Precambrian Research 224 (2013) 11–22

Contents lists available at SciVerse ScienceDirect

Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Trading partners: Tectonic ancestry of southern Africa and western Australia, in Archean supercratons Vaalbara and Zimgarn

Aleksey V. Smirnov[a,b,*], David A.D. Evans[c], Richard E. Ernst[d,e], Ulf Söderlund[f], Zheng-Xiang Li[g]

[a] Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI 49931, USA
[b] Department of Physics, Michigan Technological University, Houghton, MI 49931, USA
[c] Department of Geology and Geophysics, Yale University, New Haven, CT 06520, USA
[d] Ernst Geosciences, Ottawa K1T 3Y2, Canada
[e] Carleton University, Ottawa K1S 5B6, Canada
[f] Department of Earth and Ecosystem Sciences, Division of Geology, Lund University, SE 223 62 Lund, Sweden
[g] Center of Excellence for Core to Crust Fluid Systems, Department of Applied Geology, Curtin University, Perth, WA 6845, Australia

ARTICLE INFO

Article history:
Received 26 April 2012
Received in revised form
19 September 2012
Accepted 21 September 2012
Available online 29 September 2012

Keywords:
Paleomagnetism
Paleoproterozoic
Yilgarn
Pilbara
Zimbabve craton
Kaapvaal craton

ABSTRACT

Original connections among the world's extant Archean cratons are becoming tractable by the use of integrated paleomagnetic and geochronologic studies on Paleoproterozoic mafic dyke swarms. Here we report new high-quality paleomagnetic data from the ~2.41 Ga Widgiemooltha dyke swarm of the Yilgarn craton in western Australia, confirming earlier results from that unit, in which the primary origin of characteristic remanent magnetization is now confirmed by baked-contact tests. The corresponding paleomagnetic pole (10.2°S, 159.2°E, A_{95} = 7.5°), in combination with newly available ages on dykes from Zimbabwe, allow for a direct connection between the Zimbabwe and Yilgarn cratons at 2.41 Ga, with implied connections as early as their cratonization intervals at 2.7–2.6 Ga. The proposed "Zimgarn" supercraton was likely distinct from Vaalbara (Kaapvaal plus Pilbara) at 2.4 Ga, but both of those entities independently fragmented at ca. 2.1–2.0 Ga, reassembling into the Kalahari and West Australian cratons by 1.95–1.8 Ga.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

Fundamental changes across the entire Earth system during the Archean–Paleoproterozoic transition (ca. 3000–2000 Ma) are reflected in global dynamics that became more similar to modern-style plate tectonics through that interval (Condie and Kröner, 2008; Reddy and Evans, 2009), although the kinematic record from that era is currently limited by a dearth of high-quality paleomagnetic data (Evans and Pisarevsky, 2008). However, recent work using a combined paleomagnetic and geochronologic approach on mafic dyke swarms within several Archean cratons, for example Slave (Buchan et al., 2009, 2012), Superior (Evans and Halls, 2010; defining member of the Superia supercraton of Bleeker, 2003), and Vaalbara (de Kock et al., 2009), has started to change this situation, enabling us to test and quantify the original connections that may have existed between them.

The Widgiemooltha mafic dykes of the Yilgarn craton (Western Australia) constitute one of the most prominent dyke swarms of the world's Precambrian shields (e.g., Sofoulis, 1966; Parker et al., 1987). The dykes generally trend east-west and outcrop over the entire craton (Fig. 1). Most of the dykes are of picrite, olivine–dolerite or quartz–dolerite composition and have not been affected by significant metamorphic events since their formation (e.g., Hallberg, 1987).

