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ScienceDirect
Lithos 98 (2007) 195–209
LITHOS
www.elsevier.com/locate/lithos

Distinct brief major events in the Karoo large igneous province clarified by new $^{40}Ar/^{39}Ar$ ages on the Lesotho basalts

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Received 4 October 2006; accepted 20 March 2007
Available online 28 March 2007

Abstract

Recent mineral separate ages obtained on the Karoo large igneous province (southern Africa) suggest that the province was built by several distinct magmatic pulses over a rather long period on the order of 5–6 Ma concerning the main erupted volume [Jourdan, F., Féraud, G., Bertrand, H., Kampunzu, A.B., Tshoso, G., Watkeys, M.K., Le Gall., B., 2005. The Karoo large igneous province: Brevity, origin, and relation with mass extinction questioned by new $^{40}Ar/^{39}Ar$ age data, Geology 33, 745–748]. Although this apparently atypical province is dated in more detail compared to many other large igneous provinces, volumetrically important areas still lack sufficient high-quality data. The timing of the Karoo province is crucial as this event is correlated with the breakup activity of the Gondwana supercontinent. The Lesotho basalts represent a major lava sequence of the province, but have not yet been precisely dated by systematic analysis of mineral separates. We analyzed plagioclase separates from five lava flows encompassing the complete 1.4-km-thick Lesotho sequence from top to bottom using the $^{40}Ar/^{39}Ar$ method. We obtained five plateau and mini-plateau ages statistically indistinguishable and ranging from 182.3±1.6 to 181.0±2.0 Ma (2σ). We derived an apparent maximum duration for this event of ~0.8 Ma by neglecting correlated errors embedded in the age uncertainties.

A critical review of previous ages obtained on the Lesotho sequence [Duncan R.A., Hooper, P.R., Rehacek, J., Marsh, J.S., Duncan, A.R., 1997. The timing and duration of the Karoo igneous event, southern Gondwana. Journal of Geophysical Research 102, 18127–18138] shows that groundmass analyses are unreliable for high-resolution geochronology, due to alteration and ^{39}Ar recoil effects. Discrepancy between our ages and a previous plagioclase age at ~184 Ma obtained by the later workers is tentatively attributed to the heterogeneity of the monitor used and/or cryptic excess $^{40}Ar^*$. The current age database suggests that at least three temporally and spatially distinct brief major events (the Lesotho and southern Botswana lava piles and the Okavango dyke swarm) are so far recognized in the Karoo province. Identification of brief and volumetrically important Karoo magmatic events allows detecting the migration of the Karoo magmatism and potentially the stress regime that affected the southern African lithosphere at this time. A filtered compilation of 60 ages obtained with homogeneous intercalibrated standards suggests a shorter duration for the main pulses of the magmatism between 3 and 4.5 Ma, compared to a whole province duration of ~10 Ma, between ~182 and ~172 Ma.

Keywords: $^{40}Ar/^{39}Ar$ geochronology; Large igneous province; Karoo; flood basalts; Lesotho sequence

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doi:10.1016/j.lithos.2007.03.002

1. Introduction

The Karoo large igneous province is one of the largest flood basalt provinces on earth (Courtillot and Renne, 2003). The main preserved volume of the province consists of basaltic sills, dykes and lava flows that extend over more than 3×10^6 km^2 (Fig. 1; Cox, 1988). Subordinate silicic intrusions and lava flows are located in the easternmost part of the province (Eales et al., 1984). The Karoo province and its Antarctica counterpart (the Ferrar-province) are thought to be related to the early disruption of Gondwana leading to the opening of the Indian Ocean.

In order to better understand the emplacement of such a large amount of magma and its relationship with the continental breakup process, it is crucial to be able to precisely characterize the temporal activity of the whole province. In the past 10 years, substantial geochronological works (mainly using $^{40}Ar/^{39}Ar$ technique) have been carried out on various parts of the province (Fig. 1; Encarnacion, 1996; Duncan et al., 1997; Jones et al., 2001; Le Gall et al., 2002; Jourdan et al., 2004, 2005, 2007; Riley et al., 2004, 2006). Altogether, these studies currently suggest that (i) the main volume of the Karoo basalts was emplaced over a substantially longer period (from 184 to 178 Ma) compared to the proposed duration of magmatism in other flood basalt provinces, (ii) the magmatism has roughly migrated from south to north, (iii) brief (< 1–2 Ma) spatially and temporally distinct magmatic events such as the giant Okavango dyke swarm and the ~800-m-thick southern Botswana lava pile can be identified, (iv) the basaltic magmatism is followed by a late stage silicic magmatism (from 178 to 174 Ma) which is likely related to the progressive thinning of the crust near the future rifted margin and (v) the magmatic activity ended with the intrusion of the MORB-like Rooi Rand dykes at 174–172 Ma, announcing the onset of the oceanisation process (e.g. Duncan et al., 1990).

