

IS ALL THAT'S GROUND A TOOL? PRELIMINARY CONSIDERATIONS ON CUBOID-SPHEROID STONE OBJECTS FROM TELL ABRAQ, UMM AL-QUWAIN (UAE)

Francesca Barchiesi^a, Luca Forti^b,
Michele Degli Esposti^c, Eugenio Bortolini^d, Federico Borgi^e

ABSTRACT – Following the restart of excavations in the eastern part of the multi-period, pluri-stratified site of Tell Abraq (Emirate of Umm al-Quwain, UAE), a series of cuboid-spheroid stone objects were found in contexts dated to the end of the 2nd-1st millennium BC (broadly, the local Late Bronze Age/Early Iron Age). This paper presents the initial results of an inquiry into the possible utilitarian function of these objects. Their characteristic shape (cuboid with rounded edges or spheroid), fairly uniform size, and the hard rocks of which they are made, initially suggested that they may have served as scale weights. Some exhibit traces of abrasive wear and fatigue, suggesting use as tools; for other objects within the assemblage, no marks were observed at all. At the same time, in the specialised archaeological literature, similar objects from various contexts are associated with alternative functions, such as pottery production and metalworking. All these hypotheses are briefly discussed here to spur an increased interest in these often neglected items. While answers cannot be provided at this stage, the basis for more comprehensive research is laid, with the intention of expanding the sample with other objects from archaeologically controlled contexts.

KEYWORDS – Iron Age, United Arab Emirates, Tell Abraq, Macrolithic Tools, Raw Material Procurement, Functional Analysis, Statistics.

RIASSUNTO – *A seguito della ripresa delle indagini archeologiche nella porzione orientale del sito pluristratificato e plurifase di Tell Abraq (Emirato di Umm al-Quwain, UAE), è stata rinvenuta una serie di oggetti litici di forma cuboide-sferoide in contesti datati alla fine del II-I millennio a.C. (in termini generali, alla Tarda Età del Bronzo/Prima Età del Ferro locale). Il presente contributo espone i risultati preliminari di un'indagine volta a chiarire la possibile funzione di tali manufatti. La loro particolare forma (cuboide con spigoli arrotondati o sferoide), le dimensioni relativamente uniformi e la durezza della materia prima con cui erano realizzati avevano inizialmente suggerito un possibile utilizzo come pesi da bilancia. Alcuni esemplari presentano tracce compatibili con un loro impiego come strumenti; per altri oggetti del medesimo insieme, invece, non è stata riscontrata alcuna traccia. Nella letteratura archeologica specialistica, manufatti analoghi provenienti da contesti anche molto differenti fra loro sono stati associati a funzioni alternative, quali la produzione ceramica o metallurgica. Tali ipotesi vengono qui brevemente discusse con l'intento di stimolare una maggiore attenzione verso questa categoria di reperti, spesso trascurata. Sebbene allo stato attuale non sia possibile formulare conclusioni definitive, vengono poste le basi per ricerche più approfondite, con l'obiettivo di ampliare il campione attraverso l'inclusione di ulteriori esemplari provenienti da contesti archeologici controllati.*

^a Department of History and Cultures, University of Bologna, Piazza San Giovanni in Monte 2, 40124, Bologna (BO), francesca.barchiesi4@unibo.it.

^b Dipartimento di Scienze della Terra “Ardito Desio”, Università degli Studi di Milano, Via Luigi Mangiagalli 34, Milano (MI), luca.forti@unimi.it.

^c Institute of Mediterranean and Oriental Cultures, Polish Academy of Sciences, Nowy Świat 72, room 327; 00-330 Warsaw, Poland, mdegliesposti@iksio.pan.pl.

^d Department of Cultural Heritage, University of Bologna, Via degli Ariani 1, 48121, Ravenna (RA), eugenio.bortolini@unibo.it.

^e UAQ-TAD Umm al-Quwain Department of Tourism and Archaeology, Sheik Ahmed Bin Rashid Al Moalla Rd - Al Raudah PO Box: 1500 - Umm al-Quwain, UAE, federico.borgi@gmail.com.

