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Distribution, architectural design and functionality of megalithic structures of the Lake Eyasi Basin in northern Tanzania

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ABSTRACT
We examined megalithic structures in the Lake Eyasi Basin of northern Tanzania to establish the provenance of the construction materials, understand the reasons for the use of particular raw material options and means of transport, as well as to identify the group or groups of people associated with their creation. The findings suggest that the megalithic culture in the Lake Eyasi Basin reflects ancient cultural advancements, ingenuity, craftsmanship, and spiritual significance. These megaliths, which appear in the form of dolmens, stone circles, or burial cairns, serve as enduring markers of bygone eras. They leave an unforgettable imprint on the landscape and our understanding of human history by cultivating a sense of curiosity about the societies that erected them. Therefore, the megaliths in the basin serve as tangible evidence of the builders' technical capabilities while also providing insight into their social organisation, daily practices, and belief systems. However, the precise purpose behind their construction, whether spiritual, astronomical, or commemorative, and the people who constructed them, continue to be a subject of scholarly debate and exploration.

ABSTRACT IN SWAHILI
Tulitafiti miundo ya megalithiki katika Bonde la Ziwa Eyasi kaskazini mwa Tanzania ili kubaini asili ya mawe yaliyotumika katika ujenzi wake, kuelewa sababu za kuchagua mawe na mbinu za usafirishaji, pamoja na kutambua kundi au makundi ya watu waliohusika katika ujenzi wake. Matokeo yanaonyesha kuwa utamaduni wa megalithiki katika Bonde la Ziwa Eyasi ni ushahidi wa maendeleo ya kale ya kitamaduni, ubunifu, ustadi wa ufundi, na umuhimu wa kiimani. Megalithi hizi zipo za aina mbalimbali kama vile dolmeni, miduara ya mawe au mafuvu ya mazishi, na huonesha kutumika kama alama za kudumu za nyakati zilizopita. Huacha athari isiyofutika katika mandhari na katika uelewa wetu wa historia ya binadamu kwa kuchochea hisia ya udadisi kuhusu jamii zilizozijenga. Hivyo basi, ni dhahiri kwamba megalithiki katika bonde hili zinaonesha ujuzi wa hali ya juu wa uhandisi na kutoa mwanga juu ya vipengele vya kitamaduni, kijamii, na huenda vya kidini vya jamii zilizozijenga. Hata hivyo, madhumuni kamili ya ujenzi wake iwe ya kiroho, ya kiastronomia, au ya kumbukumbu pamoja na watu waliojenga, bado ni mada inayoendelea kujadiliwa na kuchunguzwa kitaaluma.

Keywords: Lake Eyasi Basin, megalithic structures, pastoral Neolithic, Iron Age, megalithic builders

1. Background of the study

The word 'megalith' comes from the combination of two Greek words, whereby *megas* refers to big and *lithos* means a stone or rock (Darvill 2010; Maritsas 2015). Therefore, megaliths refer to structures made of big stones (Laporte et al. 2012; Grillo & Hildebrand 2013; Holl 2021), and according to Maritsas (2015), megaliths are categorised into two types, namely: over-ground structures (i.e., menhirs and alleys of menhirs, cairns, certain henges, cromlechs and dome tombs) and surface or under-ground structures (i.e., tombs including dolmens). These structures are distributed across multiple regions, including Africa, Europe, Asia, the Americas, and Australia. While some scholars have proposed the Sahara and parts of central Africa as early centres of megalithic traditions, the origins and pathways of

their wider dissemination remain debated and are not yet conclusively established (Darvill 2010; Krzemińska et al. 2018; Monaco et al. 2020).

In Europe, the megaliths generally date to the Neolithic period between 5000 and 3000 BC. Their distribution is widespread, particularly along Atlantic and western European regions, with marked regional variability. Evidence suggests megaliths appeared in France around 4500 BC, in the British Isles by 3700 BC, and in Scandinavia by 3600 BC. Neolithic megalithic tombs are documented along the Atlantic coast and extend from the Mediterranean to Scandinavia, encompassing the British Isles, northern European plains, and parts of southern France and northern Italy (Renfrew 1983; Scarre 1992). Europe has approximately 35 000 megaliths, including stone circles and standing stones. One of the most renowned sites, Stonehenge in England, dates back about 5000 years (Scarre 1992; Darvill 2010). Scholars such as (Renfrew 1983; Darvill 2010; Hoskin 2011; Krzemińska et al. 2018) argue against a single point of origin, proposing instead multiple, independent developments linked to local Neolithic trajectories rather than diffusion from a common source. This timeline places megalith construction in the Neolithic, predating Egyptian pyramids by over a millennium, emphasising local innovation tied to agricultural societies.

Megalithic culture in Africa spans diverse regions, from North Africa to Madagascar and the Sahara, reaching the Horn and East Africa (Wendorf & Schild 1998; Zena et al. 2021). In the Sahara, thousands of megalithic structures, primarily dating to the Middle Holocene, are scattered across the desert. These include burial monuments for animals and humans, with landmarks highlighting the cultural interconnections among early pastoralist communities. The variability in stone structure types, influenced by local materials and time when they were introduced, indicates their multifunctional purposes (Wendorf & Schild 1998; Monaco et al. 2020). The Horn of Africa, encompassing Ethiopia, Eritrea, Djibouti, and Somalia, is particularly notable for its megalithic traditions, with Ethiopia regarded as a central locus of this culture, where numerous stele sites occur across the northern, central, and southern regions, alongside notable dolmens and tumuli at Aksum, North Shewa, South Wollo, and Harer (Teklu 2020; Zena et al. 2021). These megalithic structures suggest permanent settlements strategically located near water, farmland, and defensible highlands (Derara 2009; Zena et al. 2021). In East Africa, prominent megalithic sites are found around Lake Turkana in Kenya, including Aliel, Jarigole, Lokori, Lothagam, and Kalokol (Davies 2013; Hildebrand et al. 2018; Sawchuk et al. 2019). These sites feature monumental pillars made from locally sourced columnar basalt. Interpretations suggest the pillars may have served as astronomical markers reflecting sophisticated cosmological knowledge (Grillo & Hildebrand 2013). The sites also include stone platforms, or cairns, and other features constructed with locally available materials, often linked to mortuary practices, which indicate cooperative social dynamics in early pastoralist communities (Davies 2013; Grillo & Hildebrand 2013). The East African Pastoral Neolithic (ca. 5000-1200 BP) introduced mobile herding economies primarily using cattle, sheep, and goats from northern sources like the Nile Valley and Horn of Africa. Communities practised nomadic pastoralism, relying on livestock, with distinctive pottery and stone tools, while adapting to climatic changes and social complexities (Ambrose 1984; Barthelme 1985).

In Tanzania, the Engaruka archaeological sites showcase extensive stone circles, enclosures, irrigation channels, and dams (Sassoon 1966). The area features stone-lined fields and terraces that reflect a dominant agricultural economy, with sorghum as a key crop. Stone circles are likely cattle pens, reflecting the importance of livestock alongside agriculture in the region (Sassoon 1966; Sutton 1978; Seitsonen 2005). Similarly, in the Lake Eyasi Basin in northern Tanzania, there have been reports of megalithic structures distributed across the landscapes that have no connection with the area's current inhabitants (Kohl-Larsen 1943; Fosbrooke 1950; Mturi 1978; Sutton 1978; Ikeda & Hayama 1982; Melhman 1989). They include burial cairns and mounds similar to the mounds reported from the Ngorongoro Crater, reported by Mturi (1978), and the pastoral Neolithic cairns of Jangwani I & II, reported by Kohl-Larsen (1943). Other monuments in the basin include megalithic walls, dolmens, circled stone structures, and stone terraces. These stone monuments are situated south of the gently sloping Oldean Mountain ranges in Olpiro and Oldogom, while others are found at Endamagha (Barjomajega) in the northeastern part of the lake (Mturi 1978; Sutton 1978; Mwitondi et al. 2021). Thick and moderately long walls characterise these built stone monuments, with an average height of

1.5 m (Mwitondi et al. 2021). The sites in the Lake Eyasi Basin are regarded as an extension of the Engaruka cultural complex (Sutton 1978); however, some structures, like dolmens from Oldogom in the Lake Eyasi Basin, have never been reported at Engaruka, which may indicate different cultural populations at different times (Mwitondi et al. 2021). Accordingly, the study of the megaliths in the Lake Eyasi Basin provides insights into the societies responsible for their construction and the practices that shaped them, through an analysis of their spatial distribution, alignments, and potential cultural significance. Furthermore, a comprehensive examination of the setting of megaliths in the region can contribute to broader discussions on the global phenomenon of megalithic cultures and their significance in human history.

