Quantifying the shared history of species and landforms to decipher late Cenozoic co-evolution of landscape and biodiversity across the Kalahari Plateau

F.P.D Cotterill[1,2,3], S. Goodier[1,3], C. O'Ryan[3], M. J. de Wit[1,2]

1. AEON - African Earth Observatory Network,
2. Department of Geological Sciences, E-mail maarten.dewit@uct.ac.za
3. Department of Molecular and Cell Biology, University of Cape Town, Rondebosch 7701, South Africa
email: fenton.cotterill@uct.ac.za

ABSTRACT

Episodic uplift and denudation of the Kalahari Plateau, the vast portion of High Africa centred on the Botswanian-Zambezian region, was initiated over 100 mya, a time span that coincides with a long term trend of global cooling from the Late Cretaceous onward. Yet, the origin and subsequent erosion history of this plateau remains poorly known, despite more than 100 years of study (e.g. E. Suess, 1904). The limiting factor in this debate is precise and accurate dating of both the ancient and recent episodic history of Kalahari landscape changes, dates that can then structure tests for controls on epeirogeny and climate change. Geomorphology in particular faces daunting challenges of tracking the evolution of landforms and the formative events that delimit their tenures. These challenges characterize the landscapes of the vast top-surface of the Kalahari plateau. First, because the Kalahari's veneer –sediments and duricrusts - comprises a condensed sequence that lacks strata suitable for dating, and second, because its gentle topography reflects numerous ancient amalgamated erosion surfaces and a complex history of palaeo-drainage dynamics. Here, we describe results of a new approach to date recent events that affected the Kalahari surface, using detailed studies of the region's biodiversity *and* biogeography. We apply methods and concepts of phylogeography to species with distributions confined closely to the landforms we wish to date. We term these species "biotic indicators of landscape evolution" because informative signals of landscape history are preserved in their genomes. We characterise their gene trees to resolve where and when changes modified the distributions of these indicator species. Dating of molecular clocks – on gene trees - confers temporal precision on these evolutionary events that acted on both biota and landform. A synthesis of such biogeographical data can quantify when landforms (e.g. rivers) changed; while phylogeographic studies quantify when these formative events occurred; when populations diverged; and/or experienced demographic expansions. All these signals quantify events that altered landscapes. Relative sensitivity to changes in a landform varies greatly between different species, so their respective phylogeography exhibits corresponding differences in what they can tell us about where and when landscapes changed. We concentrate on aquatic organisms, especially fishes, because they are especially informative biotic indicators, given their sensitivity to habitat changes. Anomalies in fish distributions often reflect relatively subtle changes to drainage systems. We find that Late Cenozoic drainage evolution across the Kalahari Plateau reflects profound genetic structuring of extant fish faunas in its wetlands today. This testifies to river captures and tenures of palaeo-lakes. Conceptualizing this region's river networks and depocentres as a wetland archipelago provides a valuable framework to synthesize patterns of biotic and landscape evolution. This confers explanatory resolution on geomorphological reconstructions of its history. Phylogeographic studies of selected species are revealing where and when these drainage systems changed. The combined evidence points to the underlying causes of this landscape evolution against which patterns of climate change may be tested.

Key words: landscape evolution, geomorphology, palaeo-drainage, biotic indicators, epeirogeny