PAROLE CHIAVE – *Età Del Ferro, Emirati Arabi Uniti, Tell Abraq, Strumenti Macrolitici, Approvvigionamento Delle Materie Prime, Analisi Funzionale, Statistica.*

1. INTRODUCTION

Since 2019, the Italian Archaeological Mission in Umm al-Quwain (IAMUQ), in cooperation with the Department of Tourism and Archaeology of Umm al-Quwain (UAQ-TAD), has resumed excavations in the eastern part of Tell Abraq (Degli Esposti *et al.* 2022, 2023). This multi-period, pluri-stratified site (fig. 1), located a short distance from the Arabian/Persian Gulf's coast, shows evidence of human occupation from the 3rd millennium BC (Early Bronze Age) to the 3rd century AD (Late Pre-Islamic period).

Here, a series of cuboid-spheroid stone objects were found in contexts dated to the end of the 2nd-1st millennium BC (broadly, the local Late Bronze Age/Early Iron Age).

This paper discusses 28 of these items (fig. 2) that exhibit a high degree of homogeneity in form (cuboid with rounded edges or spheroid), material (stones of sim-

ilar types), and size (with measurements typically falling within a specific range). Notably, a significant portion shows no evidence of macroscopic use-wear. As highlighted by Dubreuil and colleagues (2015: 112), differentiating use-wear from manufacturing marks (see paragraph 4.3) remains a critical challenge in ground stone tool analysis. Additionally, the potential impact of post-depositional processes on these artefacts warrants consideration.

Inquiring about the potential function of these objects led to various hypotheses, presented here as a preliminary introduction to the issue. The first hypothesis proposes that they functioned as balance weights. Other valid hypotheses more commonly discussed in the literature are also presented, such as crushers used in secondary metallurgical activities, potentially as part of a post-casting/finishing process (Delgado-Raak, Risch 2008;



Fig. 1 – Left: the location of Tell Abraq along the western coast of the UAE, with other south-eastern Arabian sites mentioned in the text (square icons). Right: orthorectified view of Tell Abraq at the end of the 2023 field season. Black and white marks the western part of the site in the territory of the Emirate of Sharjah. The red line identifies the area excavated by the IAMUQ, from where the discussed stone objects came.



Fig. 2 - 28 cuboid-spheroid stone objects from Tell Abra q (UAE). Numbers of find. First row (from left to right): 273, 161, 465, 308, 112. Second row (from left to right): 100, 311, 478, 87, 309, 199, 141. Third row (from left to right): 62, 491, 88, 111, 131, 477, 335. Fourth row (from left to right): 130, 80, 272, 468, 99, 274, 205. Fifth row (from left to right): 66, 102.

Caricola 2020), and polishers for ceramic manufacture (Squitieri 2019; Squitieri *et al.* 2022). In addition, some preliminary considerations on the procurement of the raw material used to produce these objects are discussed: material selection is a fundamental aspect for understanding an artefact's function and effectiveness, as specific properties can favour certain uses (Dubreuil *et al.* 2015: 134).

The different hypotheses, although preliminary, are discussed here and will need to be tested against a larger dataset from secure archaeological contexts. While it is hoped that continued excavation at Tell Abra q yields such a dataset,¹ this note aims at spurring renewed attention towards this type of objects, possibly leading to datasets from other sites becoming available for a more comprehensive study.

2. GEOLOGICAL BACKGROUND OF THE STUDY AREA

The site of Tell Abra q is located in the coastal region of Umm al-Quwain (UAE) in the southern sector of the Arabian/Persian Gulf. The general landscape of UAQ displays diverse features, including elevated areas exceeding 200 metres inland at the foothills of the al-Hajar Mountains, as well as extensive dune fields and coastal lagoon environments (Forti *et al.* 2024). A series of Quaternary coalesced alluvial fans (*bajadas*) occur along the southwestern foothills margin of the al-Hajar Mountains (in the geological map are reported as AFS, AFGO, AFGL, AFGM, AFGH, AFGG, fig. 3). Within the UAQ territory, these alluvial fans comprise a poorly sorted mix of angular rock fragments. These rock fragments come from various geological formations outcropping in

¹ Since the initial submission of this paper, a subsequent field season at Tell Abra q has yielded eight additional ground stone items of the same type discussed here.