2. Materials and methods

The study was undertaken at Lake Eyasi Basin in Mang'ola, Karatu (northern Tanzania), using a mixed-methods approach (Fig. 1). Geographic Information Systems (GIS) software was used to analyse spatial relationships and distribution patterns of megalithic structures, and to create digital maps (Fig. 1) to visualise site locations, structures, and landscape features, which in turn established typologies and illuminated ancient construction techniques. Rulers and tape measures were used to measure the depth, length and width of structures, which allowed us to accurately document their physical characteristics. Through a qualitative approach, the study employed an interpretive analysis to decipher and contextualise archaeological artefacts, features, structures and sites based on their cultural, symbolic, or ritual significance (Roberts 2016). This approach often relies on in-depth descriptions and theoretical frameworks to understand the meanings and functions of archaeological remains (Guillen 2019). Moreover, the qualitative approach used in this study included contextual analysis that emphasised the analysis of archaeological materials within their spatial, temporal, and cultural contexts (Roberts 2016). This involved considering the associations, relationships, and contexts of artefacts or structures to reconstruct past activities and understand the significance of archaeological contexts. The context analysis helped to understand the choice of stone types used in monument construction, as well as their extraction and construction techniques. These choices were sought to provide insights into the symbolic value attributed to certain stone types, to assess the technical expertise of the builders, and to establish the importance of communal efforts and/or social organisation. The data were collected through archaeological surveys, document reviews, and archive studies. Surface and subsurface surveys revealed the spatial distribution and construction techniques of the megalithic structures, while archaeological archives (i.e., documents generated from previous archaeological projects) provided insights into previous ethnographic research, offering perspectives on local cosmology and cultural attachment to these sites. Together, these methods provided a nuanced understanding of the megalithic culture in Lake Eyasi, showing its setup and shedding light on the social and symbolic dimensions of these ancient societies.

3. Research results

Distribution and setting of the megalithic sites in the Lake Eyasi Basin

The megalithic structures in the Lake Eyasi Basin are predominantly found in the northeastern and northern areas, particularly around the Endamagha and Olpiro villages. The cultural landscape of gentle plains and prominent escarpments significantly influenced their placement and construction techniques. The builders strategically selected sites at foothills or between escarpments, reflecting both cultural and environmental considerations (Mturi 1978; Sutton 1978; Mehlman 1989; Mabulla 2007; Mwitondi et al. 2021). Generally, the basin is characterised by elevated terrains with steep escarpments on the eastern and western sides, shaped by tectonic activity of the East African Rift (Dawson 2008). To the east, the dramatic rise of the Rift Valley escarpment forms a striking boundary, while the Alipi Escarpment to the west ascends sharply from the lake's western shore (Yanda & Madulu 2005). These elevated features, including the volcanic highlands like the Oldeani Mountain and the Ngorongoro Crater to the northeast, create a varied topography that influenced settlement choices. Vegetation cover in the basin is diverse, with lush areas near water sources and sparser vegetation on the plains and escarpments. The presence of water bodies, particularly the complex hydrogeological system supporting groundwater resources, was crucial in determining the locations of these megalithic structures. The availability of water likely played a role in supporting communities, providing a sustainable environment for their cultural practices (Bourel et al. 2021). Thus, the interaction between elevation, vegetation, and water

availability in the Lake Eyasi Basin played a pivotal role in shaping the cultural landscape, guiding the strategic placement of megalithic structures in relation to the natural terrain and resources.

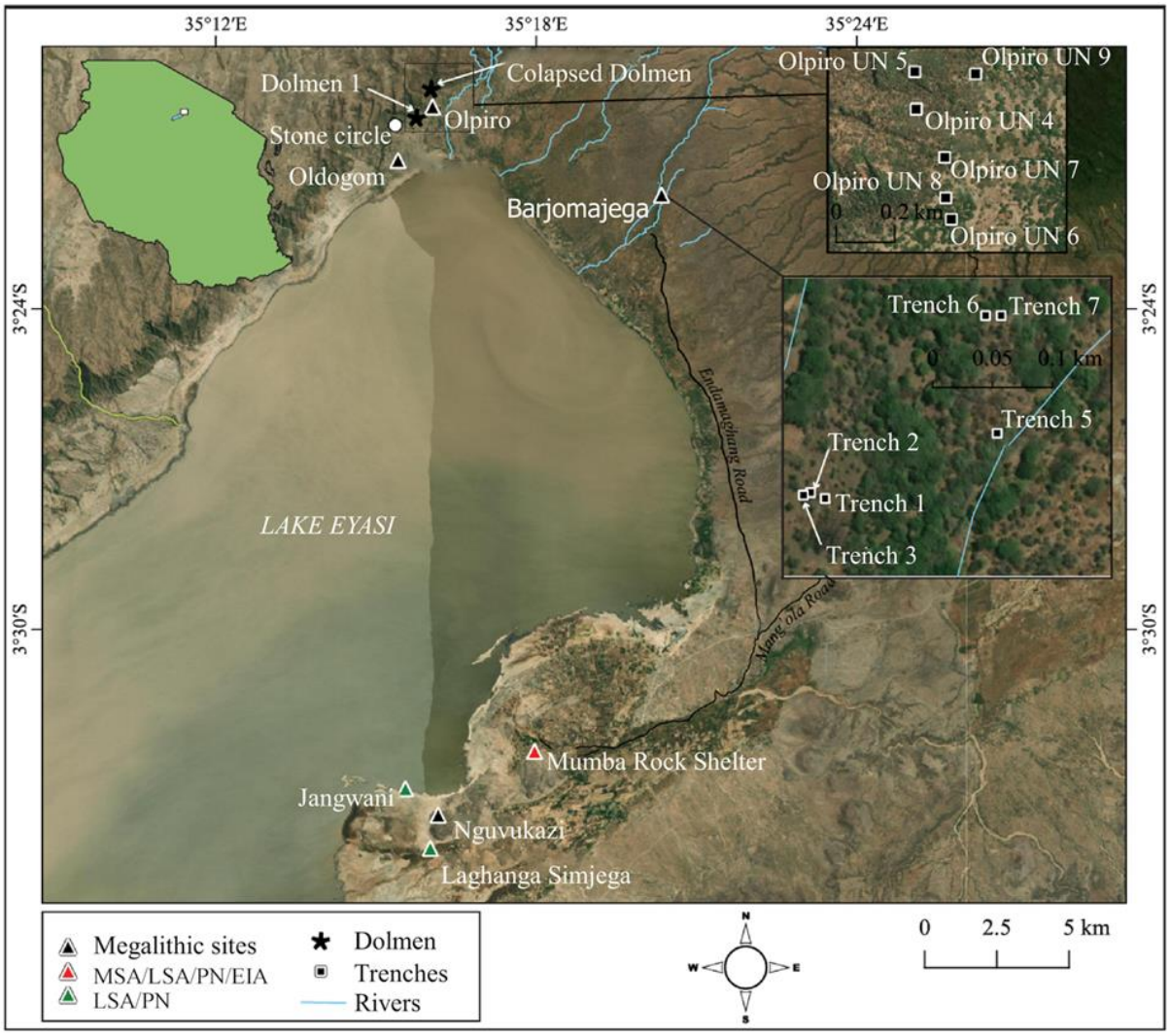

Figure 1. Map showing the megalithic sites in the Lake Eyasi Basin.

