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Eolian contribution to soils on Mount Cameroon: Isotopic and trace element records

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Abstract

We determined Sr, Nd and Pb isotopic compositions and major- and trace-element compositions of soil samples recovered from three soil profiles developed on relatively young pyroclastic deposits, less than 10,000 years old, of the Mount Cameroon volcano. The time elapsed since then is short compared with the half-lives of Rb, Sm, U and Th, suggesting that radioactive decay can be neglected. We therefore assumed that (i) these polyphase soils developed on isotopically homogenous substrates and (ii) any isotopic variation within such profiles cannot be due to selective dissolution of primary minerals with isotopic compositions different from that of bulk bedrock. Any Sr, Nd or Pb isotopic variation would therefore record an allochtonous input occurring either in a solid or dissolved state.

Sr and Nd isotope compositions change systematically with depth in the soil profile; in particular, $^{87}Sr/^{86}Sr$ ratios are far greater in the humic horizons than in the underlying horizons, except in the CA9H soil profile. Although smaller than for Sr isotope compositions, $^{143}Nd/^{144}Nd$ ratios displayed an inverse relationship with a decrease towards the uppermost organic-rich horizons. These isotope shifts correlate with changes in Sr and Nd contents, suggesting an allochtonous input characterized by significantly different isotope compositions and slightly lower Sr contents but higher Nd contents. Pb isotopic compositions and Pb concentrations in the uppermost horizons were distinct from those of underlying horizons in the soil sequences.

Since an anthropogenic contamination such as from leaded petrol cannot explain the Pb shifts, a natural source has to be invoked for Pb, as well as for Sr and Nd. Considering both the wind paths in West Africa and the isotopic shifts registered in the uppermost horizons, Saharan dust appears to be the best candidate to explain such variations. These inputs probably happened in winter when dry warm Harmattan wind blows from the northeast. A maximum of 8% of Saharan dust accretion was calculated for the Mount Cameroon soils. This corresponds to average dust deposition rates between 1.3 and 0.8 g cm^{-2} ka^{-1}, values that are much higher than those found in Hawaiian soils by Kurtz et al. [Kurtz, A.C., Derry, L.A., Chadwick, O.A., 2001. Accretion of Asian dust to Hawaiian soils: Isotopic, elemental and mineral mass balances. Geochim. Cosmochim. Acta 65, 1971–1983.], and are probably related to shorter distance between dust source and deposit.

Any elemental mass balance calculated in the upper organic-rich horizons should be then corrected from allochtonous wind-borne Saharan dust before evaluating weathering-linked chemical mobilities.
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Keywords: Eolian dust; Sr–Nd–Pb isotopes; Trace elements; Soils; Mount Cameroon

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1. Introduction

Because soils form through weathering of the underlying parental rock, their mineral and chemical evolution should follow a predictable sequence of weathering reactions. Element mobility should be related to mineral breakdown as weathering proceeds (Nesbitt and Wilson, 1992; Aiuppa et al., 2000; Hill et al., 2000). Elements hosted primarily in the glassy groundmass or in the easily weatherable minerals (e.g. olivine, plagioclase or pyroxene) can be (i) redistributed within the weathering profile through retention within secondary minerals (clays, zeolites, phosphates, Fe–Mn oxyhydroxides, etc. (Hellman and Henderson, 1977; Condie et al., 1995; Terakadu and Fujitani, 1998) or (ii) lost from the soil through dissolution and transport by a fluid phase.

However, this 'ideal' scheme can be perturbated by the contribution of allochtonous wind-borne material. Addition of eolian dust to the soil sequences has been reported in numerous locations (Grousset et al., 1992; Simonson, 1995; Prospero, 1996; Greaves et al., 1999; Kurtz et al., 2001; Monastra et al., 2004) and the addition of such material–although at low level–of contrasting origin can significantly complicate our understanding of the chemical mass balance of the soils and of its evolution through time. The impact of such atmospheric contribution on soil chemistry can range from subtle for remote spots to dominant in the extreme case of large loess accumulation (Pye and Zhou, 1989).

