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Permanent groundwater storage in basaltic dyke fractures and termite mound viability

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ABSTRACT

Many basaltic dykes of the Ethiopian flood basalt province are observed in the northwestern Ethiopian lowlands. In this area, the termites preferentially build their epigeous mounds on the top of dolerite dykes. The relationship between termite mounds and dykes is investigated from the analysis of their distribution along one of these dykes, of thickness 2–5 m, that we could follow over 2000 m. Termite mounds are periodically spaced (mean distance 63 m, $R^2 = 0.995$), and located exclusively where the topographic relief of the dyke is not more than 2 m above the surrounding area. From these observations and from the geological context, a hydrological circuit model is proposed in which (1) dykes are preferential conduits for groundwater drainage during the rainy season due to pervasive jointing, (2) during the dry season, the portion of the dyke forming a local topographic relief area dries up more quickly than the surroundings, the elevation difference between the dyke summit and the surroundings being a factor restricting termite mound development. For dyke topographic relief >2 m, drying is an obstacle for maintaining the appropriate humidity for the termite colony life. Periodic termite mound spacing is unlikely to be related to dyke or other geological properties. It is more likely related to termite population behaviour, perhaps to clay shortage, which restricts termite population growth by limiting the quantity of building material available for mound extension, and triggers exploration for a new colonization site that will be located along the dyke at a distance from the former colony that may be controlled by the extent of the zone covered by its trail pheromones. This work brings out the importance of dykes in channelling and storing groundwater in semiarid regions, and shows that dykes can store groundwater permanently in such settings even though the dry season is half the year long. It contributes also to shedding light on water supply conditions tolerated by termite populations, and factors governing termite mound distribution.

1. Introduction

After several years of work in the Ethio-Sudanese plain of northwestern Ethiopia, where the largest dyke swarms of the Ethiopian volcanic province are observed, it has become obvious that relationships exist between the distribution of these dykes and the distribution of termite mounds. The dykes are dominantly doleritic (Mège and Korme, 2004a,b) and the host rock is made of the corresponding lava flows. During field work in January 2008 we investigated the relationships between basaltic dykes and termite mounds in the Ethio-Sudanese plain in the Qwara district of Ethiopia in more detail. We report on the results of this work in this paper.

Termites play a significant role in a variety of ecosystems, in which they increase or contribute to maintain biodiversity (e.g., Glover, 1967; Braack and Kryger, 2003). They are also amazing soil ecosystem engineers and soil processors (Bignell, 2006). How they modify the soil properties has been a subject of intense research due to their influence on many pedogenetic processes (Boyer, 1973; 1975a,b), especially soil porosity, water infiltration, and runoff (Yakushev, 1968; Garnier-Sillam et al., 1991; Ouedraogo and Lepage, 1998; Léonard and Rajot, 2001), and soil pH rise (Donovan et al., 2001); on soil textural changes, including transportation of deep clay particles to the surface (e.g., Grassé and Noirot, 1959; Mando and Miedema, 1997; Johnson et al., 2005) and organic matter transformation by termite gut microbiota (Brauman, 2000; Fall et al., 2007), all these factors having profound agricultural implications (Harris et al., 1994; Miller et al., 1994; Duboisset, 2003). In contrast, the detailed relationships maintained between geology (pedology excluded) and termite colony settlement have been scarcely investigated, usually attracting attention on the accumulation of Ag, Au, Cr, Cu, Mn, Mo, Ni, Pb, and Zn in termite mounds (West, 1965, 1970; D'Orey, 1975; Watson, 1970, 1972; Wild, 1975;

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Brooks, 1983; Prasad et al., 1987; Kebede, 2004; Melchiorre et al., 2006) by displacement of small soil particles by termites from deep soil levels to the surface. These works have been partly inspired by an account given by Herodotus (Ἱστορίαι III, 102–105) relating exploitation of auriferous sands accumulated by ants in a dry location of northern India or Pakistan, supported by other accounts of "ant-gold" occurrence in the Mahābhārata (II, 52) and in ancient Mongolian (Laufer, 1908) and Tibetan (Ball, 1881, pp. 124–128; Francke, 1924; Burnay, 1931) texts and oral stories. Most scientific investigations demonstrate the role of termites in rising metals from underground (some of which will be discussed later in this article), and the Mahābhārata probably testifies to the Indian knowledge of gold-bearing sand digging by termites. However, the issue is complex (a detailed discussion can be found in Dube, 1993); some of the accounts, especially by Herodotus, may refer to exploitation by the Tibetan Minaro people of auriferous soil excavated by the long-tailed marmot, *Marmota caudata* (Peissel, 1984; Simons, 1996), instead of auriferous sand digging by termites, an interpretation that Laufer (1908) and Francke (1924) favoured in spite of their knowledge of the mammal interpretation.

Termite colonies are widespread in Ethiopia like in many other African countries. Along a few roads of southern and eastern Ethiopia an inventory of termite populations has been done and published (Cowie et al., 1990). Nevertheless, putting aside the environmental damage caused by termites in southern Ethiopia (Wood, 1991, and reports referenced therein) and the potential control methods (Abdurahman, 1990; Abebe, 2002), overall little information is available about the biology, ecology, and ethology of these termites (Grassé, 1937; Kevan, 1953; Barnett et al., 1988; Cowie and Wood, 1989; Cowie et al., 1990), and none appears to be available in the Ethio-Sudanese plain west of lake Tana, where the study area is located (Fig. 1b).

