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The necropolis of Jebel Zebouzi (El Kef): integrated and multiscale archaeological analysis of protohistoric megalithic structures from Northern Tunisia

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1. Introduction

1.1. Mediterranean North-Africa funerary landscape: a brief review

North Africa, especially in the portion facing the Mediterranean Sea, is characterized by the existence of a great number and variety of pre-Roman funerary monuments in numbers exceeding tens of thousands[1]. Their amount and high visibility make them among the best known examples of evidence of the pre-Roman age, though this does not translate into an accurate and detailed understanding.

Numerous and varied are the forms and typologies of those monuments, going from the large monumental tombs pertaining to the Numidian reigns and influenced by Punic and Roman-Hellenistic examples, to the more autochthonous rock-cut chamber tombs locally known as *haouanet*[2]. The landscape is further dotted by *bazinas*, large mounds that conceal funerary chambers invisible from the outside, tower-shaped monuments or *chouchet*, tumuli, i.e. circular mound of small stones with no burial chamber, and lastly dolmen: generally described as having a burial chamber made from slabs of about 1 m in length and surmounted by megalithic slabs often surrounded by a circle of big stones[3].

Notwithstanding their name, unlike their European "homonymous", North-African dolmens rarely conceal communal or collective inhumation nor have any side access. Dolmens, compared to other examples of funerary structures, usually occur over a vast territory, and can

[1] Camps (1961).

[2] Camps and Longerstay (2000), 3361–3387; Stone (2007), 43–74.

[3] Camps (1995a), 2490–2509; Camps (1995b), 17-31; Sanmartí *et al.* (2012), 21–44.

be grouped in hundreds or thousands. They are sometimes found along with other monument types, mostly tumuli or *bazinas* though in smaller number[4], constituting large necropolises. The early excavations of a few such structures revealed the presence of ceramic materials pertaining to disparate chronological frameworks, from Punic to Roman, suggesting that those structures might not predate the 3rd century BCE[5]. This position, firstly widely shared, was refuted even by the same Gabriel Camps, who demonstrated that they putatively should be ascribed to the Late Bronze Age or even earlier[6], as at least corroborated also by further, more methodologically modern research, which dated some human remains around 800-500 BCE (ca. 2500 cal BP -so called Hallstatt Plateau)[7].

Moreover, not further clarified are the links between the northern, Mediterranean tradition of 'dolmenic' architecture[8] and the southern, Saharan building tradition of large conical tumulus[9], for which Tunisia offers a rare opportunity of study by being a natural and cultural juncture of these two domains.

What is also clearly emerging is that these funerary arrangements were, with all certainty, reused in the past for grounds still not firmly ascertained[10]. These processes, which might entail forms of cultural appropriation and modification of memory and history and the renegotiation and building of cultural identity and power performances, are difficult to disentangle[11]. Reuse and modification of ancient monuments after extended periods of abandonment are frequent throughout the world: reuse can range from one-time visits, and the placing of human remains and artefacts to the rearrangement of architectural elements and remodelling of entire structures[12]. No cultural continuity is required since discontinuous reuse can bridge centuries and even millennia, further complicating the "riddle" and detailed assessment of those archaeological realities dotting the Mediterranean North Africa.

As a matter of fact, as widely noted by other scholars, after 200 years of research on these megalithic necropolises, little is still known, from the spatial arrangement to the funerary traditions up to the very issue of their dating[13].

The present paper proposes a detailed analysis of some of these sites, envisaging a complete field survey and the excavation of some of the monuments. Remote and on-foot survey of the necropolises has been achieved through various techniques like drone imagery and photogrammetry. Data have been analysed in order to reconstruct the stratigraphical and spatial configuration of this necropolis advancing hypothesis of horizontal and vertical social complexity and the use of space in a multifaceted archaeological landscape.

1.2. Eco-geographical context and previous research

The Wadi Serrat, with a length of ca.100 km, stretches in the Northwest region of Tunisia. The basin is a tributary to the Wadi Mellegue in the High Tell in NW Tunisia close to the Algerian border (governorate of el Kef). This region spans approximately 15,000 square kilo-

4 Camps (1995a) 2490–2509; Camps (1995b), 17–31.

5 Camps (1961).

6 Camps (1995a) 2490–2509; Camps (1995b), 17–31.

7 Cicilloni, *et al.* (2009); Kallala *et al.* (2018), 25-58; Kallala *et al.* (2014), 19-60; Sanmartí *et al.* (2012), 21-44.

8 Miniaoui (2012), 7–23; Paris and Ghaki (2010), 71–74.

9 Paris and Ghaki. (2010), 71–74; Monaco *et al.* (2020).

10 Sanmartí *et al.*, (2015), 287-304.

11 Chadwick and Gibson (2013); di Lernia (2006), 50–62; Knapp (2009), 47–59; Rowley-Conwy (2006), 103–130; Weiss-Krejci (2015), 307–24.

12 Knapp (2009), 47–59; Weiss-Krejci (2015), 307–24.

13 Camps (1995b), 17-31; Cruz-Folch and Valenzuela-Lamas (2018), 175-189; Sanmartí *et al.* (2015), 287-304.

metres in a southwest to northeast orientation. It is characterized by a mountainous terrain, with an average elevation of about 700 meters a.s.l., marking it as the highest area in Tunisia. The altitudes gradually diminish from west to east and south to north, featuring a central topographical depression. The southern High Tell is notable for its clustered peaks, whereas intra-mountain plains distinguish the central area. Known as the Tunisian water reservoir, this region is home to the country's primary hydrographic network[14]. The region features two main landscapes: lowlands and ridges, with rugged surfaces prevailing. Tectonic activity, climate variability, and historical human impact have shaped Holocene landscapes[15]. The Wadi Serrat basin, covering 2188 sq km at around 700 m asl, is surrounded by Cretaceous and Eocene calcareous reliefs[16]. The basin's area climate is semiarid continental [17], with harsh and sometimes snowy winters [18] and temperatures which vary greatly between seasons.

In an area ca. 50 km south-west of El Kef, Tunisian authorities planned the construction of a large dam, whose completion resulted in a drainage basin of more than 1800 km². These circumstances triggered the conception of a salvage archaeological mission concentrating on the area of the dam, to explore and undertake a thorough documentation and study campaign of the various archaeological contexts in the area (Fig.1). The research area extends on the southern bank of the Wadi Serrat with a transect of ca. 7 km² including the Jebel Zebouzi. This is a limestone hill with an altitude of ca. 600 m asl stretching over the surrounding alluvial plain. The relief extends in a semiarch west to east, very steep on its northern flank more aggraded on the opposite southern and western and eastern sides. In the latter in particular a stepwise structuring of the relief accompanies the climb towards the somital plateau, whereas the southern and western slopes raise more gently towards the heights. Vegetation cover is limited to some bushes of Mediterranean flora with the absence of tree cover. Today, the area is devoted to husbandry, mainly sheep and goats, and cultivated fields in the alluvial plains lambing the relief (Fig.1).

2. Materials and methods: an integrated multiscale strategy

2.1. High resolution imagery through UAV survey, geomatic, GIS and photogrammetry

UAV Drone flight and remote sensing

The drone mapping work developed over two field campaigns (2020-2021). The work involved mapping around 11 km² using drones equipped with S.O.D.A._10.6_5472x3648 (RGB) cameras, with almost 4,900 images processed. This work resulted in a high-resolution digital model of the terrain (DTM) stretching over the research area, with a particular focus on the Jebel Zebouzi (Fig. 2).

Geospatial analysis

In order to gain a deeper understanding of the spatial relationship and clustering characteristics of these megalithic structures further analysis were conducted using different techniques common in spatial pattern analysis[19], and executed via different native plugins in the FOSS environment of QGIS (version 3.28.12). Kernel Density Analysis (KDA) was first

[14] Ben Ghazi (2021); Zielhofer and Faust (2008), 580-588.

