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A palaeomagnetic and $^{40}Ar/^{39}Ar$ study of mafic dykes in southern Sweden: A new Early Neoproterozoic key-pole for the Baltic Shield and implications for Sveconorwegian and Grenville loops

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ABSTRACT

We present the results of palaeomagnetic and $^{40}Ar/^{39}Ar$ studies of the Proterozoic mafic dykes in the Norrköping and Falun areas of the southern Sweden. The primary remanence of two 939 ± 3 Ma dykes is supported by the rigorous baked contact test. The remanence direction of two other dykes, one of which was previously U–Pb dated at 946 ± 1 Ma is close to the reverse direction of 939 Ma dykes. Using these results together with previously published 935 ± 5 Ma palaeomagnetic data from the Göteborg-Slussen mafic dykes and some dykes from the Falun area we calculated the mean 946–935 Ma palaeopole for Baltica (0.9° S, 240.7° E, A_{95} = 6.7), which can be qualified as the key pole. Using this pole together with other date we conclude that the Grenville and Sveconorwegian loops of Laurentian and Baltican Apparent Polar Wander Paths are temporary displaced by 100–150 m.y. We propose new palaeogeographic reconstructions of Baltica and Laurentia at ca. 940 Ma and ca. 850 Ma. We also present two new Mesoproterozoic non-key poles from 1410 Ma and 1595 Ma dykes.

1. Introduction

Assembly of continents into a late Precambrian supercontinent, Rodinia, has been suggested in a number of studies (e.g. McMenamin and McMenamin, 1990; Dalziel, 1991, 1997; Hoffman, 1991). Models of Rodinia are mostly based on ca. 1350–1000 Ma orogenic belts, tectonic links between mobile belts across the cratonic margins, global analyses of the balance of Neoproterozoic and Early Palaeozoic continental margins and some palaeomagnetic data. Early Neoproterozoic tectonic reconstructions suggest a connection between Baltica and Laurentia (e.g. Hoffman, 1991; Dalziel, 1991, 1997; Weil et al., 1998; Dalziel et al., 2000; Pisarevsky et al., 2003; Li et al., 2008) in Rodinia. Since palaeomagnetism is the only tool for reconstructing the latitudinal position and orientation of cratons it plays an important role for these reconstructions. However, reliable palaeomagnetic data are sparse (e.g. Buchan et al., 2001) and more "key" palaeomagnetic poles, i.e. well dated poles that fulfill criteria for original magnetization, etc. (Van der Voo, 1990; Buchan et al., 2000) are needed for testing the palaeogeographic reconstructions. Due to the often high contents of magnetite, fast cooling and thereby small magnetic grain sizes and stable remanent magnetizations, mafic dykes are often excellent recorders of the Earth magnetic field. Palaeomagnetic data from mafic dykes forms a significant part in the palaeomagnetic databases (e.g. McElhinny and Lock, 1996; Pesonen et al., 2003; Pisarevsky, 2005).

In southern Sweden Early Neoproterozoic dyke swarms are widespread and have been the target for a large number of palaeomagnetic studies (e.g. Poorter, 1975; Patchett and Bylund, 1977; Bylund, 1985, 1992; Bylund and Elming, 1992; Bylund and Pisarevsky, 2002; Pisarevsky and Bylund, 1998, 2006). Most of these studies are from dolerite dykes in the Protogine Zone (PZ; Fig. 1) that defines a metamorphic boundary that separates the Southwest Scandinavian province in the west from the Transscandinavian Igneous Belt (TIB; Patchett et al., 1987) and the Southern Svecofennian subprovince (SSv) in the east (e.g. Gaál and Gorbatschev, 1987). The TIB and the Southwest Scandinavian province formed by crystal growth of the Baltic Shield with a westward younging during the TIB (ca. 1850–1670; Gorbatschev, 2004) and the Gothian period (1700–1550 Ma) (e.g. Åhäll and Larson, 2000; Andersen

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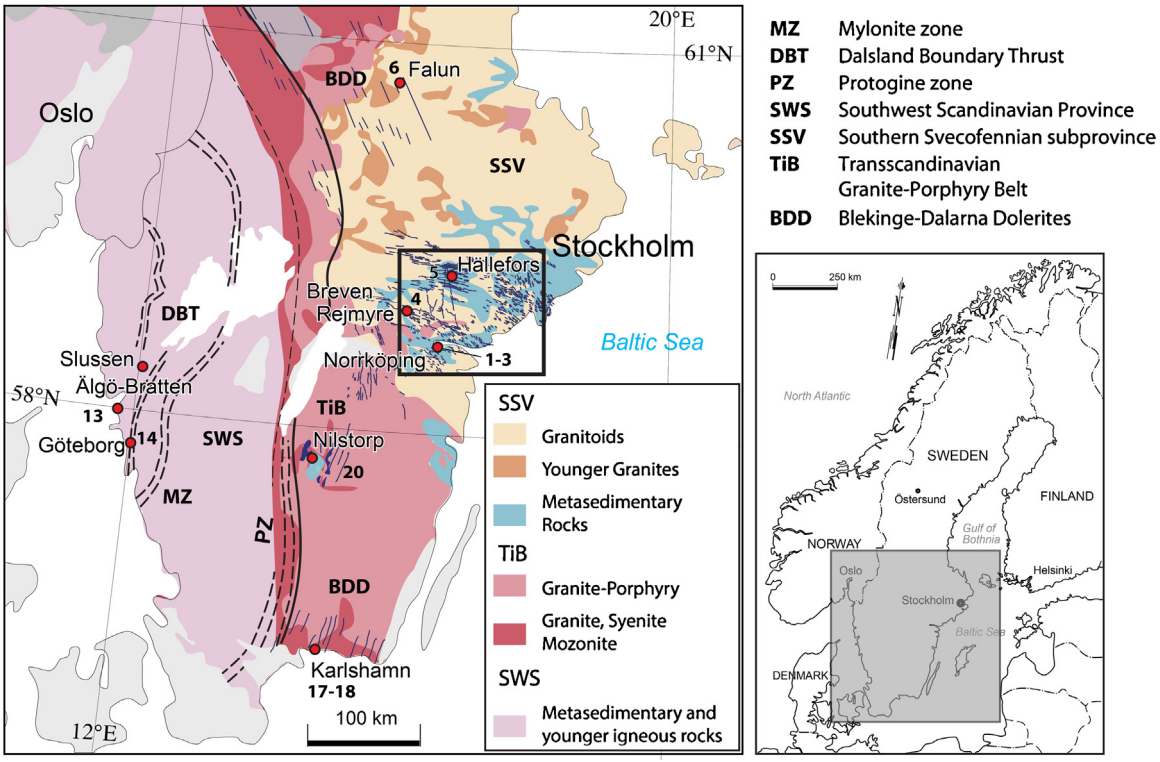

