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# THE JOJOSI DONGAS: AN INTERDISCIPLINARY PROJECT TO STUDY THE EVOLUTION OF HUMAN BEHAVIOUR AND LANDSCAPES IN OPEN-AIR CONTEXTS

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**ABSTRACT**
Hunter-gatherer groups conduct most of their activities in open landscapes as they provide drinking water, food, and raw materials, and offer spaces for social gatherings. The remains left behind at such sites allow for unique archaeological insights into the spatial patterning of prehistoric behaviour. The Stone Age record in southern Africa remains best-known from sheltered sites. A paucity of stratified open-air localities precludes understanding the full spectrum of past hominin activities. Here we introduce an interdisciplinary project in KwaZulu-Natal to study the evolution of human behaviour and landscape dynamics during the Pleistocene in the open-air context of a stratified hillslope with sediments exposed in so-called dongas, a landform created by gully erosion. The project encompasses field and laboratory approaches, combining archaeological, geographical, geological, chronometric, and palaeoenvironmental data. After reviewing relevant open-air research in archaeology and geography, we identify the Jojosi Dongas as a promising research area. Our fieldwork results from 2022-2023 demonstrate the high archaeological, geographical, and geological potential of this landscape. Foot surveys found abundant MSA artefacts spread throughout the dongas, one area with ESA tools, but little to no traces of LSA or later material. Most finds lie on the surface with rarer stratified material occurring in exposed profiles. The surface MSA material is characterised by almost exclusive hornfels use, frequent cortical pieces, many large blanks and cores, and rare retouched tools. These features differ markedly from lithic trends observed in well-known shelter sites, likely the result of differences in site function. Based on the nature of the surface assemblages and the presence of a large outcrop of high-quality hornfels, we hypothesise that the Jojosi Dongas may have been a specialised quarry and workshop area. The stratified MSA occupations are the focus of ongoing excavations and further studies will aim to test our preliminary interpretations provided here.

**Keywords**: Middle Stone Age, Earlier Stone Age, open-air archaeology, geomorphology, survey

## 1. Introduction

The global Palaeolithic and Stone Age records are heavily influenced by taphonomic and post-depositional processes, with an increasing loss of information through time (Surovell et al. 2007; Perreault 2019). Site contexts from which archaeological data derive are among the many factors biasing the Pleistocene archaeological record. Pleistocene archaeology in many parts of the world is best known from caves and rock shelters with their favourable preservation and constrained topology.

Acting both as places of shelter and sediment traps, these contexts favour repeated human occupations and the accumulation of deep, albeit complex, stratified sediments that allow for diachronic analysis of behavioural change, and the construction of chrono-cultural sequences. At the same time, caves and rock shelters constitute small and peculiar morphological features within landscapes. They provide limited space for habitation and reflect only part of the full range of prehistoric behaviours. While allowing for good control of time and change, there is little resolution in space. In contrast, open-air sites allow for a unique understanding of spatial patterning of hominin behaviour across landscapes as they are less constrained by discrete physical zonation – indeed they raise the question of what constitutes a **site** (Foley 1981) – and may comprise contiguous areas covering many square kilometres. These sites can provide complementary information to sheltered locations as many places essential for the hunter-gatherer lifestyle exist only in this wider landscape context. They provide access to resources, such as drinking water (rivers, channels, lakes), food (migration routes and habitats of prey, edible plants), and raw materials (rock outcrops, trees), and also provide open spaces for large-scale aggregations of humans and animals (ritual places, gatherings of animals at waterholes).

Ethnographic research has shown that mobile hunter-gatherer groups spend much of their time in open-air locales with the majority of daily domestic and social activities taking place here (e.g., Gould 1968; Binford 2001; Kelly 2013). Studying the archaeology of these open-air sites has the potential to provide information on a wide array of past activities and their material traces, informing us on larger-scale patterns of mobility, settlement, and the very spatiality of behaviours among hunter-gatherer groups (Foley 1981; Isaac 1981; Conard 2001; Gamble & Porr 2005; Sharon et al. 2014; Tryon et al. 2014; Kindermann et al. 2018; Karlin & Julien 2019). Why, then, do we know much less about the global Stone Age from open-air contexts? The primary hindrance is the potential for the accumulation and preservation of archaeological material due to the effects of erosion, weathering, deflation, etc., and the added difficulty of finding such traces in a stratified or *in situ* context. Working on open-sites requires a firm understanding of their formation within the spatial and temporal framework of the landscape processes to which they were exposed. Typically, then, open-air archaeology draws on geomorphology and geological studies to understand the dynamics and evolution of the landscape, the specific site formation processes, and related sediment dynamics that contextualise the behavioural record (Tensorer et al. 2007; Malinsky-Buller et al. 2011; Sharon et al. 2014; Uthmeier & Chabai 2018). Whatever the challenges may be in a particular case, the foregoing discussion showcases that understanding the full spectrum of past actions and material culture in the Stone Age will have to include and integrate data from open-air sites.

Here, we present a new research project in the Jojosi Dongas that focuses on the little-known open-air archaeology in the eastern part of South Africa in the KwaZulu-Natal province (KZN), by following an interdisciplinary landscape-scale approach. After an overview of open-air archaeological and geographical research in South Africa, we introduce the Jojosi project within its local research context. We then report on initial results from our geographical and archaeological fieldwork in 2022 and 2023 and discuss the behavioural interpretation of these findings in the framework of ongoing investigations.

*Open-air research in South Africa: archaeology and geography*

Today, South African Stone Age archaeology is known worldwide for fossil and archaeological finds from the Earlier Stone Age (ESA) cave infill deposits within the UNESCO Cradle of Humankind or spectacular finds from Middle Stone Age (MSA) rock shelters that have transformed our understanding of the early cultural evolution of *Homo sapiens* (d'Errico et. al. 2005; Texier et al. 2010; Thompson et al. 2010; Villa et al. 2010; Henshilwood 2012; Wadley 2015; Rots et al. 2017; Backwell et al. 2022; Scerri & Will 2023). Open-air research has been less prominent over the past decades and with marked geographical differences. Initially it focused on large-scale survey activities in the Vaal River gravels and its tributaries, beginning in the early 20th century (Johnson 1907; Collins & Smith 1915; Goodwin 1928; Söhnge & van Riet Lowe 1937; van Riet Lowe 1952) and continuing ever since (Sampson 1985; Sampson et al. 2015; Kuman & Gibbon 2018; Leader et al. 2018; Ecker et al. 2021). Further landscape surveys and the identification of stratified open-air sites to understand land use and settlement patterns proceeded in the Western Cape (Oestmo et al. 2014; Mackay 2016; Shaw et al. 2019). Notable research has come from Elandsfontein (Klein 1978; Braun et al. 2013), Geelbek and Anyskop (Kandel et al.

2005; Kandel & Conard 2012) as well as Hoedjiespunt (Berger & Parkington 1995; Will et al. 2013). More recent work in the Tankwa Karoo and Cederberg regions has demonstrated flexible inhabitation of landscapes by highly mobile hunter-gatherer groups from various chronological periods in arid, marginal environments (Hallinan & Parkington 2017; Mackay et al. 2018; Shaw et al. 2019; Hallinan 2022). Since the 1990s, intense research at open-air sites has also been carried out in the Free State (see summaries in de Ruiter et al. 2011; Bousman et al. 2023a, b). Most recent archaeological work in the Lovedale dongas has shown task-specific site functions preserved within stratified deposits in open-air alluvial channel and floodplain settings exposed within erosional gullies (Wroth et al. 2022).

In the KZN province, the most intensely studied sites are located in the Southeastern Coastal Platform geomorphic province (Partridge et al. 2010). Here, the Indian Ocean Coastal Belt Biome comprises dense subtropical vegetation or large areas of modern sugar-cane fields, complicating survey work. Although archaeological investigations are documented in the late 19th and early 20th century, many of these endeavours have been non-systematic or destructive, some derive from surface collections or are poorly documented, and many sites are covered today by housing and road developments (Sanderson 1879; Feilden 1884; Lebzelter & Schmidt 1926; Lebzelter 1930; Malan 1948; Davies 1949; see also Bader & Will 2017). In this region – even more so than in others – modern Stone Age research has focused on excavating sheltered sites with an emphasis on the MSA, such as at Sibhudu, Border Cave, Umbeli Belli, and Umhlatuzana (Will et al. 2014; Bader et al. 2015; Bader et al. 2018; Sifogeorgaki et al. 2020; Backwell et al. 2022). These localities with long stratified sequences have been key for understanding the cultural stratigraphy and behavioural evolution of early modern humans in southern Africa (Lombard et al. 2012, 2022; Wurz 2016; Will et al. 2019), but provide only snapshots of behaviour limited in space and by ecology. This situation precludes assessments of regional landscape use and environmental adaptations over the Middle and Late Pleistocene which requires integration of rock shelter sequences with open-air data (Mackay 2016; Hallinan & Parkington 2017; Shaw et al. 2019; also see Chabai & Uthmeier 2018; Kindermann et al. 2018). The presence of key sites in KZN that are rich in MSA and LSA materials, however, speaks to the high potential for locating open-air sites. The Grassland and Savanna Biomes of the region's interior may in turn facilitate access to sediments and provide a different geographical focus. So far, the interior areas remain mostly unstudied and devoid of known stratified sites, particularly for the ESA and MSA (Fig. 1).

In contrast to archaeological work, many geomorphological, sedimentological, and geochronological studies have been conducted in the interior of KZN. In eastern South Africa, Quaternary sheetwash and gully-infill sediments attributed to the Masotcheni Formation provide ideal conditions for open-air archaeological preservation and exploration. These sediments are widespread in the region and diverse in substrate material, often found in colluvial settings within the Ladysmith Basin and adjacent Southeastern Coastal Hinterland geomorphic provinces (Botha 1996; Partridge et al. 2010; Botha et al. 2016). The deposits are commonly stratified, coarse to medium-grade, sandy sheetwash, representing palaeo-gully infill alluvial sediments that accumulated throughout the Late Pleistocene and Holocene (Botha & Fedoroff 1995; Wintle et al. 1995; Clarke et al. 2003; Temme et al. 2008; Keen-Zebert et al. 2013; Lyons et al. 2013; Bosino et al. 2021). The stratification is interpreted as reflecting cyclical fluctuations in landscape stability. During climatic and vegetation-cover conditions that favour degradation of soil on upper slopes by sheet and rill erosion, the sediment is transported mainly as unconfined sheetwash deposits that accrete on the lower footslopes (Botha et al. 1994). During phases of relative landscape stability, weathering of the surficial sediment results in soil development. Phases of instability remove topsoils and remnant subsoils are buried, leading to the accretion of a sedimentary succession comprising stratified colluvium and interbedded buried palaeosols (Botha et al. 1992; Botha & Fedoroff 1995). Both the erosion activity and pedogenesis reflect past environmental conditions, such as hydroclimatic changes between aridity and humidity, the changing vadose zone hydromorphic status of soils and underlying sediments, the type and density of associated vegetation cover, and changing local geomorphic processes. The impact and timing of palaeoenvironmental conditions have been studied using a range of research methods, including sedimentology, litho- and pedostratigraphy, micromorphology and geochemical techniques (e.g., Wintle et al. 1994; Botha & Fedoroff 1995; Clarke et al. 2003; Lyons et al. 2013; Tooth et al. 2013; Lyons et al. 2014), as well as through computational modelling (Temme et al. 2009; Temme & Veldkamp 2009). From an archaeological perspective, the stratified sediment bodies provide favourable conditions for preservation and the palaeosols permit interpretation of the palaeoenvironmental context, two important pre-requisites that render the Masotcheni Formation a suitable geo-archive for open-air archaeological research. Recent gully erosion, a common feature affecting the hillslope colluvial mantles in central KZN, also aids archaeological prospecting by exposing sedimentary units and interbedded archaeological materials in gully (donga) sidewalls.