[15] Ben Ghazi (2021); Faust *et al.* 2004, 1757–1775.

[16] Karoui-Yaakoub *et al.* (2016).

[17] Zielhofer and Faust (2008), 580-588.

[18] Faust *et al.* (2004), 1757–1775.

[19] Baxter *et al.* (1997), 347-354; Drennan (2009); Verhagen (2018); Lloyd and Atkinson (2004), 151-165.

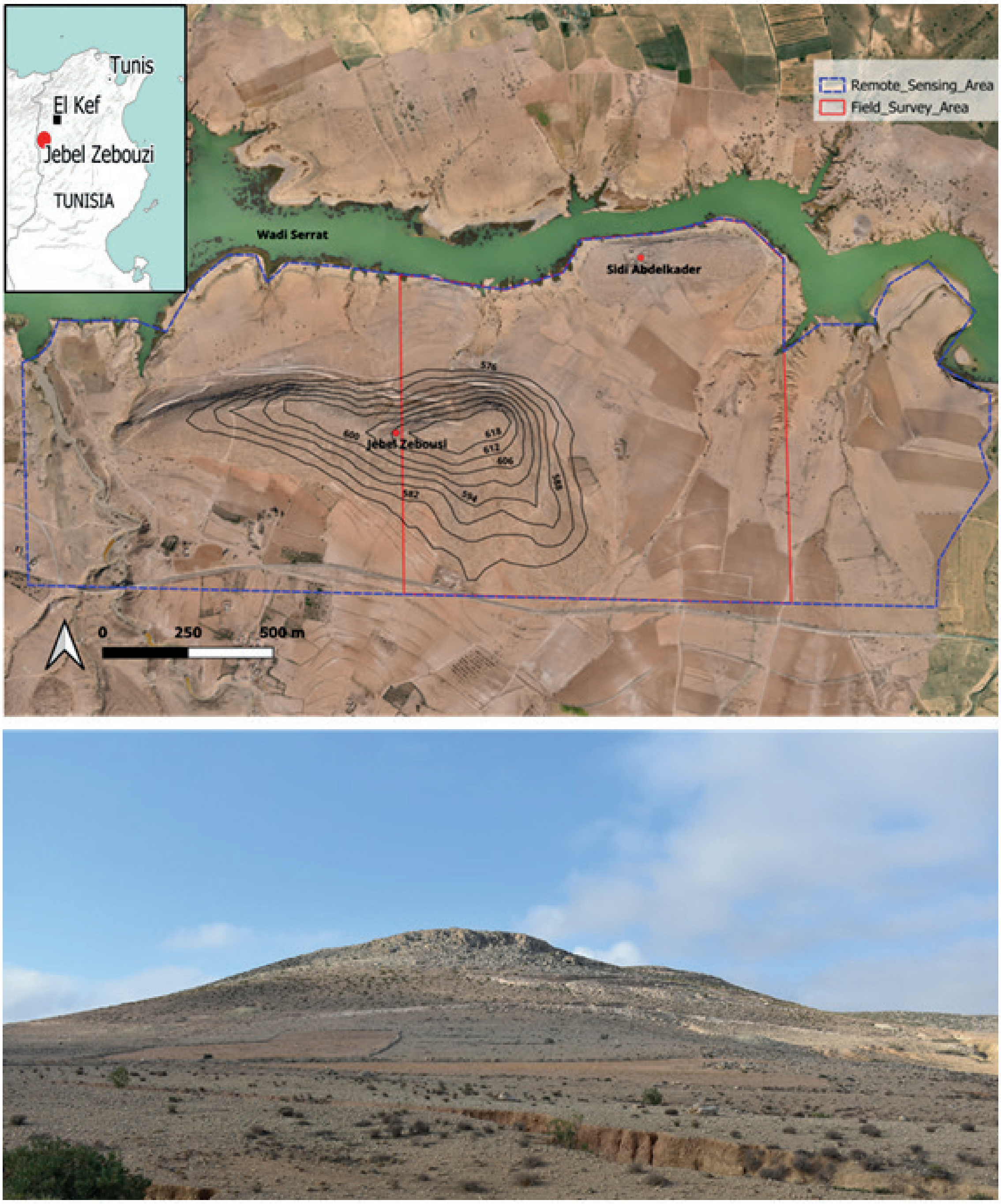


Figure 1: The study area (upper) and its current geomorphological and anthropical setting (bottom).

used to identify and visualize the density and distribution patterns of megalithic structures across the landscape[20]. By setting a radius of 90 meters, the analysis provided a clear picture of where these structures were most densely concentrated. Following the KDA, Nearest Neighbour analysis (NNA) was applied to further investigate the spatial relationships between the megalithic structures[21]. This statistical technique helps to quantify the degree of clustering or dispersion among spatial features, which in this context refers to the arrangement and prox-

[20] Baxter *et al.* (1997), 347-354; Drennan (2009); Verhagen (2018).

[21] Clark & Evans (1954), 445-453; Dixon (2006); Carrero-Pazos (2019), 2097–2108.

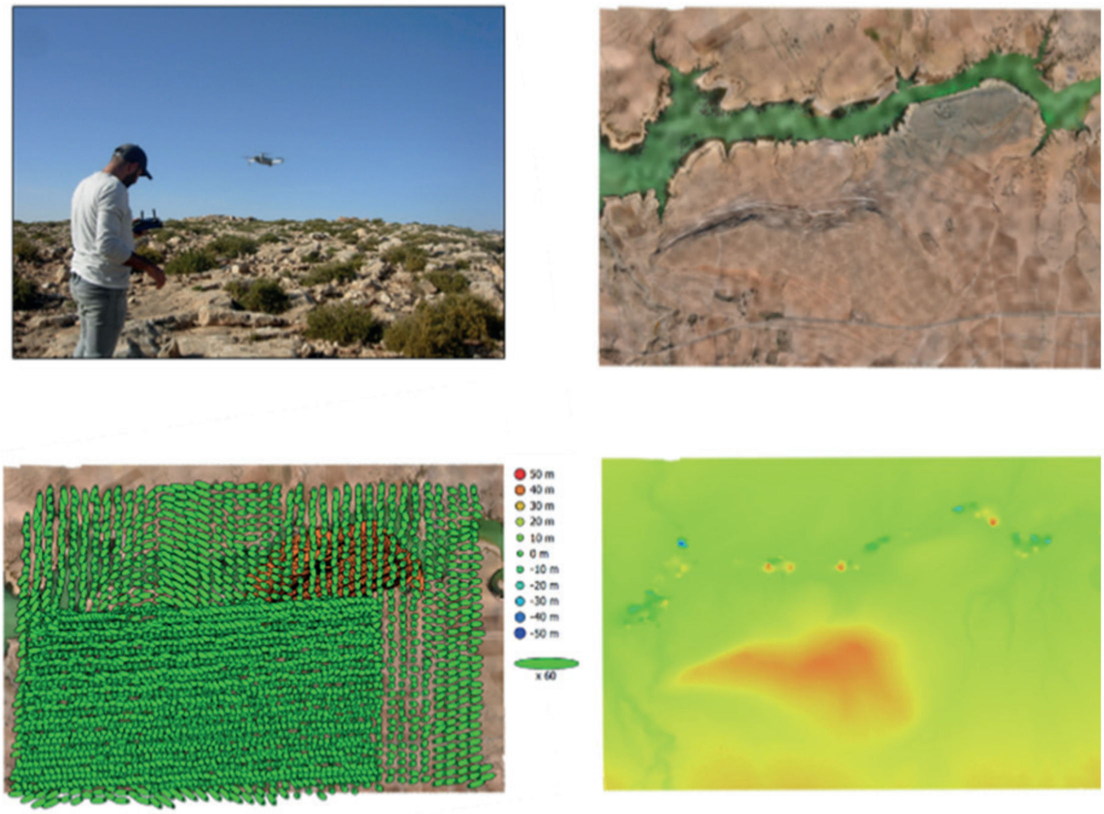


Figure 2: Phases of the UAV survey (upper left) over the Jebel Zebousi and the surrounding area (upper right) with the specifics of the camera elevations (bottom left) and the resulting DTM (bottom right).

imity of the archaeological sites or other kind of evidence. NNA is valuable for understanding whether the structures were randomly distributed, clustered, or regularly spaced and hence estimate possible social or environmental influences on the placement of these monuments[22].