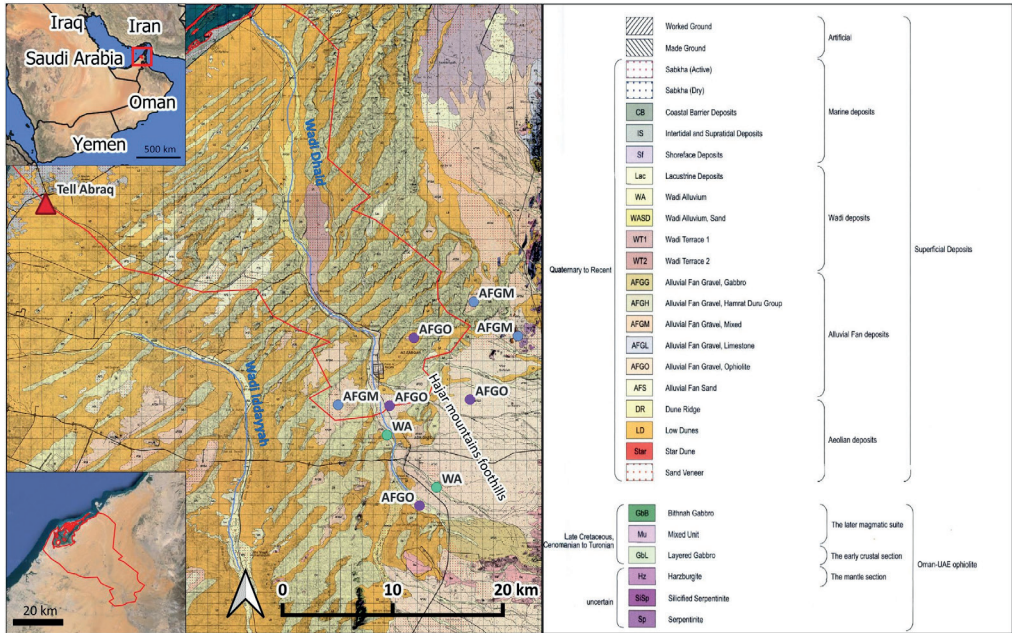


Fig. 3 – Topographic and geologic map of the study area with the indication of the possible main raw material sources (geological map modified from British Geological Survey, UAE Ministry of Energy 2006).

the al-Hajar Mountains. Some are from the UAE-Omani ophiolite (Cretaceous), which includes mantle peridotites – typically harzburgite and gabbros –, while others belong to Jurassic to Pliocene sedimentary, metamorphic, and igneous sequences (Al Farraj, Harvey 2004; Thomas *et al.* 2006).

These alluvial fans are dissected by several wadi systems, the most significant being Wadi Dhaid and Wadi Iddiyah². During periods of intense rainfall, these wadis carry large amounts of rock fragments, including gravel, pebbles, and sand, downstream. The deposits left by flowing water constitute the alluvium, and features like river terraces are found along the course of both wadis (WT1, WT2 and WA in the geological map, fig. 3) (Thomas *et al.* 2006).

3. MATERIALS AND METHODS

Ground stone tools are the most represented find class at the site after pottery, as is indeed often the case. Twenty-eight of these stone objects were examined, and six were exported to Italy for preliminary microscopic analysis. What made them stand out in the field and directed their choice for the study is their broadly uniform, cuboid morphology, characterised by rather flat and regular surfaces. All the items displaying these characteristic shape, which clearly differentiate them from more irregular ground stone tools, were sampled. Their weights range from 72 to 293 g (Tab. 1: column 7); dimensions can vary, but the majority of objects have surfaces measuring between 4 and 6 centimetres (Tab. 1: columns 8-10). The chosen objects come from a variety of contexts, including surface collection and

² Fluvial bodies and basins go under several different names depending on the emirate they flow through and nearby landmarks. The same *wadi* might even have different names on official geological maps. The names used here are the most widely recognised ones.

