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Late Quaternary palaeoclimatic changes revealed by luminescence dating, mineral magnetism and Diffuse Reflectance Spectroscopy of river terrace palaeosols: a geoarchive 'Super Site' in the southern African interior?

Richard Lyons (1), Stephen Tooth (2), and Geoff Duller (2)

(1) Department of Environmental Science, Xi'an Jiaotong-Liverpool University, Suzhou, China (Richard.Lyons@xjtlu.edu.cn), (2) Institute of Geography and Earth Sciences, Aberystwyth University, Aberystwyth, UK

Recent advances in optically stimulated luminescence (OSL) dating have enhanced the retrieval of palaeoenvironmental information from geoarchives (e.g. sand dunes, fluvial deposits) in the drylands of interior southern Africa. We present detailed mineral magnetic and Diffuse Reflectance Spectroscopy (DRS) measurements for an OSL-dated river terrace palaeosol succession along the middle reaches of the Modder River, western Free State, South Africa. The ∼8 m thick overbank alluvial succession consists predominantly of sandy mud to muddy sand, within which four stacked palaeosols have developed (in order from oldest to youngest: lower grey, red, upper grey, and brown). The OSL chronology indicates that overbank sedimentation occurred at a generally steady, continuous average rate of ∼0.15 mm/yr from at least 44 ka until ∼0.83 ka, which suggests that the palaeosols are accretionary, having formed contemporaneously with sedimentation. Given that the sedimentation rate (and thus time for soil development), topography, and sediment source appear not to have changed significantly over time, climate seems to be the key soil-forming factor controlling palaeosol magnetic and DRS properties. Results for the magnetic measurements vary both within and between palaeosols, and can be related primarily to changes in the concentration of ultrafine-grained (<∼50 nm) pedogenic ferrimagnetic (magnetite/maghemite) minerals. Concentrations of these magnetic minerals are generally low from >44–∼40 ka (lower grey palaeosol) and ∼20–∼11 ka (upper grey palaeosol), but increase significantly from the base to the top of the red (∼40–∼20 ka) and brown (∼11–∼0.83 ka) palaeosols. The rise in pedogenic ferrimagnetic minerals up through the Holocene-age brown palaeosol is especially pronounced. We interpret temporal trends in the magnetic record to reflect primarily changes in temperature and rainfall (both amount and seasonality) and its influence on weathering intensity, with greater pedogenic magnetic enhancement occurring during warmer and/or wetter (especially seasonally wet/dry) climates. The DRS data generally support these inferences and, in particular, point to a steady decrease in hematite:goethite ratios from ∼28–∼13 ka, which is consistent with a decrease in temperatures and/or an increase in rainfall over this period. This is then followed by a steady increase in hematite:goethite ratios from ∼13 ka onwards, which indicates a warming climate and a shift to more seasonal rainfall. This geoarchive represents a notably continuous and detailed record of late Quaternary palaeoclimatic change in the drylands of interior southern Africa, especially when compared to other well-studied geoarchives in the region (e.g. sand dunes and palaeolake shorelines), which typically record climatic extremes rather than more 'average' conditions due to the temporally sporadic nature of sedimentation. Moreover, records of palaeoclimatic change are particularly scarce in this region of interior southern Africa, but may be crucial for developing understanding of late Quaternary changes in the positioning of the boundary between westerly (Atlantic Ocean) and easterly (Indian Ocean) rain-bearing systems.