2.2. The field survey and excavation

The exploration and surveys in the area heads back to 2009, when the Jebel Zebouzi, the Sidi Adelkader and the nearby Jebel Mzita were first identified and surveyed by Ridha Boussofara (INP) and Jaafar Ben Nasr (University of Kairouan) which brought to the identification of the necropolis, and the excavation of 4 of these dolmens (in 2010). During a successive field campaign (2016) two more tombs were stratigraphically excavated confirming some of the observations made, like the almost complete absence of grave goods and funerary remains. Unfortunately, no further information is available for this research phase.

To tackle and further explore this archaeological landscape, a systematic survey activity was carried out during the 2021 Tunisian-Italian field mission in Northern Tunisia (INP-Sapienza), using intensive on-foot surveys and excavation of funerary monuments chosen for their apparent good state of preservation.

The area interested by the intensive foot survey is 1.5 km^{2}. and is included in the broader research area extending over 5x5 km^{2} object of the 2021 Tunisian-Italian field mission. It is located on the southern shores of the Wadi Serrat reservoir, encompassing the Jebel Zebouzi

22 Carrero-Pazos *et al.* (2019)

(Fig. 1), including the medieval Berber village (Sidi Abdelkader) on its northern foothills[23]. The survey team was composed by three people equipped with hand GPS and DSLR camera. The foot survey was organized dividing the area into several geometrically regular transects. The tracks covered 500x500 m transects running North-South following the orientation of the hill's natural slope. A total of 121 monuments were identified, described, and catalogued by filling a field-form with the main geographical, topographical, structural, and archaeological information. The gathered information has been later digitized in post-processing desktop activity in a Microsoft-Access relational database, linked to a geo-database realized on QGIS. The fieldwork consisted of the full description of the site, the measurement and the detailed description of the monuments in the field-form, and the comprehensive photographic and graphic documentation. Tests to provide the archaeological significance and the state of preservation of each monument have also been performed by checking the presence of surface materials.

3. Results

3.1. Testing visibility and identification through integrated approaches

We provide in this section the results of the integrated approaches through remote sensing and foot-survey. To assess the strength of the combined method we will compare the results of the two methods independently and then compare them through statistical hypothesis testing.

Drone imagery has enabled the acquisition of high-resolution images of the study area, improving the visibility of a calcareous terrain that is uneven but uniformly whiteish, typically hindering visibility. Additionally, the structures under examination were constructed using the same material as the underlying substrate of their respective locations. This, combined with the inherent visibility limitations of remote sensing and the often-suboptimal state of preservation, frequently complicates the identification of these monuments.

To address this challenge and establish an objective criterion for distinguishing genuine monuments, an Uncertainty Index (UI) ranging from 0 to 2 was developed. This UI is calculated as the mean of two separate variables, each also ranging from 0 to 2: 2 denotes a possibility, 1 indicates a very high probability, and 0 signifies certainty.

Each monument is assigned two numerical attributes corresponding to each of the two variables, with their mean yielding a final UI value (0, 0.5, 1, 1.5, 2) representing the degree of uncertainty. The two variables pertain to the architectural features of the monuments and the characteristics of the area where they are situated.

For the architectural variable, a value of 0 is assigned to monuments that clearly and unambiguously exhibit their defining characteristics, such as the stone circle and the covering slab. A value of 1 is given to monuments that appear to have elements potentially interpretable as characteristic, but which are insufficiently clear for definitive classification due to poor preservation or limited visibility. A value of 2 is attributed to elements whose shape and dimensions may suggest a resemblance to known monuments but lack sufficiently distinct features.

The second variable, the topographic variable, is based on the characteristics of the area where each monument is located. The territory is divided into three distinct zones, each assigned a numerical attribute (Fig. 3). Monuments receive the same value as the zone in which

[23] Boukchim and Marzouki (2024).

they are situated. A value of 2 is assigned to zones characterized by intensive agricultural activity surrounding the Jebel Zebouzi, which could have destroyed/obliterated the evidence by ploughing and/or been heavily anthropized. Despite the expectation that archaeological visibility should be enhanced in these zones, it is challenging to discern whether the evidence present is modern material displaced or accumulated, or actual monumental remains. A value of 1 is assigned to zones with limited visibility or characterized by slopes that render the presence of monuments unlikely. Limited visibility may result from the quality of drone-acquired images or from the territory itself, often featuring stone clusters indistinguishable from the covering slabs of dolmens. A value of 0 is assigned to zones, and consequently to the monuments located within them, that have the highest probability of detection and analysis. These areas are marked by good visibility and a significant density of monuments. By integrating these variables, the Uncertainty Index provides a standardized method to objectively assess and categorize the certainty with which monuments can be identified within varying environmental and preservation contexts. Remote sensing hence allowed to identify 401 monuments in total, with a different uncertainty index (Tab. 2).

Methods	**Mnts_detected**	**SQKM SURVEYED**
Remote_sensing	401	3.5 sq Km
Foot_survey	117	1 sq Km

Table 1: Total number of monuments identified divided by survey method.

Evidence_type	**UI_0**	**UI_0.5**	**UI_1**	**UI_1.5**	**UI_2**	**tot**
DOLMEN	19	117	160	69	7	372
TUMULUS	4	7	5	0	0	16
BAZINA	2	4	4	3	0	13
TOT	*25*	*128*	*169*	*72*	*7*	***401***

Table 2: The total of monuments identified by remote sensing with their Uncertainty Index (UI) (0 to 2 based on the UI calculated as described in the text).

To assess the relative effectiveness of remote sensing and foot survey methods in detecting archaeological monuments, we implemented a detailed approach by calculating the differential rate for remote sensing and foot survey and statistically assessed their power with a t-test and Chi-squared test. We assessed the effectiveness of remote sensing and foot surveys in detecting monuments by comparing their coverage and detection densities. Remote sensing covered 3.5 square kilometres and detected 319 unique monuments, resulting in a density of 91.14 monuments per square kilometre. In contrast, foot surveys covered 1 square kilometres with 35 unique detections, yielding a density of 43.75 monuments per square kilometre. Statistical analysis included a one-sample t-test and a Chi-squared test. The t-test showed a mean detection density of 130.41 monuments per square kilometre, but this was not statistically significant from zero ($p=0.07695$): this suggests that while the combined detection density is considerable, it doesn't statistically deviate from no effect at the conventional threshold. The Chi-squared test revealed a highly significant difference in detection counts between the methods. Remote sensing shows significant statistical advantages. The integrated strategy