In the Olpiro village, the megalithic sites of Olpiro (3°19’52” S, 35°15’57” E) and Oldogom (3°19’51” S, 35°15’57” E) lie within the Gregory Rift Valley system, which extends from northern Tanzania through Kenya and Ethiopia to the Middle East. Located along the escarpments of the Oldeani Mountains in the Ngorongoro Conservation Area (NCA), this region features numerous river streams, the most notable being the perennial Olpiro and Oldogom rivers (Mwitondi et al. 2021). These rivers, originating in the Oldeani Mountains and flowing into Lake Eyasi, provide a constant water source that may have been crucial to local communities (Fig. 2). However, during the dry season (May-October), some perennial rivers in the area, such as the Olpiro, experience reduced water discharge, making the presence of permanent water sources a significant factor in the placement of the megaliths. The megalithic ruins in this area vary widely in shape, size, and arrangement and are spread across the Olpiro village. Some stone structures are located on the foothills of the Oldeani Mountains and on its floodplains, while similar structures can be found around 20 km northwest of Oldogom en route to the Masamburai NCA entry gate.

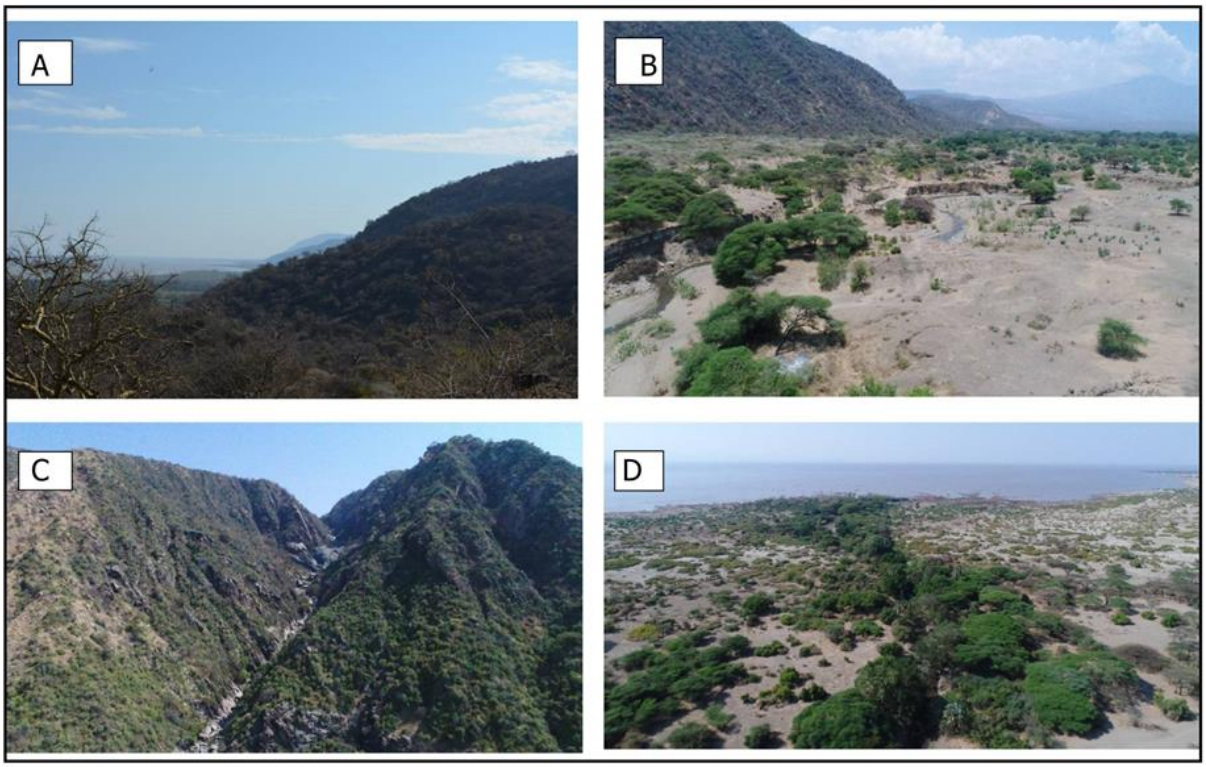

Figure 2. Aerial views facing the northwestern part of Lake Eyasi (a), the Olpiro River towards the northwestern part of Lake Eyasi (b), the Oldogom River descending from Oldeani Mountain (c), and the Oldogom River entering the western side of the lake (d).

Further northeast in the village of Endamagha, the Barjomajega site (3°22'27" S, 35°20'09" E) also lies within the Gregory Rift Valley and features prominent Pleistocene volcanic rock outcrops (Domínguez-Rodrigo et al. 2007). The site is located around 25 km from the notable Mumba Rock Shelter, and is named after the Barjomajega tree, which is a tree species without any conceptual meaning in the Datoga language currently colonising the area. The site sits on a gentle slope of the eastern escarpment, marking the basin's edge and benefiting from natural wind protection (Fig. 3). The Endamagha River, along with its perennial streams, flows through the village, supporting irrigation during the dry season.

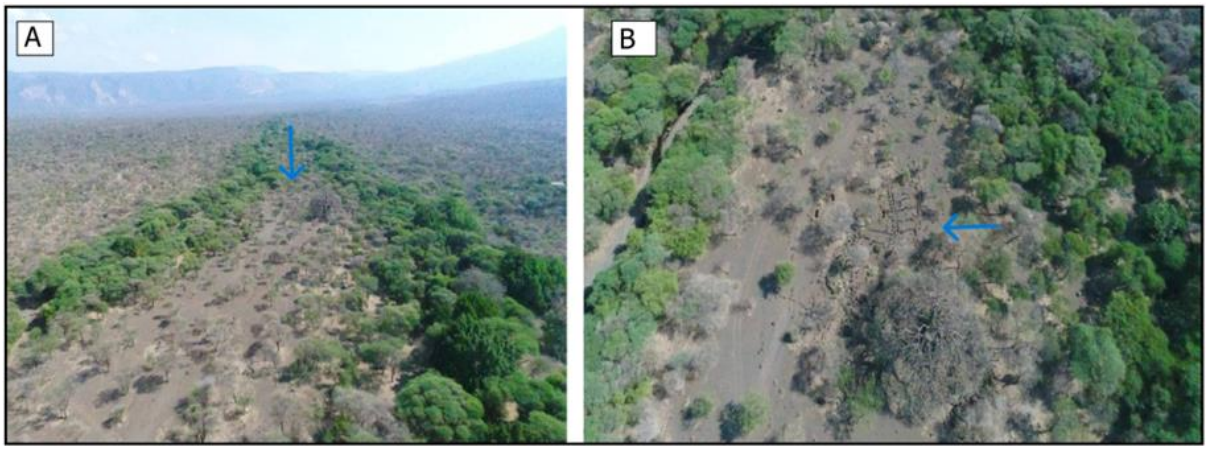

Figure 3. The Endamagha River and associated streams (a), and the Barjomajega megalithic site (shown with blue arrow) between the two river streams (b).

The Barjomajega megaliths, situated 4 km from the northeastern corner of Lake Eyasi, comprise prominent stone structures with foundations approximately 1 m wide, alongside large rooms measuring 6.7x6.4 m. The placement of megaliths around Lake Eyasi reflects a strong interconnection between environmental features and cultural practices. Builders appear to have selected locations based on

access to perennial water sources and protective topography. In addition, these sites were situated within landscapes probably associated with cultural significance, such as proximity to ancestral spaces, ritual locales, or places linked to collective memory, thereby making the megalithic sites an integral part of the region's historical heritage.

Types of megaliths, construction techniques, and their functional roles

Housing structures: The megalithic housing structures exhibit considerable complexity, particularly at Olpiro and Barjomajega. At Olpiro, the remnants of housing foundations (Fig. 4a & b) reveal a well-planned design with four distinct compartments or rooms. The foundations' walls were built using flat, unrefined slabs and polygonal stones oriented toward the southeast of Lake Eyasi, accompanied by a good fixing of a basement made of flat, refined stones, which were revealed by test excavations (Fig. 4b).

