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Water chemistry and effect of evapotranspiration on chemical sedimentation on the Mkuze River floodplain, South Africa

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ABSTRACT

The Mkuze Wetland System, forming part of the iSimangaliso World Heritage Site, is South Africa's largest freshwater wetland area and is known to act as a sink for naturally occurring solutes within the landscape. The chemistry of groundwater and porewater samples, collected from two transects on the Mkuze River floodplain, was investigated to identify processes involved in the control of solute concentrations. Results show that solutes in the groundwater become increasingly concentrated under the influence of evapotranspiration, resulting in the saturation, precipitation, and accumulation of less soluble compounds. Trends in porewater chemistry and calculated saturation indices support previously documented mineralogical and sediment geochemical investigations, with $CaCO_3$ and silica precipitation, and Fe-rich smectite neoformation identified as the major controls on solute concentration. The association of these mineral phases with zones of high salinity suggests that mineral precipitation is an active process on the floodplain which results in the progressive development of salinity, particularly in areas dominated by deep-rooted trees. Similarities between geochemical processes documented in the Okavango Delta (Botswana) and those identified in this study suggest that evapotranspiration-induced chemical sedimentation is an important process in southern African wetlands, which has the potential to influence vegetation distribution, hydrological flows, and local topography.

1. Introduction

Solutes entering a wetland are subjected to a variety of transformations that occur as a result of the interaction between hydrological, geochemical and biological processes. Such processes typically predispose wetlands to accumulate large quantities of solutes. Most research into mechanisms and sites of chemical retention in wetland systems has focused on the plant macronutrients of nitrogen and phosphorus (Johnston, 1991; Day et al., 2004; Verhoeven et al., 2006). These studies, conducted over varying climatic and hydrogeomorphic settings, show that most wetlands effectively retain and incorporate nitrogen and phosphorus into the biomass of the ecosystem. However, less commonly considered are solutes such as Si, Ca, Mg, Na, and Cl which have the potential to modify wetland systems due to the reduced capacity of plants to remove these solutes in large quantities.

Although floodplain wetlands are common features of rivers in southern Africa (Tooth and McCarthy, 2007), providing vital habitat to a wide range of unique biodiversity, an in-depth understanding of their hydrochemical and sedimentation processes is limited. An exception is the Okavango Delta in northern Botswana, which has been the focus of a variety of detailed studies examining vegetation ecology, geomorphology, hydrology, and geochemistry (McCarthy and Ellery, 1995, 1998; Ellery et al., 2000; Bauer-Gottwein et al., 2007; Ramberg and Wolski, 2008). Situated in a semi-arid climatic region, ~96% of the annual discharge into the Delta is lost to the atmosphere (McCarthy and Metcalfe, 1990). Much of this occurs via evapotranspiration, particularly on islands where deep-rooted trees facilitate groundwater losses. This leads to the concentration of solutes in the groundwater, eventually causing minerals such as calcite and amorphous silica to reach saturation and precipitate in the soil. Mass balance calculations indicate that ~360,000 t of chemical sediments accumulate per annum in the swamps of the Okavango, representing significantly more than the contribution from clastic sediment (McCarthy and Ellery, 1998). Chemical accumulation is thus a major driver of ecosystem structure and function in the Okavango. Mineral precipitation causes volume increase and expansion in the soil that plays a role in modifying landscape topography (McCarthy and Metcalfe, 1990),

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while the development of highly saline groundwater results in marked vegetation zonation (McCarthy and Metcalfe, 1990; McCarthy et al., 1993). Similar chemical accumulation processes, although on a more limited scale, have also been documented on the Nyl River floodplain, South Africa (Tooth et al., 2002).

Chemical precipitation and solute retention within soils as a result of an evaporation sequence, originally presented by Hardie and Eugster (1970), has been widely documented (Gac et al., 1977; Deocampo and Ashley, 1999; Barbiero et al., 2002). In southern Africa, wetlands are generally subjected to conditions where potential evapotranspiration exceeds rainfall. Mass balance calculations for the Mkuze Wetland System (Barnes et al., 2002), South Africa (Fig. 1), have shown that this vast freshwater system is an important sink for naturally occurring solutes, particularly Si, K, Ca, Mg, and Na (Table 1). Recent detailed analyses of floodplain sediments have revealed the subsurface accumulation of $CaCO_3$, amorphous SiO_2 and Fe-smectite (Humphries et al., 2010), suggesting similarities with biogeochemical processes documented within the Okavango Delta wetlands.

