Solid Earth, 7, 1331–1347, 2016
www.solid-earth.net/7/1331/2016/
doi:10.5194/se-7-1331-2016
© Author(s) 2016. CC Attribution 3.0 License.

Solid Earth Open Access EGU

Mid-crustal shear zone development under retrograde conditions: pressure–temperature–fluid constraints from the Kuckaus Mylonite Zone, Namibia

Johann F. A. Diener[1], **Åke Fagereng**[1,*], **and Sukey A. J. Thomas**[1]

[1]Department of Geological Sciences, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa
[*]present address: School of Earth & Ocean Sciences, Cardiff University, Cardiff CF10 3AT, UK

Correspondence to: Johann F. A. Diener (johann.diener@uct.ac.za)

Received: 19 April 2016 – Published in Solid Earth Discuss.: 22 April 2016
Revised: 4 August 2016 – Accepted: 28 August 2016 – Published: 16 September 2016

Abstract. The Kuckaus Mylonite Zone (KMZ) forms part of the larger Marshall Rocks–Pofadder shear zone system, a 550 km-long, crustal-scale strike-slip shear zone system that is localized in high-grade granitoid gneisses and migmatites of the Namaqua Metamorphic Complex. Shearing along the KMZ occurred ca. 40 Ma after peak granulite-facies metamorphism during a discrete tectonic event and affected the granulites that had remained at depth since peak metamorphism. Isolated lenses of metamafic rocks within the shear zone allow the P–T–fluid conditions under which shearing occurred to be quantified. These lenses consist of an unsheared core that preserves relict granulite-facies textures and is mantled by a schistose collar and mylonitic envelope that formed during shearing. All three metamafic textural varieties contain the same amphibolite-facies mineral assemblage, from which calculated pseudosections constrain the P–T conditions of deformation at 2.7–4.2 kbar and 450–480 °C, indicating that deformation occurred at mid-crustal depths through predominantly viscous flow. Calculated T–M_{H_2O} diagrams show that the mineral assemblages were fluid saturated and that lithologies within the KMZ must have been rehydrated from an external source and retrogressed during shearing. Given that the KMZ is localized in strongly dehydrated granulites, the fluid must have been derived from an external source, with fluid flow allowed by local dilation and increased permeability within the shear zone. The absence of pervasive hydrothermal fractures or precipitates indicates that, even though the KMZ was fluid bearing, the fluid/rock ratio and fluid pressure remained low. In addition, the fluid could not have contributed to shear zone initiation, as an existing zone of enhanced permeability is required for fluid infiltration. We propose that, following initiation, fluid infiltration caused a positive feedback that allowed weakening and continued strain localization. Therefore, the main contribution of the fluid was to produce retrograde mineral phases and facilitate grain-size reduction. Features such as tectonic tremor, which are observed on active faults under similar conditions as described here, may not require high fluid pressure, but could be explained by reaction weakening under hydrostatic fluid pressure conditions.

1 Introduction

Crustal-scale deformation is commonly localized into major faults, in the upper crust and ductile shear zones in the lower crust (e.g. Savage and Burford, 1973; Kirby, 1985; Zoback et al., 1985; Scholz, 1988; Wittlinger et al., 1998). This observation requires the presence of weakening mechanisms that both initiate and sustain strain localization into lithospheric high-strain zones (Rutter et al., 2001). Such mechanisms include (1) high fluid pressures, which reduce the effective coefficient of friction and lead to localized and transient embrittlement (Hubbert and Rubey, 1959; Sibson, 1980; Rice, 1992) as well as enhance microfracturing and mass transfer processes (Cox and Etheridge, 1989); (2) grain-size reduction and activation of diffusive mechanisms, particularly in the presence of a reactive fluid phase (Rutter, 1976; Brodie and Rutter, 1987); (3) geometric softening by alignment of easy slip planes and the shear plane, by de-

Published by Copernicus Publications on behalf of the European Geosciences Union.