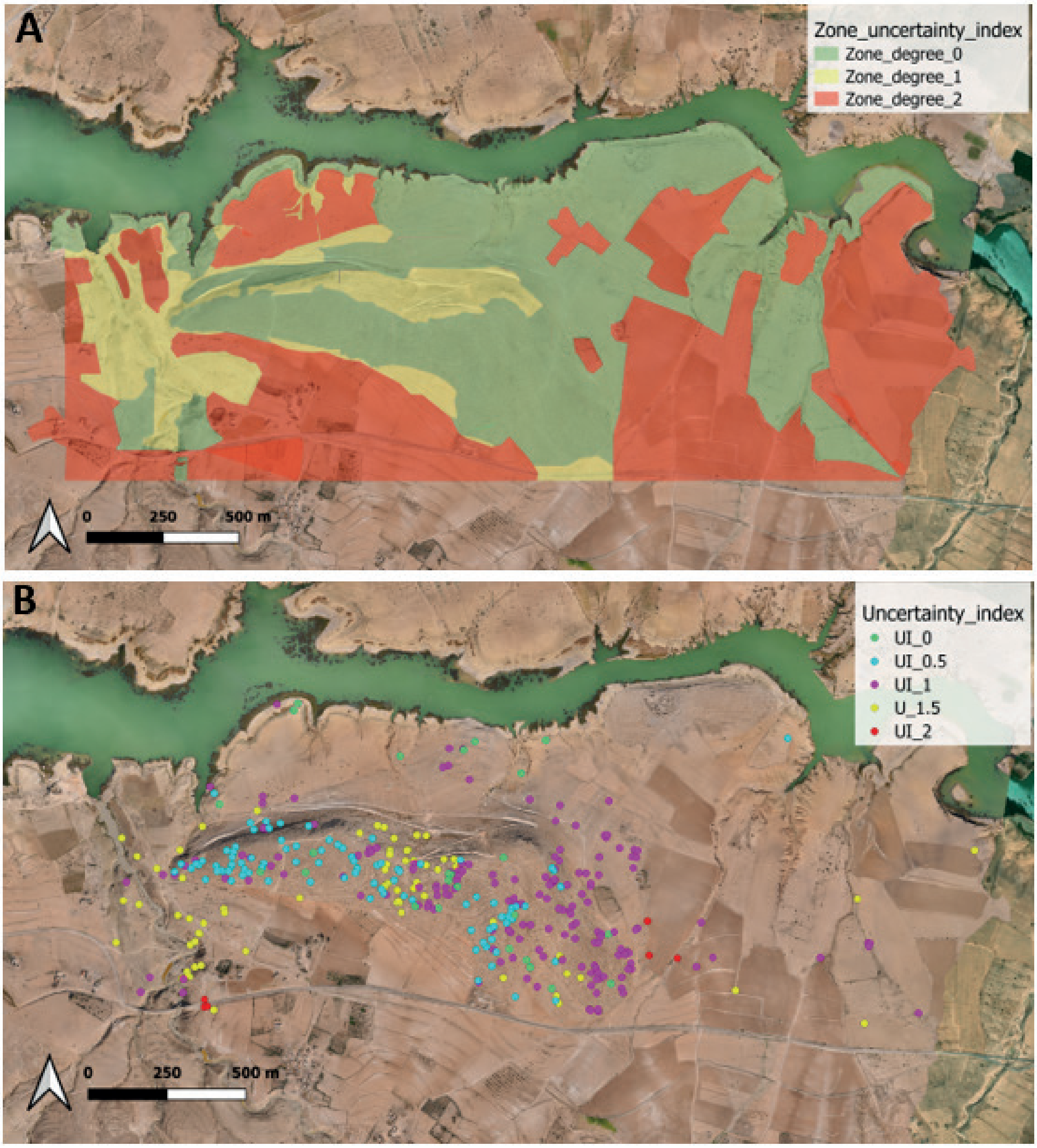


Figure 3: The research area on the left bank of the Wadi Serrat divided by uncertainty index based on natural and anthropic factors (A) and the monuments classified by their total uncertainty index (B)

allows the coverage of much larger areas and in a more time efficient timeframe, coping with the more time- and manpower-consuming foot survey. This combined strategy would maximize the strengths of each method, ensuring more thorough coverage and identification of archaeological features. Taking into account the monuments that have a lower uncertainty index (Grade 0 and 0.5), we account that remote sensing and foot survey methods exhibit similar effectiveness in detecting monuments, as indicated by the non-significant results of the Chi-squared test. The comparable detection counts suggest that either method can be effectively employed. The results from the one-sample t-test highlight substantial variability and uncertainty in the detection densities. This suggests that while the methods can be effective, their performance might be influenced by various factors such as terrain, vegetation cover, and the preservation state of the monuments.

3.2. The megalithic structures and funerary practices

A typological (re)assessment of the megalithic evidences at Jebel Zebouzi

Various types of megalithic architecture were recognised during the field survey, most of which are dolmen (Tab.1), *i.e.* a funerary structure that in its elementary form consists of two or more walls formed of stones variously embedded in the ground that support a large horizontal lithic slab[24]. This layout represents the most basic and simple, though some changes can be recorded.

The remaining evidence is categorized as *bazinas* (N=6), referring to artificial mounds of stones and earth above ground, with topographical significance denoting a mound[25]. The architecture of a *bazina* closely resembles that of a tumulus but includes an external architectural covering, representing an evolved form of the basic tumulus structure. Additionally, 13 unspecified monuments were recorded. These lack specific features that could classify them into a particular type and are therefore recorded as "monuments." These mostly consist of heaps or arrangements of stones in some structural layout but without distinctive characteristics.

Classified according to the number of burial chambers[26] among the dolmens, two main types were identified:

- Simple dolmen (single burial chamber) (97%);
- Multiple dolmen (two or more burial chambers) (3%).

Simple or single chamber dolmens are primarily quadrangular (83%), with some being circular (13%) or irregular in shape (4%). Multiple chamber dolmens are all quadrangular in layout.

The construction method for dolmens is mostly mixed (80%), using both dry walls and slabs/orthostats for the main chamber. The monolithic supports that form the lateral walls sustaining the cover slab and creating the actual burial chamber are often replaced by dry stone walls. These walls are constructed using stones of various sizes or blocks, which determine the number of masonry rows and the height of the construction. The height of the funerary chamber averages around 40 cm and never exceeds 75 cm (Table 3).

Nearly all of these monuments are encircled by a ring of stones and/or and slabs of various sizes and shape (Fig. 4). A few have multiple (1%) or double (15%) stone ring enclosures, while most have either a single stone ring enclosure or none. Their mean diameters (N-S and E-W) are 5 and 6 respectively.

[24] Camps (1995a), 2490-2509.

[25] Camps (1961).

[26] Camps (1995a) 2490-2509.

Figure 4: A simple or single chamber dolmen (A); a multiple dolmen (double chamber) with a single ring (B); a double ring simple dolmen (C); and a simple dolmen with multiple rings (D).

The orientation of dolmens is defined by the direction of the burial chamber opening. Over half (>52%) are oriented towards the east, with others facing north or south (Fig. 5). The outer ring circumference averages 5 meters, ranging from approximately 2 meters to a maximum of around 12 meters.

Metric	Average; Max; Min Height	Average; Max; Min cover slab area	Average; Max; Min. N-S diameter	Average; Max; Min E-W diameter	N single chamber	N multiple chamber
Values	0.4 m; 0.75; 01 m	2.6 sqm; 9.3 sqm; 0.9 sqm	5 m	6 m	114 (FS)	3 (FS)

Table 3: Basic metrics of the investigated/surveyed/etc dolmens

As regards the size of the dolmens, referred to as the size of the cover slab for which the total area in sqm was calculated, the intact dolmens identified during the on-foot survey present an average of 2.1 m^2; and a maximum of 9.3 m^2 and a minimum of 0.5 m^2.

Similar values were observed among the evidence identified via remote sensing. However, only the maximum extent of the cover slab in square meters and the extent of the putative rings enclosing the monument could be assessed.