Inv. N°	Trench	SU	Excavation campaign	General shape	Raw material	Weight (g)	D1 (cm)	D2 (cm)	D3 (cm)	Notes	Volume (ml)	Specific weight
62	4	43	2020	Sub-spherical		219	5.7	5.4	4.8	Rough surfaces	79	2.772
66	4	82	2020	Sub-spherical		226	5.5	4.8	4.4	Traces of copper. 3 crushed surfaces	59	3.831
80	2	5	2020	Irregular		259	6	5.4	4.8	1 surface with possible hammering marks	86	3.012
87	1	3	2020	Cuboid	quartz/ feldspathic vein	140	4.6	4.5	4.3	1 surface is slightly smoother than the other more rugged ones. No clear mark of crashing	53	2.642
88	1	3	2020	Sub-cubical		137	5	4.2	3.7	2 opposite surfaces crushed/concave	53	2.585
99	2	108	2020	Sub-cubical		236	5.3	4.6	3.9	1 surface looks non-symmetrically shaped on one edge	62	3.806
100	2	108	2020	Flattened sub-spherical		198	5.5	5.5	3.8	Very polished on every surface	79	2.506
102	1	109	2020	Sub-spherical		146	4.1	3.8	3.7	No polished surfaces, rough	32	4.563
111	1	111	2020	Sub-spherical		140	4.7	4.4	4	1 very small concavity on 1 surface	52	2.692
112	1	111	2020	Cuboid		155	4.6	4.3	4.2		59	2.627
130	2	108	2020	Flattened sub-spherical		226	5.8	5.6	3.6	2 opposite flat surfaces slightly concave	66	3.424
131	2	108	2020	Cuboid		177	4.6	4.6	4.3	1 concavity on one surface	59	3.000
141	2	108	2020	Irregular		23	2.6	2.5	2.1	No macro wears	7	3.286
161	2	153	2020	Cuboid	gabbro	140	4.1	4	3.8	1 slightly concave surface	45	3.111
199	2	187	2020	Sub-cubical		134	4.6	4.2	3.9	1 particularly polished surface, other 2 surfaces with a probable natural blow.	49	2.735
205	4	71	2020	Semi-spheroid		72	4.1	3.8	2.7	Broken. Half of original 140 weight?	20	3.600
272	4	94	2021	Cuboid	gabbro/ diorite	192	5	4.9	4	Yellowish/orange patina on 1 surface. 1 smoothed side with a worn-out edge	59	3.254
273	2	5	2021	Cuboid	peridotite	294	5.9	4.8	5.1	Diffused yellowish patina covers much of the surface	99	2.970
274	4	218	2021	Sub-spherical		161	5.4	4.5	4.3	Hammering traces on 1 surface (at least)	50	3.220
308	3	209	2021	Cuboid	grano- diorite	155	4.4	4.3	4.3	1 flatter surface. Several points of impact	53	2.925
309	3	119	2021	Cuboid	peridotite	138	4.1	4.1	4.4	2 concavities in two opposite surfaces and one more rough-hewing	36	3.833
311	4	43	2021	Parallelepiped		373	5.4	7	5	4 flat surfaces, 2 opposite convex surfaces	126	2.960
335	2	263	2021	Irregular cuboid		51	3.5	3.2	3	No macro wears	10	5.100
465	7	263	2022	Cuboid	peridotite	153	4.4	4.3	4.1	3 surfaces with concavities, 1 other surface with possible crush	53	2.887

468	4	319	2022	Irregular	peridotite	148	5.7	5.2	3.3	1 very polished surface. Reused after fragmentation?	53	2.792
477	4	295	2022	Sub-cubical	peridotite	148	4.9	4.3	4.3	1 possible crush on 1 surface (natural?)	56	2.643
478	4	295	2022	Cuboid	peridotite	138	4.3	4.2	4.2	Rough surfaces	51	2.706
491	4	427	2022	Cuboid	peridotite	293	6.1	5.2	4.9	1 surface very smooth, the others rough	100	2.930