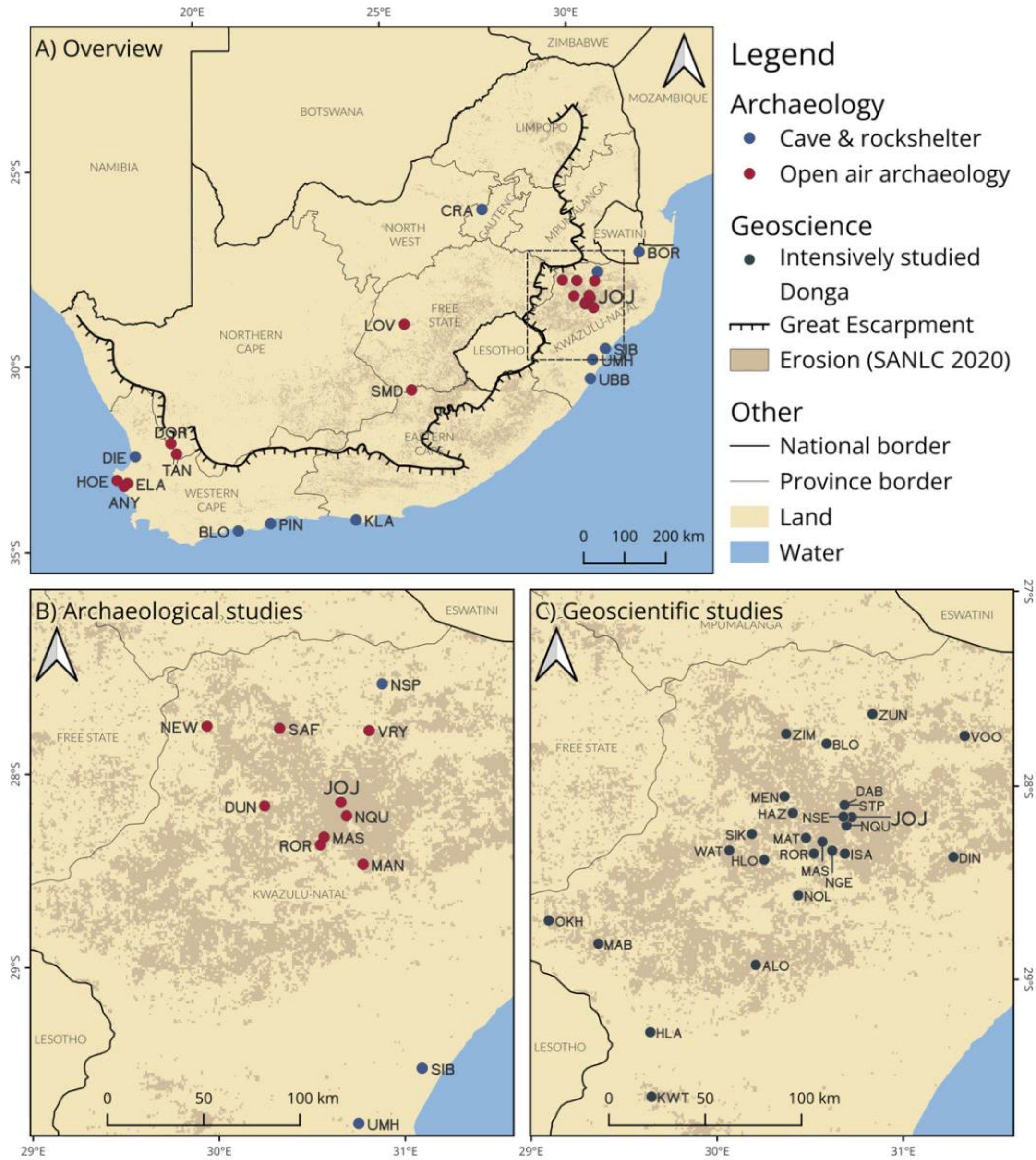


**Figure 1.** Sheltered and open-air localities in South Africa and KZN mentioned in text. Stone Age sites in South Africa (a) (HOE=Hoedjiespunt, ANY=Anyskop, ELA=Elandsfontein, DIE=Diepkloof Rock Shelter, DOR=Doring River, TAN=Tankwa Karoo, BLO=Bloemfontein, PIN=Pinnacle Point, KLA=Klasies River, LOV=Lovedale, CRA=Cradle of Humankind, SIB=Sibhudu, SMD=Smaldeel, UMH=Umhlatuzana, UBB=Umbeli Belli, BOR=Border Cave). Sites of archaeological relevance in the focus area of KZN (b) (NEW=Newcastle, DUN=Dundee, SAF=Sandspruit Farm, ROR=Rorke's Drift, MAS=Masotcheni, JOJ=Jojosi, NQU=Nquthu, MAN=Mangeni Falls, VRY=Vryheid, NSP=Natalspa). Sites of geoscientific relevance (c) (OKH=Okhombe Valley, MAB=Mabhulesini, HLA=Hlatikulu, KWT=KwaThunzi, ALO=The Aloes, WAT=Waterkloof, SIK=Sikhunyana, HLO=Hlomohlomo, MEN=Menteith, HAZ=Hazeldene, MAT=Matatana, ROR=Rorke's Drift, MAS=Masotcheni, NGE=Ngedla, ISA=Isandhlwana, NOL=Nolonka, NSE=Nsekwini, DAB=Dabekazi, STP=St Pauls, JOJ=Jojosi, NQU=Nquthu, ZIM=Zimbutu, BLO=Blood River, ZUN=Zungwini, VOO=Voordrag, DIN=Dingaanstad). Erosion features were derived from the South African National Land Cover (SANLC) Dataset (2020) provided by the Department of Environment, Forestry and Fisheries.

Donga is a local term used in southern Africa for a landform created by gully erosion, which describes the removal of soil or sediment by incising dendritic and linear channels through the concentrated flow of water (Poesen et al. 2003). Once initiated, dongas grow rapidly in length and depth and expand in area, making it the most destructive form of soil degradation (Sidorchuck 2021). Donga morphology is controlled by several environmental factors (e.g., landscape position, bedrock geology, sediment and soil types, climate and weather extremes, vegetation cover) and anthropogenic drivers (e.g., overstocking and overgrazing, land management practices such as slash and burn agriculture, field ploughing, and road cuts). In South Africa they occupy roughly 600 000 ha (Mararakanye & Le Roux 2012) and Olivier et al. (2023) estimate erosion rates of 30 to 123 t/ha per year in prone regions. Most dongas occur in the Eastern Cape and central KZN, stretching from the Great Escarpment foothills to the river basins of the coastal hinterland, with 0.9% of the land area affected (see Fig. 1). For this reason, donga erosion nowadays poses a major threat to agriculture and built infrastructure and has become the focus of conservation research, predictive modelling, and Earth observation systems. For archaeology, the phenomenon is both a blessing and a curse: on the one hand, erosion destroys archaeological sites beyond recovery, but on the other hand, exposure in the donga walls reveals otherwise deeply buried artefacts and sites. Ongoing donga expansion rejuvenates the outcrops, which facilitates repeated archaeological exploration within these landforms.

*Open questions, current limitations, and research opportunities*

Current research into the southern African Stone Age relies heavily on archaeological material from caves and rock shelters, particularly in KZN. There are few open-air sites that preserve undisturbed assemblages and even fewer sites where materials buried intact within stratified deposits are accessible using modern excavation techniques. What characterises the archaeology of Pleistocene open-air sites in KZN? Is it different from sheltered localities, and if so, why? What function did sites in open landscapes have during the Pleistocene? To what degree has the current Stone Age record in southern Africa, most well-known from sheltered sites, been impacted by the prevalence of specific occupation types and locational preferences? Answers to these questions, and a full understanding of past human adaptations and land use, require the incorporation of multiple localities of different types and functions. Only with more systematic surveys, fieldwork, sampling, and multidisciplinary data collection from open-air sites, followed by comparison with sheltered site data, can we then begin to answer these questions and realise the true significance of the KZN record.

Any such work in the Stone Age requires close collaboration between archaeologists, geographers, geomorphologists, and geologists. All steps of archaeological inquiry, from locating and mapping of sites to their excavation and interpretation, are strongly influenced by factors of sediment derivation, transport mechanisms, and depositional facies in response to the changing landscape dynamics, both past and present. What caused the phases of landscape activity, and can we learn anything about the environmental conditions encountered by early hunter-gatherers? Can we relate the sediment dynamics and timing of events to the successions exposed in nearby dongas, and can this help us to understand whether these events were active only locally or on a wider regional scale? What can current sediment dynamics tell us about the recent state of landscape stability? Is the transition from unstable conditions to landscape stability coeval across the land surface? Do the phases of donga growth followed by localised infill and greening of vegetation-stabilised dongas take place simultaneously across the region? Many of these questions can be tackled by close collaboration between the different disciplines listed above.

## 2. An interdisciplinary project in the Jojosi Dongas

*Geographic and geological setting*

The study area is situated in the uppermost reaches of the Jojosi River Valley, a tributary to the White Mfolozi River, at elevations of 1160-1200 m (28°08'30" S, 30°39'01" E; Fig. 2). The Jojosi River springs from the flank of a sandstone and dolerite escarpment separating two geomorphic provinces, the elevated plateau of the Ladysmith Basin to the west and the lower Southeastern Coastal Hinterland to the east (Partridge et al. 2010). The escarpment comprises resistant sandstone of the Vryheid Formation which also underlies large parts of the plateau. Below the scarp lies a dense dendritic drainage basin corresponding to a widespread dolerite sill exposure. A dominant sill rises above the valley, forming the watershed to the south, and Telzeni Hill, the watershed to the north (Fig. 3). The sites are located on the dolerite footslopes where the chemically weathered dolerite bedrock is buried by a complex sequence of Quaternary sheetwash and gully-infill sediments. The study area lies in the temperate climate zone with a subtropical highland climate (Köppen-Geiger class Cwb; Conradie 2012). Within this Summer Rainfall Zone, precipitation is highly seasonal, with humid summers and dry winters. The predominant vegetation type of the region is the Income Sandy Grassland, a part of the Sub-Escarpment Grassland Bioregion (Mucina & Rutherford 2006).

