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Visualising scales of process: Multi-scalar geoarchaeological investigations of microstratigraphy and diagenesis at hominin bearing sites in South African karst

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ABSTRACT

Multi-scalar geoarchaeological investigations were conducted on several samples of sediment (dolomite cave sediments, ferricrete ridge, speleothem, tufa and tufa cave sediments) from four early hominin fossil-bearing sites (Taung Type Site, Haasgat, Drimolen Main Quarry, Elandsfontein) in different South African karst environments. The study was designed to test the value of geoarchaeological techniques for identifying and characterising environments of deposition and diagenetic processes involved in site formation within different mediums and different karst environments. The traditional petrographic method is weighed against two relatively new methodological contributions to site formation and diagenesis: Computed Tomography (CT) and automated Quantitative Evaluation of Minerals using Energy Dispersive Spectroscopy (QEM-EDS), employing QEMSCAN® technology. An integrated micro-sampling approach is outlined for successful cross-correlation between techniques. The study demonstrates that different analyses vary in their ability to visualise different types of process – primary and secondary. Thin section petrography remains the 'gold standard' for analyses conducted at the micro-scale, while QEM-EDS and CT offer exciting potential to perform meso-scale analyses and are best utilised as complementary rather than alternative techniques to petrography.

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1. Introduction

Scalar issues are fundamental to the discipline of geoarchaeology, which encompasses a range of analytical and interpretive scales from the landscape to the archaeological deposit (Stein, 1993; Butzer, 2008; Denham, 2008; Jones, 2010; Bateman et al., 2010; Fouache, 2013; McNamee et al., 2013). This study presents a mixed-method multi-scalar approach to geoarchaeological investigation, defined here as the use of complimentary investigative methods at varying scales of resolution to increase the interpretative potential for studying human-environmental relations. A multi-scalar approach provides links between macro-scale (landscape) studies and micro-scale (site stratigraphy and deposit) characterisation (Butzer, 2008). This process, referred to by Butzer (2008:403) as 'scale-switching, from the large to the small and back' is at the core of geoarchaeology.

Multi-technique geoarchaeological investigations greatly enhance the interpretative potential for identifying environmental processes which act across varying scales between the archaeological deposit and the landscape. Moreover, using a mixed-method framework of analysis, integration of different techniques can overcome limitations associated with each respective technique and provide comparative and complimentary datasets for cross correlation and multi-proxy validation (Canti, 1995; Denham, 2008; Shillito et al., 2011; Milek and Roberts, 2013; Canti and Huisman, 2015:104–105). The multi-scalar mixed-method geoarchaeological investigation presented here combined thin section

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petrography (micro-scale) with automated QEM-EDS (QEMSCAN) and selective Computed Tomography (CT) (meso-scale).

1.1. Sites and samples

The results of five rock samples are drawn from a broader study investigating environments of deposition and diagenetic processes at four hominin fossil-bearing karstic sites in South Africa: Taung Type Site, Haasgat, Drimolen Main Quarry and Elandsfontein (Fig. 1). The presentation is selective and focuses on the respective ability of each technique to visualise primary and secondary processes for different sediment types (dolomite cave sediments, ferricrete ridge, speleothem, tufa and tufa cave sediments) across multiple analytical scales.

Haasgat and Drimolen are early Pleistocene (between 2.3 and 1.4 Ma) hominin-bearing palaeocave deposits (Keyser et al., 2000; Adams, 2012; Herries et al., 2014; Adams et al., 2016; Leece et al., 2016a,b). Both sites formed within ~2.6 Ga Malmani dolomite and are now palaeokarst remnants of heavily eroded ancient caves. Drimolen contains *Paranthropus robustus* and early *Homo*, whereas Haasgat has only recently yielded a hominin tooth (Moggi et al., 2010; Leece et al., 2016a,b). The sample from the Drimolen Main Quarry (DRM09) is a speleothem that appears to cap the stratigraphic sequence within the palaeocave. The speleothem formed within a more recent cave that formed at the interface between the dolomite and palaeocave sediments. The sample was taken to establish stratigraphic relationships for dating purposes. The Haasgat sample (HGTFH24) was used in a palaeomagnetic study of the site and yielded inconclusive results (Herries et al., 2014) that are thought to represent alteration of the sample by later karstic processes; the current investigations are designed to clarify the sample's diagenetic history.

Samples TH41 and TH33 are from the Buxton-Norlim Limeworks, which is located 15 km northwest of the town of Taung, some 300 km west of Drimolen and Haasgat (Kuhn et al., 2016). The limeworks is famous for the discovery in 1924 of the first early hominin from Africa and the type specimen of *Australopithecus africanus*, the Taung Child (Dart, 1925). The skull originates from the Type Site that consists of two remnant pinnacles of tufa (the western Dart Pinnacle and eastern Hrdlička Pinnacle), the rest has been mined away. Associated with these pinnacles are two different clastic sedimentary units that contain fossils and have previously been interpreted as cave fills (McKee, 1993). The older of these units is a ~3.0–2.6 Ma (Herries et al., 2013) pink micrite, which is the source of the Taung Child Skull, and thought to have formed simultaneously as an open air deposit (Hopley et al., 2013; Herries et al., 2013). Sample TH33 was recovered from this deposit at the base of the Hrdlička Pinnacle. Sample TH41 is a quartz rich, calcite cemented sample that was recovered from a younger (2.6–2.0 Ma) red sandstone at the base of the Hrdlička Pinnacle, which potentially represents the infill of more recent caves that formed within the tufa and pink micrite, and contains extensive primate fossils. Sampling was designed to further clarify the depositional environment of fossil-bearing deposits at Taung.