Tab. 1 - Measurements and descriptive notes of the 28 examined objects from Tell Abraq. Objects highlighted in light grey were subjected to microscopic observations with a Dino-Lite microscope (see Paragraph 4.3).

extensively reworked topsoil. Overall, they do not date earlier than the Late Bronze Age (specifically, the mid-2nd millennium BC), but those from unsealed contexts can be as late as the first centuries AD, consistent with the long chronology of human activities at the site (Degli Esposti *et al.* 2025).

The most reliable contexts from the point of view of a correlation between them and an actual use of these cuboid items are SU 71 and 82 (provenance contexts of F205 and F66 respectively), a use surface and the associated anthropogenic accumulation dated between 800-550 BC. SU 111, dated between 1500-1300 BC, also derives from human activities within one of the Late Bronze Age buildings discovered at the site. While the absolute date is under re-consideration and might reflect the use of old wood in the structure, it is interesting to note that from the same contexts other ground stone tools were recovered, namely four anvil stones, bearing witness to productive activities to which F11 and F112 might, therefore, be linked.

Other stone tools that are associated with late use surfaces are F468, F477, and F478, even though the relative contexts (SU 319 and SU 195) are quite superficial and not unlikely to include reshuffled materials.

All the six items selected for preliminary traceological analysis come from mixed and reworked contexts, with the possible exception of F87 from SU 3, a late use surface that is, however, rather near the modern surface. SU 94, the prov-

enance context of F272, is worth of note as it consists in a stone tumble, potentially affecting the preservation of the original surfaces of the studied item.

For the determination of main raw material lithologies, a macroscopic observation approach (using standard geological definitions) was conducted, together with a rock acid test (HCl) used to identify carbonate minerals and observation through a double magnifying glass (30x22 mm - 60x12 mm). As an aid to the lithological identification, the specific weight of each item was also calculated (Tab. 1: column 13).

Following preliminary lithological description, HCl testing, and identification of the materials, the geological map of the area (British Geological Survey, UAE Ministry of Energy 2006) was consulted to identify potential source areas close to the site.

The morphology of the objects was analysed, as it is potentially indicative of how they were used (how they could be handled and moved) (Dubreuil *et al.* 2015: 108; Breglia *et al.* 2016: 6). However, morphology alone is not sufficient to determine the tool function or the object of the action (Wright 1994; Adams 1999). A functional approach was, therefore, adopted for a preliminary use-wear analysis (observation of grain shapes, pits, striations, and fractures), drawing from the published literature (Adams 2002, 2014; Hamon 2008; Dubreuil *et al.* 2015).

Low-magnification microscopic observations (20x-45x) were conducted using a

Dino-Lite AM 4113 ZT-A microscope. Detailed photographs were captured alongside the microscopic examination.

Exploratory data analysis was carried out to identify patterns of interest in the observed dataset, and differences between emerging groups were ascertained through classical hypothesis testing using R version 4.4.0 (R Core Team 2024). More in detail, Principal Component Analysis (PCA) was performed on the joint distribution of D1, D2, D3, and volume (see Tab. 1) using the packages FactoMineR (Le *et al.* 2008) and Factoextra (Kassambara, Mundt 2020). Pairwise Euclidean distances were calculated on the first two principal components which accounted for 93.3% of the total variance using the function “distance” in the package ecodist (Goslee, Urban 2007). The resulting distance matrix was then analysed using Partitioning Around Medoids (PAM) using the function pam in the package cluster (Maechler *et al.* 2023), which identified four groups as the best result using the Average Silhouette Width method. The distribution of weight and specific weight across the four clusters was then explored through box-and-whiskers plots, and we tested for the presence of differences between groups. Cluster 3 resulted in being non-normally distributed (Shapiro-Wilk test, Tab. S1-2³) for both weight and specific weight. Despite Levene’s test (performed using the car package, Fox, Weisberg 2019) detected homogeneity of variance (Tab. S3-4), considering the small sample sizes, we proceeded using non-parametric Kruskal-Wallis tests to ascertain for significant differences among all groups, and Dunn Tests as post-hoc to identify pairwise significant differences (using the package FSA, Ogle *et al.* 2023). All codes for replicating the analyses are included in the appendix to this paper.

