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Research paper

New K–Ar age determinations of Kilimanjaro volcano in the North Tanzanian diverging rift, East Africa

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Abstract

The Kilimanjaro is the African highest mountain and culminates at 5895 m high. This huge volcanic edifice is composed of three main centres along a N110°E-striking axis (Shira, Kibo and Mawenzi from W to E), and emplaced in a key area where a major N80°E-oriented volcanic lineament intersects a first-order NW–SE basement fault-like discontinuity. Seventeen K–Ar ages (on microcrystalline groundmass) acquired on lavas and intrusive facies from the three eruptive centres confirm that the Plio-Quaternary volcanicity of Kilimanjaro is clearly polyphased. The oldest phases of volcanic activity begun at ~2.5 Ma in the Shira vent and our data suggest that the latest important phases occurred around 1.9 Ma, just before the collapse of the Northern part of the edifice. Magmatic activity then shifted eastwards in the Mawenzi and Kibo twin centres where initial volcanism is dated at ~1 Ma. Two K–Ar ages obtained for the most recent Mawenzi rocks from the *Neumann Tower-Mawenzi group* (492 ka) and *Mawenzi eruptive centre* (448 ka), near the present summit, are linked to the final stage of edification for this centre. Whereas the eruptive activity ceased in the Mawenzi, it still continued on Kibo since sub-actual time. The oldest dated rocks from Kibo (482 ka) is obtained on a dyke from the *Lava Tower group* cropping out at 4600 m high. The main phase of magmatism on Kibo is recorded by two lava formations with a great spatial extension – the *Rhomb Porphyry group* and the *Lent group* – that have been emplaced in a short time interval at ~460–360 ka (including two erosive stages) and 359–337 ka, respectively. Based on the dating of *Caldera rim group* lavas, it is shown that the edification of the present cone was accomplished in a period ranging from 274 to 170 ka. The new ages obtained for the main episodes of volcanic activity on Kibo appear to roughly coincide with the oldest known Quaternary glaciations. The interaction between eruptive phenomena and the ice cover is assumed to have played an important role in triggering collapse processes and associated lahars deposits. The last volcanicity, around 200–150 ka, is marked by the formation of the present summit crater in Kibo and the development of linear parasitic volcanic belts, constituted by numerous Strombolian-type isolated cones on the NW and SE slopes of Kilimanjaro. These belts are likely to occur above deep-seated fractures that have guided the magma ascent, and the changes in their directions with time might be related to the rotation of recent local stress field.

Keywords: Kilimanjaro; East African Rift; K–Ar dating; volcanic history; Tanzania

1. Introduction

The Eastern Branch of the East African Rift System (EARS) diverges southwards at 3°S from a single and narrow (<50 km) NS-trending volcanic rift valley in southern Kenya to form a 300 km-wide three-arm rift system – the North Tanzanian Divergence (NTD hereafter) of Dawson (1992) – as approaching the Tanzanian craton (Ebinger et al., 1997). The abrupt change in the style of rifting and magmatism coincides with a ~50 km-wide transverse volcanic chain extending ~at N80°E, *i.e.* perpendicular to the main rift axis, over more than 200 km from the Ngorongoro crater to the Kilimanjaro volcano eastwards. South of the so-called Ngorongoro-Kilimanjaro Volcanic Belt (NKVB in the text), the only evidence of rifting at the surface are a series of basement tilted blocks and associated half-graben basins. There,

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the rapid and nearly total disappearance of magmatism indicates that the thermal influence of the mantle plume responsible for the extensive volcanic complexes in the Kenya rift further N is no longer effective over the North Tanzanian rifted domain. The NKVB comprises numerous (~20) individual volcanic edifices ranging in age from 8 Ma to Present (Dawson, 1992). Existing radiometric dataset have been preferentially devoted to volcanic rocks in the central and western parts of the NKVB that connect the S Kenya axial trough (N) and the Eyasi-Manyara rift arms (S) (Foster et al., 1997). Very few ages determinations have been yet obtained about the easternmost part of the NKVB that lies in an off-axis position with regards to the main rifted domain in Kenya (Fig. 1). Therefore, no accurate age migration of magmatism has been so far established throughout the NKVB, as a whole. Paradoxally, recent radiometric dating has not been applied to Mount Kilimanjaro though forming the most prominent volcanic construction of the East African Rift. Compiling the seven published ages for the three cones (Shira, Kibo and Mawenzi) forming Kilimanjaro (Evernden and Curtis, 1965; Baker et al., 1971; Evans et al., 1971; Bagdasaryan et al., 1973; Wilkinson et al., 1986) shows a polyphased volcanic history over the past 2 Ma, between ~2.3 and ~0.17 Ma (Dawson,1992), but given the uncertainties about these data (for example, 2.3±0.4 Ma, Bagdasaryan et al., 1973), it is difficult to establish a genetic link between the Shira, Mawenzi and Kibo magmatic activities.

