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New findings on the tectono-metamorphic history of the western Rhenish Massif (Germany) by K–Ar dating of metasedimentary illite

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ABSTRACT

Metapelites, clay-rich sandstones and volcanics from Cambrian, Ordovician and Lower Devonian strata of the western Rhenish Massif underwent a complex regional Variscan tectono-thermal evolution, as shown by mineralogical and K–Ar isotopic analyses of the illite to mica components from three NW-SE transects. The metamorphic degree extended from an anchimetamorphic to an epimetamorphic intensity during two major episodes of illite crystallization at 328 ± 6 and 282 ± 12 Ma. A further late orogenic or post-orogenic extensional activity could also be detected, but not precisely, around 270 Ma, probably recorded by the precipitation of illite in new or reactivated extensional faults with upward moving heat flows.

Three studied cross-sections through the massif display a distribution of the illite crystallinity index that scatters within the diagenesis-to-anchizone range with increased crystallization grades along the thrust zones. The determined K–Ar ages probably frame the Variscan convergence in the western Rhenish Massif, which allows calculation of a "shortening velocity" of 140 km in 40 Ma, or of about 0.35 cm/a, that can be suggested on the basis of a total shortening of about 50% for the entire massif.

1. Introduction

Isotopic dating of diagenetic to incipient metamorphic processes and of slaty cleavages in siliciclastic rocks was reported by many authors in many circumstances (e.g., Clauer, 1974; Kralik, 1982; Kligfield et al., 1986; Clauer et al., 1995; Kirschner et al., 1995; Zhao et al., 1999). However, results raising difficulties and inconsistencies due to incomplete isotopic resetting of minerals and/or incomplete separation of mineral assemblages with mixed ages were also published (e.g., discussion in Clauer and Chaudhuri, 1998). The major difficulty identified relates to the occurrence of natural or artificial mixtures of detrital and authigenic mineral particles in the small (<2 μm) silicate clay-enriched size fraction, especially of shale- to slate-type rocks. Supplementary fractionations into <0.4, 0.4–1 and 1–2 μm size fractions, for instance, are suitable to improve the separation of the smallest, often pure authigenic, from coarser mainly detrital sheetsilicate particles. It is also appropriate to study rocks of a slightly higher metamorphic grade, as temperatures of about 300 °C and above are sufficient to reset completely the K–Ar system of metapelites (Leitch and McDougall, 1979).

Geochronological studies of clay-rich size fractions from fine-grained pelite type rocks that were slightly metamorphosed, especially in fold and thrust belts, remain a real challenge to understand how nucleation of authigenic minerals combines with alteration of initial rock minerals that are often similar in size, morphology and chemical composition. In this respect, the Rhenish Massif appeared to be a very appropriate study area with deformed and metamorphosed shale to slate type rock units that obviously underwent a complex polyphased evolution.

The western Rhenish Massif belongs to the Rheno-Hercynian realm of the mid-European Variscan orogenic belt, where the regional metamorphism seems to have mainly occurred synkinematically (Weber, 1972; Ahrendt et al., 1978, 1983; Teichmüller et al., 1979); some prekinematic metamorphic occurrences have also been reported (e.g., Fielitz and Mansuy, 1999). The development of a cleavage foliation is in most cases connected to sheetsilicate blastesis, mainly of illite and chlorite type. In the eastern part of the belt, isotopic determinations of tectonothermally overprinted rocks along a NW-SE geotraverse allowed reconstruction of the temporal development of the tectonic activity. However, isotopic dates biased by incomplete resetting of detrital or previously diagenetic minerals were also reported (Ahrendt et al., 1978, 1983).