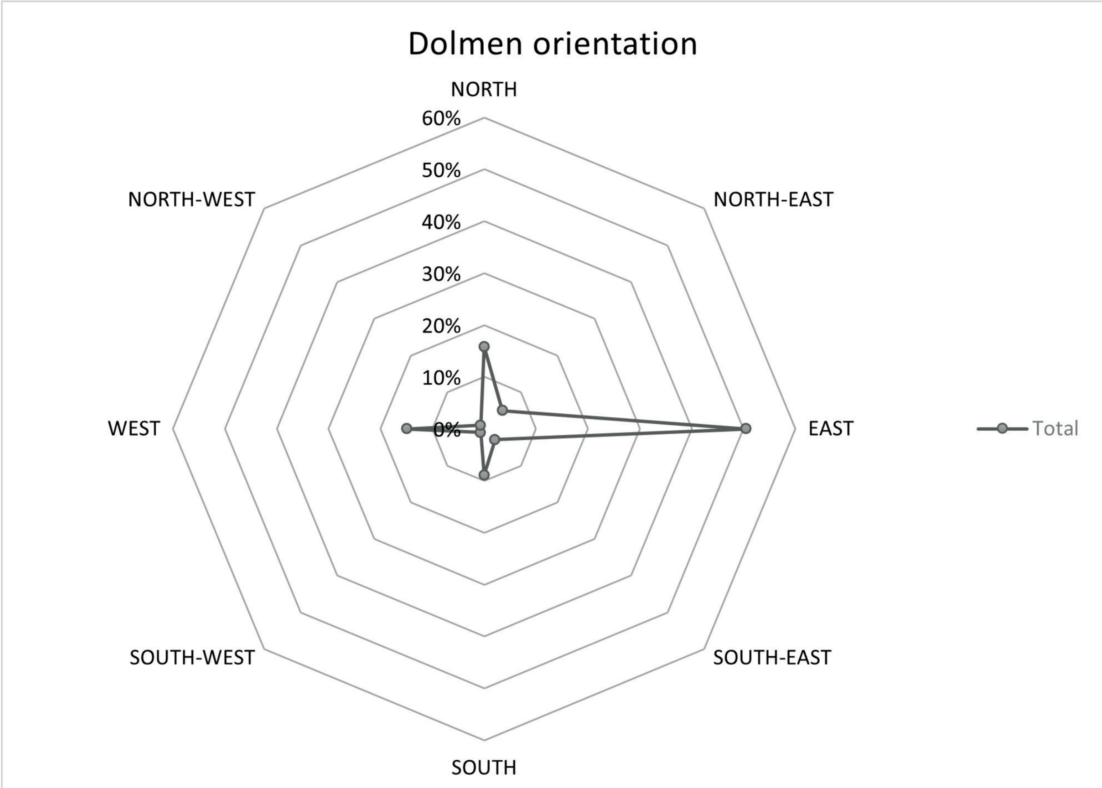


Figure 5: The orientation of the dolmens based on the opening of the burial chamber.

Funerary rites and inhumations

As part of the fieldwork, the research program also envisaged selective stratigraphic excavations, with the aim of i) testing the state of preservation of the evidence; ii) highlighting and documenting the type of use and possible funeral rituals; iii) documenting and recovering material evidence to attempt a chronological and cultural attribution.

In 2021, three monuments (MNT_018; MNT_075; MNT_0101) were stratigraphically excavated: after the excavation, each monument was restored to its original state, according to INP guidelines and the standards of the Archaeological Mission in the Sahara.

MNT_0101. The first monument is a dolmen with a large limestone slab, approximately 120x80 cm, covering a burial chamber constructed with large stones and slabs, utilizing both orthostat and dry wall techniques. Despite its intact appearance, it contained very few archaeological materials: some undecorated and undiagnostic pottery sherds, and only a human clavicle, indicating that the burial has been looted in the past. The infillings were mainly composed of sandy sediment with gravel, stones, and rocks, with four Stratigraphic Units (SUs) recognized. SU1 and SU2, both composed of sandy sediment, differ only in the number of stones, which are more frequent in SU2. SU3 is also sandy and incoherent, covering the top of SU4, which is composed of medium-sized, flat, quadrangular stones, where the human bone and pottery fragment were recovered. The absence of more bones could indicate the possibility of a secondary burial or post-depositional disturbance.

MNT_075. The monument is a modest-sized dolmen with a cover slab measuring 80x90 cm, opening towards the north. It partially leans on the slope of the structure, forming its back wall, reminiscent of Camps' "*dolmen creuse*"[27] (1961). The stratigraphic investigation yielded only pottery sherds, mostly from the surface and some from SU1, a deposit composed mainly of undifferentiated sand, gravel, and stones. SU2, consisting of firm and compact clayey sand with gravel and stones, contained the remains of a caprine, represented by some molar teeth still in anatomical connection. At first glance, it appears that an ancient disturbance occurred, given the firmness of the sediment. However, no human remains are present, despite the monument appearing intact upon initial visual inspection.

MNT_018. The third excavated monument is a quite large dolmen with a covering slab of 220x140 cm. The burial chamber of big limestone slabs held a multiple burial (MNI:2), without any evidence of grave goods. The burial seems to be interested by a post-depositional disturbance probably linked to the same funerary ritual. Three Stratigraphic Units (SUs) have been distinguished: SU1, the covering layer of sand and little sized stones; SU2, the proper burial; SU3, a flat arrangement of stones where the bodies have been arranged upon. During the excavation of the monument, a primary multiple burial was identified, with evidence indicating the asynchronous reduction of previously interred individuals. The grave, filled with a mix of clay and limestone, contained at least two individuals (MNI = 2). The skeletal remains were in a poor state of preservation, with the cortical surfaces severely damaged by the soil composition. The most recent burial was found lying on its left side (left *decubitus*), with the upper left limb bent under the head. The left portion of the skull, including the I molar, I and II premolar, incisor, and canine teeth, was preserved but in poor condition. The skull orientation was towards NNE, with the spine aligned SW-NE. Due to the poor state of preservation, determining the sex of the individual was not possible; dental wear suggests an adult individual. Scattered throughout the burial chamber were various skeletal elements, including two contralateral femurs, tibiae in the NE corner, and a disarticulated right upper limb (Fig. 6). Additional bones included a left humerus under the thorax, another lower limb in the NE portion, and an upper limb in the central area. The poor preservation prevented measurements or assessments of pathologies. Throughout the grave scattered anatomical elements included the skull, teeth, portions of the *rocca petrosa*, various upper and lower arm bones, hand phalanges, a right femur, ribs, vertebrae, scapula/clavicle, a radius, fibula and several ribs. Notably, phalanges of upper and lower limbs were all lying flat above the stone pavement, except for two phalanges which were found vertically lodged between stones near the NW wall of the burial chamber. The absence of small bones in the upper layers (SU1) and their presence in the bottom layer (SU3) indicate that decomposition occurred *in situ* before subsequent disturbances and reductions.

3.3. Integrated study for a spatio-temporal patterning

The processing with descriptive and analytical geostatistical techniques of the data has revealed some specific patterns.

The spatial point pattern analysis of the dolmens reveals significant clustering within the dataset. The observed mean distance between the dolmens is 30.47 meters, substantially lower than the expected mean distance of 49.08 meters for a random distribution. This results in a Nearest Neighbour Index (NNI) 0.62, indicating a clustered pattern. The Z-score of

[27] Camps (1961).

Figure 6: The dolmen MNT_18 before (upper left) and after excavation with the disposition of the human bones (upper right) and the stone layout where the first inhumation was placed (lower left).

-10.49 further supports this conclusion, showing that the clustering is statistically significant (Tab. 4). Based on these results, a kernel density analysis was conducted using a radius of 90 meters, approximately triple the observed mean distance, to better understand the spatial distribution and density of the dolmens. The analysis was conducted on a selection of identified monuments, including all the dolmens discovered during the foot survey and those identified via remote sensing with an uncertainty index of up to 0.5 (see above for details). This selection totalled 253 objects.