On the basis of recent field work campaigns (October 2003 and January–March 2005) and newly-acquired unspiked K–Ar ages determinations of effusive and intrusive volcanics from Kilimanjaro, the main purposes of the present study are first to precise, in terms of duration, temporal/spatial distribution and emplacement mechanisms, each successive magmatic phase that finally led to the built-up of the Kilimanjaro polyphased volcano. Some assumptions about basement structural control and stress field conditions during the youngest parasitic volcanic episode are also presented. Most of the representative volcanic formations of Kilimanjaro have been sampled on the southern flank of the edifice and 17 rock samples have been selected and dated by Unspiked K/Ar method. Petrological and geochemical characteristics of dated lavas and dykes are not detailed in this work but will be extensively discussed in another paper. However, the range of petrological compositions of Kilimanjaro lavas (unpublished data) is illustrated in the Total-Alkali–Silica classification diagram (Fig. 3) of Le Bas et al. (1986) and allows us to distinguish clearly the three main centres and the final parasitic stage.

At a greater scale, compiling existing radiometric ages about volcanic edifices in the NTD allows us (1) to deduce the easterly shift of magmatism along the NKVB during Neogene time, and (2) precise the tectono-magmatic significance of Kilimanjaro with respect to the North Tanzanian rift framework.

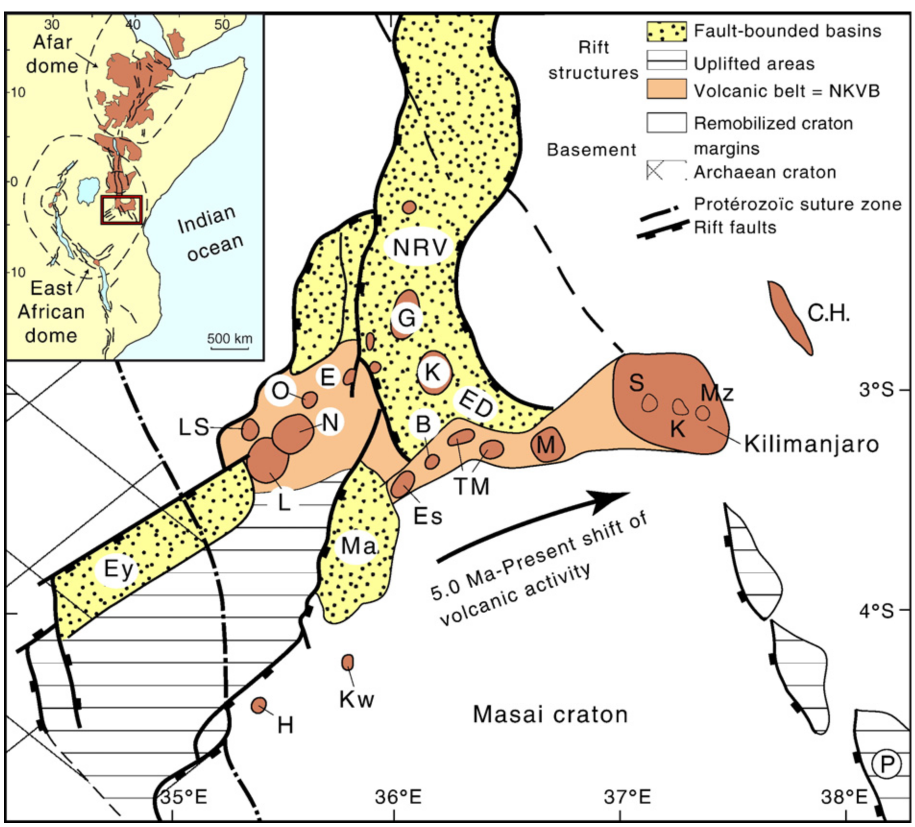

Fig. 1. Sketch structural map of the transition zone between the South Kenya rift and the North Tanzanian Divergence. Note the location of Mount Kilimanjaro at the eastern end of the transverse volcanic belt (NKVB: Ngorongoro-Kilimanjaro Volcanic Belt). H: Hanang, Kw: Kwaraha, L: Loolmalasin, LS: Lemagrut-Sadiman, N: Ngorongoro, O: Olmoti; E: Empakai, G: Gelai, K: Ketumbeine, Es: Essimingor, B: Burko, TM: Tarosero-Monduli, M: Mt Meru, S: Shira, K: Kibo, Mz: Mawenzi, C.H.: Chyulu Hills; Ey: Eyasi basin, Ma: Manyara basin, NRV: Natron Rift Valley, ED: Engaruka depression; P: Pare mountains. Inset: location of the North Tanzanian volcanic province at the Southern extremity of the Eastern branch of the East African rift system.