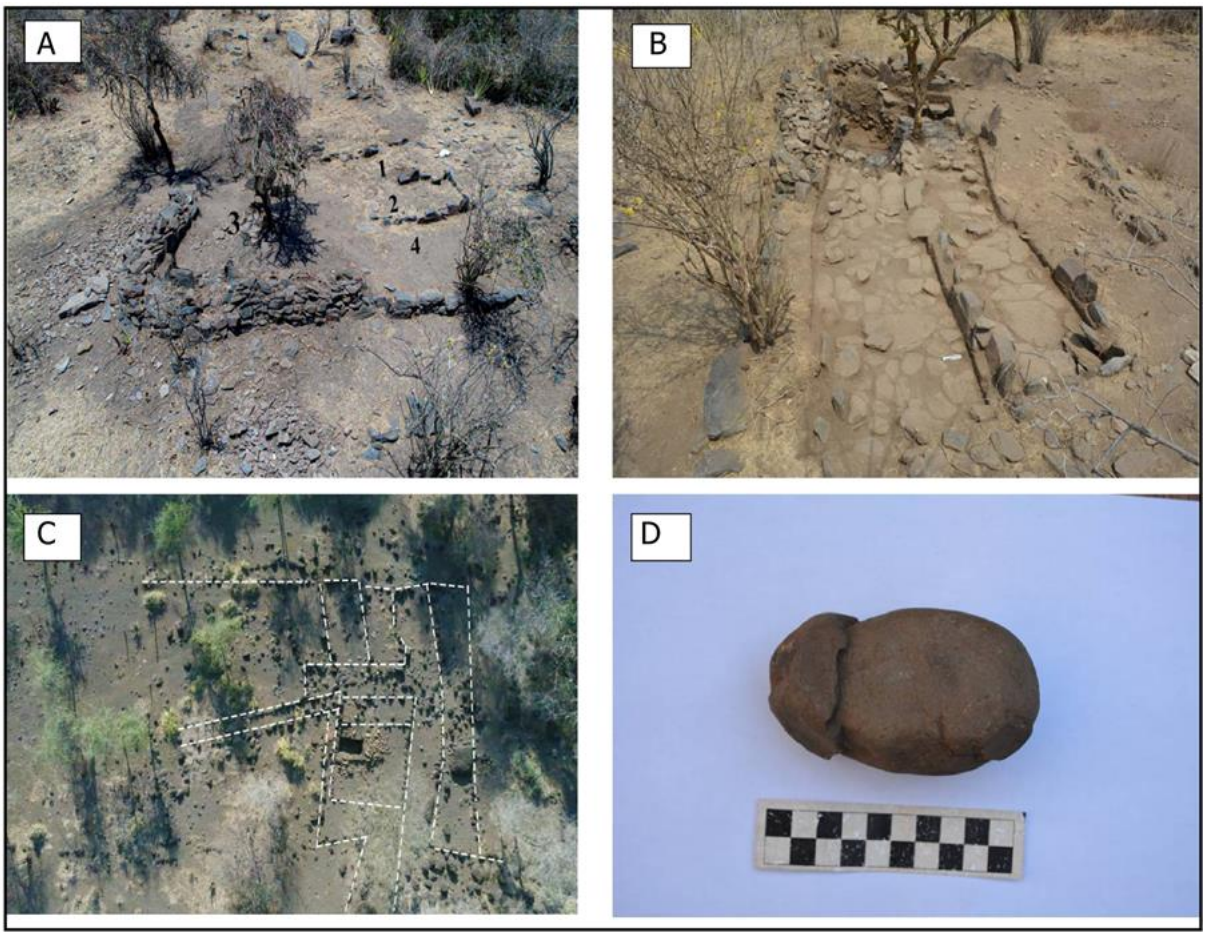

Figure 4. Housing structure with the indication of room partitions from Olpiro (a). The excavated housing structure at Olpiro revealing the constructed floorplan (b). A layout of a megalithic housing structure at Barjomajega (c). A stone phallic symbol recovered from a burial cairn near the housing structure at Barjomajega (d).

At Barjomajega, substantial stone-built structures were documented, including rooms measuring up to 6.7 m in length (Fig. 4c). These rooms are characterised by carefully constructed corridors that channel movement from the exterior into interior spaces, indicating deliberate spatial organisation and controlled access. The external surroundings of these structures include several stone cairns of varying sizes located adjacent to the buildings. Four cairns were excavated to assess their function. None of the excavated cairns contained human skeletal remains, indicating that they were not primarily used for burial. In some of the excavated cairns, a small number of undiagnostic pottery sherds were recovered, while others were devoid of material culture. A small assemblage of artefacts was recorded in association with the architectural remains, consisting of a limited number of undiagnostic pottery fragments and a few lithic artefacts (Fig. 4d). One lithic artefact was recovered in close association with

the cairns adjacent to the housing structure. The lithic artefact recovered near the cairns exhibits an elongated, rounded morphology that resembles a circumcised male reproductive organ. In ethnographic and archaeological contexts from eastern and southern Africa (Dart 1929; Mire 2015), objects with phallic symbolism are frequently associated with initiation rites, fertility symbolism, and the transition of males into new social statuses. On this comparative basis, it is thought that the artefact may have functioned as a symbolic object related to male circumcision initiation practices.

Stone walls: The basin is also home to large stone walls (Fig. 5), often free-standing and devoid of interior compartments. These structures are highly distributed in Olpiro, and they typically range from 30-100 cm in height and 90-100 cm in width. Constructed by systematically stacking undressed stones, the walls were built upon foundations 50 cm deep. Large flat stones were carefully placed on either side of the wall for stability, and smaller pebbles were used at the base to secure the structure. The function of these walls remains uncertain, though their craftsmanship suggests a significant investment of labour and planning.

Figure 5. An extended megalithic wall at the Olpiro site.

Semi-circular stone structures: A semi-circular stone formation is another notable type of megalithic structure in the region. These arrangements consist of large stones placed in an arc-like shape, with careful spacing and orientation. Averaging 5 m in diameter, some of these structures (Fig. 6) were likely aligned with celestial events, perhaps for ceremonial or ritualistic purposes. The levelled interior and stone arrangement also suggest possible use for temporary food storage or livestock pens.

Dolmens: Dolmens in the Lake Eyasi Basin, particularly at Oldogom and Olpiro, are among the most structurally distinctive features. Six dolmens were documented, with two being well preserved. The dolmens consist of upright stones supporting a horizontal capstone, forming a small chamber underneath. Dolmen 1, for instance, is 75 cm high and 280 cm wide, with a length of 300 cm and an east-facing entrance. The slabs in the top inner part of the dolmen were well arranged, indicating that the stones were dressed before they were put in place, or that the slabs were carefully selected. This suggests that the construction of a dolmen required a predetermined design and planning for its intended functional role. The capstones are arranged with precision, indicating a thoughtful selection of granite slabs, which are often smoother on the inside. Dolmen 2, constructed from sedimentary rocks, exhibits similar structural qualities but with a west-facing entrance. The designation of these structures as dolmens is based on their formal resemblance to prehistoric examples from Sicily, particularly in overall

shape rather than size or construction materials (Mwitondi 2022). In other contexts, similar forms have been associated with burial or ceremonial practices.