The Mkuze Wetland System represents the largest supplier of freshwater to Lake St Lucia, the largest and most important estuarine system in Africa. The Mkuze Wetland System and Lake St Lucia are both recognised as Ramsar Convention wetlands of international importance and form part of the iSimangaliso World

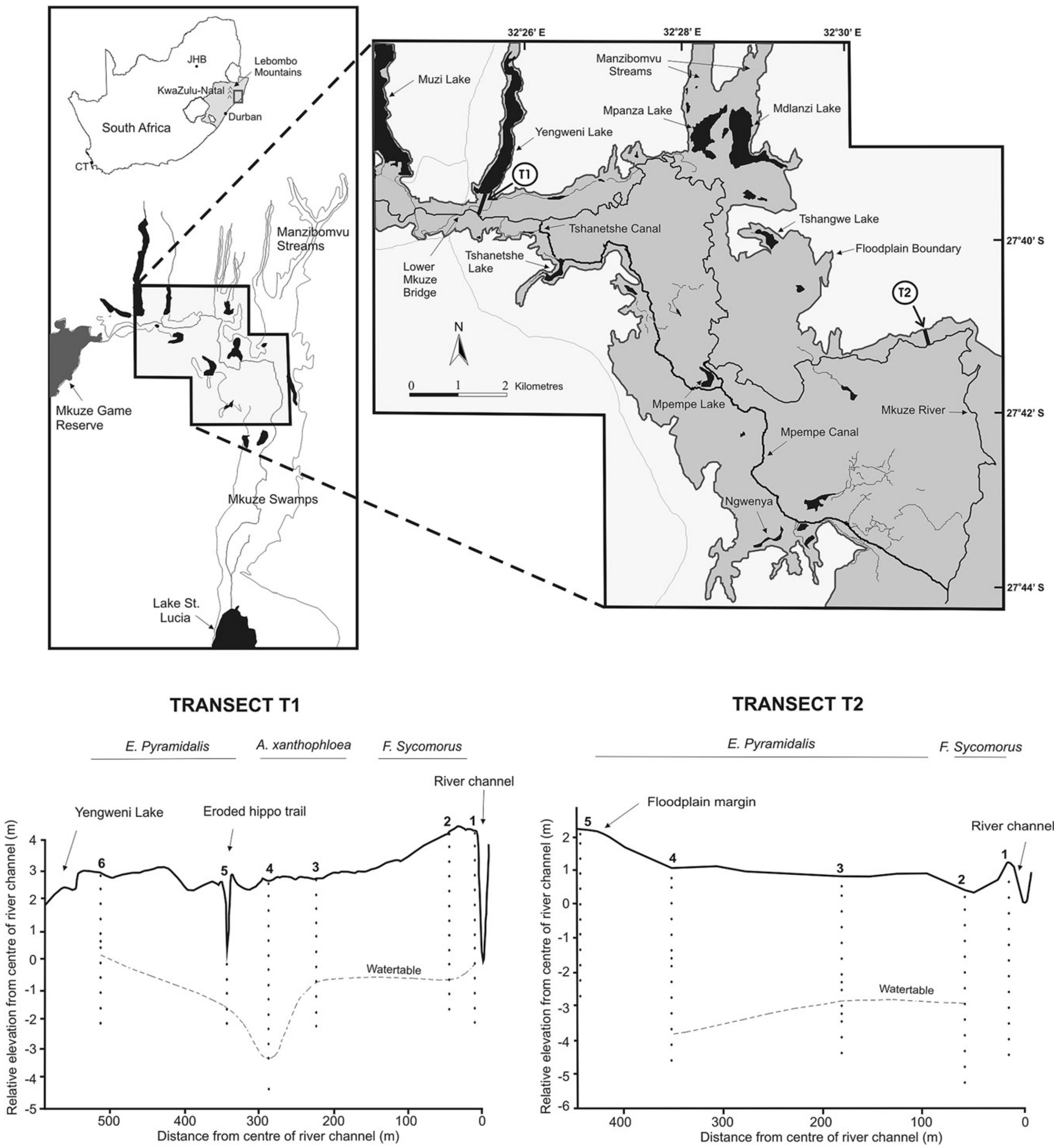

Fig. 1. Location of the study area, showing dominant vegetation and cores taken along Transects T1 and T2.