Fig. 1. The geology of the south-western part of the Fennoscandian Shield (a). The inlet in figure (a) marks the area where this study was concentrated on.

et al., 2004, Högdahl et al., 2004). From the late Palaeoproterozoic time the continental margin of a suggested continuous Laurentia-Baltica was the location of long lived subduction and terranes' accretion (e.g. Åhäll et al., 2000; Karlström et al., 2001; Andersen et al., 2004; Bingen et al., 2008; Pisarevsky and Bylund, 2010). The Sveconorwegian (in Laurentia Grenvillian; ca. 1150–900 Ma) continent-continent collision resulted in deformation and metamorphism of the Gothian orogen in Southwestern Sweden (e.g. Åhäll and Gower, 1997). The event resulted in a major deformation zone, the Mylonite Zone (Fig. 1; e.g. Gorbatschev, 1980), a zone that has been active during both Sveconorwegian thrusting and subsequent phases of exhumation (e.g. Stephens et al., 1996; Berglund, 1997). $^{40}Ar/^{39}Ar$ hornblende ages from the Mylonite Zone indicate deformations as late as ca. 915 Ma ago (Page et al., 1996), while ca. 40–70 km away from the Mylonite Zone two Sveconorwegian ages were identified, at 934–931 Ma and 1007–960 Ma, the younger ages suggested to be related to orogenic uplift. Deformation up to 40 km east of the Protogine Zone has been demonstrated from structural mapping (Wahlgren et al., 1994). Palaeomagnetic data older than ca. 900 Ma from southwestern Sweden should therefore be used with caution, since they may have been subjects to metamorphic overprints or tectonically disturbed and therefore not necessarily representing the Baltic Shield as a whole.

Palaeomagnetic results from 935 ± 3 Ma mafic dykes (Göteborg-Slussen dykes; Fig. 1) in the Southwestern Scandinavian province, west of the Mylonite Zone, were presented by Pisarevsky and Bylund (2006). The data are of good quality, however, no full field test demonstrating an original magnetization was presented. Here we will present a new ca. 935 Ma-highly reliable pole for the Baltic Shield. This is based on new palaeomagnetic data fulfilling field test of primary magnetization and $^{40}Ar/^{39}Ar$ age determinations from mafic dykes in the eastern part of the Southern Svecofennian subprovince. This pole is compared and combined with the palaeomagnetic data from the 935 Ma dykes in the Southwest Scandinavian province and 946 Ma dykes from Dalarna. The new combined palaeomagnetic pole forms an important input to the discussion of the shape and timing of the Sveconorwegian Apparent Polar Wander Path (APWP) loop (e.g. Patchett and Bylund, 1977; Elming et al., 1993), which is similar in shape to the Grenville Loop in the Laurentia APWP (e.g. Hyodo and Dunlop, 1993; Weil et al., 1998) and has been a basis for palaeogeographic reconstruction of Baltica vs. Laurentia at 935 Ma.

2. Geology, sampling and laboratory technique

Mafic dykes in the southeastern part of the Southern Svecofennian subprovince (Figs. 1 and 2) comprise several dyke swarms,

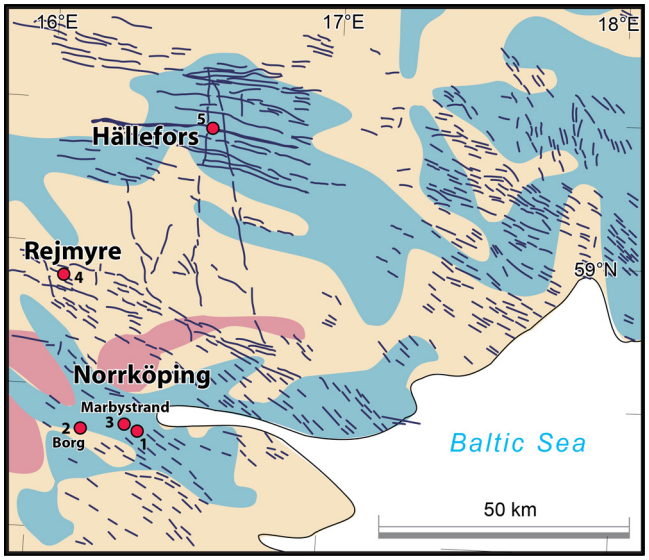

Fig. 2. Basic dykes in southern central Sweden (modified from Risku-Norja, 1992). Sampling localities for this study are marked by filled circles.