Sample EFT9427 comes from the hominin and Acheulian-bearing fossil deposits of Elandsfontein. The site consists of a large calcrete ridge onto which an extensive dune field has been deposited (Braun et al., 2013). Within the dunes are abundant fossils and Acheulian artefacts, including a skull cap of *Homo heidelbergensis* dated to c1.1 and 0.6 Ma (Klein et al., 2007; Braun et al., 2013). Criss-crossing the dune field are a series of raised ferricrete ridges, which may be the core of more ancient eroded dunes (Braun

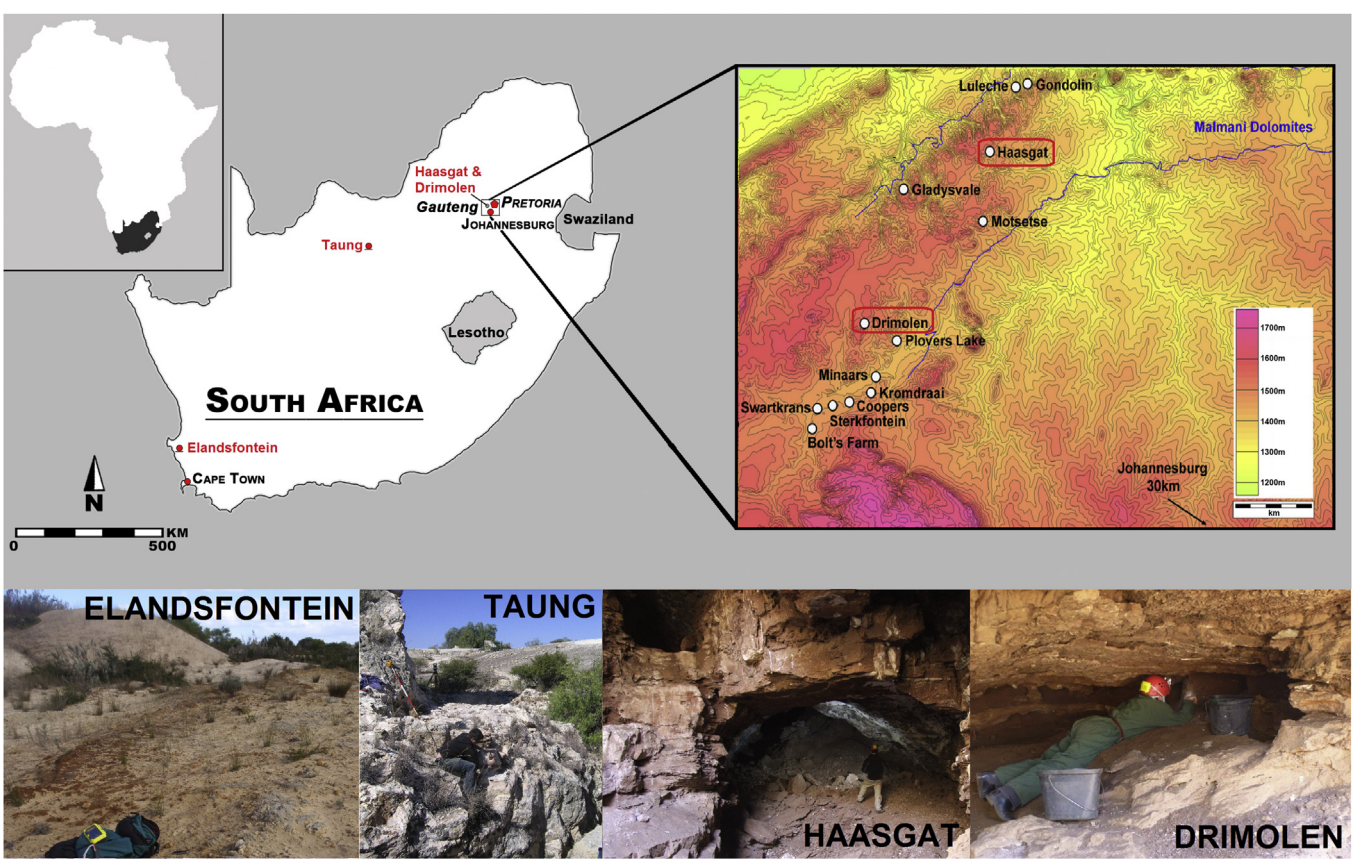

Fig. 1. Site location map and photographs of each site.

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