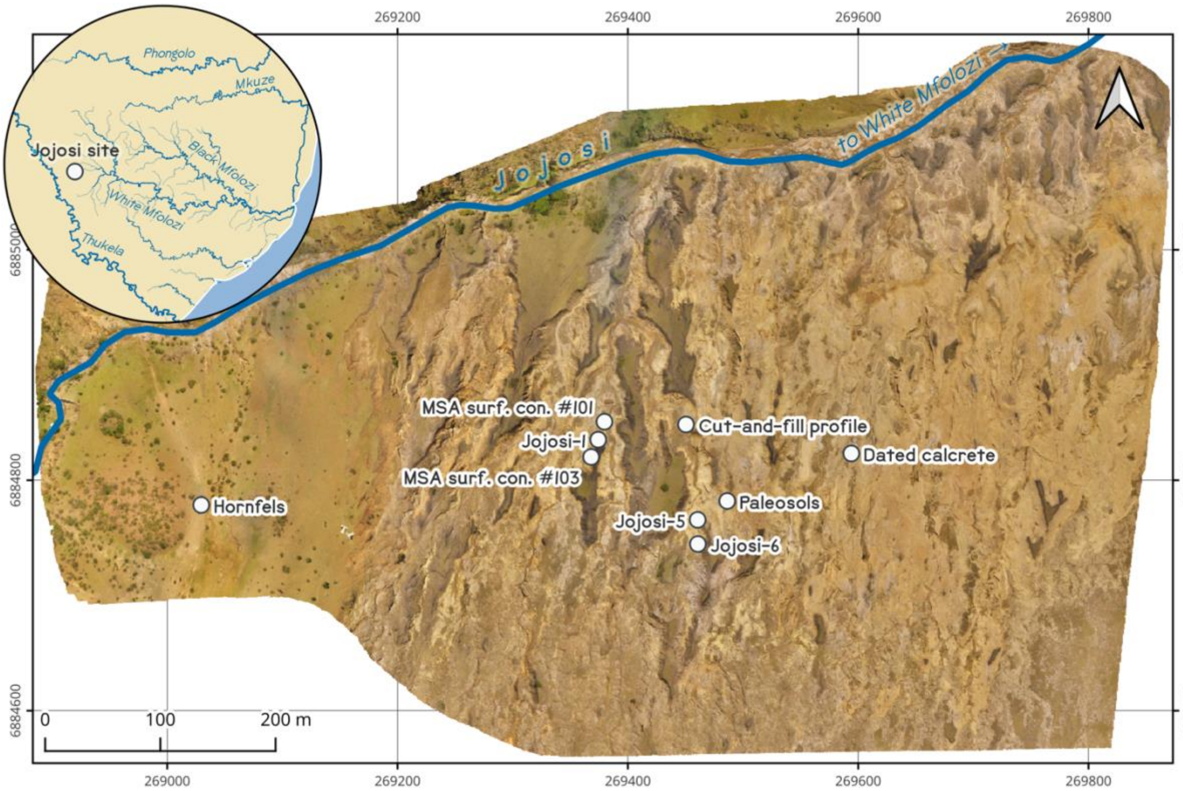


**Figure 2.** Detailed view of the main study area and important locations mentioned in the text. Go to https://skfb.ly/oyTSW for an interactive 3D view.

*Previous research*

The Southeastern Coastal Hinterland in the interior of KZN, north of the Thukela River and south of the Phongolo River, has seen widespread geoscientific exploration but little archaeological study. Here we summarise only the most important points with a focus on Jojosi. A detailed description on previous work in the broader area can be found in the Supplementary Online Material (SOM) 1.

Earlier studies with a geoscientific focus on the Jojosi site by Botha (1996) and Botha et al. (1994) describe several unconformity-bounded depositional units and illustrate multiple phases of cut-and-fill sediment bodies. However, the nature of the dolerite-derived sediment that predominates the Jojosi Basin precludes a direct correlation of palaeosols or sedimentary units here with those described from the surrounding region. The cut-and-fill profile mapped in Figure 2 and shown in Figure 3b is used in Boardman et al. (2012) as an illustrative depiction of gully-fill sequences, but it is not discussed any further. A unique hardpan calcrete profile interbedded within the Jojosi sedimentary succession yielded radiocarbon ages of ~37 ka and ~28 ka (Pta-5759, Pta-4927/4975), which allows a tentative chronological correlation with buried palaeosols exposed in the St Paul's, Nquthu and Menteith localities. Concerning the complex Jojosi palaeo-donga cut-and-infill succession, the question arises as to how this succession can be correlated directly with the luminescence chronology framework at surrounding locations. Successful dating of the landscape cyclicity inherent in the Jojosi colluvial succession will permit stratified archaeological finds to contribute to an enhanced understanding of the role of Stone Age cultures in the context of the long-term Masotcheni Formation accretion, using chronostratigraphic indexing and derived palaeoenvironmental insights.

Previous archaeological work in the northern interior of KZN has provided ample evidence of ESA, MSA, and some LSA artefacts in surface contexts scattered over wide areas (see SOM 1). These stone tools are predominantly associated with well-developed and well-studied sheetwash and alluvial sediments, and the material is commonly found in large numbers located on erosional donga surfaces. In fact, the earliest reports of Stone Age artefacts in KZN appear to go back to dongas (Feilden 1884). The few excavations in northern KZN conducted in sheltered sites have provided ample LSA material in their occupation sequences, but little MSA (Mazel 1996). The area of the Jojosi Valley was initially described during the systematic mapping and geological investigations by Greg A. Botha in the late 1980s. He first noticed the high archaeological potential of the Jojosi Donga complex (see Botha 1996: appendix 7.1). Based on his assessment, a project headed by Aron D. Mazel (then Natal Museum) performed the first and so-far only documented excavation of an open-air locality in KZN during a short campaign in 1991. Unpublished field notes and comprehensive photographic records by Mazel report distinct artefact concentrations eroding out of the profile walls of the dongas from lenticular-shaped features (Mazel 1991). He excavated four of these features, which we now call Jojosi 1-4. The lithic assemblages, all attributed to the MSA, were never studied in detail and the results of the excavations were not published except for a newspaper article (Unknown Author 1991) and a note (Botha 1996: appendix 7.1). The nature of these stone tools and the sedimentary context, geographical extent, and age of the purported MSA occurrences remained unknown. Among all known sites in the area and based on previous work, the Jojosi Dongas possess the highest potential for uncovering *in situ* material in stratified sediments from an open-air Stone Age context in KZN. After a visit to the site in 2021 and a first perusal of the Jojosi 1-4 collections stored at the KZN Museum, we decided to start a new large-scale field project in 2022.

*Introducing the new project: scope, aims, and methods*

The overarching goal of the Jojosi project is to study the evolution of human behaviour and landscapes in open-air contexts of southeastern Africa in the understudied region of KZN, during the late Middle and Late Pleistocene. This work will include the systematic survey, excavation, and analysis of stratified open-air Stone Age archaeological sites, and concern the acquisition of high-resolution, multidisciplinary data. From a geographical, geological, and geoarchaeological perspective, central research questions concern: 1) the formation of palaeo-donga infill deposits at Jojosi in their wider regional framework; and 2) the accumulation, embedding, and potential alteration of archaeological material. The archaeological scope of the project aims to understand the extent, age, recurrence, and nature of occupations in the Jojosi landscape, assessing their function and characterising technological and techno-economic behaviours. These data are contextualised with: 1) regional knowledge from sheltered sites in KZN to study the distinctiveness and culture-historical attribution of the archaeological signals at Jojosi; and 2) inter-regional information from open-air contexts to evaluate similarities and differences in the spatial use of southern African landscapes in the Late Pleistocene. Contrasting open-air and sheltered localities from distinct ecological and geological circumstances is a crucial step to assess the impact of different site functions and occupation types, for understanding specific behavioural repertoires including landscape use and mobility patterns. Finally, we are interested in the dynamic relationship between landscapes, environments, and humans, such as the extent to which both geological aspects and natural resources (i.e., raw materials, surface stability, grassland ecologies), climatic fluctuations, or self-induced changes to the surroundings (i.e., niche construction), influenced behavioural and occupational patterns.

Our methodological approach comprises an interdisciplinary framework, combining archaeological, geographical, geological, chronometric, and palaeoenvironmental data. In 2022 we initiated systematic survey and mapping of archaeological finds of the Jojosi landscape followed by targeted small-scale excavations in 2023, embedded in a wider geographical and geological study of the region. The ongoing field studies are facilitated by the traditional landowners, the Molefe Tribal Council, and the excavation permit issued by the KZN Amafa and Research Institute to MW (PermitID: 3848 REF: SAH22/18276 CaseID: 18276). For the purpose of introducing the research project here, we provide an overview of all the methods employed within this project, including those that will be scheduled for future analyses beyond the scope of this paper. We also provide the initial results from our fieldwork seasons in 2022 and 2023. Multidisciplinary analytical and laboratory work is currently underway, such as the study of excavated material, but it is not the subject of this contribution.

The archaeological work encompasses field-based and laboratory aspects. The large study area (>3 $km^2$) necessitated initial foot surveys to understand the extent and nature of archaeological occurrences within the erosional landscape. The foot surveys followed the terrain due to its complex 3D morphology consisting of multiple gully and wall features (up to 10 m; Fig. 3) and aimed at rapid identification and mapping of relevant archaeological material. Teams of two archaeologists tracked their paths and identified specific archaeological occurrences via handheld GPS and the KoBo Toolbox (https://www.kobotoolbox.org/). The KoBo Toolbox is a free open-source tool for field data collection using mobile devices, supporting the full data cycle from design to collection, storage, and analysis. We used the system on mobile phones to gather textual, coordinate, and photographic data. No artefacts were collected. Attribution of surface material to a period (ESA/MSA/LSA) rested on appraisal of diagnostic artefacts and established typo-technological traits comparable to other surveys in South Africa (e.g., Hallinan & Parkington 2017). Handaxes, cleavers and clusters of large cores and/or flakes on coarse-grained raw material with minimal preparation were interpreted as ESA, whereas prepared and radial cores, flakes and/or blades with faceted platforms and retouched forms such as points, were regarded as markers for the MSA. Microlithic forms, bladelets and bipolar cores, particularly on quartz, were interpreted as being from the LSA. We note the limits of this approach, such as equifinality in lithic types and the coarse-grained resolution of this appraisal.

