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New chronology for the southern Kalahari Group sediments with implications for sediment-cycle dynamics and early hominin occupation

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ABSTRACT

Kalahari Group sediments accumulated in the Kalahari basin, which started forming during the breakup of Gondwana in the early Cretaceous. These sediments cover an extensive part of southern Africa and form a low-relief landscape. Current models assume that the Kalahari Group accumulated throughout the entire Cenozoic. However, chronology has been restricted to early–middle Cenozoic biostratigraphic correlations and to OSL dating of only the past ~300 ka. We present a new chronological framework that reveals a dynamic nature of sedimentation in the southern Kalahari. Cosmogenic burial ages obtained from a 55 m section of Kalahari Group sediments from the Mamatwan Mine, southern Kalahari, indicate that the majority of deposition at this location occurred rapidly at 1–1.2 Ma. This Pleistocene sequence overlies the Archaean basement, forming a significant hiatus that permits the possibility of many Phanerozoic cycles of deposition and erosion no longer preserved in the sedimentary record. Our data also establish the existence of a shallow early–middle Pleistocene water body that persisted for >450 ka prior to this rapid period of deposition. Evidence from neighboring archeological excavations in southern Africa suggests an association of high-density hominin occupation with this water body.

Introduction

The Kalahari is mostly a flat, semi-arid to semi-humid savannah dominated by an extensive blanket of unconsolidated sand comprising one of the largest continuous sand bodies on Earth (Baillieul, 1975; Thomas, 1991). Decades of geological work have established an approximate chronologic framework for the formation of the Kalahari basin and its deposits, collectively referred to as the Kalahari Group (Passarge, 1904; Thomas and Shaw, 1990; Thomas, 1991; Haddon, 2000; Thomas and Shaw, 2002; Haddon and McCarthy, 2005). This framework is based on field relations between sedimentary units and on basic understanding of the tectonic evolution of the southern African continent. However, although this framework implies that the overall accumulation of this group spans the Cenozoic and generally follows epeirogenic tectonic processes that shaped the region (Moore, 1999; Moore and Larkin, 2001; Moore et al., 2009), neither the depositional age of the Kalahari Group, nor hiatuses within the group, have been established using numerical dating methods.

Numerical dating of the Kalahari Group sediments is mostly restricted to the unconsolidated covering sand (Stokes et al., 1998; Thomas et al., 2000) and most of the Kalahari Group remains undated. Currently, the oldest resolved optically stimulated luminescence (OSL) age in the unconsolidated sands is 300–500 ka (Thomas et al., 2000; Bateman et al., 2003). However, these ages are close to the limit of the OSL method and unambiguous ages are restricted to the late Pleistocene (Thomas et al., 2000; Bateman et al., 2003). Our understanding of the history of the Kalahari Group has therefore been restricted by the lack of a robust chronostratigraphic framework. Such a framework is critical to understanding the morphological, sedimentological, and climatic evolution of southern

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Africa and to revealing relationships between environmental conditions and the early development of hominins in the interior of southern Africa.

Here we take advantage of a unique exposure of the Kalahari Group sediments that lies directly above the Archaean basement in the Mamatwan Mine, Northern Cape, South Africa, and apply for the first time cosmogenic nuclide measurements to provide a new and continuous chronological framework for the Kalahari Group (from the surface sands to the underlying basement). Our results suggest that in the Mamatwan Mine area, the majority of deposition occurred rapidly at 1–1.2 Ma and the unconformity at the base of the sedimentary succession represents a time gap of >2 Ga. Although the results apply directly to the study site, they suggest the possibility that the chronology of the Kalahari Group elsewhere in the basin may also be younger than generally accepted.

The Kalahari basin

Rifting associated with the breakup of Gondwana during the early Cretaceous (Brown et al., 2000) involved both horizontal movements of lithospheric plates (Summerfield, 1988) and uplift, which generated flexural bulges around the perimeter of the southern African continent. These structural bulges are expressed morphologically by the African Great Escarpment. Landward of the escarpment, continental subsidence resulted in the development of the extensive intercratonic interior basin of the Kalahari (Dingle, 1982; Summerfield, 1985; Thomas and Shaw, 1990). Initiation of the Kalahari basin set the scene for deposition of the Kalahari Group—an extensive succession of sediments, up to 450 m thick, covering much of southern Africa (Fig. 1).