Mount Cameroon is an ideal target to study both chemical mobilities and dust accretion in soils for the following reasons: (i) the parental rock has a rather uniform chemical composition since Mount Cameroon is a volcanic edifice of essentially basaltic composition, (ii) the hot and wet climate (Sieffermann, 1973) promotes weathering and leads to rapid changes in chemical compositions, (iii) the wind regimes in this part of equatorial Africa bring significant amounts of Sahara-sourced aeolian materials (Kalu, 1979).

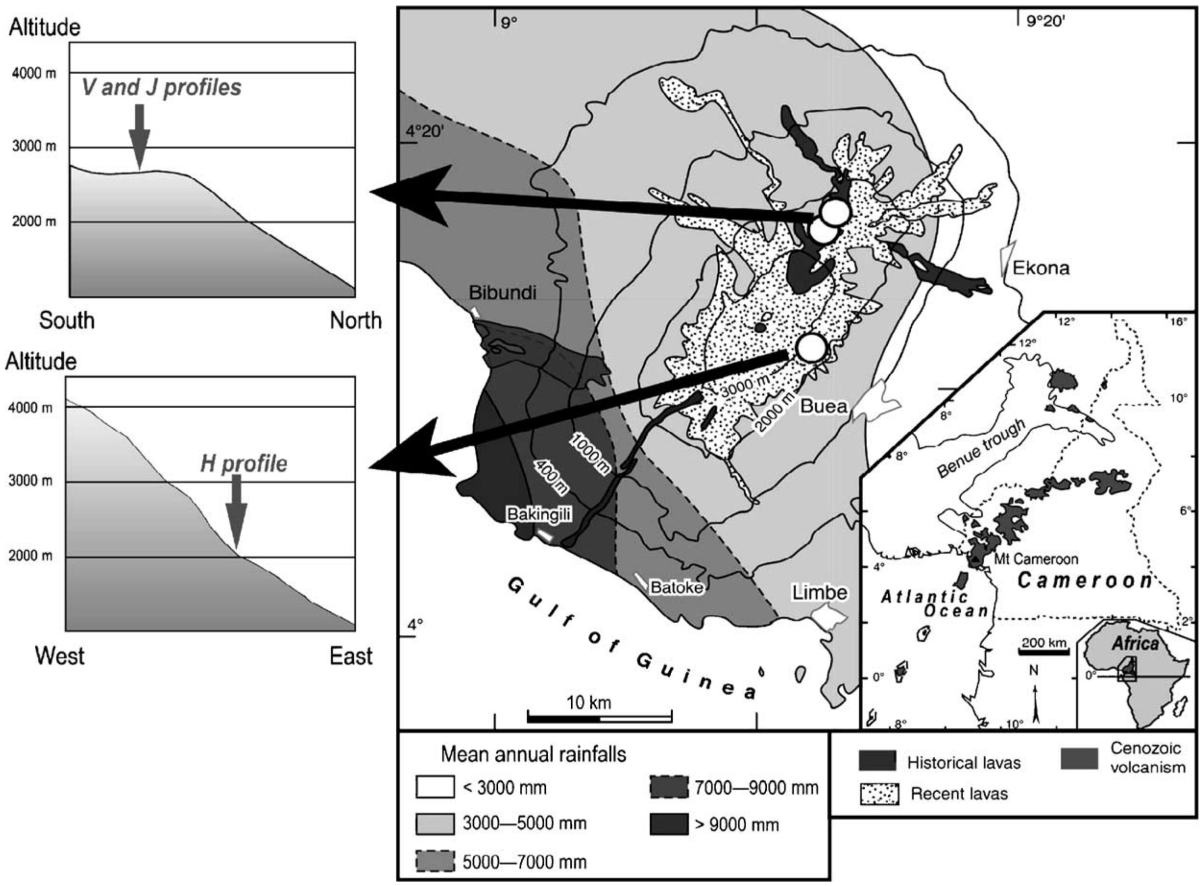

Fig. 1. General map showing the location of Mount Cameroon and of the Cameroon Line in West Africa (modified from Lee et al., 1994). Altitudes and mean annual rainfalls expressed in mm/year are also reported (Sieffermann, 1973). The locations of the three soil profiles are shown by empty circles and simplified sections showing the relief are given.