Metric	**Value**
Observed Mean Distance	30.46913253
Expected Mean Distance	49.07993257
Nearest Neighbour Index	0.620806324

Table 4: Nearest neighbour analysis metrics (N=253).

Three main clusters were identified, each associated with unique geomorphological features: one on the eastern slope and summit of Jebel Zebouzi, another on a fluvial/alluvial terrace near an abandoned Berber settlement, and the third on the western flank of Jebel Zebouzi (Fig. 36). Over 70% of the dolmens are concentrated on the eastern flanks and summit of Jebel Zebouzi (Fig. 7).

The main clustering, taken into consideration both the foot and the remote sensing surveyed monuments, is located on the eastern flanks and the top of the Jebel Zebousi, where more than 70% of the evidences are concentrated.

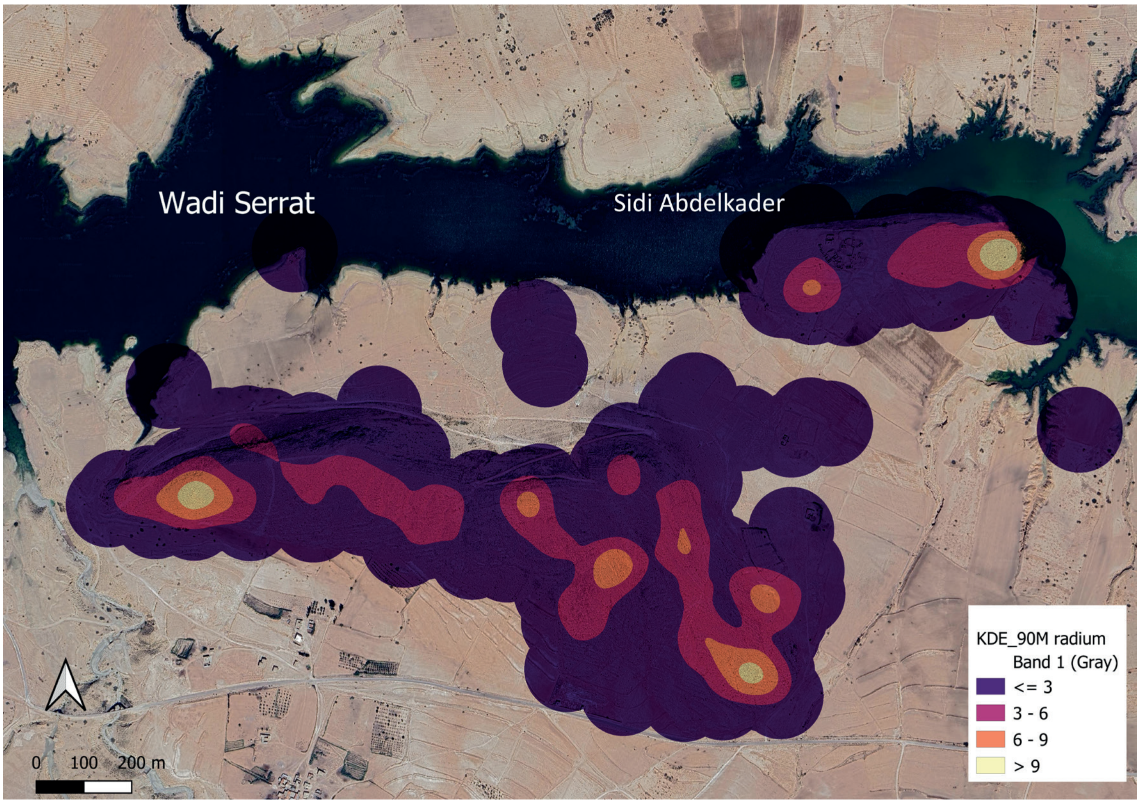


Figure 7: The identified cluster by kernel density analysis

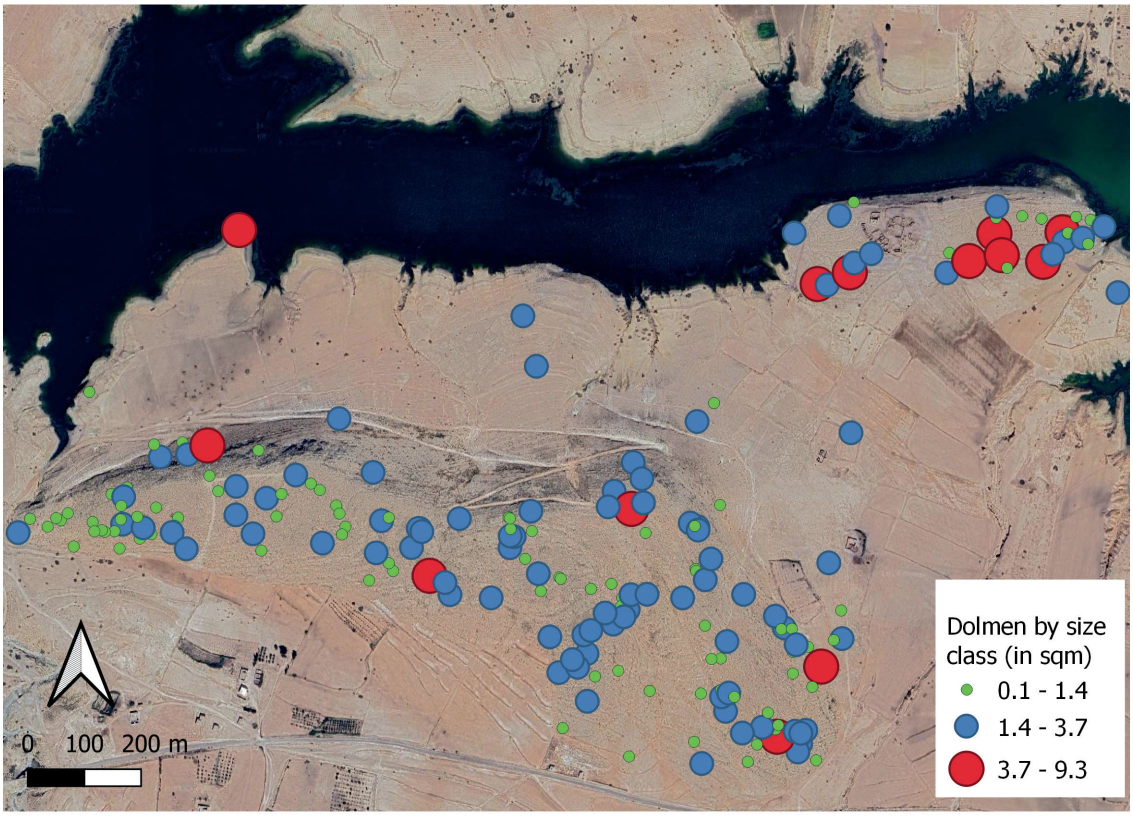
Considering the sizes of the dolmens, calculated as the area of their cover slabs, they were categorized into three classes using the Jenks (Natural Breaks) classification algorithm (Fig.8), native into the QGIS environment (QGIS v.3.34 8-1): class 1 (0.1-1.4 sqm (small); class 2 (1.4-3.7 sqm (medium); class 3 (3.7-9.3 sqm (large). This method establishes class breaks that group similar values together while maximizing differences between classes based on data-specific patterns[28].

The Kernel density analysis of the dolmens reveals three primary clusters, each potentially exhibiting chronological differentiation. This conclusion is drawn from a detailed examination of the dimensional and structural layouts of the dolmens. The dolmens located within the Berber "village" cluster are, on average, slightly larger and exhibit greater uniformity compared to those in the "hillside" cluster. In contrast, the "hillside" cluster demonstrates a multimodal distribution of sizes, encompassing a balanced representation of large, medium, and small dolmens.

