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Noble gas composition of Indian carbonatites (Amba Dongar, Siriwasan): Implications on mantle source compositions and late-stage hydrothermal processes

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ABSTRACT

Within a stepwise crushing study we determined the noble gas composition of several calcite separates, one aegirine and one pyrochlore-aegirine separate of the carbonatite ring dyke complex of Amba Dongar and carbonatite sill complex of Siriwasan, India. Both carbonatites are related to the waning stages of volcanic activity of the Deccan Igneous Province ca. 65 Ma ago. Major observations are a clear radiogenic $^{4}He^{*}$ and nucleogenic $^{21}Ne^{*}$ imprint related to in situ production from U and Th in mineral impurities, most likely minute apatite grains, or late incorporation of crustal fluids. However, in first crushing steps of most calcites from Amba Dongar a well-resolvable mantle neon signal is observed, with lowest air-corrected mantle $^{21}Ne/^{22}Ne$-compositions equivalent to the Réunion hotspot mantle source. In case of the aegirine separate from Siriwasan we found a neon composition similar to the Loihi hotspot mantle source. This transition from a mantle plume signal in first crushing step to a more nucleogenic signature with progressive crushing indicates the presence of an external (crustal) or in situ nucleogenic component unrelated and superposed to the initial mantle neon component whose composition is best approximated by results of first crushing step(s). This contradicts previous models of a lithospheric mantle source of the carbonatitic magmas from Amba Dongar containing recycled crustal components which base on nucleogenic neon compositions. Instead, the mantle source of both investigated carbonatite complexes is related to a primitive mantle plume source that we tentatively ascribe to the postulated Deccan mantle plume. If, as is commonly suggested, the present location of the Deccan mantle plume source is below Réunion Island, the currently observed more nucleogenic neon isotopic composition of the Réunion hotspot might be obliterated by significant upper mantle contributions. In addition, compared with other carbonatite complexes worldwide a rather significant contribution of atmospheric noble gases is observed. This is documented in cut-off $^{20}Ne/^{22}Ne$-ratios of ca. 10.2 (Amba Dongar) and 10.45 (Siriwasan) and cut-off $^{40}Ar/^{36}Ar$-ratios of about 1500. This atmospheric component had been added at shallow levels during the emplacement process or later during hydrothermal alteration. However, understanding the late-stage interaction between atmospheric gases and magmatic mantle fluids still requires further investigation.

1. Introduction

Carbonatites are magmatic rocks that occur in small volumes throughout the history of Earth, with oldest carbonatite complexes dating back into the Palaeoproterozoic and Neoarchean (e.g. Hogenakkal, India, Pandit et al., 2016). They are commonly related to active lithospheric thinning processes and their emplacement is frequently associated with large igneous provinces and rift formation. A modern example is the only active carbonatite volcano Oldoinyo Lengai in Tanzania, belonging to the East African Rift system. The petrogenesis of carbonatites is still not fully resolved, but mostly their origin is attributed to mantle sources (e.g. Bell and Simonetti, 2010; Jones et al., 2013). Carbonatites could form as a result of immiscibility or fractional crystallization processes between silicate and carbonatitic magmas (e.g. Gittins, 1989;

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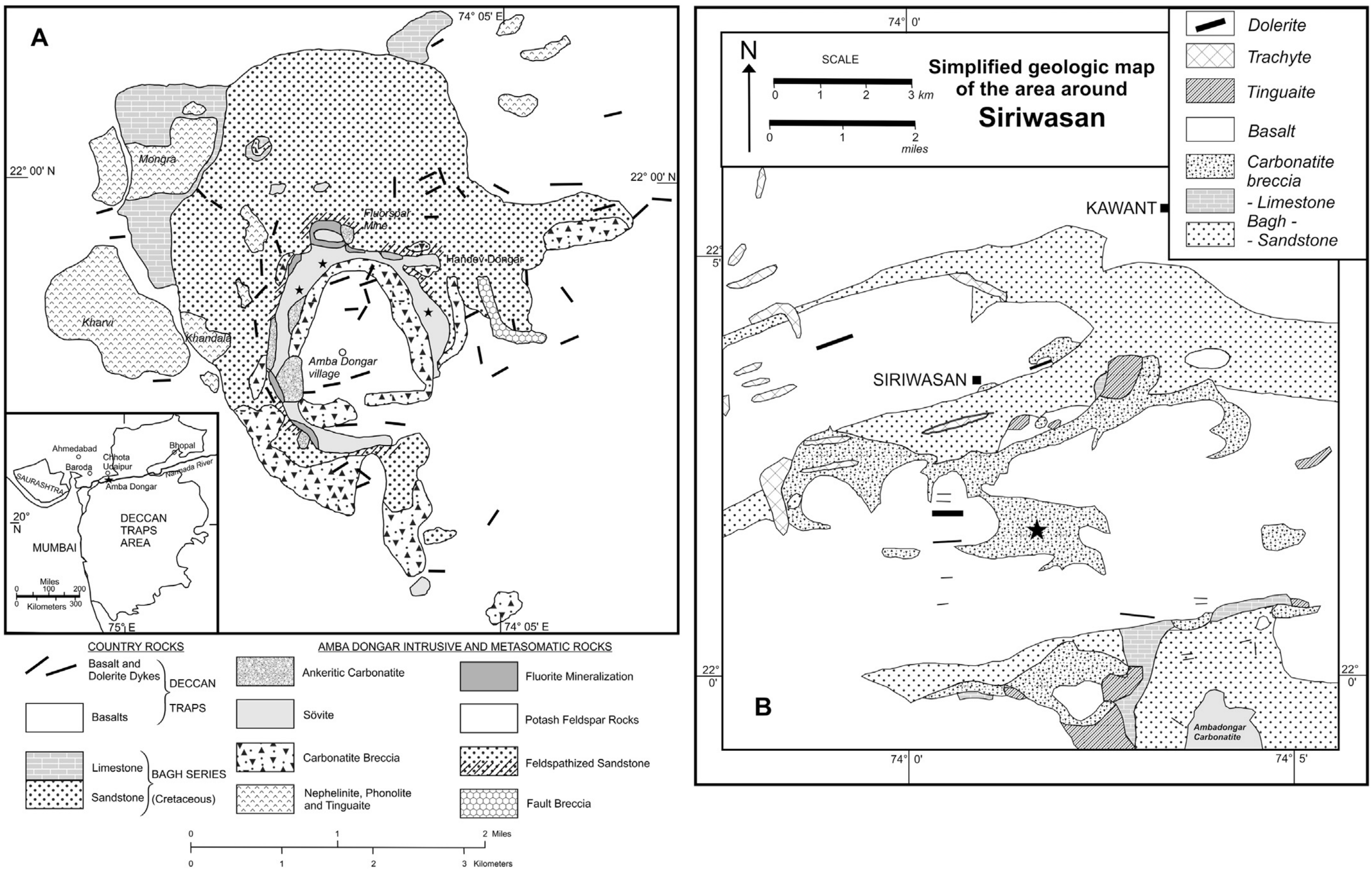

