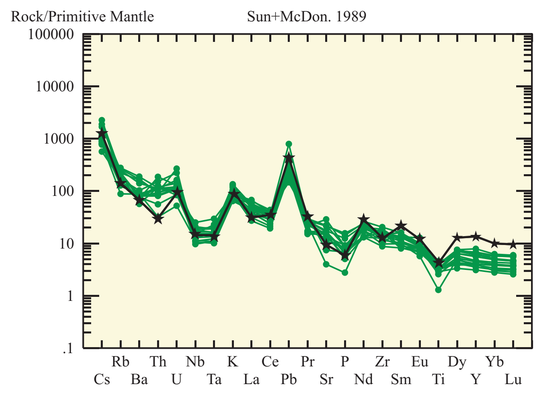
S- and I-type classification scheme (HINE et al., 1978): green = Hornblende gneisses, blue = biotite gneisses, red = garnet bearing gneisses

The geochemical composition of the igneous rocks, especially the Rb, Nb and Y concentrations, reveals similarities to magmatic arc granites imply an active margin environment.



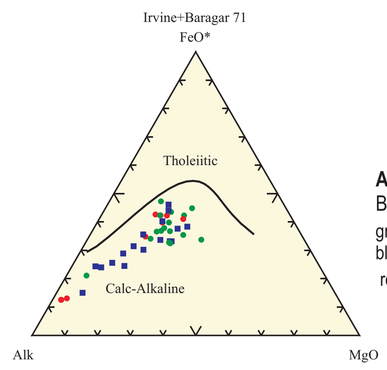
Discrimination diagram of the geotectonic position of the Heubach granitoids (PEARCE et al.,1984):
ORG = Ocean Ridge Granites
VAG = Volcanic Arc Granites
WPG = Within Plate Granites
syn-COLG = Syn-Collision Granites
green = Hornblende gneisses
blue = biotite gneisses
red = garnet bearing gneisses

Accordingly, normalization to primative mantle composition shows significant negative anomalies of Nb, Ta and Ti and positive anomalies of incompatible elements (e.g. Cs, U, Pb, K). The S-type signature indicate also the influence of synorogenic granites.



Spider diagram (SUN & MCDONALD, 1989): green = hornblende gneisses, black = amphibolites

The AFM diagram is illustrating the calc-alkaline character of the gneisses of Heubach and thus underlines the subduction-related origin as well.

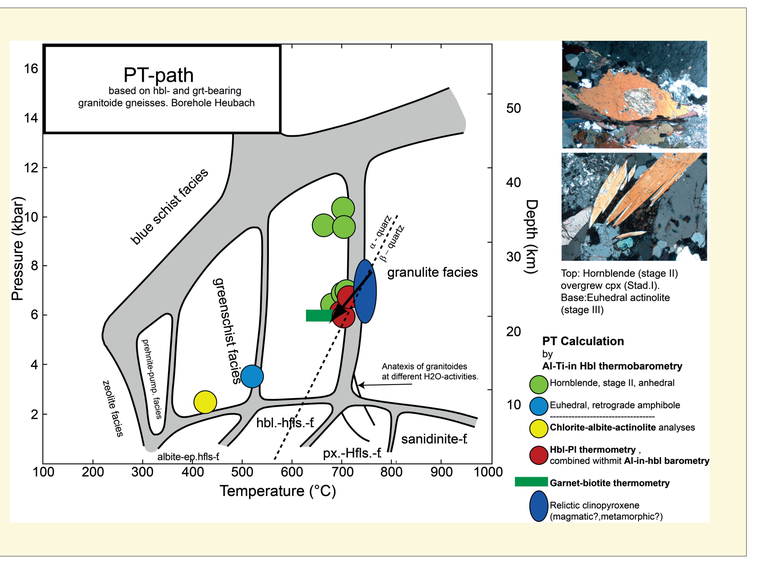


AFM-diagram (IRVINE & BARAGAR, 1971):
green = Hornblende gneisses
blue = biotite gneisses
red = garnet bearing gneisses

PT-path

Hornblende, plagioclase and K-feldspar recrystallized dynamically. In places quartz displays chessboard subgrain texture, indicating temperatures higher than 700°C at pressure of about 0.7 GPa. Hence, the mineral assemblages and fabrics demonstrate that the metamorphic event took place under medium pressure – high temperature conditions of higher amphibolite to lower granulite facies.

Analyses of garnet-bearing samples by classic thermometry indicate temperatures of 600-705 °C and retrograde and post-kinematic re-equilibration at 550-670 °C. Thermobarometric studies on hornblende-bearing samples yield similar conditions (680-740 °C, 0.55-0.75 GPa). The uplift through greenschist facies conditions is documented by the formation of chlorite, actinolite, and albite.



Conclusions

These results confirm investigations of WILLNER et al. (1991) who reported granulite facies metamorphism for a kyanite-garnet-bearing assemblage in the Böllstein Odenwald (763-805 °C, 0.78-0.86 GPa). The established clockwise PT-path indicates that the gneisses of the Heubach region reached lower crustal depth, probably during an or early Variscan stage and rose to mid crustal level during a later Variscan phase at the end of the lower Carboniferous. The most likely scenario is an evolution in a syn- to postcollisional setting, probably in a convergent geodynamic system.

Literature

STEIN, E. (2001): Mineral. Petrol., 72, 7-28.
WILLNER, A.P. et al. (1991): Geol. Rundsch., 80, 369-389.

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