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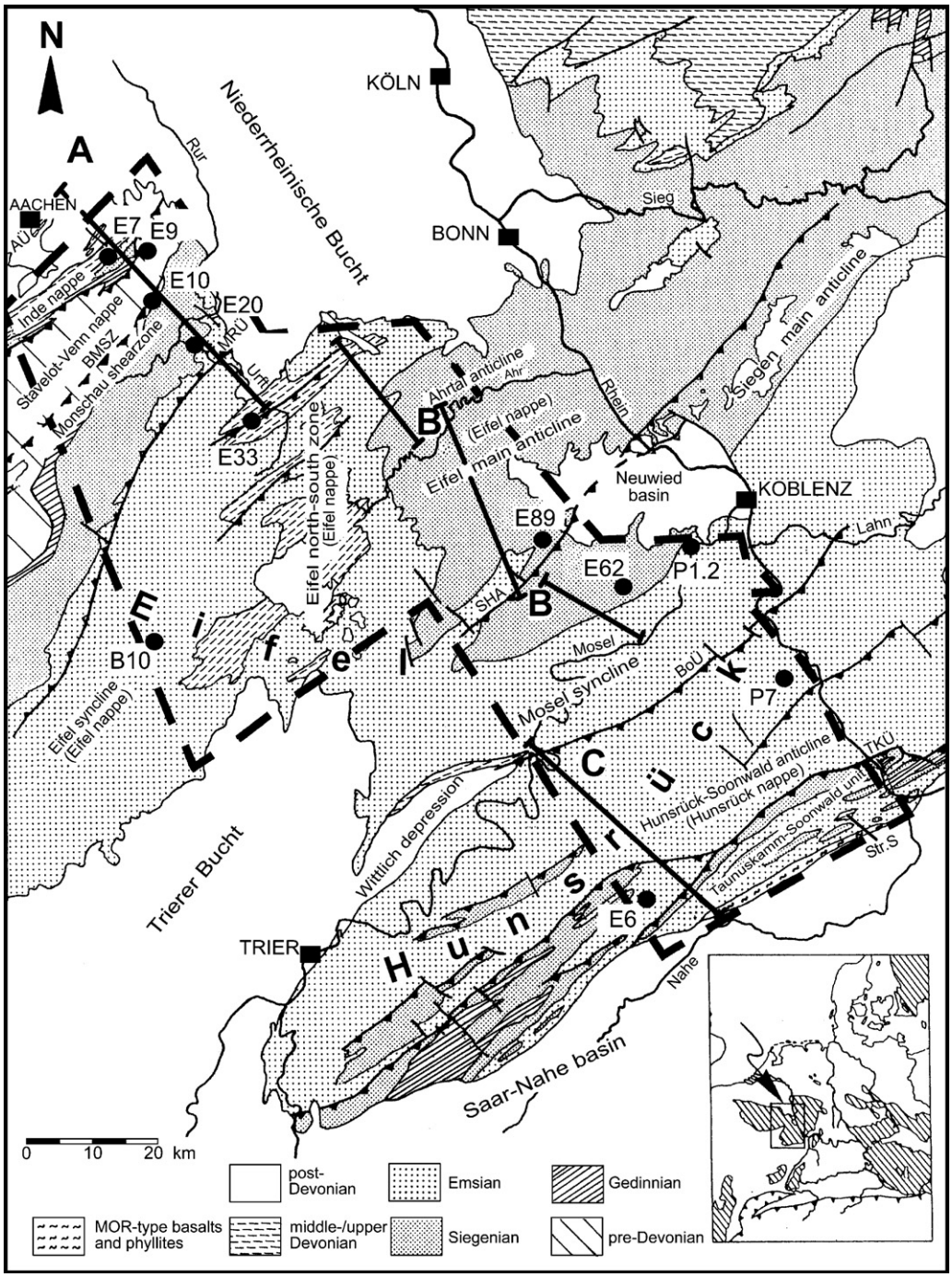

Fig. 1. Simplified geological setting of the studied area framed by a thick dashed line in the western Rhenish Massif (after Walter, 1992). The sample locations are marked by dots. The letters A, B and C are identifying the three cross-sections described in the text. AÜ stands for the Aachen overthrust, BMSZ for the basal overthrust plane of the Monschau shear zone, BoÜ for the Boppard overthrust, MRÜ for the Malsbenden backthrust, SHA for the Siegen Main Thrust, Str.S for the Stromberg syncline, and TKÜ for the Tanuskamm overthrust. For the Hunsrück area, only the Emsian strata are indicated, Siegenian has also local occurrences.

Since regional metamorphism has also been described recently in the western part of the belt from the city of Aachen in the northwestern region of the massif to the Hunsrück area in the southeastern (Nierhoff, 1994), the aim of this study was to provide additional information on this western regional tectonic and metamorphic activity by K–Ar dating of illite to mica type fractions separated from various types of rocks collected in varied tectonometamorphic environments. This work is based on a detailed XRD study of the clay fraction from samples taken along three transects aided by scanning and transmission electron microscopic observations. The location of the study material follows a general NW–SE geotraverse that covers most of the western Rhenish Massif (Fig. 1), allowing a comparison with strain analyses and balanced cross-sections presented earlier by Schievenbusch (1991), Dittmar and Oncken (1992) and Winterfeld (1994).

2. Geological setting and summary of previous studies

2.1. Regional geological and tectonic setting

The Rhenish Massif is basically a Variscan framework of stratigraphic units that have been tectonically subdivided by thrust faults