4. RESULTS

4.1 Lithological identification

Lithological identification recorded the association of several minerals within the stone objects, defined as plagioclase, amphibole/pyroxene, and quartz, belonging to the UAE-Omani ophiolite complex. In particular (Tab. 1: column 6):

F87: quartz-felspathic vein (fig. 4: 1);

F161: gabbro (fig. 4: 2);

F272: gabbro/diorite (fig. 4: 3);

F273: gabbro (fig. 4: 4);

F308: grano-diorite (fig. 4: 5);

F309: fine gabbro (fig. 4: 6).

Peridotite is also very frequent (fig. 4: 8).

The UAE-Omani ophiolite or Semail Igneous Complex covers a vast area of the al-Hajar Mountains and consists in ophiolite suite and serpentinite, including variable occurrences of pillow lava, gabbro, and diorite, and some other ultrabasic rock types (Rioux *et al.* 2016; U.S. Geological Survey, Arabian American Oil Company 1963). In the British Geological Survey and UAE Ministry of Energy (2006) geological map, the Semail Igneous Complex was recognized in the Oman-UAE ophiolite.

4.2 Cluster analysis, and the distribution of weight and specific weight

The PCA run on morphometric variables resulted in the first two PCs bearing almost all the total variance (fig. S1), with a strong correlation among all variables except D3, which is still positively correlated to the others (fig. S2). Partitioning around medoids identified four clusters with a best score of 0.55 average silhouette width (Tab. 2; fig. 5; Tab. S5). The distribution of weight across the four groups shows a marked and almost linear decline from Cluster 1 to 4 (fig. 6),

³ The letter S in front of Tab. or fig. stands for “supplementary”, indicating materials that can be found in the Appendix at the end of the article.

hinting at a strong correlation with the distribution of morphometry and volume. While observed variance seems to be consistent for groups 1 and 2 (IQR=35, 39g; Tab. S6), Cluster 3 exhibits the lowest variability (IQR=21g), followed by Cluster 4 (IQR=24.5g). Median values (Cluster 1=293, Cluster 2=198, Cluster 3=148, Cluster 4=51; in grams) are much closer between Clusters 2 and 3 than between Cluster 1-2 or Cluster 3-4. Kruskal-Wallis test confirmed the presence of significant differences in the distribution of weight

(Chi-squared= 17.101, df = 3, p-value < 0.001), while Dunn Test suggests an overlap between all clusters except for Clusters 1-3 and 1-4 (Tab. S7). The ratio between the median value of Cluster 3 (the most standardised one) and all the remaining Clusters shows some regularities, with the median value for Cluster 1 weighting twice as Cluster 3 (1.98), Cluster 2 weighting 1.34 times the median of Cluster 3, and the median of Cluster 4 weighting almost a third of the median of Cluster 3 (0.34).