The age of the Widgiemooltha dyke swarm is constrained by isotopic dating of its three largest dykes. Nemchin and Pidgeon (1998) reported a baddeleyite U–Pb age of 2418 ± 3 Ma for the westernmost extension of the ~600-km-long Binneringie Dyke (Fig. 1). Electron microprobe U–Pb analyses of baddeleyites from an eastern location of the Binneringie Dyke yielded a slightly younger age of 2410.3 ± 2.1 Ma (French et al., 2002). A baddeleyite U–Pb age of 2410.6 + 2.1/−1.6 Ma was also obtained for the Celebration Dyke (Doehler and Heaman, 1998). Fletcher et al. (1987) reported Rb–Sr and Sm–Nd isochron age of 2411 ± 38 Ma for the ultramafic core of the ~180-km-long Jimberlana intrusion, located south of the Binneringie Dyke (Fig. 1). These data broadly confirm the earliest geochronological study of the Widgiemooltha dyke swarm (Turek, 1966), which yielded a 2420 ± 30 Ma Rb–Sr

* Corresponding author at: Department of Geological and Mining Engineering and Sciences, Michigan Technological University, 630 Dow ECE Building, 1400 Townsend Drive, Houghton, MI 49931, USA. Tel.: +1 906 487 2365.
E-mail address: asmirnov@mtu.edu (A.V. Smirnov).

0301-9268/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.precamres.2012.09.020

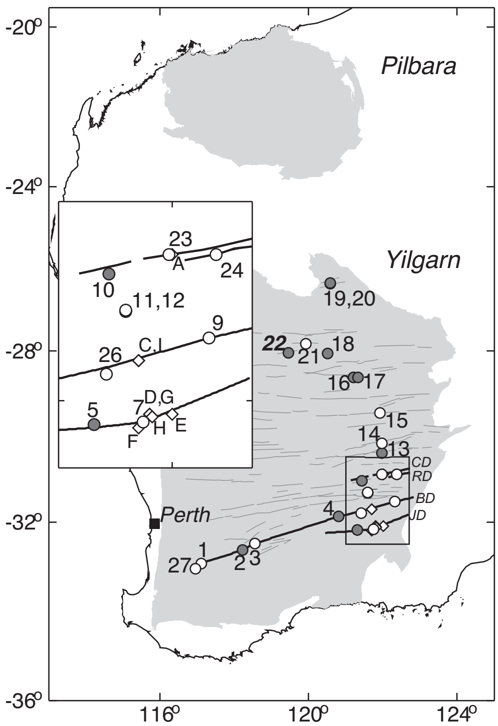

Fig. 1. Locations of sampling sites of this study (circles) and of Evans' (1968) (diamonds) sampling sites. Open (or grey) symbols show the sites used (or not used) to calculate the mean paleomagnetic directions. Shaded areas show the Yilgarn and Pilbara cratons. Thin gray lines indicate the Widgiemooltha dyke swarm; solid lines show the Binneringie (BD), Jimberlana (JD), Celebration (CD), and Randalls (RD) dykes. Inset map shows the area studied by Evans (1968).

age (using a decay constant of $1.39 \times 10^{-11}\,\mathrm{yr}^{-1}$); and the consistency of isotopic ages attests to the excellent preservation of the dykes.

Magnetic surveys show both positive and negative anomalies associated with the Widgiemooltha dykes (e.g., Tucker and Boyd, 1987), suggesting the presence of dual-polarity remanent magnetization. The only previous paleomagnetic study of the Widgiemooltha dyke swarm (Evans, 1968) found remanence directions of both polarities from four independently cooled dykes. However, that study was confined to a limited area in the southeastern Yilgarn (Fig. 1), it did not employ modern demagnetization and processing techniques, and it lacked a rigorous field test to confirm the primary origin of dyke magnetization. Here we report new high-quality paleomagnetic data from the Widgiemooltha dyke swarm, with implications for tectonic style of craton amalgamation and separation during the Archean–Paleoproterozoic transition.

2. Methods

We sampled 27 sites representing 14 separate Widgiemooltha dykes spanning most of the Yilgarn craton (Fig. 1). Five to thirty-two field-drilled oriented core samples were collected from each site. Orientation was done with both solar and magnetic compasses. Low-field thermomagnetic analyses, remanence unblocking temperature and magnetic hysteresis measurements indicate the presence of pseudosingle-domain magnetite or low-Ti titanomagnetite in most dykes (Fig. 2).