The surveys provided the basis for choosing excavation areas. We adapted archaeological excavations to the complex sediment geometry and the specific kinds of archaeological occurrences in the dongas, neither allowing large-scale digging of horizontal planes as usually done in an open-air setting. Instead, excavations consist of multiple, targeted explorations of outcropping archaeological material in small areas within the often non-contiguous sediment bodies. These occurrences receive individual numbers in ascending order (e.g., Jojosi-5) and are analytically treated as separate sites and assemblages. We measured the encountered artefacts >2 cm in size in 3D with a total station and an EDM programme in a local grid system associated with an Access database (e.g., Dibble & McPherron 1988; McPherron & Dibble 2007). All sediments are screened through a sieve of 10 mm and 1 mm to recover smaller archaeological finds. The material is stored and curated in the KZN Museum in Pietermaritzburg. Future laboratory work will cover quantitative and techno-typological analyses of excavated stone tools, but also refitting, spatial, morphometric, functional, and provenience studies. Blocks of intact sediment jacketed in plaster will allow micromorphological study to understand sediment formation around occupation zones.

Chronometric and palaeoenvironmental data were also collected during fieldwork. The almost complete lack of charcoal and organic material precludes the application of radiocarbon dating. Instead, we apply luminescence methods that have been implemented successfully on donga sediments elsewhere in the region (e.g., Botha et al. 1994; Botha 1996; Lyons et al. 2013; Colarossi et al. 2020). Our sampling strategy follows the dual goal of understanding the timing of sediment deposition but also the associated accumulation of the archaeological material. Optically stimulated luminescence (OSL) dating of natural minerals, such as quartz and feldspars, allows for constraining the depositional age of the sediments (e.g., Huntley et al. 1985; Hütt et al. 1988; see Rhodes 2011 for a review). Due to rare organic preservation, palaeoenvironmental analyses will rely on the collection of sediment samples for the study of phytoliths and detailed soil texture and chemical analyses. Rare, fossilised bone and teeth will be subject to standard zoological analyses.

To better understand the current (resource) landscape and its complex formation processes, we employ multiple geological and geographical approaches. In the field, we study the phenomenon of donga landscapes from a stratigraphic perspective, focusing on the formation of sedimentary bodies and relict palaeosols, thereby establishing an environmental context for the archaeological finds. We apply the method devised by Botha (1996), describing the Quaternary successions in terms of allo- and pedostratigraphy, which allows us to distinguish and capture sedimentological and pedological overprint properties complementarily. Sediment samples are analysed for texture and geochemistry by the KZN Department of Agriculture Laboratory. The Council for Geoscience laboratory in Silverton (Tshwane, Gauteng) will perform X-Ray Diffraction (XRD) analysis. We will apply visible-near-infrared (NIS-NIR) soil spectroscopy of 350-2500 nm wavelength to characterise the electromagnetic reflectance fingerprints of the stratigraphic units (Stenberg et al. 2010; Sommer 2021).

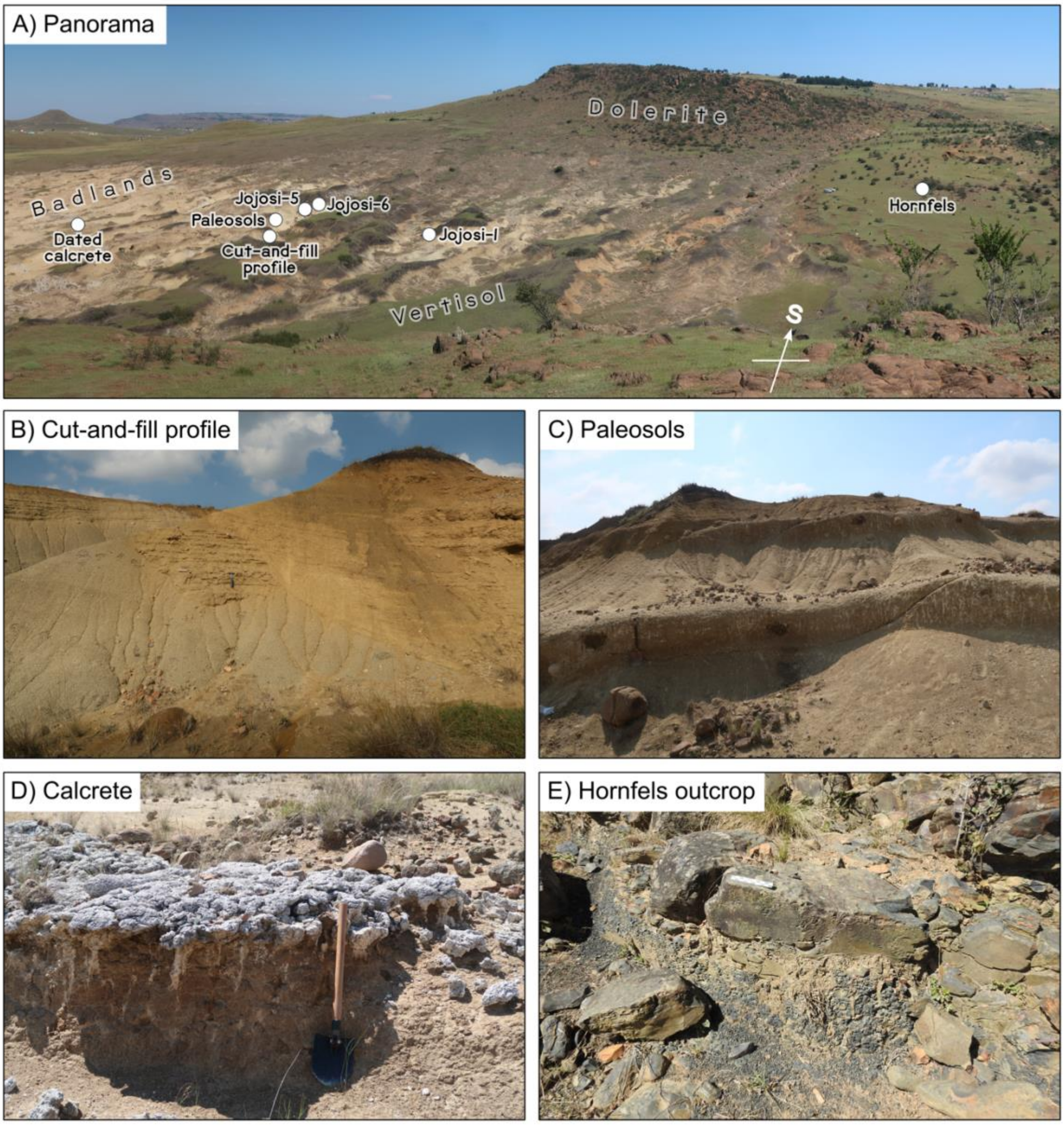


**Figure 3.** Overview of the study area and key sites. Panoramic overview of the upper Jojosi valley (a). Donga fill sediments display several phases of erosion and deposition (b). Two buried palaeosols (c) and calcrete (d) indicate phases of soil formation. Hornfels outcrop used as raw material source for stone tool manufacture (e). Go to https://skfb.ly/oyTSW for an interactive view.

Recent donga erosion is studied to understand the influence of natural and anthropogenic factors and the synchronicity of landscape activity. This work allows inferences to be made on the prehistoric evolution of dongas, but also their impact on modern land use and present-day communities. To this end, we create a regional inventory of existing donga types, quantify their extent, and derive their geographic properties from digital terrain models, topographic indices, and regional environmental data. We derive the dynamics of erosion from a time series analysis of historical aerial photographs dating back to the 1940s, orthophoto maps, and younger spaceborne imagery. Photogrammetry based on a UAV (unmanned aerial vehicle) survey of the Jojosi dongas in 2022 and 2023 helps in quantifying erosion rates at a small spatial and temporal scale. We feed the data into a regional geostatistical analysis to identify potential drivers of donga erosion and develop a predictive model to estimate the current potential for land degradation (Vanmaercke et al. 2021; Olivier et al. 2023).

## 3. Initial results from the field campaigns in 2022 and 2023

Initial findings from field work in 2022 and 2023 encompass the geographical and archaeological results from our systematic foot and UAV surveys – with an emphasis on the distribution, extent, and nature of archaeological surface material in the donga landscapes – and preliminary observations from the excavations. We also report on work concerning OSL sampling, connecting our research to the 1990s excavations of Jojosi 1-4, and processes of modern donga erosion. An overview of the key research areas and encountered features in the landscape is provided in Figure 3.

*Field observations on the geography and geology of the (resource) landscape*

We characterised the geoscientific and geographical nature of the area by mapping geomorphological features through both field observation and UAV survey, generating a 3D model that is publicly accessible at https://skfb.ly/oyTSW. In the field, we described sedimentological characteristics across the study area and at the relevant sites, namely the cut-and-fill profile (Fig. 3b), a paleosol profile (Fig. 3c) and Jojosi-5 (Figs 8-9). The sedimentological samples collected at these localities are currently under analysis.

Our topographic analysis indicates that the geographical setting of Jojosi is typical for the colluvial hillslope mantles of the Masotcheni Formation, accumulating as unconfined sheetwash sediment or palaeo-gully infill deposits on a footslope with an inclination of <10%. Mapping of sediment bodies at gully exposures revealed mixed sedimentary input from weathered and eroded Vryheid Formation sandstone and shale bedrock with limited sediment derived from weathered dolerite, the latter of which is usually indicated by reddening of the sediments (see Botha 1996). The Jojosi River Basin is unique in this respect as the entire ~30 km$^2$ area is underlain by a thick dolerite sheet. The colluvial sedimentary succession is derived from eroded dolerite saprolite exposed on the upper hillslopes. Our initial investigations of the colluvium indicate up to four stratigraphic units in the succession that can be correlated over larger areas, but can only be observed in direct contact at a few locations (see cut-and-fill profile, Fig. 3b). The underlying dolerite consists of bedrock in the upper parts of the footslope and is deeply weathered in the lower parts with a silty clay texture. The bedrock is covered by colluvial deposits >10 m thick which can be subdivided into three unconformity-bounded sedimentary units. These units vary considerably in thickness and lateral continuity. The stratified sediments are well-cemented and have higher sand content than the parent weathered rock and palaeosols, ranging from sand to clay-loam. The majority of sediment is unsorted, but there are also units with alternating bands with well-sorted sandy and silty channel deposits. The basal contacts of the units are often sharp and associated with cobbles and boulders, pointing at their erosive nature.

Typically for the donga fill stratigraphy, former donga walls and cross-sections are still visible in the outcrops. Such nested sediment bodies within the Quaternary succession suggest a cut-and-fill morphology caused by multiple episodes of erosion and deposition in a donga environment. In addition, sedimentary units also show some evidence of earlier soil formation, which is summarised in the Jojosi Pedocomplex, but could not be correlated with sites outside the study area (see Botha 1996). These include two clay-rich palaeosols that are recognisable by calcified root channels (Fig. 3c). Catenal variation in these calcisol profiles is evident from the development of carbonate nodules and a massive hardpan calcrete horizon that grades down into vermicular mottles (Fig. 3d), which indicate soil-forming processes in the subsoil. An earlier study by Botha (1994) provided radiocarbon dates indicating calcrete formation at ~37 and ~28 ka (minimum ages), which correlates with the Dabekazi Pedocomplex occurrences in the surrounding area, although the temporal relationship between the sediment deposition and calcrete formation remains unclear. We aim to answer these stratigraphic questions with further sediment analysis and luminescence dating.