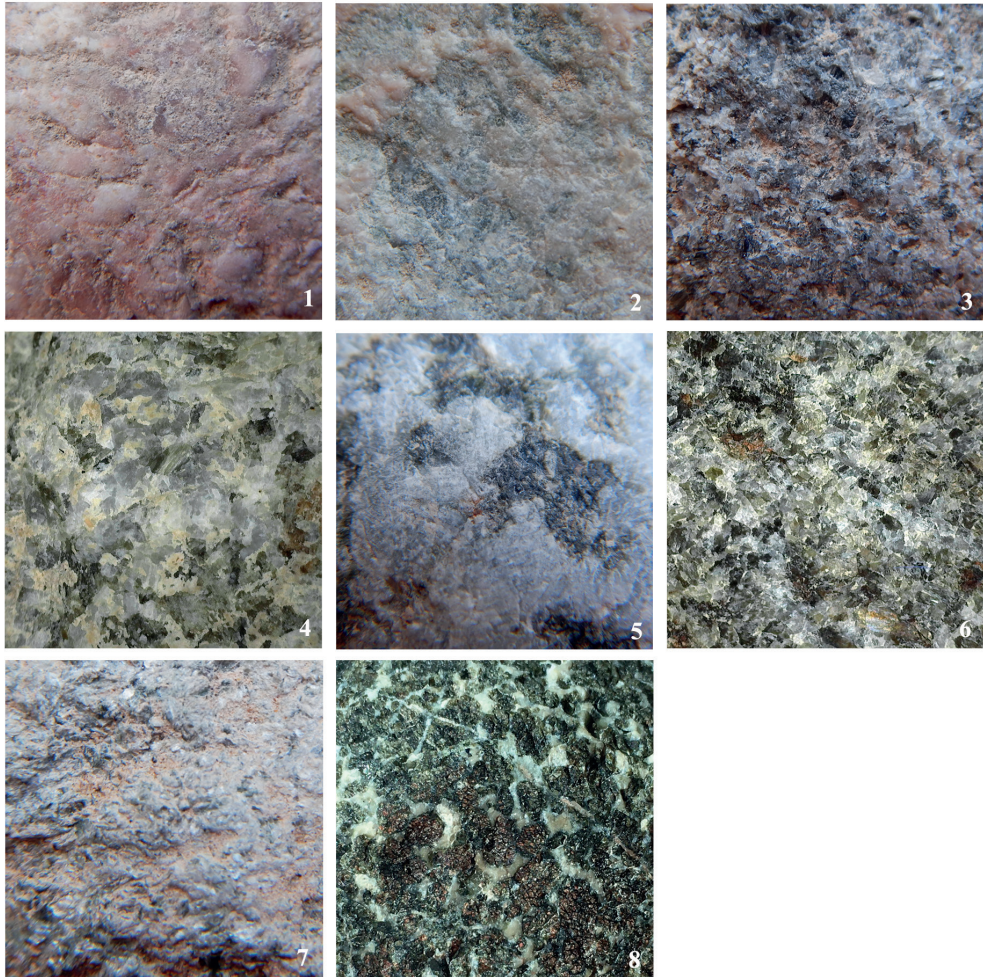


Fig. 4 – Close-up photos of 8 finds, not to scale. 1: F87, quartz-felspathic vein. 2: F161, gabbro. 3: F272, gabbro/diorite. 4: F273, gabbro. 5: F308, grano-diorite. 6: F309, fine gabbro. 7: F335, non id. 8: F477, peridotite.

Inv. N°	Trench	SU	Shape	Cluster	Context chronology
62	4	43	Sub-spherical	1	post-Iron Age (topsoil)
66	4	82	Sub-spherical	3	Iron Age
80	2	5	Irregular	1	post-Iron Age (topsoil)
87	1	3	Cuboid	3	Iron Age
88	1	3	Sub-cubical	3	Iron Age
99	2	108	Sub-cubical	3	Iron Age (but with mixed material)
100	2	108	Flattened sub-spherical	2	Iron Age (but with mixed material)
102	1	109	Sub-spherical	3	Iron Age
111	1	111	Sub-spherical	3	Late Bronze Age
112	1	111	Cuboid	3	Late Bronze Age
130	2	108	Flattened sub-spherical	2	Iron Age (but with mixed material)
131	2	108	Cuboid	3	Iron Age (but with mixed material)
141	2	108	Irregular	4	Iron Age (but with mixed material)
161	2	153	Cuboid	3	Iron Age (early)
199	2	187	Sub-cubical	3	post-Iron Age
205	4	71	Semi-spheroid	4	Iron Age
272	4	94	Cuboid	3	Late pre-Islamic or later
273	2	5	Cuboid	1	post-Iron Age (topsoil)
274	4	218	Sub-spherical	3	Late pre-Islamic or later
308	3	209	Cuboid	3	post-Iron Age
309	3	119	Cuboid	3	Iron Age
311	4	43	Parallelepiped	1	post-Iron Age (topsoil)
335	2	263	Irregular cuboid	4	Iron Age
465	7	263	Cuboid	3	Iron Age
468	4	319	Irregular	2	Late Bronze Age ?
477	4	295	Sub-cubical	3	Late Bronze Age ?
478	4	295	Cuboid	3	Late Bronze Age ?
491	4	427	Cuboid	1	post-Iron Age

Tab. 2 - Attribution of each object in the present dataset to one of the four clusters obtained through Partitioning Around Medoids + indication of their context chronology.