Magnetic remanence measurements were conducted at Yale University and Michigan Technological University using automated three-axis DC SQUID 2G rock magnetometers housed in magnetically shielded environments. After measurement of the natural remanent magnetization (NRM), the samples were cycled through the Verwey transition at ∼120 K (Verwey, 1939) by immersing them into liquid nitrogen for about two hours in order to reduce a viscous component carried by larger magnetite grains (Schmidt, 1993). Next, a low alternating field (AF) pre-treatment (to 100 mT in 20 mT steps) was applied to remove any remaining low-coercivity viscous or isothermal remanence. Finally, 15–20 thermal demagnetization steps were performed in an inert (nitrogen) atmosphere. Progressive demagnetization was carried out until the magnetic intensity of the samples fell below noise level or until the measured directions became erratic and unstable (typically at 580–590 °C).

The characteristic remanent magnetization (ChRM) for samples displaying nearly linear demagnetization trajectories was isolated using principal-component analysis (PCA) (Kirschvink, 1980). The best-fit line was used if defined by at least three consecutive demagnetization steps that trended toward the origin and had a maximum angle of deviation (MAD) less than 20°. For the majority of dykes, the ChRM was isolated within a narrow (10–25 °C) temperature range above 520 °C (Figs. 3–5). The mean directions were calculated using Fisher statistics (Fisher, 1953). A site mean was accepted for further calculations if it was obtained from three or more samples, the confidence circle (α_{95}) was smaller than 15°, and the precision parameter k was greater than 50.

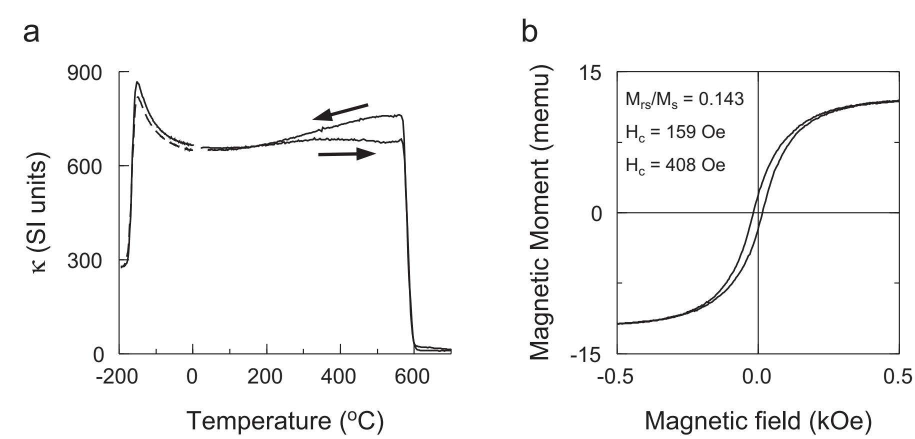

Fig. 2. (a) A typical low-field thermomagnetic curve ($\kappa(T)$) measured in argon from −192 °C to 700 °C using an AGICO KLY-4S magnetic susceptibility meter at Yale University. The $\kappa(T)$ curve indicates the presence of a single magnetic phase with a Curie temperature between 570–580 °C (low-Ti titanomagnetite or magnetite). The presence of nearly stoichiometric magnetite is further supported by a characteristic peak observed at about −153 °C, associated with the Verwey (1939) transition. (b) A typical magnetic hysteresis loop indicating pseudo-single domain behavior of the sample. Abbreviations are H_c, coercivity; H_{cr}, coercivity of remanence; M_{rs}, saturation remanence; M_s, saturation magnetization.

Download English Version:

https://daneshyari.com/en/article/4723333

Download Persian Version:

https://daneshyari.com/article/4723333

Daneshyari.com