Further analysis indicates a clear structure of spatial differentiation based on the dimensional attributes of the architectural evidence. This differentiation suggests the presence of both vertical and horizontal topographic hierarchies within the clusters. Specifically, in the "hillside" cluster, larger dolmen structures are predominantly located at the summit, with their sizes decreasing progressively along the ridge and slopes, highlighting a vertical hierarchical organization (Fig. 8).

Moreover, a horizontal hierarchy is evident in the cluster situated west of the Berber village. In this area, the spatial arrangement follows a centripetal pattern, where larger dolmen structures are positioned towards the periphery, creating a distinct gradient of size from the

[28] Chen *et al.* (2013), 47–50; Gillings *et al.* (2020); Verhagen (2018).



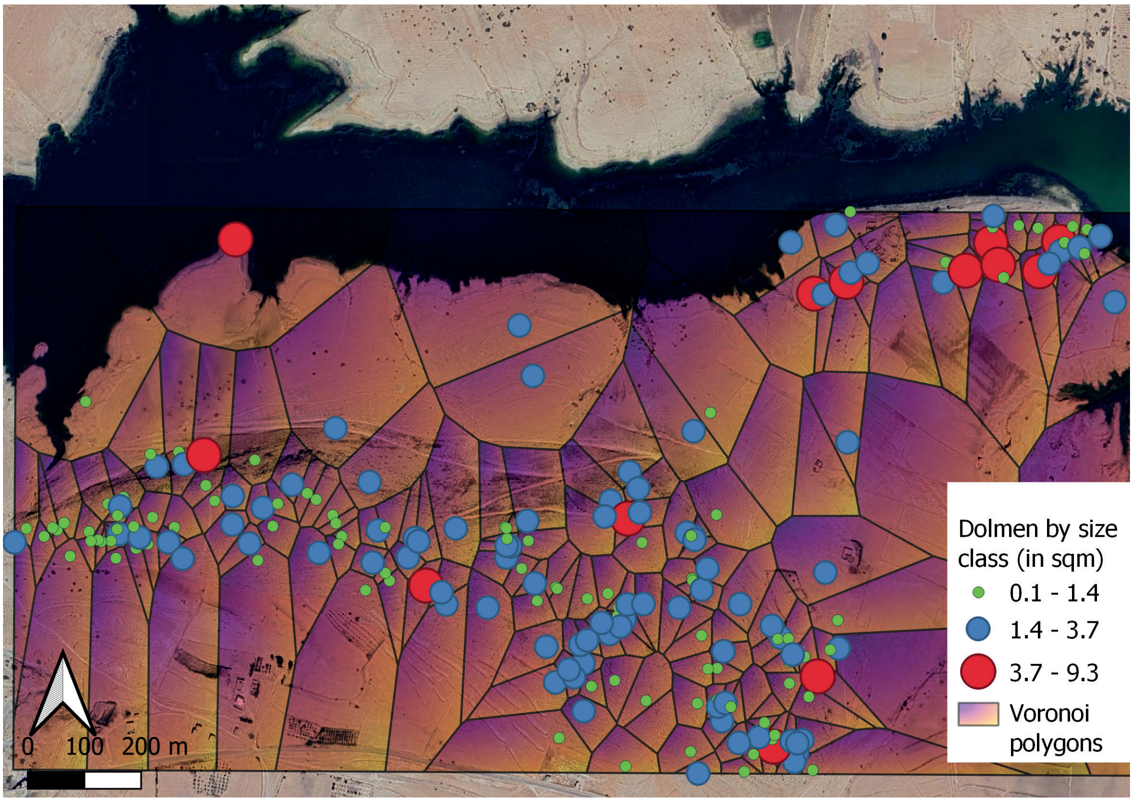


Figure 8: Distribution of dolmens (N=253) based on their size class and the overlay with the calculated Voronoi polygons.

outer edges inward (Fig. 8). This spatial distribution pattern underscores the complexity and variation in the layout and construction of dolmen clusters, reflecting not only chronological differences but also potentially differing social or cultural influences on their construction.

Overall, the analysis underscores the importance of considering both vertical and horizontal spatial relationships when studying dolmen clusters. These relationships can provide significant insights into the social and cultural dynamics of the communities that constructed them. The observed patterns of size distribution and spatial hierarchy may indicate varying functions, statuses, or chronological phases of the dolmen clusters, contributing to a deeper understanding of the prehistoric landscape in which they are embedded.

4. Discussion

The multi-scalar and multi-method approach provide valuable insights into situating these architectural evidences within specific technical, technological, and cultural traditions. This, in turn, helps clarify their complex assignments in terms of chronology and socio-cultural affiliations.

The spatial analysis of the dolmens reveals clusters, which may indicate chronological differentiation. This differentiation is inferred from the dimensional and structural layouts within these clusters. The dimensional attributes suggest a vertical and horizontal topographic hierarchy. In the "hillside" cluster, larger structures are situated at the summit, decreasing in size along the ridge and slopes. This vertical hierarchy highlights a possible deliberate placement of larger dolmens at higher elevations, likely indicating a form of social stratification or the importance of visibility in the landscape.

A horizontal hierarchy is evident in the cluster west of the Berber village, where a centripetal pattern is observed. Larger dolmens are positioned toward the outer edges of the cluster. This may imply spatial organization with significant structures marking the periphery, potentially reflecting social or functional zoning within the dolmenic landscape. The findings prompt further investigation to determine whether these spatial patterns have social significance or are influenced by logistical and topographical factors. The strategic placement of larger dolmens might reflect social hierarchy, with prominent families or groups occupying more visible and prestigious locations[29]. Alternatively, these patterns could result from practical considerations, such as the ease of transporting and constructing larger dolmens or the availability of suitable construction materials[30].

Whether these findings hold social significance or are instead linked to logistical/topographical causes or a mixture of both requires further verification and analysis. The social cost in labour expense can be tentatively addressed, particularly considering the weight of some of the closing slabs, estimated at around 8 tons on average. By calculating the specific weight (approximately 2711 kg/m^3) of limestone[31] per approximate average volume of the dolmens, it becomes evident that constructing these monuments required significant labour investment. Even if the cover slabs were sourced from the immediate vicinity of the structures, as suggested by evidence of *in situ* mining activity, raising the slabs necessitated at least the workforce of more than three people cooperating.

The labour investment indicates a social commitment to communal work, possibly inferring a social structure where labour mobilization was prompted by a central or hierarchical

[29] Ard *et al.* (2021); Barrett (1990), 179-189; Cruz-Folch and Valenzuela-Lamas (2018), 175-189; Hildebrand (2013), 155-172.

[30] Cummings and Richards (2021); Ko (2007).

[31] Michalska and Szczepaniak (2014).

structure[32]. This motivates whether this can be linked to a protohistoric reality featuring a centralized power structure and whether it can help disentangle the question of their chronology. Following Camps[33] and other research that excludes a Neolithic chronology and cultural contact with Neolithic North Mediterranean horizons for these monuments, primarily due to the absence of clear material culture with those chrono-typological features, it is also evident that they do not show any clear contact with Neolithic cultures of the northern Sahara[34]. It seems more likely that, as recently suggested, they might be linked to later chronological and cultural spheres, mainly set in the late Bronze or Iron Age[35].

The dolmens of North Africa exhibit a distinct characteristic that sets them apart from the 'Neolithic' dolmens found in Europe: their placement within necropolises of varying densities. This distinction holds potential significance for interpreting these monuments within a chronological-cultural framework, potentially linking them, as aforementioned, to broader trends of economic and political segmentation observed during the transition to the Iron Age[36]. This is testified within our case study and can be compared in numerous other cases throughout the region[37]. An even more recent origin, or at least reuse and disturbance, in connection with the nearby Roman-age settlement of Mahjouba cannot be ruled out[38]. For certain scholars, the construction of those monuments, along with others which characterize only the northern part of Tunisia and Mediterranean North Africa, is linked to foreign influences[39].

