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Natural equilibria and anthropic effects on sediment transport in big river systems: The Nile case

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The Nile River flows for $\sim$ 6700 km, from Burundi and Rwanda highlands south of the Equator to the Mediterranean Sea at northern subtropical latitudes. It is thus the longest natural laboratory on Earth, a unique setting in which we are carrying out a continuing research project to investigate changes in sediment composition associated with a variety of chemical and physical processes, including weathering in equatorial climate and hydraulic sorting during transport and deposition. Petrographic, mineralogical, chemical, and isotopic fingerprints of sand and mud have been monitored along all Nile branches, from the Kagera and White Nile draining Archean, Paleoproterozoic and Mesoproterozoic basements uplifted along the western branch of the East African rift, to the Blue Nile and Atbara Rivers sourced in Ethiopian volcanic highlands made of Oligocene basalt.

Downstream of the Atbara confluence, the Nile receives no significant tributary water and hardly any rainfall across the Sahara. After construction of the Aswan High Dam in 1964, the Nile ceased to be an active conveyor-belt in Egypt, where the mighty river has been tamed to a water canal; transported sediments are thus chiefly reworked from older bed and levee deposits, with minor contributions from widyan sourced in the Red Sea Hills and wind-blown desert sand and dust. Extensive dam construction has determined a dramatic sediment deficit at the mouth, where deltaic cusps are undergoing ravaging erosion. Nile delta sediments are thus recycled under the effect of dominant waves from the northwest, the longest Mediterranean fetch direction. Nile sands, progressively enriched in more stable minerals such as quartz and amphiboles relative to volcanic rock fragments and pyroxene, thus undergo multistep transport by E- and NE-directed longshore currents all along the coast of Egypt and Palestine, and are carried as far as Akko Bay in northern Israel. Nile mud reaches the Iskenderun Gulf in southern Turkey.

A full knowledge of the Nile sediment system not only has wide paleoclimatic, paleoceanographic and archaeological implications, including a better understanding of Quaternary environmental changes in northern Africa, water circulation and sapropel development in the Mediterranean Sea, and impact on the Egyptian civilization by natural phenomena, but is also strongly needed to mitigate undesirable impacts of human activities on natural equilibria and to improve watershed, reservoir and coastal management.

Mineralogical data (Shukri, 1950) integrated by new petrographic, heavy-mineral and geochemical analyses (Padoan et al., 2011) show how sediments derived from Archean gneisses exposed through northern Uganda and from Panafrican basements drained by Ethiopian tributaries of River Sobat become progressively enriched in quartz at the expense of unstable components across the Sudd and Machar Marshes (grey shaded area). Petrographic, mineralogical, and isotopic signatures are gradually homogenized along both the Bahr el Jebel/Bahr ez Zeraf and the Sobat and remain finally unchanged down to Khartoum, which suggests massive sediment dumping in the marshes. This explains why White Nile sediment contribution to the main Nile downstream Khartoum is virtually negligible (Garzanti et al., 2006).

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