Fig. 1. Map of a) Amba Dongar and b) Siriwasan area and general overview of the Deccan Province, India (insert in a)). Modified from Viladkar and Wimmenauer (1992) and Sukheswala and Borges (1975). Note location of Amba Dongar to lower right on Siriwasan map b). Sample locations are indicated by black stars.

Lee and Wyllie, 1998). Alternatively they may represent primary mantle melts produced by melting of a carbonated peridotite from sources with local enrichments of mantle carbon. Finally, they may be the result of magmatic assimilation and fractionation processes during passage of a carbon-rich silicate melt through crustal rocks (e.g. Ray et al., 2000a).

Intrusion of the Amba Dongar carbonatite ring dyke complex and the Siriwasan carbonatite sills is related to the waning stages of the Deccan large igneous province in India ca. 65 Ma ago (Ray et al., 2000b). Situated at the northern rim of the Deccan basalts (Fig. 1a) only a thin layer of basalts of several tens of meter cover the actual center of the Amba Dongar carbonatite. Geochemical data of Amba Dongar show no evidence of contributions from crustal sources. For example, early-stage calcite carbonatites exhibit typical mantle δ^{13}C and δ^{18}O values (Ray and Ramesh, 2006; Viladkar and Ramesh, 2014). In addition, the Sr–Nd isotopic composition of Amba Dongar carbonatites more resembles the least contaminated Deccan basalts (Simonetti et al., 1995; Mahoney et al., 2000) and is close to the composition of the mantle source of the Réunion hotspot which is considered as the modern position of the former Deccan mantle plume source. Because of its high concentration of Sr and Nd the carbonatitic magma is less prone to potential contamination. Hence, it is possible that the carbonatites of Amba Dongar and Siriwasan may represent true deep mantle melts. In opposite to this contention noble gas compositions reported by Basu and Murty (2006) indicate a clear crustal component with a typical nucleogenic ^{21}Ne contribution (by the nuclear reaction $^{18}O(\alpha,n)^{21}Ne$) as a consequence of higher concentrations of U and Th in the crust. Alternatively, and advocated by Basu and Murty (2006), the same isotopic neon composition could be achieved by reactivation of subducted material within the subcontinental mantle during the waning stages of Deccan activity. Additional nitrogen isotope data (Basu and Murty, 2015) are similarly interpreted as supporting a subduction-related component in the mantle source of Amba Dongar carbonatites. Finally, based on Sr isotopic data, Ray et al. (2000a) proposed a model of a simultaneous assimilation and fractional crystallization process for the genesis of the alkaline rocks of Amba Dongar and assessed a contribution of 5% crustal material in these rocks.

Actually, carbonatitic magmas show a transition from calciocarbonatite to Mg-dominated carbonatite and finally ferrocarbonatites (in Amba Dongar the dolomitic carbonatites are rare). The ferrocarbonatite is associated with hydrothermal activity with potential incorporation of locally available crustal fluids by interaction with meteoric water. Furthermore, carbonatites contain a variety of U-bearing minerals, e.g. apatite and pyrochlore. During careful handpicking of calcite separates it is possible to minimize the contribution of such impurities. However, it is difficult to avoid inclusions of clear mineral phases like apatite in calcite, in particular if grain sizes are small (Fig. 2a, b). We show in this study that the nucleogenic neon signature of Amba Dongar carbonatites can be explained as an artefact of contamination with e.g. apatite or late crustal fluids and that the real neon signature is representative of a mantle plume source, tentatively ascribed to the Deccan mantle plume.

2. Geology and samples

2.1. Geology

The Amba Dongar carbonatite ring dyke complex (Fig. 1a) consists of a petrogenetic sequence of major volume of calciocarbon-