Our observations on recent soil degradation show that donga erosion has transformed much of the study area into badlands. The current dongas reach depths of more than 10 m and are up to 30 m wide. Their cross-section is typically trapezoidal towards the mouth and V-shaped at the headcuts, according to the classification system by Weidelt (1976). In steeper parts, the headcuts no longer exist and the channels fade out onto saprolite or bare bedrock deprived of all sediment and soil cover. The gully drainage channel network was originally dendritic but it has since degraded as erosion has lowered the interfluve ridges, merging them into what Ireland et al.'s (1939) taxonomy defines as an extensive compound system. Where erosion has not yet degraded the land, vertisol is the predominant soil type (Dijkshoorn et al. 2008). This strongly structured soil type is rich in active clay minerals that swell or shrink under humid and arid conditions, forming cracks that make these soils very susceptible to erosion. In addition to the natural factors that facilitated donga erosion during the Quaternary, anthropogenic factors like small-scale crop farming and use as grazing land have driven recent land degradation.

An important observation from the perspective of prehistoric landscape use by humans is a large superficial outcrop of hornfels exposed along the dolerite/siltstone contact about 500 m west of the archaeological focus area (Fig. 3e). The argillaceous rocks were baked and physicochemically altered by contact-metamorphism with the hot igneous intrusions that formed the dolerite. Due to their favourable characteristics for knapping, such outcrops were commonly sought after as sources of raw material during the Stone Age. Heavily patinated artefacts surround this outcrop – including diagnostic MSA pieces like those found within the dongas – and testify to some exploitation of hornfels from this locality, though large parts of the exposure and other outcrops might still be covered by sediments today.

*Archaeological fieldwork and preliminary results*

Figure 4 shows the survey trails of the two archaeological teams exploring different areas of the donga sediments. In total, the foot surveys covered a distance of 41 km over an area of ~3.5 km². The UAV survey provided high-resolution photogrammetry (up to 1 cm resolution) over the ca. 1 km² of the main study area. Our foot surveys provide important insights into the nature and distribution of archaeological material in the erosional landscape. Discovered artefacts comprised lithics exclusively that were encountered in all parts of the survey area, but with variable frequency and clustering. The southwestern (main study area) and northern parts of the dongas revealed a marked surface spread of stone artefacts within the deeply incised gullies and on interfluve ridges consisting of intact soil-covered terraces. Here, the material can be described as a nearly contiguous scatter of stone tools of various sizes intermixed with (angular) hornfels blocks, sometimes forming pavements of stone flakes several layers deep (Fig. 5). We estimate the number of stone tools >2 cm to go into the millions. Most material is concentrated on a lag deposit on the floor of the erosional gullies with much less archaeological material visible on the profile walls. In contrast, longer reaches to the northeast and east were devoid of material, even in the gullies. The surveys and results are thus most detailed for the southwestern part and coarser for the other areas.

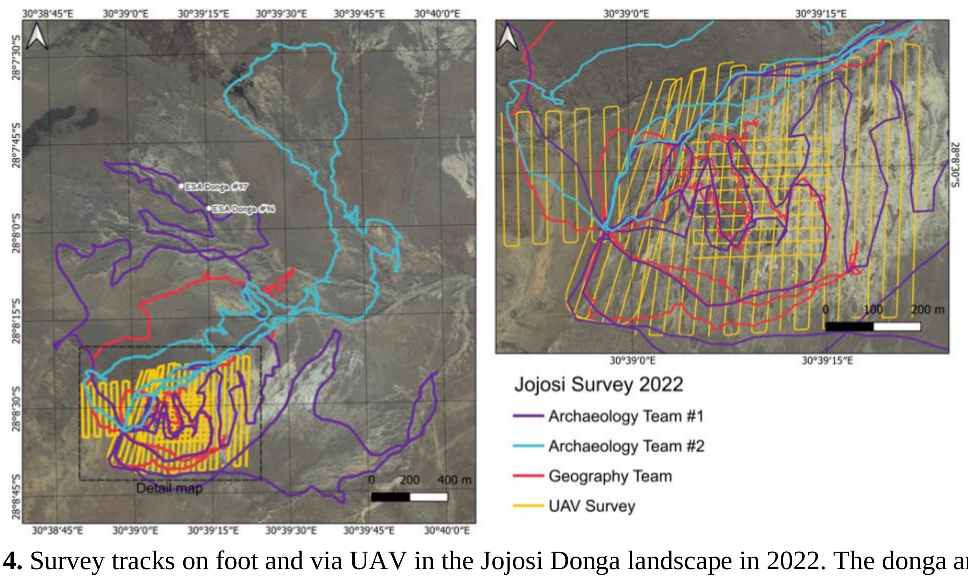


**Figure 4.** Survey tracks on foot and via UAV in the Jojosi Donga landscape in 2022. The donga area with frequent ESA material in the northern part of the survey area is marked by two dots. The detail map in the southwest shows the main study area of the dongas, where most sites of interest occur (shown in Figure 2).

Regarding the nature of the surface archaeological material, almost all artefacts (>99%) are made from hornfels, which is surprising considering the extensive dolerite outcrop just north of the dongas (Fig. 2). Fresh hornfels features grey, dark-grey and blue-blackish varieties with sharp edges. However, the majority of lithics display post-depositional alteration, with visibly varying stages of surface patination from prolonged exposure to the elements, including ferruginous varnish and light-grey to reddish discoloration (Fig. 5). Artefacts in the gullies with heavy patination display blunted edges and abraded dorsal ridges, but little edge chipping. Hornfels artefacts actively eroding from the donga profiles often feature sharp edges and little to no abrasion. Other encountered raw materials for stone tools include dolerite and rare chert, quartzite and quartz. Well-rounded pebbles or cobbles of quartzite occur sporadically and could represent manuports derived from areas of Dwyka tillite that are exposed several kilometres downstream in the Jojosi Valley. The find-rich areas are most strongly associated with hornfels whereas zones with fewer stone tools to the north and east feature other materials such as quartzite.

Based on a typo-technological reading in the field, the most commonly identifiable artefacts belong to the MSA which can be found almost anywhere in the landscape we surveyed (Fig. 4). We studied a few square metres of two high-density surface concentrations in the main area (GPS points #101 and #103; see Fig. 2) to get a better understanding of their technology (Fig. 5). Here, debitage products including both faceted flakes and blades represent the most frequent find category. They commonly preserve large amounts of cortex and include rejuvenation and preparation products such as core tablets. The blanks are often large, featuring many blades up to 100 mm as a conspicuous element (Fig. 6a). Various types of *Levallois* and platform cores, with prepared platforms for the production of flakes and blades, occur (Fig. 6d). Platform variants (n=22) are more frequent compared to *Levallois* (n=15) and occurred at both localities. Blade platform cores (n=12) outnumber those for flakes (n=10). Reduction usually proceeds unidirectionally on one main removal surface, but bifacial and bidirectional reduction occurs as well. Many cores are large (>100 mm) and discarded in a prepared but non-exhausted state. If present, retouched forms are rare (<1%) including unifacial points (n=3), scrapers (n=1), and laterally retouched blades (n=1; Fig. 6b). The surface material of these selected areas is typical for the main donga, but its nature precludes attribution to specific technocomplexes at this stage of analysis. Bifacial points or backed pieces are missing, suggesting an absence of the Still Bay and Howiesons Poort.

In contrast to the widespread MSA, ESA tools appear rarely and are concentrated in specific areas to the north (see below). While lithic scatters with mostly large flakes devoid of diagnostic core types could be attributed to a macrolithic LSA, the large number of sites exhibiting a clear MSA signal renders this possibility unlikely. We found no obvious LSA record apart from very rare microliths of chert or quartz closer to the river, fitting with the absence of any built structures, pottery, or metal artefacts encountered during our surveys. All in all, the Jojosi landscape is very rich in lithics of the Stone Age, but they reflect particular spatial and temporal patterns.

Based on the ubiquity and density of archaeological material, we decided not to map all individual stone tools or surface concentrations – which would be practically impossible – but focused instead on recording the much rarer material embedded in sediments and specific surface concentrations. Due to the complexity and size of the terrain, we do not claim comprehensiveness for these identifications. Our results showcase the scientific potential of this landscape and the nature of its archaeological occurrences. Moreover, the landscape remains dynamic with ongoing erosion in the area leading to the destruction of *in situ* material in the next decades, while at the same time uncovering evidence of currently invisible find concentrations. In total, our survey documented 22 occurrences (sites) with GPS points, photographs, and additional data recorded in the KoBo Toolbox. Of these sites, n=11 were identified as having stratified material with surface scatters eroding out from these profiles, n=4 as having stratified material without any actively eroding material, n=5 as having interesting surface scatters with special finds, and n=2 as Other. The interesting surface concentrations feature scarce agglomerations of ESA material or fresh hornfels MSA artefacts associated with high amounts of small debitage, indicating on-site knapping and recent erosion from their primary context.

**Figure 5.** Typical high-density scatters of stone tools encountered during the 2022 survey, within the Jojosi main study area, with the majority of material belonging either to the MSA or being undiagnostic (top). MSA surface concentration #101 with high density of material and fresh hornfels artefacts (bottom).

Stratified archaeological material was commonly identified as a thin stone line visible within the sedimentary profile. From visual inspection, we differentiated between three such occurrences embedded in palaeosols or parent sediments (Fig. 7): 1) *in situ* concentration of artefacts; 2) concentration of stone tools from secondary context; and 3) massive colluvium or lag deposits with accumulation of both artefacts and raw material blocks. Figures 7a and 7b show two of the potential *in situ* concentrations. In the field, we identified them based on the occurrence of a thin lens of exclusively hornfels artefacts including small debitage with fresh edges and grey colour. In n=11 cases, they are associated with a scatter of non-weathered artefacts eroding from right under this horizon, spreading from the steep sidewall until the gully floor. Secondary concentrations had a similar constricted horizontal and vertical appearance within the sedimentary profiles but included weathered hornfels finds, no small debitage and some non-artefactual material, likely deriving from the colluvium substrate

(Fig. 7c). We interpreted these localities as being characterised by the secondary deposition of artefacts after prolonged surface exposure. In two localities closer to the river, we noted massive deposits of large hornfels blocks (>30 cm) mingled with stone tools of different preservation stages, along with other pebbles and cobbles that are natural accumulations (Fig. 7d).

