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Did hot, high heat-producing granites determine the location of the Oslo Rift?

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Abstract

The Late Carboniferous–Early Permian Oslo Rift formed in apparently cold, stable lithosphere of the Fennoscandian Shield in a tensional stress regime widely documented in Northwest Europe at that time. The Rift formed obliquely to older, crustal structures that display only limited Permian reactivation, and, although numerical modelling suggests that the present-day lithospheric structure would serve to focus tensional stresses in the Oslo region, the assumption that no lithospheric evolution has occurred since the Palaeozoic is by no means obvious. Here, I show that, up to 5 km thick, regional-scale Late- to Post-Sveconorwegian granites in the vicinity of the Oslo Rift, with heat-production rates averaging ca. 5 $\mu W/m^3$, nearly three times higher than the surrounding Sveconorwegian gneisses, would have increased the temperature in the lower crust and lithospheric mantle by up to 100 °C, resulting in significant thermal weakening of the lithosphere in this area. Given a tensional stress regime, weakening by these high heat-producing element granites would have made the Oslo area a favoured site for passive rifting and may have been a first-order parameter locating rifting to this part of the Fennoscandian Shield. The thermo-rheological effects of such granites must be considered along with other factors in future models of initial rift mechanisms in the Oslo Rift, and probably in other rifts elsewhere.

Keywords: Oslo Rift; Permo-Carboniferous rifting; High heat-producing granite; Fennoscandian Shield; Rheological profile

1. Introduction

Rifting of continental lithosphere is a fundamental process in the growth and evolution of continents, and has received widespread attention from geologists since before the advent and general acceptance of plate tectonics (e.g., Gregory, 1896; Brøgger, 1898, 1933; Anderson, 1955). Continental rifts preferentially develop in zones of lithospheric weakness resulting from inherited crustal or lithospheric structural elements (e.g., van Wijk, 2005). Alternatively, elevated local geotherms, related either to higher than normal heat production within the crust (e.g., Ranalli, 1991) or mantle upwelling (e.g., Kendall et al., 2005), will result in a general weakening of the lithosphere that could promote rifting given a tensional stress field. Rifting may also initiate in areas where lithospheric architectural features serve to focus extensional stresses and has been proposed as a possible mechanism for formation of the Oslo Rift (Pascal and Cloetingh, 2002; Pascal et al., 2002, 2004).

The Late Carboniferous–Early Permian Oslo Rift is among the most intensely studied continental palaeorifts in the world in terms of magmatic evolution and rift development, yet the fundamental question of how

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a rift could develop in the cold, stable lithosphere of the southwestern Fennoscandian Shield remains a puzzle. Although pre-existing, Sveconorwegian structures probably played a part in controlling the architecture of the Oslo Rift (e.g., Swensson, 1990; Sundvoll and Larsen, 1994), Pascal and Cloetingh (2002) argued that their role was relatively secondary. This argument is supported by the high angle between the main Sveconorwegian structural elements and the Oslo Rift (Fig. 1). The preservation of Cambro-Silurian (i.e., pre-rift) sediments in down-faulted rift blocks excludes major pre-rift uplift, and sedimentological observations suggest that the area was at sea level immediately prior to rifting (Olaussen, 1981). These observations indicate a passive origin for the Oslo Rift; thus, rifting in response to mantle upwelling (cf. Kendall et al., 2005) is unlikely (Pedersen and van der Beek, 1994).

The present-day lithospheric geometry of the southwestern Fennoscandian Shield is characterised by thick

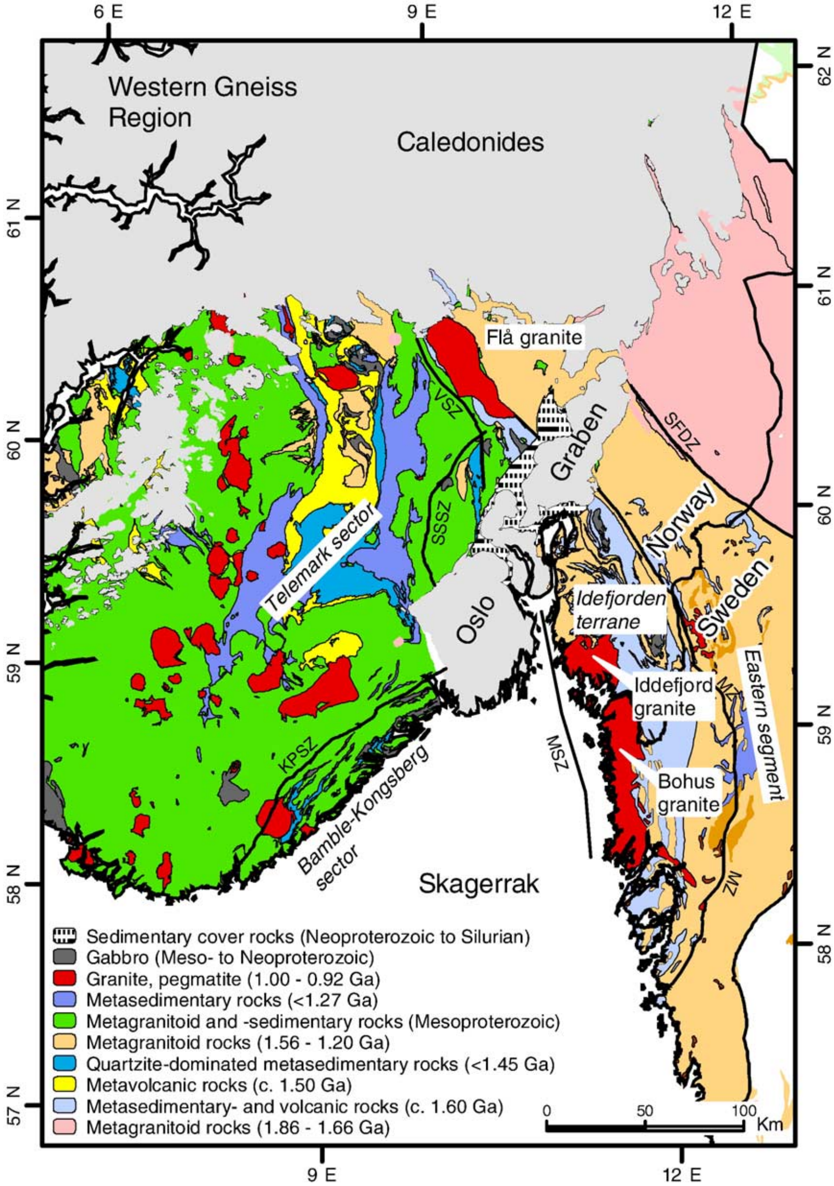

Fig. 1. Simplified geological map of the southwestern Fennoscandian Shield, modified after Koistinen et al. (2001). Abbreviations: KPSZ—Kongsberg–Porsgrunn Shear Zone, SSSZ—Saggrenda–Sokna Shear Zone, ÅVSZ—Åmot–Vardefjell Shear Zone, ÖMSZ—Östfold–Marstrand Shear Zone, MZ—Mylonite Zone, SFDZ—Sveconorwegian Frontal Deformation Zone.