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Review article

Hominin-bearing caves and landscape dynamics in the Cradle of Humankind, South Africa

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ABSTRACT

This paper provides constraints on the evolution of the landscape in the Cradle of Humankind (CoH), UNESCO World Heritage Site, South Africa, since the Pliocene. The aim is to better understand the distribution of hominin fossils in the CoH, and determine links between tectonic processes controlling the landscape and the evolution and distribution of hominins occupying that landscape. The paper is focused on a detailed reconstruction of the landscape through time in the Grootvleispruit catchment, which contains the highly significant fossil site of Malapa and the remains of the hominin species *Australopithicus sediba*.

In the past 4 My the landscape in the CoH has undergone major changes in its physical appearance as a result of river incision, which degraded older African planation surfaces, and accommodated denudation of cover rocks (including Karoo sediments and various sil- and ferricretes) to expose dolomite with caves in which fossils collected. Differentially weathered chert breccia dykes, calibrated with ^{10}Be exposure ages, are used to estimate erosion patterns of the landscape across the CoH. In this manner it is shown that 2 My ago Malapa cave was ~50 m deep, and Gladysvale cave was first exposed; i.e. landscape reconstructions can provide estimates for the time of opening of cave systems that trapped hominin and other fossils.

Within the region, cave formation was influenced by lithological, layer-parallel controls interacting with cross-cutting fracture systems of Paleoproterozoic origin, and a NW–SE directed extensional far-field stress at a time when the African erosion surface was still intact, and elevations were probably lower. Cave geometries vary in a systematic manner across the landscape, with deep caves on the plateau and cave erosion remnants in valleys. Most caves formed to similar depths of 1400–1420 mamsl across much of the CoH, indicating that caves no longer deepened once Pliocene uplift and incision occurred, but acted as passive sediment traps on the landscape.

Caves in the CoH are distributed along lithological boundaries and NNE and ESE fractures. Fossil-bearing caves have a distinct distribution pattern, with different directional controls, a high degree of clustering, a characteristic spacing of 1700 m or 3400 m, and a characteristic bi-model fractal distribution best explained by a combination of geological and biological controls. It is suggested that clustering of fossil-bearing caves reflects a Lévy flight patterns typical for foraging behavior in animals. The controlling element in this behavior could have been availability of water in or near groups of caves, resulting in preferential occupation of these caves with accumulation of diverse faunal fossil assemblages.

The tectonic drivers shaping the dynamic landscape of the CoH did not involve large, seismically active fault lines, but complex interactions between multiple smaller fractures and joints activated in a far field stress controlled by uplift. The landscape of the CoH, with its caves and water sources and dissected landscape provided a setting favored by many animals including hominins. A modern day analog for what the CoH would have looked like 2 My ago is found 50 km east of Johannesburg, near the SE margin of the Johannesburg Dome.

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1. Introduction

It was in Africa that anthropoid primates gave rise to a lineage of hominins, our ancestors, through a series of evolutionary steps recorded in the fossil record of mainly eastern and southern Africa. Here hominin fossils are preserved along rifts, in the sediments of ancient lacustrine and riverine systems and in caves, raising the fundamental question whether the distribution of these fossils is the result of preferential preservation in sedimentary trapping sites, or whether the fossil distribution reflects a deeper relationship between hominins and the African landscapes in which they lived (e.g. King and Bailey, 2006). Understanding the relationship between the evolving landscape and fossil sites is, therefore, fundamental to understanding hominin evolution. This paper investigates that relationship for the fossil sites in the Cradle of Humankind, South Africa, focusing on the landscapes near Malapa, which hosts the important *Australopithecus sediba* fossils which represent a possible ancestral species to the genus *Homo* (Berger et al., 2010; Pickering et al., 2011a).

The geological record suggests that key evolutionary events in Africa coincided with important changes in the African landscape and climate (e.g. Vrba, 1995; Reed, 1997; Bobe et al., 2002; Bobe and Behrensmeyer, 2004; Passey et al., 2010). Since 35 Ma, the Earth's climate has cooled (Zachos et al., 2008) as the high plateaus in eastern and southern Africa rose to become one of the largest topographic anomalies on the planet's surface characterized by at least 500 m of positive residual elevation, commonly referred to as the African "superswell" (Nyblade and Robinson, 1994). Paleoclimate modeling (Sepulchre et al., 2006) indicates a causal link between uplift of the African plateau, and climate and landscape changes, with strong aridification and an increase in open grasslands since the Miocene (Bobe and Behrensmeyer, 2004; Feakins et al., 2005). Climate change had profound effects on distribution patterns of flora and fauna (deMenocal, 1995; deMenocal and Bloemendal, 1995; Hill, 1995; Kingston et al., 2007) and could have played a key role in the appearance and dispersal of early hominins (White, 1995; Vrba, 1995; Potts, 1998; Trauth et al., 2007; Maslin and Christensen, 2007; deMenocal, 2004, 2011). Attempts have been made to link the onset of extreme climate variability since the mid-Pliocene with fundamental evolutionary changes in hominins, including cranial expansion (e.g. Trauth et al., 2007; deMenocal, 2011; Donges et al., 2011).

Large-scale, long-term climate and vegetation changes in Africa are readily attributed to tectonic drivers, but tectonic effects are rarely considered as influencing hominin evolution within timeframes of less than 1 My and at scales that coincide with the territorial distribution of individual animal groups. Yet, uplift of the African plateau had dramatic impacts on the landscape occupied by hominins at a wide variety of scales (e.g. Reynolds et al., 2011; Bailey et al., 2011). In East Africa uplift was accompanied by the formation of the East African Rift System (Tiercelin and Lezzar, 2002), intimately associated with significant hominin finds (e.g. Tobias, 1985; Asfaw et al., 2002; White et al., 2009). Uplift of the African plateau rerouted large river systems including the Nile, the Congo and the Zambezi (Stankiewicz and deWit, 2006; Roberts et al., 2012), and accommodated the development of ecological corridors as well as biogeographic barriers along rift valleys and their bounding escarpments, creating complex, dynamic landscapes (e.g. O'Brien and Peters, 1999; Bailey et al., 2011), and the sediment traps necessary for the preservation of hominin fossils.

Local dynamic landscapes are created and sustained by active tectonic settings, and involve heterogeneous topography with diverse habitats (Bailey et al., 2000, 2011), with the potential to provide stable water sources, greater biodiversity and ample refuges (e.g. cliffs, gorges, caves etc.) that offer protection to hominins. Tectonically active zones rejuvenate the landscape at regular intervals (i.e. coincident with seismic events) and provide a buffer to long-term negative effects of climate change (e.g. Bailey et al., 1993; King et al., 1994; King and Bailey, 2006). Bailey et al. (2011) argue that dynamic landscape features characterize many of the South African hominid sites, including those in the Cradle of Humankind and suggest that the fossil distribution pattern represents a preference for hominins to occupy these sites, possibly even driving behavioral and morphological adaptations (Reynolds et al., 2011).