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Provenance versus weathering control on the composition of tropical river mud (southern Africa)

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ABSTRACT

This study presents an integrated mineralogical–geochemical database on fine-grained sediments transported by all major rivers of southern Africa, including the Zambezi, Okavango, Limpopo, Olifants, Orange and Kunene. Clay mineralogy, bulk geochemistry, Sr and Nd isotopic signatures of river mud, considered a proxy of suspended load, are used to investigate the influence of source-rock lithology and weathering intensity on the composition of clay and silt produced in subequatorial to subtropical latitudes.

Depletion in mobile alkali and alkaline-earth metals, minor in arid Namibia, is strong in the Okavango, Kwando and Upper Zambezi catchments, where recycling is also extensive. Element removal is most significant for Na, and to a lesser extent for Sr. Depletion in K, Ca and other elements, negligible in Namibia, is moderate elsewhere. The most widespread clay minerals are smectite, dominant in muds derived from Karoo or Etendeka flood basalts, or illite and chlorite, dominant in muds derived from metasedimentary rocks of the Damara Orogen or Zimbabwe Craton. Kaolinite represents 30–40% of clay minerals only in Okavango and Upper Zambezi sediments sourced in humid subequatorial Angola and Zambia. After subtracting the effects of recycling and of local accumulation of authigenic carbonates in soils, the regional distribution of clay minerals and chemical indices consistently reflect weathering intensity primarily controlled by climate.

Bulk geochemistry identifies most clearly volcaniclastic sediments and mafic sources in general, but cannot discriminate the other sources of detritus in detail. Instead, Sr and Nd isotopic fingerprints are insensitive to weathering, and thus mirror faithfully the tectonic structure of the southern African continent. Isotopic tools thus represent a much firmer basis than bulk geochemistry or clay mineralogy in the provenance study of mudrocks.

"If you can walk you can dance. If you can talk you can sing."
[Zimbabwe Proverb]

1. Introduction

Fine-grained sediments carried in suspension represent most of the solid load supplied by large rivers to the oceans (Hay, 1998). And yet, provenance of muds and mudrocks is a field of sedimentary geology that has not seen major advances in decades (Blatt, 1985), largely because silt and clay can hardly be studied by classic optical or single-grain geochronological methods. The fundamental principles of clay mineralogy and its dependence on climate and geology of source areas have long been established, and much work has been done on muds deposited in the deep sea (Biscaye, 1965; Chamley, 1989; Thiry, 2000). The composition of fine-grained sediments transported by large rivers worldwide has been studied extensively, but chiefly with geochemical methods (Martin and Meybeck, 1979; Canfield, 1997; Gaillardet et al., 1999; Bouchez et al., 2011; Lupker et al., 2012). Much remains to be learned about the relationships between mineralogy and chemistry of the suspended-load (Garzanti et al., 2011), specifically as regards the relative contribution of parent-rock lithology versus chemical weathering in different climatic conditions (Borges et al., 2008).

Tropical southern Africa is perfectly suited for such an investigation, being characterized by marked longitudinal and latitudinal climatic gradients, from sub-humid Mozambique to hyperarid Namibia, and from humid Angola to the arid Kalahari in Botswana (Fig. 1; McCarthy et al., 2000; Jury, 2010). In this vast area, straddling the Tropic of Capricorn between 30°S to 15°S, source rocks range from Archean cratonic basements and Proterozoic mobile belts to Mesozoic sediments and flood basalts (Fig. 1).

Information on the mineralogy and geochemistry of sediments carried by major African rivers is far from complete (Viers et al., 2009).

