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A volcanic district between the Hoggar uplift and the Tenere Rifts: Volcanology, geochemistry and age of the In-Ezzane lavas (Algerian Sahara)

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ABSTRACT

The In-Ezzane volcanic district (EZD), located at the triple junction of Algeria, Niger and Libya belongs to the Eastern Hoggar, covers 350 km^2 and includes 9 volcanic edifices that are probably aligned along NW–SE faults, parallel to the Tafassasset valley. The low volume (0.7 and 1 km^3) of emitted lavas, the similar morphology of the monogenic cones and the lack of differentiated rocks indicate that the volcanic activity of the EZD was restricted in time and volume. The new K–Ar age (i.e. 2.86 ± 0.07 Ma) indicates that the EZD is contemporaneous with the last alkali volcanism paroxysm in Hoggar and with the nearby Libyan volcanics. The EZD alkali basalts (mainly basanite) show a remarkable homogeneous compositions both in major elements ($44.8 \leqslant SiO_2 \leqslant 45.8$ wt.%; $5.2 \leqslant (Na_2O + K_2O) \leqslant 6.2$ wt.%), trace elements ($4.3 \leqslant Th \leqslant 5.5$ ppm; $34.7 \leqslant La \leqslant 44.7$ ppm; $16.1 < La/Yb_{(N)} < 21.6$) and radiogenic isotopes ($0.70285 < {}^{87}Sr/{}^{86}Sr < 0.70303$; $0.51298 < {}^{143}Nd/{}^{144}Nd < 0.51301$; ($19.212 < {}^{206}Pb/{}^{204}Pb < 19.340$, $15.589 < {}^{207}Pb/{}^{204}Pb < 15.602$ and $38.834 < {}^{208}Pb/{}^{204}Pb < 38.903$). Relative to the Hoggar alkaly basalts the EZD basalts appear systematically impoverished in incompatible elements and show a depleted signature both in Sr and Nd isotopes (almost MORB-like). The Pb isotopes are relatively enriched and intermediate between tholeiites and alkali basalts of the Hoggar. This unusual geochemical signature, is uneasy to reconcile with the known characteristics of the Hoggar swell, and would rather fingerprint a circum cratonic mantle lying beneath the west border of the Murzuq craton (Libya).

1. Introduction

The In-Ezzane volcanic district (EZD), located at the triple junction of Algeria, Niger and Libya (Fig. 1) belongs to the Eastern Hoggar. It has never been studied as far as we know, in spite of its particularly interesting position in the geodynamical setting of North-Central Africa. Indeed the EZD is situated both on the southern margin of the Hoggar swell (around 400 km far from the top) and on the eastern shoulder of the Tafassasset basin which corresponds to the NW extension of the Tenere Rift system (Fig 1). Therefore, it may represent, with the Todgha district (Air, NE Niger; Cantagrel and Karche, 1983), one of the two indicators of a recent magmatic activity associated with the Tenere evolution. On the other hand, recent works on the Hoggar basement (Bertrand and Caby, 1978; Black et al., 1994; Fezaa et al., 2010; Liégeois et al., 2012), show that the EZD is situated both on the fringe of the Murzuk craton and around 300 km East to the inferred western boundary of the EAC craton (Fig. 1).

This study combines field observations, K–Ar age, and geochemical data (major and trace elements) as well as isotopic compositions (Sr, Nd and Pb) on the lavas in order to replace the EZD within the frame of the recent magmatic activity of the Hoggar swell and, at a larger scale, within those of Northern Africa.

2. Field observations

The main lava outcrops (between 10°40′ and 11°E meridians, 23°15′ and 23°N parallels) cover 350 km^2 and draw roughly a NNW-SSE ellipsis near 30 km long and 10 km large (Fig. 2). The volcanics lay horizontal sandstones and shales of Cambro-Ordovician age discordant on the easternmost Hoggar terrane, the Edembo terrane (Fig. 1). This terrane of Archean to Paleaoproterozoic age reworked during the Panafrican has tectono-metamorphic

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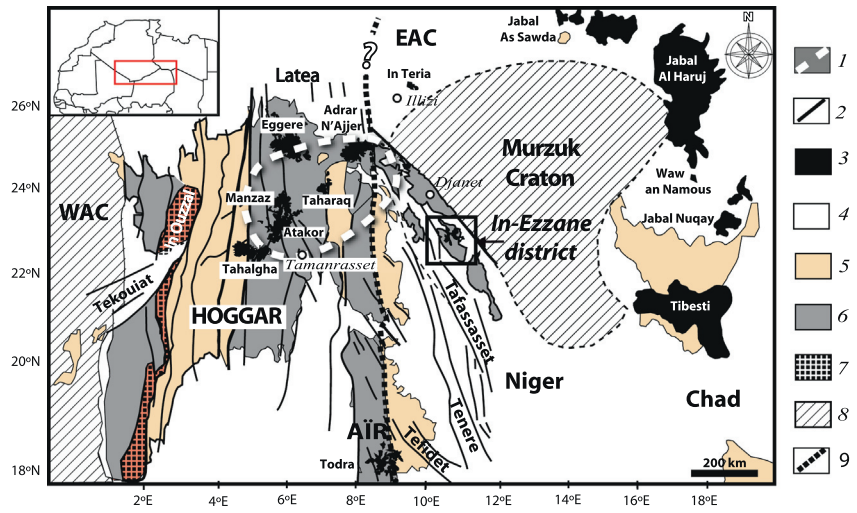

