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Assessing the paleoenvironmental potential of Pliocene to Holocene tufa deposits along the Ghaap Plateau escarpment (South Africa) using stable isotopes

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ABSTRACT

The tufa deposits of the Ghaap Plateau escarpment provide a rich, yet minimally explored, geological archive of climate and environmental history coincident with hominin evolution in South Africa. This study examines the sedimentary and geochemical records of ancient and modern tufas from Buxton-Norlim Limeworks, Groot Kloof, and Gorrokop, to assess the potential of these sediments for providing reliable chronologies of high-resolution, paleoenvironmental information. Chronometric dating demonstrates that tufa formation has occurred from at least the terminal Pliocene through to the modern day. The stable isotope records show a trend toward higher, more variable $\delta^{18}O$ and $\delta^{13}C$ values with decreasing age from the end of the Pliocene onwards. The long-term increase in $\delta^{18}O$ values corresponds to increasingly arid conditions, while increasing $\delta^{13}C$ values reflect the changing proportion of C_3/C_4 vegetation in the local environment. Analysis of the Thabaseek Tufa, in particular, provides valuable evidence for reconstructing the depositional and chronological context of the enigmatic Taung Child (*Australopithecus africanus*). Collectively, the results of the present study demonstrate the potential of these deposits for developing high-precision records of climate change and, ultimately, for understanding the causal processes relating climate and hominin evolution.

Introduction

At the south-eastern margin of the Kalahari Desert in the North West Province of South Africa, the dolomitic Ghaap Plateau forms a prominent east–west trending escarpment at the boundary with the quartzites and slates of the Precambrian Transvaal Supergroup (Altermann and Wotherspoon, 1995) (Fig. 1a). The 275 km long escarpment possesses 70–120 m high cliffs from which springs have emerged during the Cainozoic; groundwater exiting the dolomite via these karst springs has deposited layers of tufaceous carbonates that have accumulated as extensive formations over the underlying bedrock and surface deposits (Butzer et al., 1978), which often contain fossils (Peabody, 1954; Curnoe et al., 2005).

In addition to the type specimen of *Australopithecus africanus* (Dart, 1925), an array of vertebrate, fossil material has been recovered from deposits associated with the Ghaap Plateau escarpment tufa formations. These fossiliferous deposits occur in many forms ranging from breccia infillings of small gullies incised into larger formations by karst depositing waterfalls; river-carved rockshelters along the valley walls; vadose caves formed entirely within the tufa; and tufaecous cappings of synchronous forming land surfaces (Humphreys and Thackeray, 1983; Klein et al., 1991; Curnoe et al., 2006; Hopley et al., 2013). Similar to the freshwater carbonate sequences recently described from early hominin localities in the East African Rift Valley (e.g. Johnson et al., 2009; Ashley et al., 2010), the terrestrial carbonates of the Ghaap Plateau escarpment are associated with a long, rich history of hominin occupation in southern Africa from at least the late Pliocene onwards (Humphreys and Thackeray, 1983; Beaumont and Morris, 1990; Beaumont and Vogel, 2006; Hopley et al., 2013).

Not only do the Ghaap tufa deposits preserve a wealth of paleoanthropological and paleolithic materials, these calcareous sediments provide contextual evidence by recording details of landscape evolution. Tufas are terrestrial carbonates formed in freshwater environments