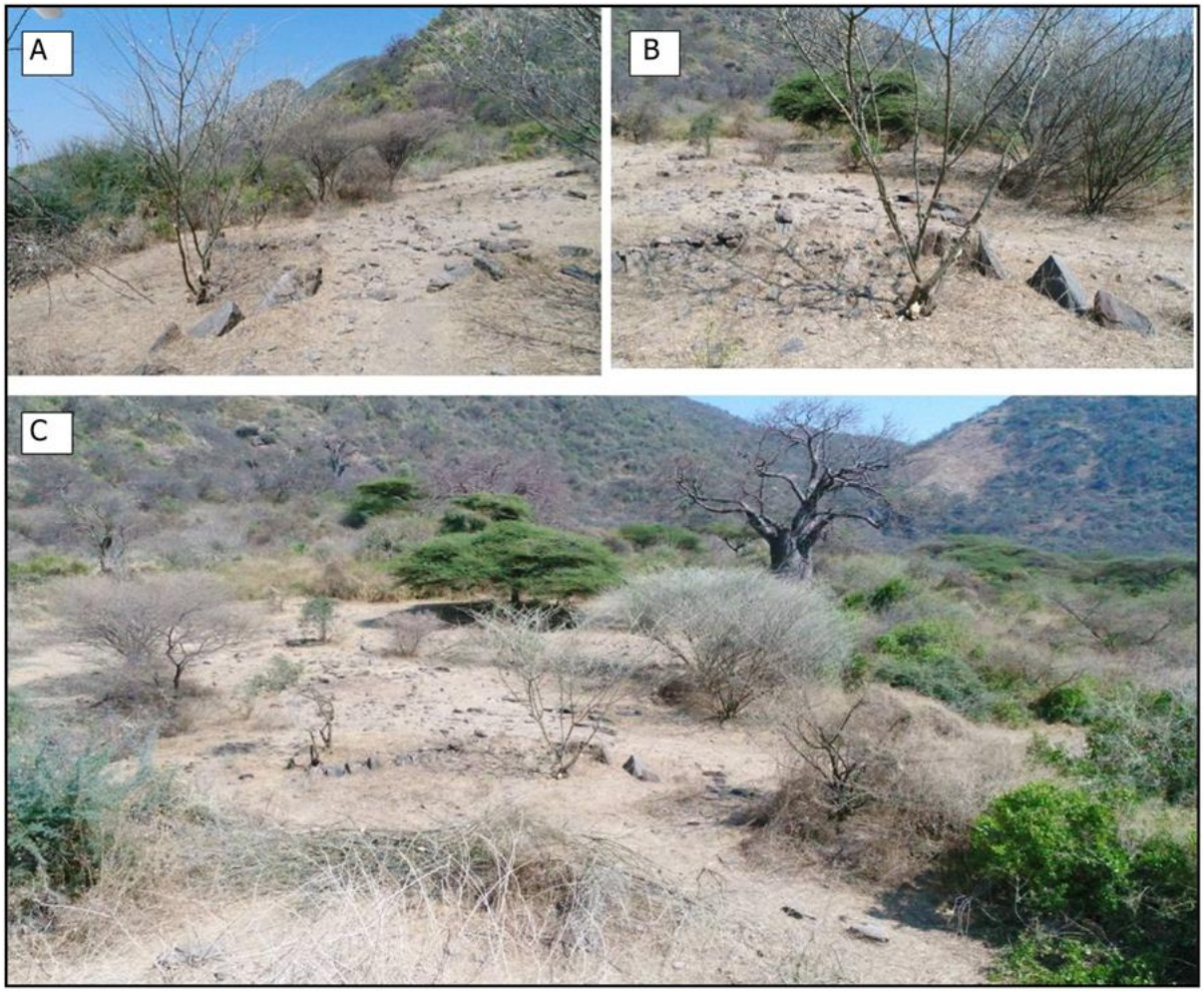

Figure 6. Multiple views of a semi-circular stone structure from the Olpiro site.

In a previous study of the region's dolmens by Mwitondi (2022), the structures were identified as being empty, intact, and in a poor state of preservation that prevented a clear interpretation of spatial layouts. However, it was possible to explain the dolmens' orientation, especially in terms of locating the direction of their entrances. Dolmen 1 points towards the east while Dolmen 2 (Fig. 7) points in the opposite direction. The orientation of dolmen openings may reflect an intentional alignment with sunrise and sunset phenomena. The east-west orientation observed in Dolmen 1 and the opposing alignment of Dolmen 2 may suggest deliberate placement rather than random construction. In several prehistoric contexts, similar orientations of megalithic structures have been interpreted as reflecting symbolic associations with sunrise and sunset cycles. Such alignments are often linked to cosmological concepts, including temporal cycles, renewal, and ritual practices (Piccolo 2013). However, in the absence of direct archaeological or ethnographic evidence such as associated ritual features, inscriptions, or calendrical markers, these interpretations remain hypothetical.

Stone circles: Stone circles are another prevalent megalithic form in the region, with notable examples at Olpiro and Barjomajega. At Olpiro (Fig. 8a-c), a stone circle measuring 8 m in diameter lies near a slope and the base of a giant baobab tree, indicating potential alignment with significant natural features. This structure comprises a 1.5 m-thick stone wall made of an inner and outer drystone wall with rubble fill. The stone circle foundation depth was approximately 1.15 m, showcasing sophisticated construction techniques, and was identified as a complex design.

Figure 7. Dolmen 2 from the Oldogom site (modified from Mwitondi et al. 2021).

The stone circles at Barjomajega (Fig. 8d) differ in style from those in Olpiro. They typically comprise single stone circles or elliptical patterns, ranging from 3-5 m in diameter. These simple designs might represent smaller-scale gatherings or symbolic enclosures. The careful selection of stones and foundational preparation, even in these smaller circles, suggest cultural significance and intentionality in construction. The stone circles at Olpiro may have served diverse roles, blending practical and ceremonial functions within ancient societies. The revelation of ash and charcoal deposits along the eastern wall during excavation suggested cooking activities. The circle's 8 m diameter could accommodate both domestic and communal roles. The circular shape and sunrise-oriented entrances also hint at ritual functions, possibly used for ancestor worship, fertility rites, initiation ceremonies, or seasonal gatherings. The symbolic alignment of the entrance may reflect spiritual or cultural beliefs, with some evidence pointing to ritualistic fires being part of these gatherings. This multifunctional use showcases how these structures were integral to daily life and spiritual practices.

Double-line stone enclosures: Double-line stone enclosures appear frequently at Olpiro and Barjomajega. These structures consist of two parallel lines of stones, separated by a uniform gap of 1 m, possibly to serve as pathways or channels for water (Fig. 9). At both sites, stones are interlocked and aligned with smaller pebbles at the base to enhance stability. The structures appear to function as pathways, possibly leading to house entrances or guiding individuals to burial cairns for ritual purposes. However, Sutton (1978) proposed an alternative interpretation, suggesting that these enclosures might have served as irrigation channels. Despite these theories, the true purpose of the structures remains uncertain. Further research and investigation are essential to clarify their function and to better understand their role within the broader cultural and environmental context of the site.

Stone enclosures: Stone enclosures are particularly prominent at Barjomajega and vary significantly in size, from 15x10 m to 30x30 m (Fig. 10). These structures are primarily built using local stones without mortar, employing dry stone techniques that ensure durability. Their polygonal and rectangular forms, and varied dimensions, suggest different uses, possibly for livestock or storage. In comparable megalithic contexts, enclosed stone structures have sometimes been interpreted as serving temporary residential or storage functions (Sassoon 1966; Sutton 1978). The robust construction of the structures

documented here allows for similar possibilities, although direct archaeological evidence remains limited.