Fig. 1. Simplified geological and structural map of Hoggar (Algerian Sahara) and of its margins modified from Black et al. (1994), Fezaa et al. (2010) and Liégeois et al. (2012). (1) Anomalous mantle extension (Dautria and Lesquer, 1989); (2) major faults; (3) Eocene to Quaternary volcanic districts; (4) sedimentary cover; (5) oceanic Panafrican terranes (juvenile and reworked); (6) Archean and Palaeoproterozoic terranes strongly reworked at Panafrican; (7) Archean and Palaeoproterozoic terranes slightly reworked at Panafrican; (8) West African craton (WAC); (9) inferred boundary for the East African craton (EAC); E: Edembo terrane.

characteristics resembling those of the terranes constituting the Latea Metacraton in the Central Hoggar (Liégeois et al., 2003; Fig. 1), which would constitute the Neoproterozoic cover of the Eastern African craton (Fezaa et al., 2010). It is noteworthy that there is another volcanic district located on the north-eastern margin of Hoggar and in the same structural setting as the EZD, the In-Teria district, near 500 km North (Fig. 1). The whole lavas from this district are highly SiO_2 undersaturated and of melilitite composition (Megartsi, 1972; Bossière and Megartsi, 1982; Dautria et al., 1992).

All EZD lavas have been emitted from only 9 volcanic edifices (noted EZ 1 to 9 on Fig. 2) that are probably aligned along NW-SE faults, parallel to the Tafassasset valley (Fig. 1). The large spread of the lava flows seems to be due mainly to the basement horizontality. Only the lava flows at the eastern and western margin of the district show elongation of near 10 km compatible with a run-off within paleovalleys.

All edifices, except EZ2, are monogenetic cones, most often with breached craters and diameters ranging between 500 and 1500 m and elevations between 50 and 100 m. The craters are always well marked and show evidence of protracted lava fountain activity. The cones EZ1 and EZ3 display several nested craters, suggesting a slight migration of the activity during eruption. The ejecta are typically strombolian and are often crosscut by dykes with thickness varying between 0.5 and 3 m. Each lava flow shows relatively large extension (between 30 and 150 km^2) but remains always thin (between 2 and 4 m) and roughly prismatic. Therefore each eruption has mobilized a small amount of magma (between 0.1 and 0.4 km^3). Consequently the total volume of emitted magma can be roughly estimated between 0.7 and 1 km^3. Several of these lava flows, as well as dykes, show embedded mantle and crustal xenoliths of small size (Ø < 7 cm).

In contrast with the Hoggar and Air volcanic districts, evidence for phreatomagmatic activity is rather scarce. However, base surge deposits of weak thickness (<2 m), has been observed locally at the bottom of the EZ3 lava flow. Further, the EZ2 edifice shows a lava lake morphology filling probably an ancient tuff ring now fully eroded.

All cones have similar morphologies characterized by (i) the formation of an external erosion cliff, 10 to 30 m high, carved in the ejecta (ii) the occurrence of a pediment, at the cliff base, c.a. 100 m wide, surrounding the edifice and often covered by eolian

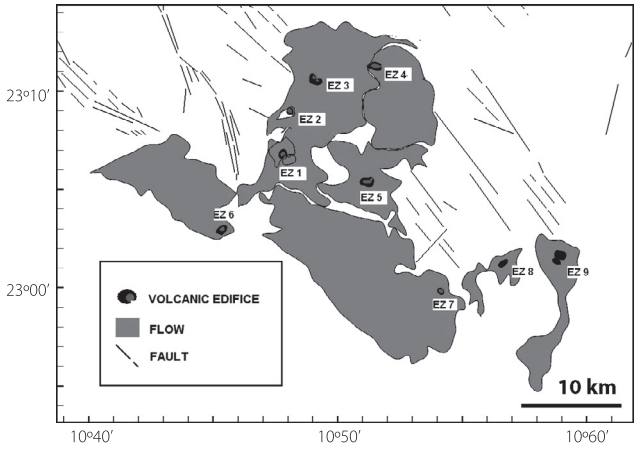

Fig. 2. Schematic geological map of the In-Ezzane district.

Fig. 3. Photo of one of the most representative In-Ezzane strombolian cone (EZ5).

sand (Fig. 3). Such morphology is commonly observed in Hoggar where it characterizes 1–3 Ma old volcanoes (e.g. in the Tahalgha volcanic district, Dautria et al., 2005). Further, the lava flow does not form marked inverted relief, suggesting a rather young age in agreement with the cone morphology. Thus, morphologically