Although it is not clear whether the interior of southern Africa was already elevated prior to the break-up of Gondwana (Partridge and Maud, 1987; Doucouré and de Wit, 2003; Burke and Gunnell, 2008), uplift of the continental margin occurred during rifting in the Cretaceous. Paleocene uplift is believed to be insignificant (Partridge and Maud, 2000). A composite erosional surface (the African Surface; Burke and Gunnell, 2008) developed over most of the African continent during the time interval between 130 and 30 Ma. Epeirogenic movements along axes located inland from the escarpment during the middle to

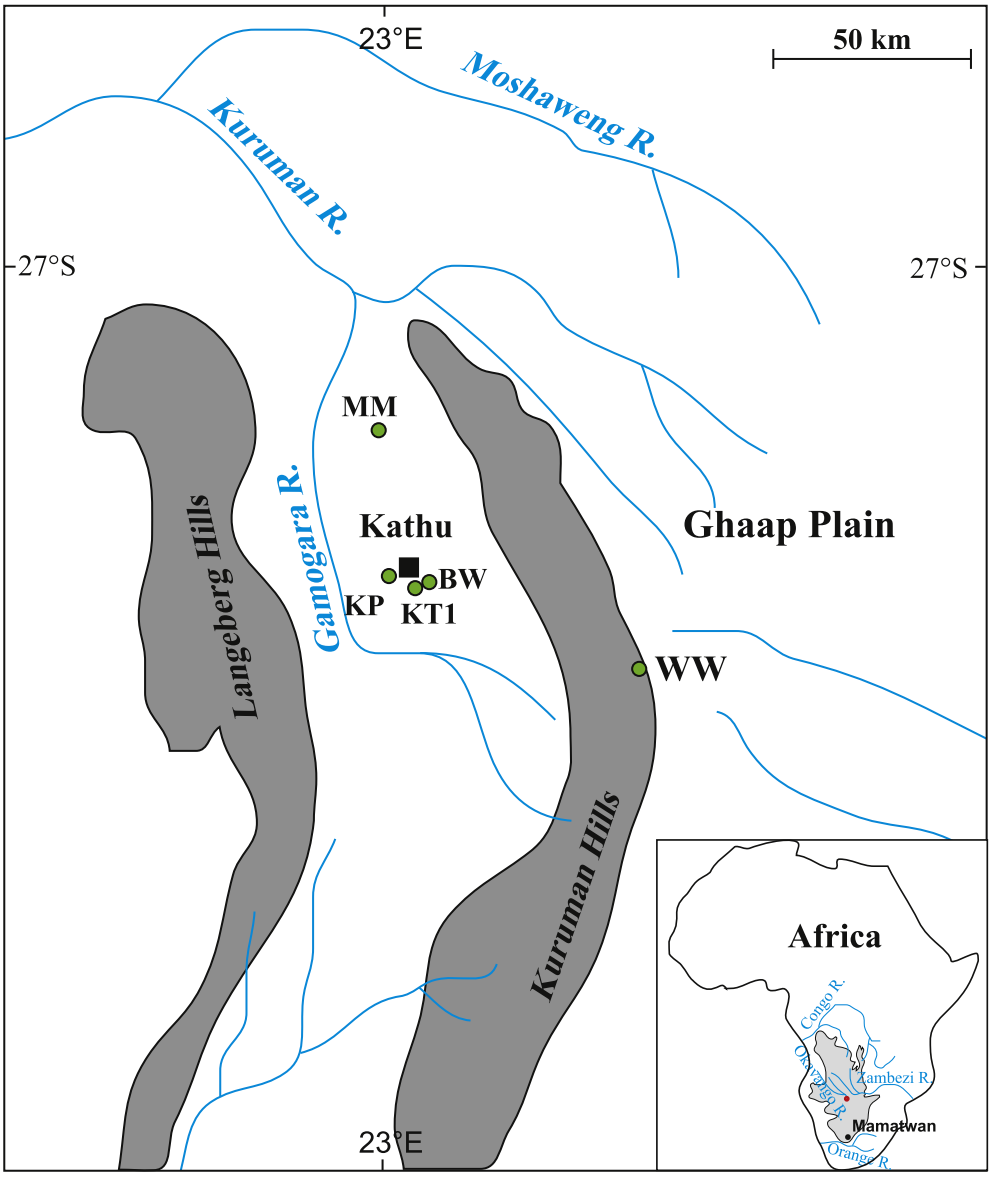

Figure 1. Location map of the Mamatwan Mine (MM; 27°22′33″S 22°58′59″E; Elevation: 1090 m asl) and the neighboring archeological sites of the Kathu Complex. KP — Kathu Pan. BW — Bestwood 1. KT1 — Kathu Township 1. WW — Wonderwerk Cave. Due to the scale of the map, the exact locations of samples Sand 13 and Sand 14 cannot be indicated. These are given in Table 1. Inset: The extent of the greater Kalahari Basin in the southern African continent (following Thomas (1991)) marked with a light gray polygon. Major drainage systems of the Kalahari are marked. Okavango Graben and the location of the Mamatwan Mine are marked with dots.