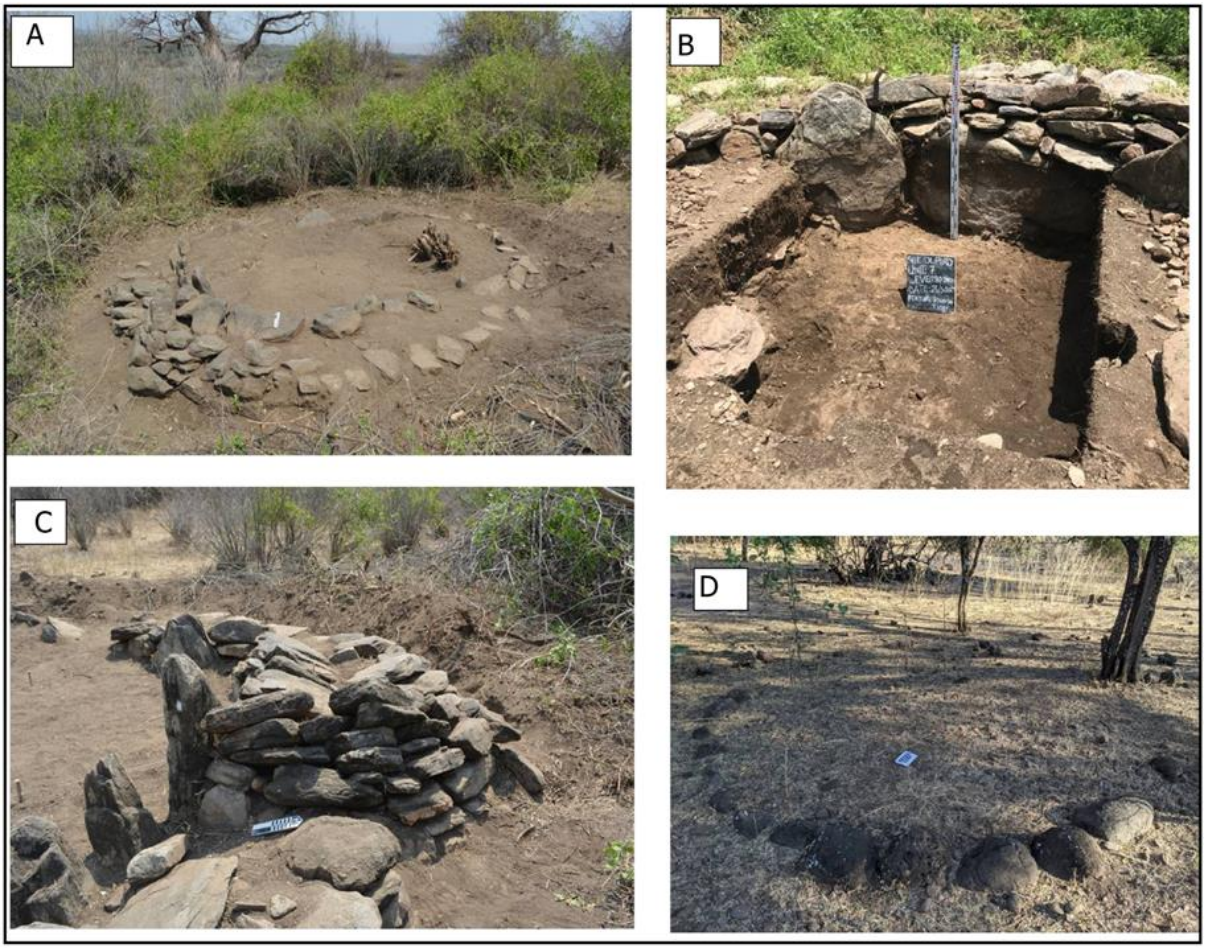

Figure 8. View of the stone circle after bush clearance at Olpiro (a), the excavations of the stone circle revealing the foundation layout (b), and the wall width of the stone circle (c). The stone circle at Barjomajega (d).

Stone cairns: Barjomajega exhibits a notable concentration of burial cairns (Fig. 11), a pattern that distinguishes the site from other locations in the Lake Eyasi Basin. The cairns generally measure between 2 and 5 m in circumference and are constructed with large stones forming a basal ring, over which smaller stones were stacked to produce mound-like structures. Excavation of several cairns yielded limited material remains, including undiagnostic pottery sherds and lithic objects, but no human remains were recovered, raising questions regarding their precise function. Based on their architectural form and comparison with similar megalithic features documented elsewhere, such as those at the Engaruka archaeological site, these structures may have served ceremonial or commemorative roles (Sutton 1978), although direct evidence for such uses remains limited. Their spatial association with nearby housing structures and their placement in relation to entrances further suggest a deliberate, possibly symbolic role within the settlement, potentially linked to practices of remembrance or ancestor veneration.

Raw-material procurement and transportation for megalith construction in the Lake Eyasi Basin

The findings reveal that basalt, granite, sandstone, and limestone were key materials used for the construction of Lake Eyasi Basin's megaliths. Each material was chosen based on specific attributes and availability around the surrounding landscape. The basin is rich in volcanic rocks, especially basalt, providing abundant material for megalith construction. Basalt found extensively around the Barjomajega site accounts for 99% of the stones used there. The area's basalt bedrock was likely quarried for stone slabs and blocks due to the durability and weather resistance of the volcanic rocks. The physical properties of basalt, including its density and mechanical strength, make it a suitable

building material for the construction of durable, modern megalithic structures. The dark colouration produced by pyroxene minerals such as augite may also have enhanced the visual prominence of these megaliths, although whether this characteristic was intentionally valued by their builders cannot be determined.

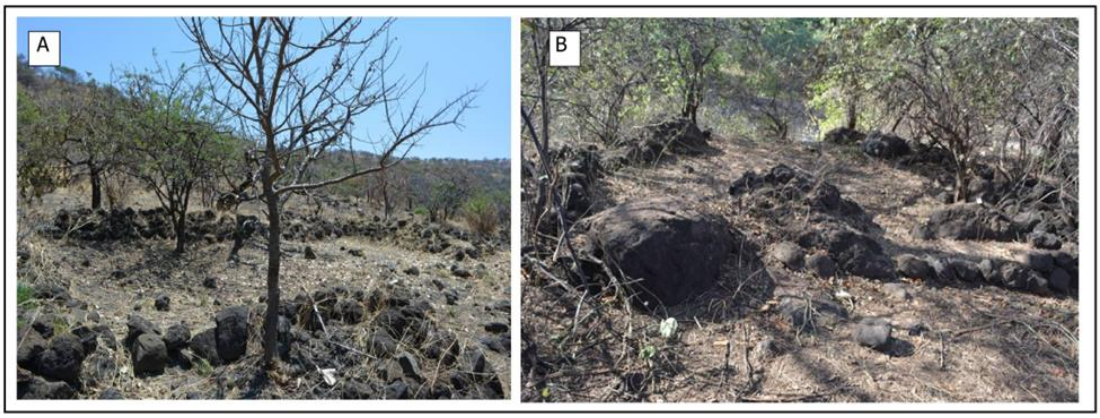

Figure 9. Stone enclosures at Barjomajega.

Similarly, at the Olpiro and Oldogom sites near the Oldeani Mountain, granite dominates, comprising 88% of the megalithic stones. The use of granite in the documented structures is likely linked to its local availability and favourable physical properties, including hardness and resistance to erosion. These characteristics would have contributed to the long-term preservation of the structures. Its abundance in the immediate vicinity of the sites also suggests that proximity and ease of access played a key role in material selection, indicating a likely preference for locally sourced lithological resources in the construction of community monuments. However, while granite's durability is evident from a modern geological perspective, it is not possible to directly attribute this property as a deliberate selection criterion by past communities. Furthermore, the workability of granite enabled skilled masons to carve and shape it, leading to detailed designs in megalithic structures like dolmens and stone walls. Sandstone and limestone were also found, though in smaller quantities than basalt and granite rocks. These sedimentary rocks, softer and easier to shape, allowed for decorative and structural applications. While less common, sandstone appeared on the capstones of dolmens, likely due to its availability and workability. Both sandstone and limestone's relative resistance to weathering made them useful for specific construction elements, even though they were not as abundant in the Lake Eyasi Basin compared to basalt and granite.

Figure 10. One of the stone cairns at Barjomajega megalithic site with the hole at the middle suggesting past excavation work.

On quarrying and transportation, the study indicates that the local availability of suitable stones was a key factor in material selection for constructing megalithic structures. Transporting heavy stones over long distances would likely have been impractical for ancient builders, given the absence of wheeled vehicles and advanced transport technology. The use of locally available materials may have helped reduce logistical challenges, potentially facilitating construction. Quarrying techniques were likely influenced by the characteristics of the local geology and the technologies available at the time. Stones appear to have been extracted from natural rock outcrops using manual methods, possibly employing simple tools such as stone and wooden picks and stone hammers. Distinctive markings observed on the capstones of dolmens suggest the effort and coordination involved in shaping and transporting the stones. The proximity of quarries, generally within 100-500 m of the construction areas, would also have eased the movement of materials to the building sites. The transport methods likely varied by site and stone size. For example, at sites near escarpments, such as Olpiro and Oldogom, builders may have used rolling techniques, leveraging friction reduction to move heavy stones along prepared paths. In flatter areas like Barjomajega, stones may have been transported by manpower alone, with teams physically carrying or pushing stones closer to the construction site. Some smaller stones may have been transported by hand, while larger blocks required organised labour and rudimentary pulleys. Efficient workforce coordination was essential, as moving these large stones would have required precise teamwork and leadership to manage the logistics of quarrying, shaping, and transportation. The emphasis on local stone resources not only streamlined construction but also allowed builders to use familiar materials and techniques, drawing on their knowledge of the stones' properties for the best structural results.