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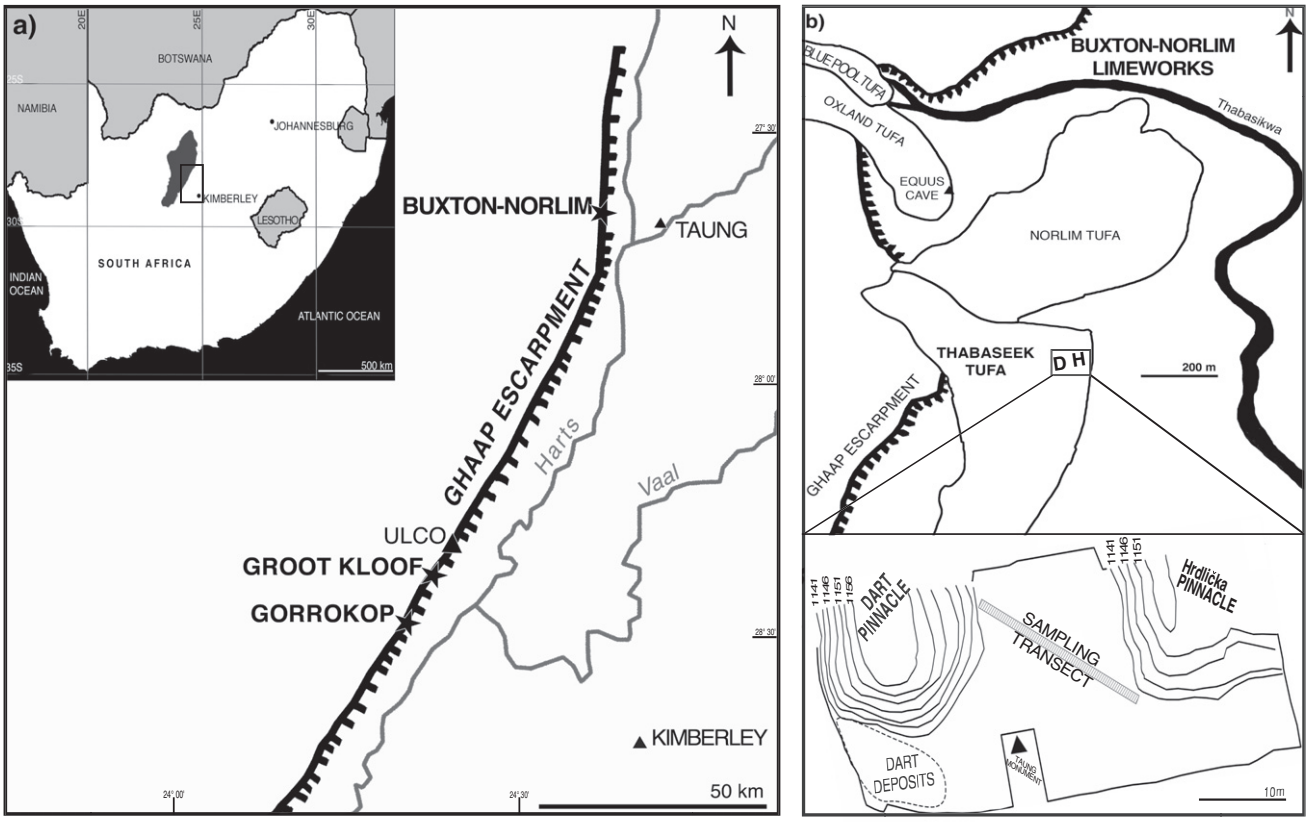
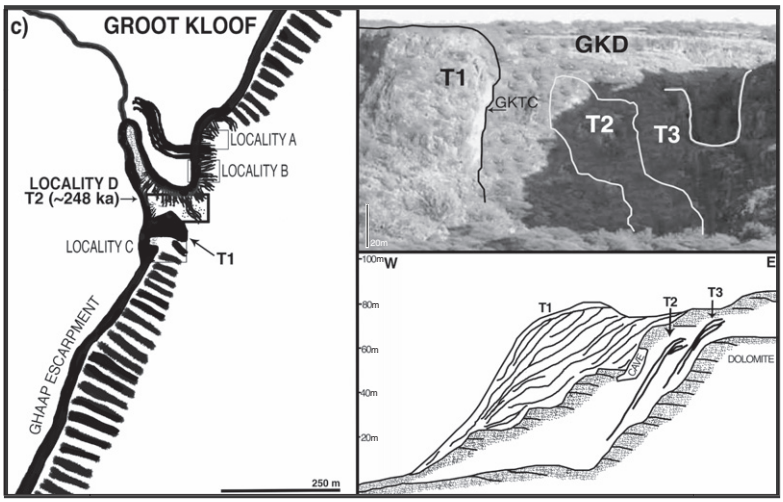
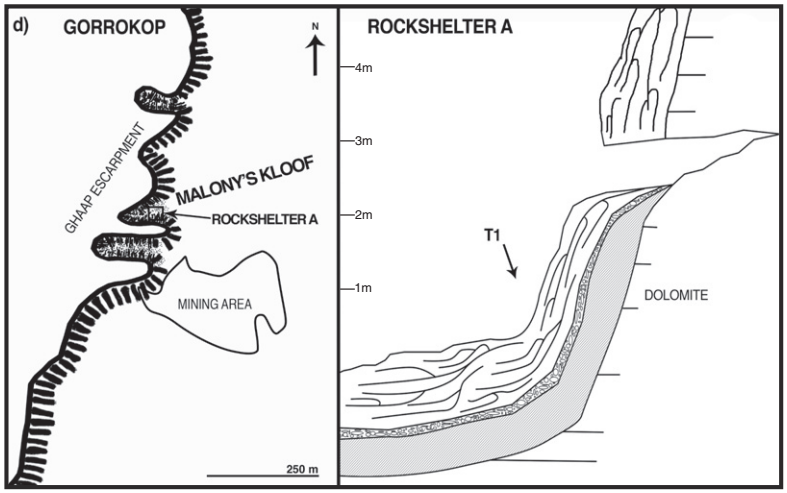

a)
BOTSWANA
NAMIBIA
JOHANNESBURG
KIMBERLEY
LESOTHO
SOUTH AFRICA
INDIAN OCEAN
ATLANTIC OCEAN
500 km
N
BUXTON-NORLIM
TAUNG
GHAAP ESCARPMENT
Harts
Vaal
ULCO
GROOT KLOOF
GORROKOP
KIMBERLEY
50 km
b)
BUXTON-NORLIM LIMEWORKS
BLUE POOL TUFA
OXLAND TUFA
Thabasikwa
EQUUS CAVE
NORLIM TUFA
THABASEEK TUFA
D H
200 m
GHAAP ESCARPMENT
DART PINNACLE
SAMPLING TRANSECT
Hrdlička PINNACLE
DART DEPOSITS
10m


c)
GROOT KLOOF
LOCALITY A
LOCALITY B
LOCALITY D
T2 (~248 ka)
LOCALITY C
T1
GHAAP ESCARPMENT
250 m
GKD
T1
GKTC
T2
T3
W
E
T1
T2
T3
CAVE
DOLOMITE


d)
GORROKOP
N
GHAAP ESCARPMENT
MALONY'S KLOOF
ROCKSHELTER A
MINING AREA
250 m
ROCKSHELTER A
T1
DOLOMITE