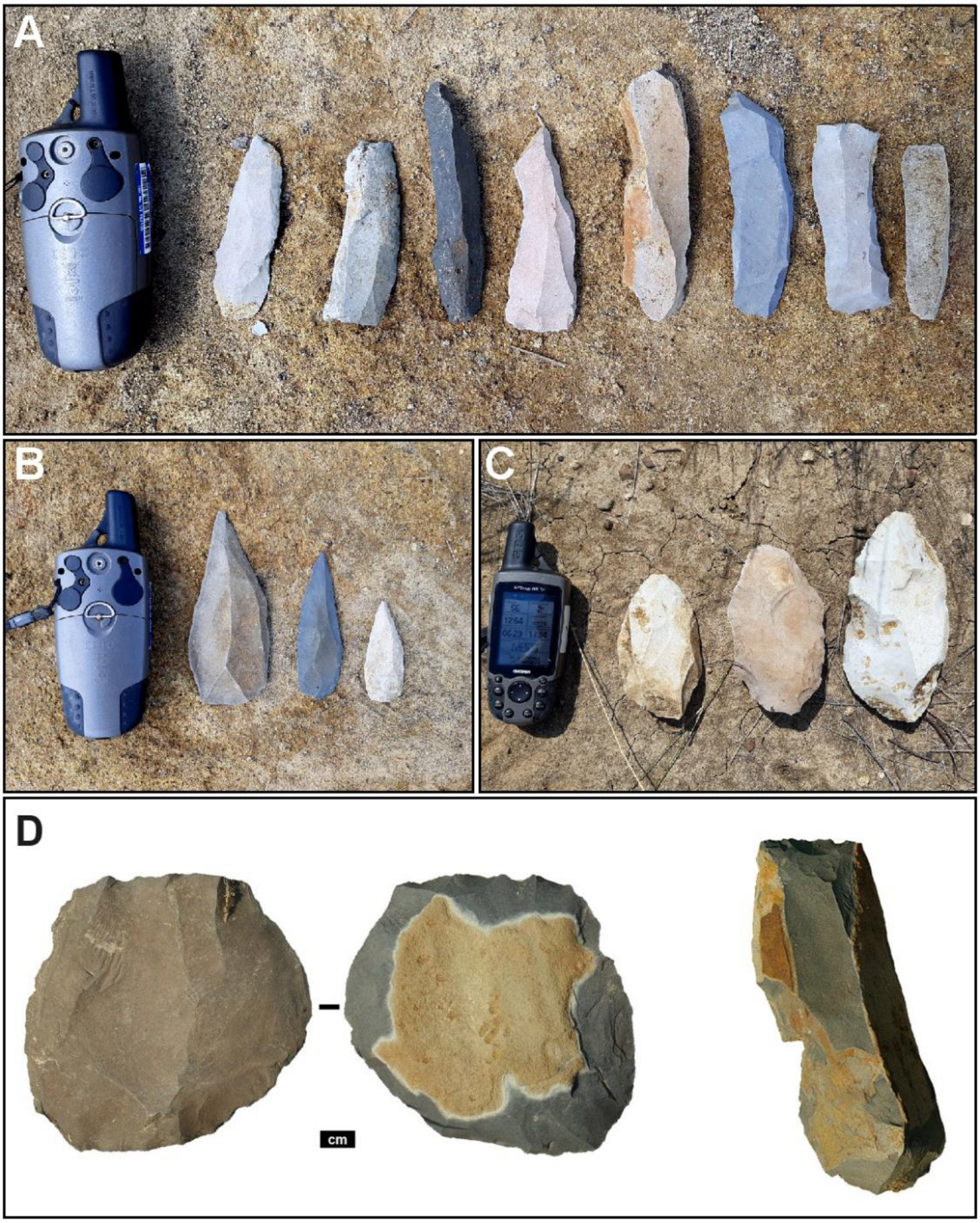


**Figure 6.** Selection of stone tools from the surface of the Jojosi Dongas with a handheld GPS for scale (height 15.5 cm). Large blades (a) and unifacial points (b) selected from MSA concentrations in the main study area. Handaxes from the ESA surface concentration in the northern part of the dongas (c). Large *Levallois* core (left) and unidirectional blade platform core (view of main removal surface) from surface concentrations #101 and #103 in the main study area (d). All artefacts are made on hornfels. Note the different stages of weathering and discoloration between but also within artefacts (e.g., upper surface of *Levallois* core with patination, lower surface without).


**Figure 7.** Selection of the three different kinds of material embedded in donga walls during surveys. Potential *in situ* MSA stone lens embedded in a typical primary donga wall (a), with freshly eroding artefacts visible in a close-up view (b). Note the tight cluster of artefacts on top of each other, with a thickness of a few centimetres, the grey colour and fresh edges of the hornfels, and the presence of small debitage. In 2023, this area was named Jojosi 6 and was partly excavated. Secondary stratified MSA hornfels artefacts within the topsoil (c). Note the occurrence of larger and small artefacts, but with the white discoloration of the hornfels. About 1 m thick, massive sheetwash or debris flow of large hornfels blocks and artefacts in the lower part of the donga close to the Jojosi River (d). Handheld GPS as a scale in the lower middle of the picture.

Some individual localities deserve further attention. In the northern part of the donga (purple survey path in Figure 4), find concentrations were generally high with similar carpets of surface MSA lithics compared to the main study area – though with much less stratified material and mostly in a secondary context. One of the dongas in this northern part, however, yielded the largest amount of ESA artefacts including numerous handaxes (Fig. 4). The handaxes are large and thick, mostly on hornfels, and intensively flaked on both sides, producing a variety of forms (Fig. 6c). Inspections of surface material found few picks and no cleavers. Our overall qualitative impression is one of a later Acheulean occurrence. Artefacts in this donga feature much less obvious MSA material and include large flakes (>80 mm) and cores without signs of preparation. While hornfels is still the most frequent rock type, other varieties such as quartzite appear in larger numbers. This northern part likely encompasses much older material and sediment when compared with the southwestern area. So far, we were not able to discern *in situ* concentrations of ESA material in the colluvial sediments, but additional target surveys are planned to understand the Acheulean occupation of this area. The northeastern part of the survey (blue survey path in Figure 4) yielded much less Stone Age material and only a few stratified MSA occurrences, exclusively from secondary context.

Fitting with the general distribution of archaeological surface material, the most interesting stratified occurrences were discovered in the southwestern donga (Figs 3 & 4). We used these findings to demarcate our main study area for the future, providing the basis for the first excavation campaign that took place over three weeks in 2023. It is also the area where initial excavations took place, by Aron Mazel in the 1990s (Jojosi 1-4). Here, MSA material is most abundant, often forming surface pavements in its western and most heavily eroded parts with a reduction in material to the east associated with less intense gullying and a more frequent formation of calcrete crusts. We found n=8 potential *in situ* occurrences of MSA hornfels artefacts in the main area, of which we classified n=3 as a prime target for excavation and another n=3 as high potential. This assessment was based on the clarity of the artefact lenses in the gully walls, the presence of small debitage, and an abundance of non-weathered artefacts in the gully directly below. These instances also feature artefacts eroding from the profiles, marking them as urgent objectives for recovery. We found such lenses clustered in two areas approximately 100 m apart. In one zone, we observed an extremely rich surface concentration of hundreds of fresh MSA hornfels artefacts directly associated with embedded material from which these stone tools were actively eroding (Fig. 8). In the field, one of the co-authors (G.A. Botha) confirmed that this feature was already identified by him during earlier surveys in the 1990s. Photographic evidence (Fig. 8b) demonstrates that these are in fact the same concentrations and that the stratified material has only eroded by a couple of centimetres in the last 30 years. This concentration and the stratified artefacts next to it were ranked as having the highest potential for recovering *in situ* material.


**Figure 8.** View of archaeological site Jojosi 5 during the 2022 survey. View of the dense surface concentration of actively eroding MSA hornfels artefacts, with fresh edges and grey colour (a). The artefacts erode out of the potential *in situ* lens indicated by a red oval. Photo taken by G.A. Botha during the early 1990s, taken ca. 30 years before the picture to the left, from a slightly different angle (b). Note the same stratified lens of hornfels artefacts in the top right corner (red oval) but with more of the sedimentary overburden still present. Close-up view of the potential *in situ* lens of MSA stone tools (c). Note the tight cluster of artefacts on top of each other, with a thickness of a few centimetres, the grey colour and fresh edges of the hornfels, and the presence of small debitage.

In April 2023, we collected this entire surface scatter (total n=8610; n=5250 pieces <20 mm) at this site, which we named Jojosi 5, and dug the stratified artefacts across ca. 2 m² with a sediment volume of 0.53 m³ (Fig. 9). After removal of the sterile overburden, archaeological material was encountered in two tightly constrained clusters of artefacts. While detailed studies are pending, Table 1 provides an overview of the surface collection and the measured, stratified finds >20 mm (n=246). Apart from three fragments of fossilised bone and teeth, the recovered material features exclusively stone tools indicative of MSA technology, comparable to the studied surface scatters. Like the unstratified lithics, unretouched blanks are most frequent, and small debitage (<2 cm) occurs in large amounts while tools are lacking. Site Jojosi 6 comprises a similar profile concentration noted only ~20 m northwest of this occurrence and likewise freshly eroding (Fig. 8a & 8b). To recover this material before being lost due to natural gully sidewall erosion, this area was targeted for the second excavation in 2023, although we could not finish the recovery of the entire artefact lens in that year. The material recovered from these trenches is currently being analysed and is the subject of a future publication.

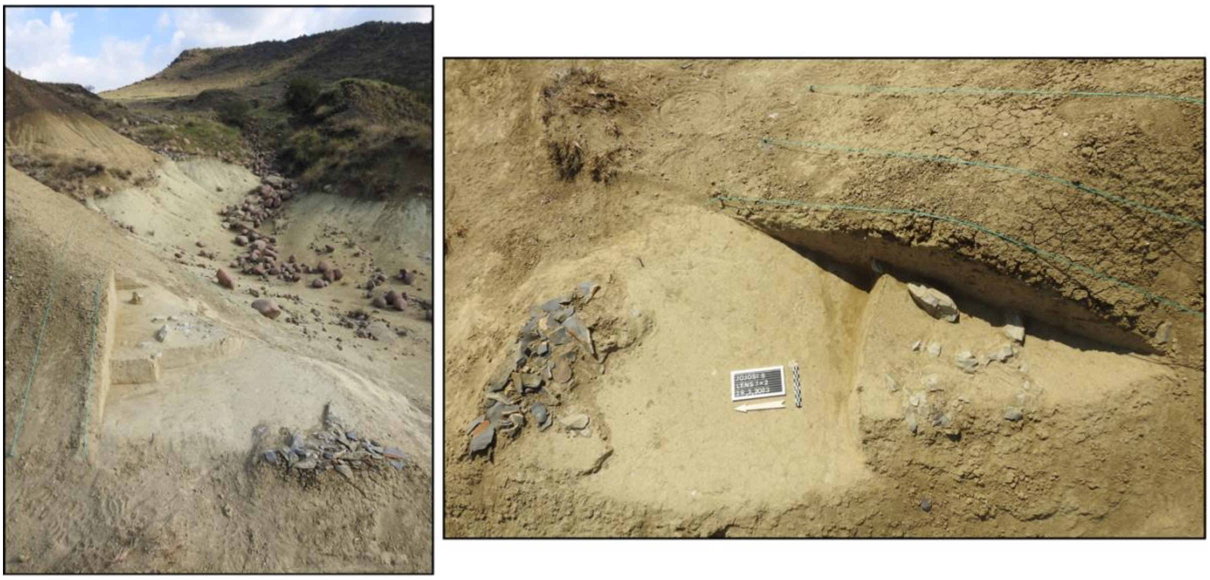

**Figure 9.** The Jojosi 5 excavation in March 2023 after removal of sediment overburden and with lithics left in place as encountered. Note the tight clustering of finds in two separate areas (lenses) and the exclusive presence of hornfels stone tools. Scale bar on right picture is 10 cm. No artefacts were found further to the east in the sediments.