Wild (1975) studied the soil brought to the surface by two termite species on serpentines from the Great Dyke of Zimbabwe, but neither its scale (several kilometres over more than 500 km) nor emplacement (as a layered intrusion, not a true dyke, Wilson and Prendergast, 1989) can be compared to those of the Farshewa dyke. Termite mounds have been reported on another volcanic setting in the northern Kruger National Park (Meyer et al., 1999), the Lebombo basalts and dolerites from the Karoo events in South Africa (Klausen, 2009). Interestingly, mound abundance has been found to be lower on basalts and associated dolerites than on other rocks such as rhyolite, granite, gneiss, and gabbro, although basaltic soils contain the same nutrients as gabbroic soils in comparable abundance. It is probable that the lower than average abundance of termite mounds in this volcanic formation is due to its location

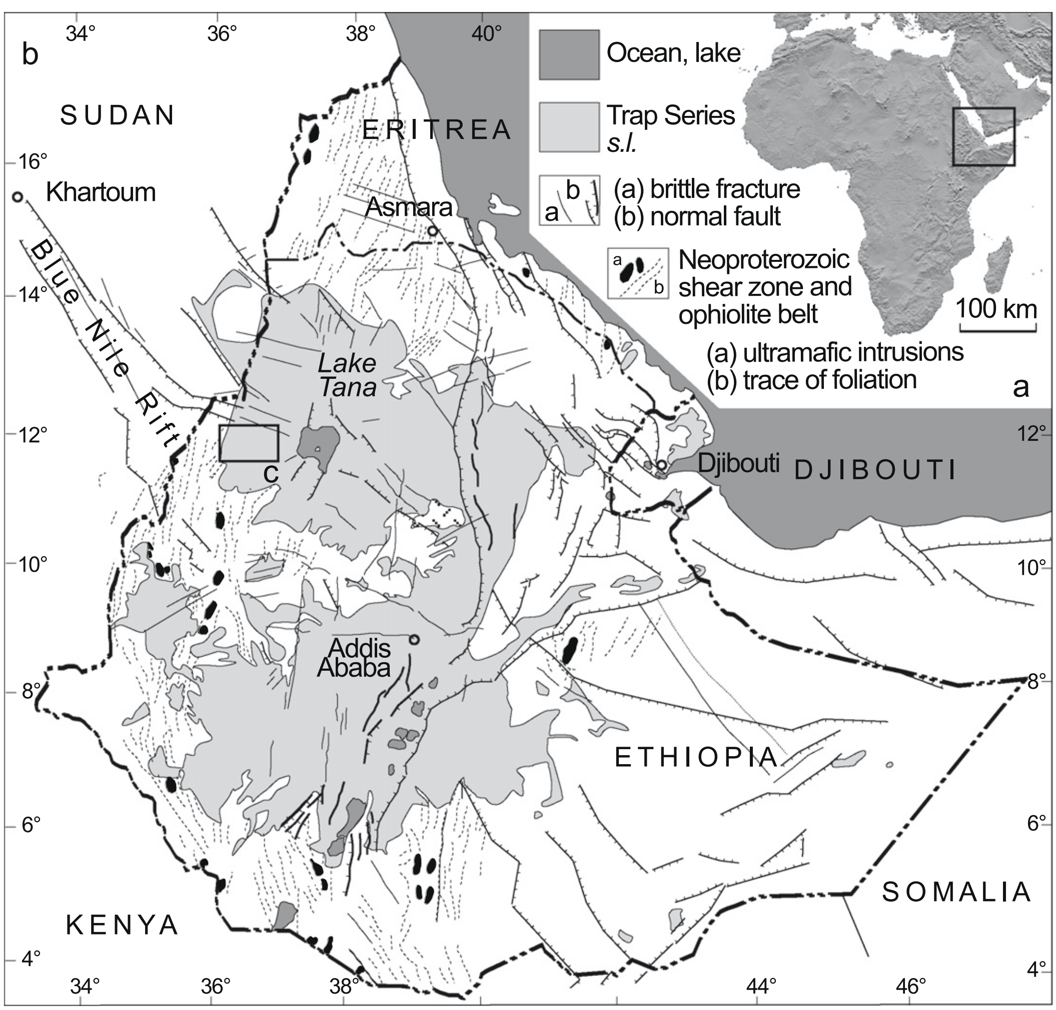

Fig. 1. Location maps: (b) is from interpretation of Landsat Geocover 1990 mosaic; (c) is an interpretative map of the study area partly based on Landsat Geocover 1990 and 2000 mosaics, ASTER imagery (15 m/pixel), Spot panchromatic imagery (2.5 m/pixel, not available in the western third of the map), results presented in Mège and Korme (2004a), field observations, and GPS measurements. The undated sandstone is probably Mesozoic (Seyid, 2002). Its eastward extent is unknown, the trap series unconformably overlies the Precambrian basement south of the study area (Mège and Korme, 2004a). In mountainous areas the fractures are observed to be vertical or near vertical.