

On the age and tectonic significance of Permo-Triassic dikes in the Bergen–Sunnhordland region, southwestern Norway

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New $^{40}\text{Ar}/^{39}\text{Ar}$ step heating data for amphiboles from three N–S to NNW–SSE-trending alkaline dikes in western Norway yield remarkably consistent plateau ages at about 221 Ma. Together with most previously published amphibole and whole-rock K/Ar ages from Sunnhordland, which cluster around 220 Ma, the new data provide convincing evidence for a Late Triassic main pulse of dike intrusion. We conclude that most (but not all) of the K–Ar data are reliable and that Permian K–Ar and fission-track ages from four dikes in the region suggest an earlier pulse of intrusion at around 250–260 Ma. However, it is argued that the previously published Jurassic whole-rock age of one of the dikes is caused by hydrothermal alteration of the groundmass. A $\sim 220\text{ Ma}^{40}\text{Ar}/^{39}\text{Ar}$ plateau (and isochron) age of unaltered hornblende is believed to reflect more closely the age of intrusion, in agreement with other ages of late dikes in the region. The Permian (250–260 Ma) and Triassic (220–230 Ma) pulses of dike injection are correlated with Permian and Triassic phases of extension in the North Sea basin to the west. The strong influence of Permo-Triassic stretching at the eastern side of the Viking Graben and only mild rejuvenation of Permo-Triassic structures in the late Jurassic help to explain the apparent absence of Jurassic magmatism in southwestern Norway.

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Introduction

Coast-parallel basaltic dikes are an unusual and important element in the post-Caledonian tectonic record of the eastern margin of the North Sea rift system. They have been used as indications for early (Permo-Triassic) extension related to North Sea rifting (e.g. Færseth et al. 1995), and syn-intrusion extension directions have been inferred from their geometries (Fossen 1998; Valle 1998). The value of such data relies strongly on knowledge of their ages, or more specifically on the reliability of previously published K–Ar ages. In the present contribution we re-evaluate the existing data in the light of new $^{40}\text{Ar}/^{39}\text{Ar}$ results from some of these dikes.

General setting and previous work

The dikes

Close to 100 post-Caledonian dikes in the Sunnhordland–Sotra region (Reusch 1888; Kvale 1937; Skordal 1948; Færseth et al. 1976; Løvlie & Mitchell 1982) occur along N–S to NNW–SSE trending lineaments that transect all ductile and many brittle tectonic structures in the region, including Caledonian thrusts and Devonian extensional shear zones and faults. In particular, they cut mylonites related to the extensional Hardangerfjord Shear Zone (Fig. 1), which is a gently ($25\text{--}30^\circ$) NW-dipping Devonian ductile shear zone in the basement connected to semi-brittle faults (e.g. the Lærdal–Gjende fault system) in

overlying Caledonian units (Fossen 1992). They also postdate abundant \sim NE–SW-trending normal faults with cohesive fault rocks and striated slip surfaces. The kinematics of the latter fault population are consistent with \sim NW–SE extension, whereas the extension direction had changed to \sim E–W at the time of dike injection (Fossen 1998; Valle 1998).

The dikes are with few exceptions less than one meter wide, and may form en-echelon-arranged subvertical segments, which are linked by fractures that may or may not be filled with dike material. Individual dikes can be traced for up to a few hundred meters along strike, although typically less than a few tens of meters.

Most dikes appear fresh but some alteration of the fine-grained matrix has occurred. The nature of the alteration is difficult to assess petrographically because of the extremely fine grain size, but it is clear that some proportion of the high temperature matrix mineralogy has not survived. Furthermore, in some cases amphiboles and pyroxenes are fractured, particularly in dike D1 (see Fig. 1 for location), which has been brecciated and calcite-cemented during reactivation of the N–S-trending fracture zone along which it intruded. The petrology of the alkaline dikes indicates derivation from a mantle source and emplacement at high crustal levels along the N–S to NNW–SSE-trending subvertical fractures (Færseth 1978).

Previous dating

Several of the dikes were dated in the 1970s by the K–Ar