**Table 1.** Archaeological material recovered from Jojosi 5, with surface finds derived from a systematic collection (see Fig. 8c). Excavated material recovered from stratified context in 2023 (Fig. 9) includes pieces measured in the field >20 mm as well as debitage <20 mm. Numbers are provisional, pending detailed analyses.

| Find category | Surface (n) | Excavation (n) |
|---|---|---|
| Blank | 2794 | 237 |
| Core | 14 | 4 |
| Tool | 3 | - |
| Hammerstone/manuport | - | 2 |
| Small debitage <20 mm | 5250 | 2093 |
| Bone/tooth | - | 3 |

*Other work*

The 2022 and 2023 campaigns also included an attempt to locate the old excavations of Jojosi 1 by A. Mazel, in addition to obtaining sediment samples for absolute dating, and conducting geographical work. G.H.D. Möller conducted a thorough study of the field notes and photographic documentation (Mazel 1991) to re-establish the location of Jojosi 1, so it could be dated via luminescence methods. These endeavours were supported by aerial reconnaissance with UAVs and a 3D terrain model with an early working version without full contextual information that can be accessed here (https://skfb.ly/oyTSW). Combining these efforts led to the successful relocation of Jojosi 1 in 2023. The lithic material, curated at the KZN Museum in Pietermaritzburg, was then assessed in a Masters Dissertation to revalorise these legacy collections. A qualitative and quantitative attribute analysis and refitting study aimed to understand the integrity of these assemblages and the techno-typological characteristics and underlying processes leading to their formation. The results provide initial insights into MSA landscape use and serve as a reference for further studies to be conducted on the newly excavated archaeological material. Due to their different focus and scale, the results will be published separately.

Our approach to establish geochronological control for the exposed donga sediments focuses on the dual objective of: 1) understanding the age and formation of the complex accretionary sedimentary succession that comprises at least five phases of gully incision and infill; and 2) situating the human occupations therein. We thus initiated comprehensive sediment sampling in various areas of the main study area for dating via luminescence methods. In 2022 and 2023, we took 26 sediment samples for luminescence dating at five locations within the Jojosi Donga catchment. Luminescence samples were either taken in opaque metal tubes or carved out as blocks, with the outer light-exposed material being removed under subdued red light conditions following sampling in the field. We took a series of luminescence samples in the sediment profiles from below, next to, and above the MSA material at Jojosi 1 (n=3) and Jojosi 5 (n=7). At Jojosi 6 (n=2) we bracketed the artefact lens with one sample above and below. Geomorphological samples were collected at two sites: 1) the cut-and-fill profile where four phases of palaeo-gully erosion and infill are exposed (n=5); and 2) a site that displays buried palaeosols within the hillslope deposits (n=8) (Fig. 2). This will allow us to constrain the ages of human activities as finely as possible but also, to understand the processes and rate of sediment accumulation. We also took a modern sample to investigate resetting of the luminescence signal during recent erosional events. This will inform us of the scatter expected in the single-grain luminescence data of the palaeosamples. The OSL dating is being conducted at the Cologne Luminescence Laboratory (CLL) by S. Riedesel. Analyses are currently ongoing and will be published alongside the excavated material. Initial tests demonstrate that the colluvial sediments can be dated using the infrared stimulated luminescence (IRSL) signal of feldspar minerals. Preliminary results support the initial attribution of the recovered stone tools at the excavated sites to the MSA, by constraining the human occupations to the late Middle and earlier Late Pleistocene.

To put Jojosi into a regional geological perspective, we investigated the forms and processes of modern donga erosion in an extended area of around 220 km² north of Nquthu. We used this extended area for our regional inventory and mapped more than 250 dongas and donga systems using current satellite imagery. We then manually categorised them following the six donga types introduced by Ireland et al. (1939). Within this extended study area, compound types are the most prominent with around 50% of the identified dongas consisting of more than one type. Around a quarter of the dongas are classified as dendritic, showing a pattern of several branching tributaries. When looking further at the compound class, the prominent type within compound dongas is again dendritic. In addition to type, we recorded donga activity. Orthophotos were compiled from georectified aerial photographs from 1944, 1956, 1981, and 2005, and current satellite imagery enables evaluating the landscape erosion over 80 years with time intervals of roughly two decades. The vast majority of the localised dongas are assumed to have been active since the first imagery from the 1944 flight campaign. These dongas show visible extension of their area and partial deepening (Fig. 10). Around 30 dongas and donga systems seem to have mainly stabilised within that period as indicated by a lack of gully growth and the presence of stabilising vegetation on previously bare, eroded areas. However, the formation of new dongas is also identifiable. We observed that their formation is likely linked to nearby road construction, with donga growth close to the roads, caused by runoff discharged by drainage pipes under the roads with the new gully expanding at a right angle, or following the course of former foot and cattle paths.

## 4. Discussion and conclusion

The Stone Age record of southern Africa remains best known from rock shelter and cave sites, despite the established importance of open landscapes for people with a hunter-gatherer lifestyle. Recent research efforts in the Western Cape, Northern Cape, and Free State underscore the importance and feasibility of open-air work (Sampson et al. 2015; Hallinan & Parkington 2017; Mackay et al. 2018; Shaw et al. 2019; Ecker et al. 2021; Hallinan 2022; Wroth et al. 2022; Bousman et al. 2023a, b). Until today, however, no comparable studies have been undertaken in KZN. Yet, the archaeological literature of the last 140 years, museum databases, and curated collections all testify to the presence and early recognition of open-air Stone Age material in the region (Feilden 1884; Lebzelter 1930; van Riet Lowe 1947; Malan 1948; Davies 1949, 1951). This previous work led us towards the dongas of central KZN. From a geographical and geological perspective, dongas have been well-studied and remain a focus of current research. Early collaboration of geologists (G.A. Botha) and archaeologists (A. Mazel) demonstrated the potential of one particular donga landscape in the Jojosi Valley, though the results were never published. The new interdisciplinary project in the Jojosi Dongas near Nquthu, introduced here, has the potential to provide unique information on the spatial patterning of the Stone Age record in KZN, facilitating a landscape-scale assessment of human behaviour. Starting with a renewed aerial and foot survey at Jojosi, we could confirm the wide extent of this specific land formation and its high archaeological potential. The land surface features ample traces of human occupation during the ESA and MSA, although not the LSA, as well as stratified MSA material in the donga profiles at about a dozen sites.

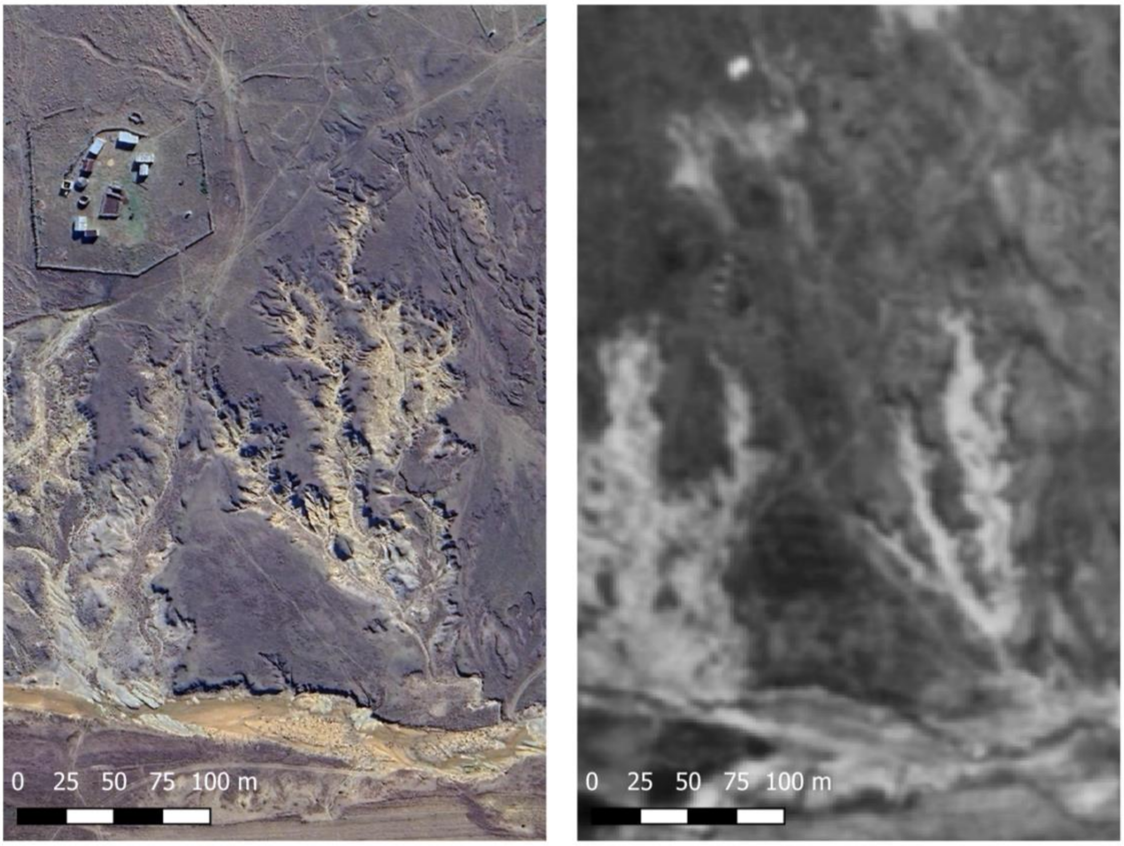


**Figure 10.** Extension of a dendritic donga at Magongoloza River identified from recent satellite imagery (left) (Google Maps/Airbus/Maxar) and a historical orthophoto from 1944 (right) (National Geo-spatial Information [NGI]).