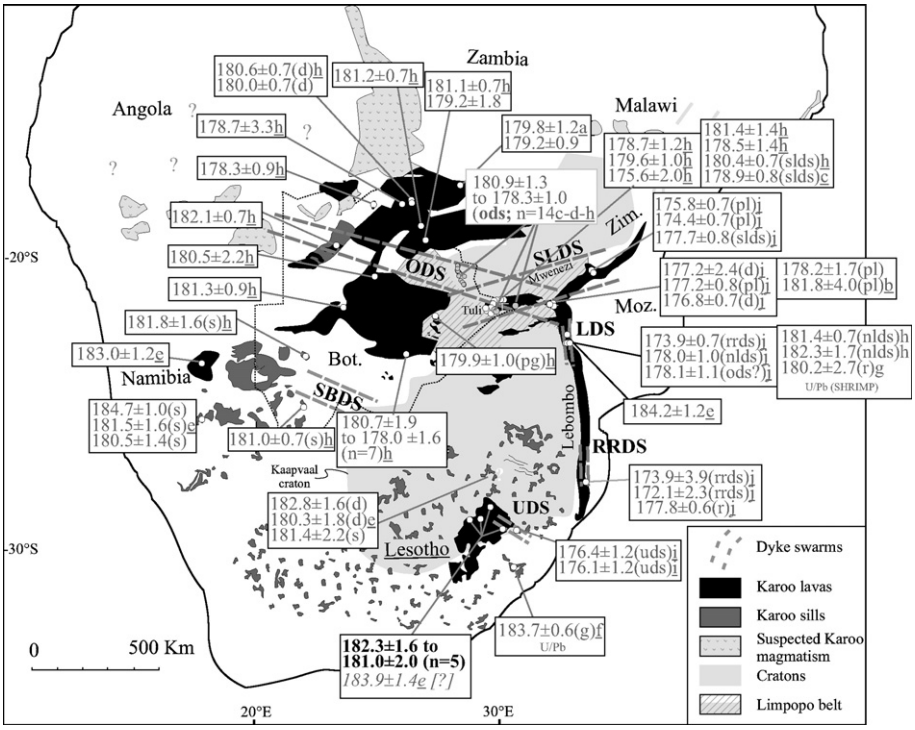

Fig. 1. Sketch map of the remnants of African Karoo flood basalts, sills and related dyke swarms (modified after Jourdan et al., 2005). ODS: Okavango dyke swarm, SLDS: Save Limpopo dyke swarm, LDS: Lebombo dyke swarm, RRDS: Rooi Rand dyke swarm, SBDS: south Botswana dyke swarm, UDS: Underberg dyke swarm. Previous (on mineral separates only) $^{40}Ar/^{39}Ar$ plateau and mini-plateau ages and two U/Pb ages are indicated ($\pm2\sigma$) (gray number). New $^{40}Ar/^{39}Ar$ plateau ages (reported herein) of the Lesotho sequence are indicated in bold. Ages alone represent lava flows, otherwise quotations in brackets beside the ages are ODS, SLDS and LDS (corresponding dyke swarm), d (dyke with not well constrained direction), s (sill), pl (pluton), r (rhyolite), g (granophyre), pg (plug). When too numerous data are reported from the same locality, only bracketing ages are mentioned for clarity; with n = number of plateau ages. Previous ages are reported in gray with underlined letter as a [Jones et al., 2001], b [Landoll et al., 1989], c [Le Gall et al., 2002], d [Jourdan et al., 2004], e [Duncan et al., 1997], f [Encarnacion et al., 1996], g [Riley et al., 2004], h [Jourdan et al., 2005], i [Riley et al., 2006] and j [Jourdan et al., 2007]. Zim. = Zimbabwe; Moz = Mozambique; Bot = Botswana.