The region of El Kef is known for its funerary monuments, particularly complex dolmens such as those at Ellès, which feature gantries at the entrances constructed with squared slabs and blocks[40] . Similar monuments are also found at Maktar, situated to the east of El Kef[41]. Previous excavations of some dolmens and bazinas in El Kef have uncovered human remains, including skulls, as well as Punic coins, pottery, and bronze ornaments[42]. Further south, in the Mahjouba area, dolmens are notably prevalent, especially in the Kasserine region at Jebel Boughanem and Khanguet Sloughi. These structures are associated with bazinas and tumuli and are characterized by simpler forms similar to those found in Mahjouba[43].

Other scholars propose an autochthonous, Libyan origin for them, related to the close contacts mediated through the Punic interconnections crossing the Mediterranean[44]. As aforementioned, the gathering of those evidences in tight necropolises might be a hint for connecting them to the evidence of late Bronze Age and Iron Age evidence of the Mediterranean. Some general suggestions have proposed a timeframe between 700 BCE and 300 BCE[45], while other scholars[46] chose to attribute them to even later dates, from 300 BCE to

32 Barrett (1990), 179-189; di Lernia (2006), 50-62; Knapp (2009), 47-59; Lim and Linares Matás (2023).
33 Camps (1995a), 2490-2509; Camps (1995b), 17-31.
34 Monaco *et al.* (2020).
35 Cicilloni *et al.* (2009); Sanmartí (2018); Sanmartí *et al.* (2015), 287-304; Sanmartí *et al.* (2012), 21-44.
36 Sanmartí (2018).
37 Camps (1995a) 2490-2509; Sanmartí *et al.*, (2015), 287-304 ; Sanmartí *et al.* (2012), 21-44.
38 Boukchim and Marzouki (2024); Kallala (2000), 87–95.
39 Camps and Longerstay 2000, 3361-3387; Paris and Ghaki (2010), 71-74.
40 Harbi-Riahi *et al.* (1985); Camps (1961).
41 Harbi-Riahi *et al.* (1985).
42 M'Timet *et al.* (1985).
43 Ghith-Hmissa (2015).
44 Cicilloni *et al.* (2009); Gatto *et al.* (2019); Sanmartí *et al.* (2015), 287-304.
45 Stone and Stirling (2007).
46 Camps (1995b), 17-31; Cruz-Folch and Valenzuela-Lamas (2018), 175-189.

Figure 9: Some examples of dolmens of various sizes identified during the field survey.

500 CE. The tendency among scholars to relate the monuments of the Maghreb to a relatively recent timeframe is largely due to traces of Punic and Roman material culture within the tombs.

The excavation yielded evidence of secondary burials, aligning with findings from other megalithic necropolises[47]. However, the poor state of preservation of the skeletal remains hinder absolute chronological assessment. This limitation reduces the capacity to situate these evidences within a clear chrono-cultural framework. The presence of secondary burials suggests a complex history of use and reuse, potentially spanning several generations or even centuries. This pattern is consistent with other megalithic sites, where monuments were often repurposed by successive communities. The lack of grave goods further complicates the possibility of determining the burials precisely.

In sum, the implications for social and political organization are manifold. The construction and organization of these dolmens provide insights into the social and political structures of the communities that built them. The significant labour investment and the apparent hierarchical organization suggest a society with the ability to mobilize and coordinate groups of people, even though not necessarily of huge entity. This capability implies some form of centralized authority or strong communal bonds. The placement of larger dolmens in prominent locations may reflect the social status of the individuals or groups buried within them. These structures could serve as markers of social hierarchy, with more prestigious burials located in more visible and accessible areas. This spatial arrangement might also reflect the community's values, emphasizing the importance of visibility and remembrance for certain individuals or groups (Fig. 9).

[47] Cicilloni *et al.*, (2009); Sanmartí (2018); Sanmartí *et al.* (2012), 21-44.

5. Conclusion

The archaeology of megalithic monuments in North Africa remains a debated topic. The nature of this architectural evidence is still difficult to grasp, and without a definite chronological framework where to locate its use and/or reuse it endures as a difficult theme to explore. A key could be the integration of the various pieces of evidence from a more expanded standpoint, both geographically and thematically. This, however, necessitates a huge investment in terms of archaeological research directed principally in the systematic excavation of a great number of evidence. The survey and documentation of new necropolises and the exploration of previously known one will offer new insights and a wealth of data which can enlarge the testing of hypothesis on large scale events, both geographically and temporarily. The study here presented goes in that direction and offers some insights into the potentiality of expanding the analytical framework and hypothesis intertwined with the chrono-cultural history if this part of North Africa.

This research shows, moreover how a detailed and multiscale and multiparametric approach allowed to gather a sufficient amount of data during a relatively short time-slice and cost-effective strategy.

The UAV flight coupled with a postprocessing analysis and foot-survey allowed to expand the relative data acquirement. Limitations are however evident and these are given mostly by the geological and topographical features of the Jebel Zebouzi hill and its environment. The calcareous nature of the emerging bedrock represents a restraint for the clear identification of monuments like dolmens, in particular by considering that the covering slabs are all realized by carving, cutting, and detaching the desired slabs from the very bedrock. Smaller slabs and rocks of the same origin, are then used to create the accessory instalments, and where no clear geometric outline is present, identification is difficult. Remote sensing consistently shows higher detection densities, emphasizing its efficiency and effectiveness in monument detection. Our analysis demonstrates that remote sensing is a highly effective method for detecting archaeological monuments, outperforming foot surveys in terms of both detection density and the total number of monuments detected. Future research will implement those data in a vaster remote sensing research program. These, moreover, will be of great value for the training of image recognition machine learning approaches, which can be advised to be extremely helpful for upcoming studies in the wider area of Mediterranean and Saharan funerary archaeology.

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Authors' contributions

RR fieldwork, data management and analysis, writing and editing
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EC fieldwork, writing and editing
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MDM fieldwork, writing and editing
HK data management and technical support
IM human osteology, paleopathology, fieldwork, writing and editing
SDL designed the research and directed fieldwork 2017,2021-2022, writing, editing and supervising

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Riassunto /*Abstract*

Abstract. This paper focuses on the integrated and multiscale archaeological analysis of the necropolis of Jebel Zebouzi in El Kef, Northern Tunisia, shedding light on the complex and diverse megalithic structures that characterize the region. North Africa features a vast array of pre-Roman funerary monuments, ranging from monumental tombs influenced by Punic and Roman-Hellenistic examples to autochthonous rock-cut chamber tombs known as *haouanet*. The landscape is further enriched with *bazinas*, *chouchet*, tumuli, and dolmens, in some cases forming extensive necropolises. Despite their visibility, the understanding of these structures remains limited. Early assumptions regarding their dating were challenged, suggesting a Late Bronze Age origin. After two centuries of research, there remains a significant hiatus in knowledge regarding the spatial arrangement, funerary traditions, and chronology of these megalithic necropolises.

To bridge this gap, the research project described in this paper has employed cutting-edge techniques such as drone imagery, photogrammetry for documentation during remote and on-foot surveys. Together with selected excavations and bioarchaeological analysis, the goal is to reconstruct some of the necropolis' stratigraphical and spatial configuration, offering insights into horizontal and vertical social complexity and the utilization of space. The study addresses hence the phenomenon of reuse and modification of these ancient monuments over time, raising questions about cultural appropriation, memory, history, and the negotiation of cultural identity. This comprehensive approach aims to contribute to the understanding of North African pre-Roman funerary practices and the cultural dynamics that shaped these megalithic landscapes.

Keywords: Northern Tunisia; Protohistory; Megalithic structures, Funerary Archaeology; Remote Sensing; Field Survey & Excavations

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