*Stone Age landscapes at Jojosi: spatial patterns and behavioural interpretations*

The preliminary results here allow us to provide some summary statements on the surface archaeology and have further stimulated some initial hypotheses on spatial patterns, human behaviour and site use. Analyses of the excavated MSA material and the re-examination of Jojosi 1 will allow us to test these working hypotheses. The Jojosi Dongas comprise a dynamic landscape with complex archaeological signatures from multiple periods of occupation. As such, they provide rare insights into landscape-scale variation in hominin behaviour. We noted a non-uniform distribution of surface material throughout the erosional landscape. Although MSA material is by far the most widely spread throughout the landscape, concentrations vary and in some cases are completely absent, while other areas yield a strong ESA signal. The MSA signal is strongest near the known outcrop of hornfels and south of the Jojosi River, whereas the ESA material appears some distance from this source and the river (Figs 2 & 4). Individual surface concentrations of fresh MSA material appear variable in constitution and technology. Rare LSA lithics were found closest to the current river. Understanding what drives this intra-landscape structure will be important when research proceeds on a larger scale. Potential causes behind these patterns may relate to diachronic differences and site use, but also the complex formation processes of the landscape and potential environmental change. As emphasised throughout this article, understanding the archaeology and behaviours at these sites requires an in-depth understanding of the overall landscape geomorphology but also, of site-specific contexts concerning sedimentary accretion and intact burial processes for the material embedded in sediments. The accretionary sedimentary succession accumulated through periodic gully incision, followed by sedimentary infill by sediment eroded from upslope. The fact that this landscape was unstable for long periods may at times have been an impediment to human occupations, although this was likely outbalanced by its attractive source of hornfels and the availability of perennial water.

MSA stone tools predominate the dongas and particularly our main study area. Yet, the material deviates in some important aspects from the well-known MSA archaeology of KZN sites, such as Sibhudu, Border Cave, Umbeli Belli, and Umhlatuzana (e.g., Will et al. 2014; Bader et al. 2015; Bader et. al. 2018; Sifogeorgaki et al. 2020; Backwell et al. 2022). Most conspicuously, the surface material differs from these sheltered sites in the almost exclusive use of hornfels, along with artefacts being predominated by debitage products. These artefacts are often large, include numerous long blades, and bear large proportions of cortex. In contrast to sheltered sites, cores feature more frequently at Jojosi whereas retouched pieces are rare. Modification is predominantly minimal, with the most identifiable pieces being unifacial points. All these characteristics render attributions to specific technocomplexes (Lombard et al. 2012, 2022) difficult. We did not observe any backed pieces or bifacial points attributable to the Howiesons Poort and Still Bay. An absence of these technocomplexes was also noted in the open-air sites of the Free State (e.g., Wroth et al. 2022), whereas the Western Cape sites generally lack Howiesons Poort but feature Still Bay occupations (Kandel & Conard 2012; Mackay 2016; Hallinan & Parkington 2017; Shaw et al. 2019).

Why are the assemblages so different from the known record of rock shelter and cave sites in KZN? Do they offer unique insights on human behaviour only available from an open-air setting? We propose three hypotheses: 1) temporal: Jojosi features MSA occupations that date to a different period – likely earlier – than the record in sheltered sites, which is mostly known from the Late Pleistocene; 2) ecological and spatial: the area around Jojosi is far removed from known sites to the north and south and is located in a different biome, with a so-far unknown archaeological signal and/or inciting different behavioural adaptations; and 3) functional: the site use of Jojosi differs from known sheltered sites based on its specific location in the wider landscape and the association with large outcrops of hornfels. While not mutually exclusive, these interpretations are closely connected to the question of the natural and cultural factors that led humans to choose this particular place on the landscape repeatedly (see e.g., Tryon et al. 2014 for the eastern African MSA). We currently favour a functional interpretation for Jojosi based on the large amounts of primary high-quality hornfels in the area and the nature of the archaeological material. Accordingly, the Jojosi landscape would reflect a specialised MSA quarry or provisioning site for acquiring hornfels. We would thus expect the stratified artefact concentrations to correspond to *in situ* knapping spots or workshops of MSA people reducing large blocks of hornfels found in the landscape or made accessible by erosion. This can be tested via dedicated refitting studies. Additional studies will need to test in what ways the temporal, geographical, and ecological factors influenced site occupation and assemblage composition.

*The Jojosi Dongas in context: site integrity and regional comparisons*
In addition to the ubiquitous surface archaeology at Jojosi, we also encountered multiple concentrations of stone tools within the sediment bodies. Are these stratified MSA occurrences time-averaged palimpsests due to complex post-depositional processes, or do they represent *in situ* short-term and contemporaneous activities in discrete zones (i.e., living floors; see e.g., Bailey 2007; Malinsky-Buller et al. 2011)? Our work supports previous observations by Mazel that these assemblages occur in narrow

lenses within the sediment body and encompass artefacts of all sizes down to a millimetre. The sediment units hosting the archaeological finds are stratified layers of sandy clay-loam texture, suggesting steady and uninterrupted accretion under a low-energy sheetwash sediment transport environment. Occasional lenses of loamy sand with a thickness of <5 cm elsewhere in the unit indicate a low degree of sorting by flowing water. We currently interpret the formation of this sediment unit surrounding the artefact lens as a series of palaeo-donga infill deposits that accumulated during a transitional phase leading to periods of relative landscape stability. Such a scenario allows for a high resolution and integrity of buried MSA knapping floors that fits with initial observations on the excavated lithic assemblages. We aim to test these hypotheses based on complete analytical data from Jojosi 1, 5 and 6, for the latter two also including recorded 3D data on the dips and inclinations of artefacts.

How do these initial observations of MSA open-air surface archaeology at Jojosi compare with recent findings in other areas of South Africa? While a complete assessment will have to wait for the detailed lithic, geological and geochronological data, we note both similarities and important differences. The large-scale study of human activities along the alluvial river terraces of the Doring River in the Western Cape found numerous spatio-temporally constrained open-air occupations of the MSA and LSA in proximity to freshwater and raw material sources (Mackay 2018; Shaw et al. 2019). In contrast to the surface finds of Jojosi, the Doring River sites feature large numbers of retouched elements and diagnostic pieces from technocomplexes such as the Still Bay and later phases of the MSA and LSA, reflecting repeated occupations and multiple activities in fluvial settings rich in diverse rock types. The findings from the Lovedale Donga in the Free State, albeit located in a comparable geomorphological setting of stratified deposits exposed in erosional gullies, differ in yet another aspect. Excavations here found typologically distinct implements from chrono-cultural stages post-dating MIS 5, with MSA humans using these sites for task-specific occupations such as hunting stations in open-air, fluvial wetland environments (Wroth et al. 2022). Being of a potentially similar site function as Jojosi, Swartkop Hill in the Namaqualand region (van der Ryst & Küsel 2013) constitutes a rare case study assessing the distinct technological characteristics of MSA quarrying activities. The site features broadly comparable traces of primary raw material reduction to Jojosi, but the lithic assemblages represent (secondary) artefact scatters of prolonged surface exposure that are loosely associated with later phases of the MSA based on typological comparisons. These assemblages also come from different, highly variable lithological zones around a landmark hill feature that attracted repeated visits. For now, our initial work suggests that the MSA lithic material of Jojosi is marked by a unique combination of archaeological and geological characteristics that complement the composition of its lithic assemblages, likely related to a specialised site function of raw material quarrying and primary processing. A comparison with well-known quarry sites of similar ages in other areas of Africa, such as for chert in Egypt (e.g., van Peer et al. 2010), will provide additional avenues for understanding Jojosi.

*Future work in the Jojosi Dongas*

Many questions remain about landscape formation, the archaeological record, and human behaviour in the Jojosi Dongas. Much of this work is ongoing or planned for the coming years. Additional excavation is required to better grasp the nature of the archaeological record but also its intra-landscape structure. Key areas for excavation concern the stratified MSA artefacts and associated surface concentrations spotted close to Jojosi 5 and 6. Detailed assessments of the recovered lithics will be based on quantitative attributes but also techno-typological, refitting, and use-wear studies. These analyses will be crucial to reconstruct MSA technological behaviours and verify site functions based on the nature, composition, and use of the assemblages (e.g., for comparison see van Peer et al. 2010; Ekshtain et al. 2012; Bisson et al. 2014; Gopher & Barkai 2014). Through refitting we can also support the integrity of some of our identified surface concentrations and establish direct connections between stratified material and recently eroded artefacts on the surface (e.g., Foley et al. 2017). In addition, we intend to explore the reasons for the potential absence of LSA material while also assessing the present ESA record with additional surveys in the parts of the dongas with abundant handaxes, to try to locate *in situ* material. If successful, this would render Jojosi the first stratified ESA site in the KZN province. Here we note an interesting parallel to ESA quarry sites for hornfels in the Karoo (Sampson et al. 2015) and the site of Smaldeel 3, in the flood basin of the Gariep Dam, which Sampson (2006) describes as an

Acheulean hornfels quarry where large blanks were produced but mostly lacked handaxes or even preforms.

In terms of methodology, we plan to add further geoscientific methods to the area (e.g., soil geochemistry, near-infrared soil spectroscopy) and compare the timing of gullied landscape formation and sediment accretion to other dongas in the area (e.g., the reference profile at St. Pauls). A study of recent donga erosion using an inventory of donga types will complement the assessment of landscape activity derived from remote sensing sources. The assessment of erosion rates from UAV-based structure-from-motion can help to understand both past changes but also ongoing erosion that impacts the quality of landscapes and traditional land-use dynamics with regards to changes in soil quality, farmland, and pasture (Le Roux et al. 2020; Olivier et al. 2023). Another relevant aspect of future work will lie in the sourcing and geochemical tracing of hornfels in the study area, both of natural outcrops and artefacts (for South Africa see, e.g., Jarvis 2000; Sampson 2006; Sifogeorgaki et al. 2023), to understand patterns of raw material transport and circulation in KZN more generally.

On a more theoretical level, we intend to embed the findings into the perspective of the potential long-term effects of Pleistocene human niche construction. Here we will focus on the effects on local landscapes, resource distributions, and behavioural trajectories (Boivin et al. 2016; Hussain & Will 2021; Roebroeks et al. 2021; Thompson et al. 2021; Stock et al. 2023). The Jojosi Dongas will be an excellent case study for such ideas as it provides evidence of a constructed lithic landscape (see Foley & Lahr 2015; Pope 2017) whose appearance and structure have been strongly modified by human agency. Repeated human visits and material input over time led to the re-distribution of raw material from natural outcrops into the landscape, likely entrenching this area in a wider settlement system (Haas & Kuhn 2019; Hussain & Will 2021). The Jojosi Dongas can provide an ideal testing ground for the application of interdisciplinary methods and theories to answer questions about behavioural adaptations and the material culture of early modern humans in the framework of changing landscapes in understudied open-air contexts in southern Africa.

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**Supplementary online material**
Will et al. Supplementary Online Material File 1

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