Although there are uncertainties due to limited tangible evidence, this study offers insights into the resourcefulness and cooperative efforts of the ancient Lake Eyasi Basin communities in megalith construction. By optimising local materials and simple yet effective transport methods, they managed to create enduring structures that still stand today. Generally, the selection of construction materials for megalithic sites around Lake Eyasi reflected a practical approach:

- Builders utilised locally available stones that met functional and aesthetic needs.
- Basalt and granite were preferred for their durability and structural strength, essential for long-lasting megaliths.
- Sandstone and limestone were used more selectively.

This strategic use of materials showcases the adaptation to available resources and hints at the technical skills and cultural considerations guiding ancient builders in the Lake Eyasi Basin.

Who built the megalith structures in the Lake Eyasi Basin?

The builders of various megalithic structures worldwide remain a subject of speculation and debate among scholars of ancient history (Renfrew 1983). However, whereas the builders of many megaliths remain anonymous, their creations provide valuable insights into the sophistication and ingenuity of ancient civilisations (Darvill 2010; Krzemińska et al. 2018). It has been revealed worldwide that the megaliths are associated with the introduction of food production (the Neolithic culture) (Wendorf & Schild 1998), whereby in East Africa, the Neolithic is said to have been introduced by Afroasiatic speakers who were practicing it in the Sahara before it became a desert (Ambrose 1984; Barthelme 1985; Marshall 1990). The desertification of the Sahara region, around 6000-3000 BC, pushed human populations to migrate towards the Horn of Africa and Nile Valley, where water and grazing land were more readily available. This encouraged interaction with Cushitic speakers, who adopted pastoralism around 5000-3000 BC (Ambrose 1982). Around 3000-2000 BC, the practice is also said to have been adopted by Nilo-Saharan groups in the Nile Valley through interactions with Cushitic and other Afroasiatic food producers (Phillipson 1977; Ambrose 1984; Barthelme 1985), who took with them the culture as they moved to the northern parts of Tanzania (Prendergast 2008, 2010). However, a study by Mwitondi et al. (2021) sought to explore the affiliations of contemporary ethnic groups with the megalithic structures found in the Lake Eyasi Basin. Through ethnographic inquiries and ethnohistoric interviews, the study interrogated whether any of the present-day communities residing around these megalithic sites could be direct descendants of their original builders.

In modern times, the Lake Eyasi Basin is a culturally diverse area inhabited by various ethnic groups, such as the Hadzabe, Barabaig (Datoga), Iraqw, Isanzu, Maasai, Iramba, and Sukuma. Originally, the initiative to uncover the origins of the megalithic culture in the basin considered the cultural context of all contemporary ethnic groups in the region. The research began with the hypothesis that the current inhabitants could provide insights into the identity of the ancient megalithic communities. However, by learning that only the Hadzabe and Datoga have ancestral ties to the basin (Marlowe 2004, 2010), the study narrowed its focus to these two groups.

Hadza/Hadzabe: The Hadzabe are among the last hunter-gatherer societies in East Africa, deeply connected to their natural surroundings in the Lake Eyasi Basin (Marlowe 2010). They have inhabited this region for generations, from ~5000-3000 years ago to the present, and are considered one of its indigenous groups (Kaplan 1978; Marlowe 2010). Many Hadza live in a remote area, mostly at each corner of the basin, surviving by foraging and hunting (Marlowe 2010). Their means of obtaining food is traditional, has been passed down through generations, and has been conservative for years. This is because the material culture among the Hadza reflects historical continuity, intertwined with gradual transformation. For example, their dwellings, which are temporary huts constructed from branches, grass, and other natural materials, have historically been built primarily by women and designed for rapid assembly and abandonment, enabling mobility across the landscape (Marlowe 2010). Men typically use handmade bows and arrows for hunting wild game and harvesting honey, while women focus on gathering roots and berries. The Hadza do not engage in food storage, agriculture, or the building of permanent housing. Instead, they live in caves or construct temporary shelters with dried grass and intertwined branches (mostly done by women) (Fig. 11) and relocate following the local wildlife (Marlowe 2004; Mabulla 2007; Bushozi 2015). It is logically true that, regarding their nomadic nature of life and their technological know-how, it is hard for them to establish a permanent settlement. Hence, it is uncertain whether the construction of these megalithic sites can be attributed to this ethnic group.

Figure 11. Hadza hunter-gatherers' residential houses.

Datoga: The Datoga people are linguistically categorised as Southern Nilotes, with origins tracing back 3000 years to southern Sudan or the highlands of western Ethiopia (Sieff 1997; Butovskaya 2012; Bihariova 2016; Mhajida 2019). They migrated southward, eventually settling in Kenya and Tanzania. Initially, traditional pastoralists transitioned to mixed agriculture around AD 1500, farming in the highlands of these countries and were said to settle in the Lake Eyasi Basin around 200-300 years ago. The pastoral subgroup of the Datoga, known as Barabaig, is particularly prominent (Butovskaya 2012; Bihariova 2016). Their traditional architecture includes round and rectangular wattle and grass-thatched houses made of wood (Fig. 12).

Figure 12. Examples of the Datoga's vernacular architecture.

Since the erection of megaliths has been predominantly associated with Neolithic cultures (Scarre 1992; Wendorf & Schild 1998; Darvill 2010; Grillo & Hildebrand 2013; Waziry 2016; Hildebrand et al. 2018; Monaco et al. 2020; Robertshaw 2021; Zena et al. 2021), the presence of such features in sub-Saharan Africa has been interpreted as evidence of cultural transmission. In East Africa, the Neolithic lifeways alongside the emergence of megalithic traditions were introduced, particularly in northern Kenya, where stone pillars, cairns, and mortuary monuments are associated with early pastoral communities (Grillo & Hildebrand 2013; Hildebrand et al. 2018; Robertshaw 2021). These megalithic structures suggest that the adoption of herding was accompanied by new ritual practices, social organisation, and expressions of collective identity within pastoral Neolithic societies (Grillo & Hildebrand 2013; Hildebrand et al. 2018). In this context, Cushitic and Nilo-Saharan groups are argued to have adopted and disseminated megalith-building traditions through interactions with Afroasiatic-speaking populations in the Sahara between 6000 and 3000 BC (Ambrose 1984; Barthelme 1985; Marshall 1990; Robertshaw 2021). However, within the Lake Eyasi Basin, the Datoga ethnic group has emerged as the primary community thought to be responsible for the construction of these megaliths. To validate this, in 2021, a research team from the University of Dar es Salaam explored the cultural connection between the Datoga ethnic group and the megalithic monuments distributed around their primary area of residence in Olpiro village, Karatu district. Evidence from elderly Datoga community members, aged 70-90 years and residing in the village for over 40 years, highlights the group's enduring detachment from these structures (Mwitondi 2022).