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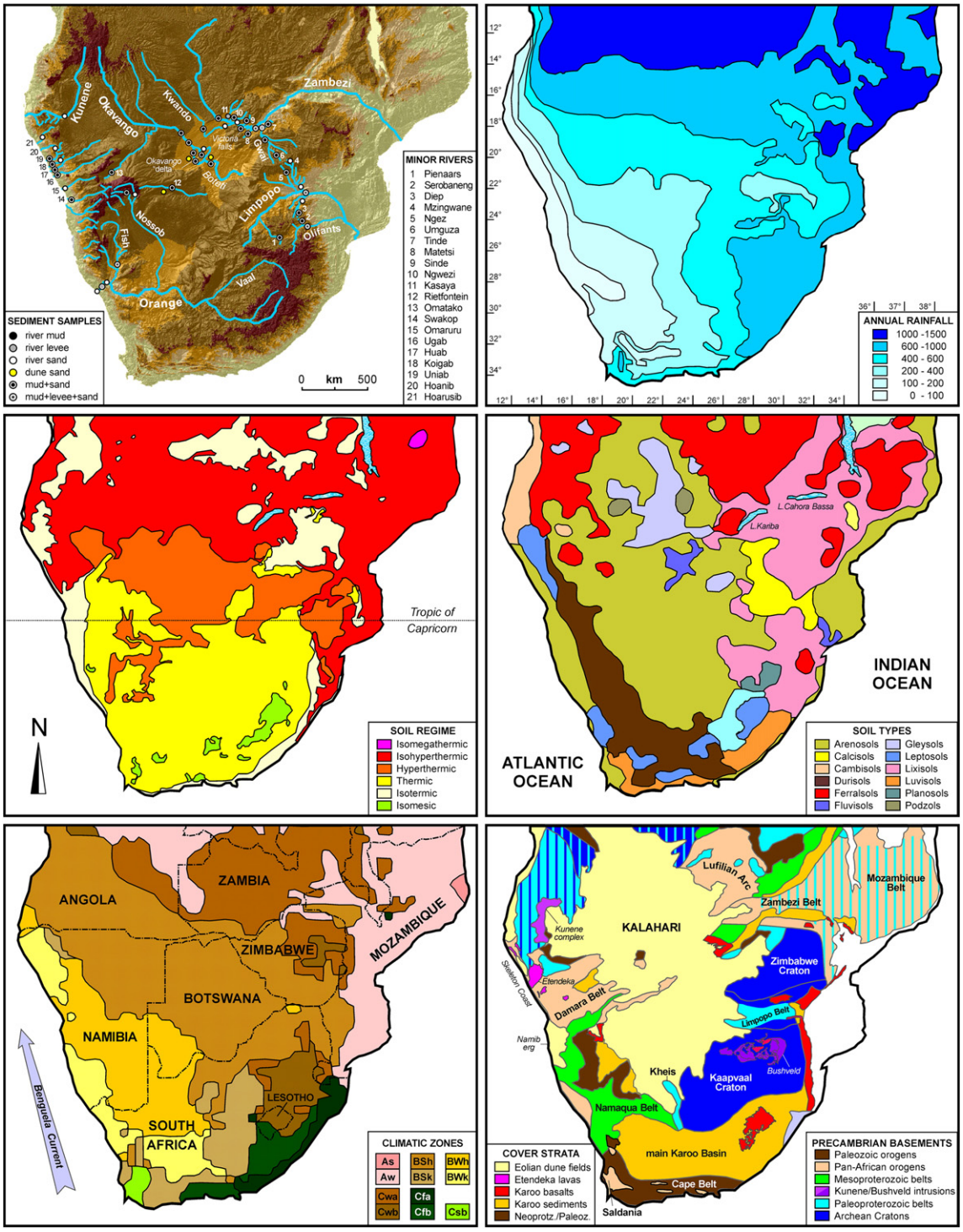

Fig. 1. Geology and geomorphology of tropical southern Africa. Topography, drainage patterns and location of studied samples are shown, as well as precipitation, soil regimes, soil types (Food and Agriculture Organization, www.britannica.com/bps/media-view/19257/0/0/0), distribution of climatic zones (Köppen–Geiger classification; Kottek et al., 2006) and main tectonic domains (Hanson, 2003; Schlüter, 2008). Climate: A = equatorial; B = arid; C = warm temperate. Precipitation: W = desert; S = steppe; f = fully humid; s = summer dry; w = winter dry. Temperature: h = hot arid; k = cold arid; a = hot summer; and b = warm summer.

We contribute to filling this gap by presenting a rich original dataset on silt-sized sediments. The different factors controlling sediment composition, and specifically how and to what extent the imprint of different parent-rock lithologies is modified by chemical weathering at the source, and subsequently by mixing along the routing system, will be analysed by diverse integrated techniques, including clay mineralogy, bulk geochemistry and isotope geochemistry. Another crucial problem that we will address is the distinction between weathered first-cycle and multicyclic sediments. This article, companion to a petrological analysis of river sands in the same region (Garzanti et al., 2014), follows studies carried out with the same rationale and methods on river muds in wet equatorial central Africa (Garzanti et al., 2013a) and dry tropical