Although interviewees recognised the presence of stone-built monuments, they were unable to provide information concerning their function, symbolism, or historical significance, even when shown photographs of some unique structures like dolmens. Given that cultural knowledge is neither perfectly nor continuously transmitted across generations, the absence of such knowledge among contemporary communities cannot be used to infer authorship or cultural affiliation of the megalithic structures. Accordingly, the construction of the monuments documented at Olpiro, Oldogom, and Barjomajega remains archaeologically unresolved and may reflect past populations, cultural practices, or historical trajectories that are no longer represented in present-day social memory. In addition, the Datoga emphasised that their formal feasts and rituals are tied to natural features such as large trees, caves, and rivers rather than the megalithic monuments (Mwitondi et al. 2021; Mwitondi 2022). Furthermore, the

Datoga's spiritual practices and orientations of significant structures differ from those of the megalithic monuments. The Datoga worship sun gods, and as part of their tradition, their house doors are deliberately designed to avoid facing the sunrise (east) or sunset (west). In contrast, the documented dolmens and stone circle doors in the region are oriented along an east-west axis (Mwitondi et al. 2021). Additionally, Datoga tombs are oriented to the northeast, symbolising their place of origin, which also contrasts with the orientation of most megalithic structures. These findings collectively indicate that the Datoga have no historical or cultural link to the construction or use of the megalithic monuments in the Lake Eyasi Basin, pointing to a different cultural or historical context for these structures.

Generally, the possibility that the Hadzabe or Datoga were responsible for the construction of megalithic monuments in the Lake Eyasi Basin is undermined by several key factors. First, neither group possesses a documented history or mythology indicating an architectural tradition involving megalithic structures. The Hadzabe, known for their minimal material culture and subsistence as hunter-gatherers, exhibit no evidence of complex construction practices. Similarly, the Datoga, with their preference for mobile pastoralist settlements, lack an architectural framework consistent with the creation of monumental stone structures. Second, anthropological evidence underscores a strong continuity of cultural practices among the Hadzabe over tens of thousands of years, with no significant deviations that might suggest a phase of complex architectural endeavours. The Datoga, who are relatively recent migrants to the region in historical terms, have no known association with earlier monumental building activities or cultures. Additionally, the absence of oral traditions related to monument building among both the Hadzabe and Datoga further weakens their proposed connection to the megaliths. Oral traditions in many societies often preserve knowledge of significant cultural practices or events, but neither group recounts stories or practices associated with the stone structures. This lack of cultural, historical, and temporal alignment with the current inhabitants suggests that the megaliths were likely constructed by earlier populations. Potential candidates may include pastoral Neolithic groups with distinctive ritual practices or early agriculturalists (Iron Age communities) who either inhabited the region before the emergence of the Hadzabe and Datoga or coexisted with them during overlapping periods of occupation. These findings open the door to exploring alternative explanations for the origins of the megalithic structures in the Lake Eyasi Basin.

4. Discussion and conclusion

The Lake Eyasi megaliths share commonalities with global megalithic traditions, including their multifunctionality, material use, and symbolic significance. Comparative studies with other East African sites and regions, such as Western Europe or South Asia reveal shared practices, such as the alignment of structures with celestial phenomena, the use of local materials, and the role of these monuments as markers of social or spiritual identity (Maritsas 2015; Krzemińska et al. 2018; Wunderlich 2019). However, the Lake Eyasi megaliths exhibit unique characteristics tied to their specific cultural and environmental context. For instance, the volcanic origin of the region's geology (Domínguez-Rodrigo et al. 2007) influenced both the choice of construction materials and the architectural styles employed. The megaliths in the basin represent a captivating yet underexplored aspect of East African archaeological heritage (Kohl-Larsen 1943; Fosbrooke 1950; Sutton 1978; Mturi 1978; Ikeda & Hayama 1982; Melhman 1989; Mwitondi et al. 2021). These structures, comprising cairns, stone circles, dolmens, and stone enclosures, offer insights into the ancient societies that constructed them and the environments they inhabited. Their presence reflects complex social, cultural, and environmental interactions fundamental to the communities that built them (Mehlman 1989; Mabulla 2007; Mwitondi et al. 2021). Placing the megaliths around Lake Eyasi Basin demonstrates a careful consideration of environmental factors. The northeastern and northern parts of the basin, particularly near Endamagha and Olpiro villages, were favoured due to their distinctive landscapes with gentle plains and escarpments. These locations provided strategic advantages, such as natural protection, resource access, and symbolic associations with the land. The positioning at foothills or between escarpments suggests a blend of practicality and cultural significance, as these features could serve as natural boundaries, ceremonial grounds, or markers of territorial claims.

The Lake Eyasi megaliths, like those found in other parts of the world, were likely multifunctional in

their use (Derara 2009; Darvill 2010; Clark & Brittain 2011; Cummings & Richards 2014). Burial monuments such as dolmens and cairns housed the remains of prominent individuals or community members, underscoring the importance of funerary practices in these societies (Maritsas 2015; Krzemińska et al. 2018; Wunderlich 2019). However, in the Eyasi Basin these structures seemed to lack human remains. Such structures, therefore, reflected some societal hierarchies, belief systems, and rituals associated with sun worship (Darvill 2010; Krzemińska et al. 2018; Fagan & Durrani 2019; Byeong-Yeol 2023). Other megaliths, such as stone circles, may have served ceremonial or astronomical purposes. Alignments with celestial events, akin to Stonehenge in England, suggest that these sites were used for calendrical or astrological observations, aiding agricultural or ritualistic practices (Wunderlich 2019). Standing stones or menhirs could have held symbolic significance, representing deities, ancestral spirits, or community identity. Some monuments might have been territorial markers, guiding travellers or delineating sacred or essential spaces within the landscape (Scarre 1992; Sánchez-Quinto et al. 2019). But in the basin, the stone circles have been thought to have been the residential houses, while the independent standing walls were thought to serve as territorial markers, as suggested by Silva (2010).

The choice of materials for constructing megaliths in the Lake Eyasi Basin reflects a deep understanding of the local geology and the practical constraints faced by ancient builders (Linares-Catela et al. 2023). Volcanic rocks like basalt and granite were extensively used for their durability and availability. Basalt's resistance to weathering made it suitable for large, long-lasting structures, while granite's hardness allowed for intricate and stable constructions. Conversely, the limited presence of sandstone and limestone meant these materials played a minimal role in the region's megalithic architecture. Therefore, local quarries served as the primary source of stone, highlighting the importance of proximity and accessibility. This reliance on nearby materials dictated the architectural choices and influenced the placement of the monuments themselves. Using detached rocks from outcrops or secondary deposits suggests that builders prioritised efficiency while balancing symbolic and aesthetic considerations. Transporting and erecting large stone blocks required advanced engineering knowledge, collective labour, and a division of specialised tasks, indicative of a highly organised society.

Moreover, a striking aspect of the Lake Eyasi megaliths is their apparent cultural disconnect from contemporary communities of the region, such as the Hadzabe and Datoga peoples. The Hadzabe, a hunter-gatherer group, and the Datoga, primarily pastoralists (Klima 1985; Sieff 1997; Mabulla 2007; Butovskaya 2012; Bushozi 2015; Bihariova 2016; Mhajida 2019), do not exhibit traditions, oral histories, or practices that align with the construction of megalithic structures (Mwitondi 2022). Their lifestyles focused on mobility and subsistence and were not conducive to the labour-intensive and permanent constructions represented by the megaliths (Klima 1985; Mabulla 2007; Bihariova 2016; Mhajida 2019). This cultural gap raises significant questions about the builders' identity and the chronology of the structures. It is reasonable to argue that the megalithic societies predated both the Hadzabe and Datoga or represented groups that disappeared from the area, leaving no direct descendants. The lack of continuity emphasises the importance of further archaeological investigation to uncover these enigmatic builders' origins, motivations, and eventual fate.

Conclusively, the megalithic monuments of the Lake Eyasi Basin offer a profound glimpse into the ingenuity, organisational capacity, and cultural values of their builders. These structures were not merely static objects but active participants in the lives of the communities that created them, serving roles that ranged from residential, ceremonial, and funerary to territorial and astronomical. Their strategic placement within the landscape underscores a deep connection between these ancient societies and their environment, with choices of location and material revealing a sophisticated understanding of geology, symbolism, and practicality. Despite the absence of direct cultural links to contemporary populations, the megaliths stand as markers of human resilience and creativity. The mystery surrounding the builders' identity highlights the need for continued research. Excavations, precise dating techniques, and comparative analyses with other megalithic traditions could help resolve unanswered questions about their origins and functionality. Ultimately, the Lake Eyasi megaliths stand as a testament to the complexity and richness of prehistoric cultures in East Africa.

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