Turning instead to the distribution of specific weights (fig. 7; Tab. S8), Cluster 1 (IQR=0.04) is the least variable group, followed by Cluster 2 (IQR=0.46) and Cluster 3 (IQR=0.56). Cluster 4 exhibits considerably higher values (median=3.6, IQR=0.9), which may hint at heavier, although more variable, raw materials. No significant differences were found among the groups (Kruskall-Wallis Chi-squared=4.7626, df = 3, p-value = 0.19). Cluster 3 seems therefore to be: 1) the most standardised group in terms of absolute weight; 2) among the most standardised groups in terms of specific weight; 3) the group with the second lowest specific weight, with Cluster 2; 4)

the group whose absolute weight is half of the heaviest group (Cluster 1) and three times the weight of the lightest group (Cluster 4); and 5) the group that includes the highest number of observations (n=17, Tab. S9) as well as the most conspicuous number of cuboid and sub-cubical objects (i.e. 13/15 or 87%; Tab. S9).

4.3 Preliminary microscopic observations (low magnification)

Following the initial evaluation of surface topography using low-magnification microscopy, a selection of objects (Finds 87, 161, 272, 273, 308, and 309; see Tab. 1 and fig. S3) was chosen for more detailed microscop-



Fig. 5 - Scatterplot of Principal Component Analysis carried out on the distribution of D1, D2, D3, and volume. The figure portrays PC1 and PC2 amounting to 93.3% of the total variance. Colours refer to the four clusters identified by analysing the distribution of pairwise Euclidean distances based on PCA coordinates using Partitioning Around Medoids. Larger circles without labels indicate group centroids.

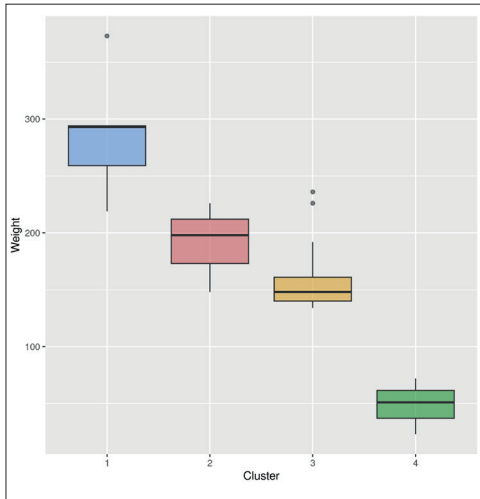


Fig. 6 - Box-and-whiskers plot showing the distribution of absolute weights (in grams) across the four identified Clusters.

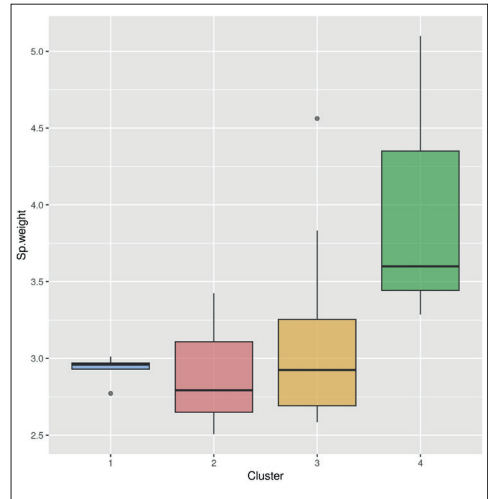


Fig. 7 - Box-and-whiskers plot showing the distribution of specific weights (expressed in Kg/dm³) across the four identified Clusters.

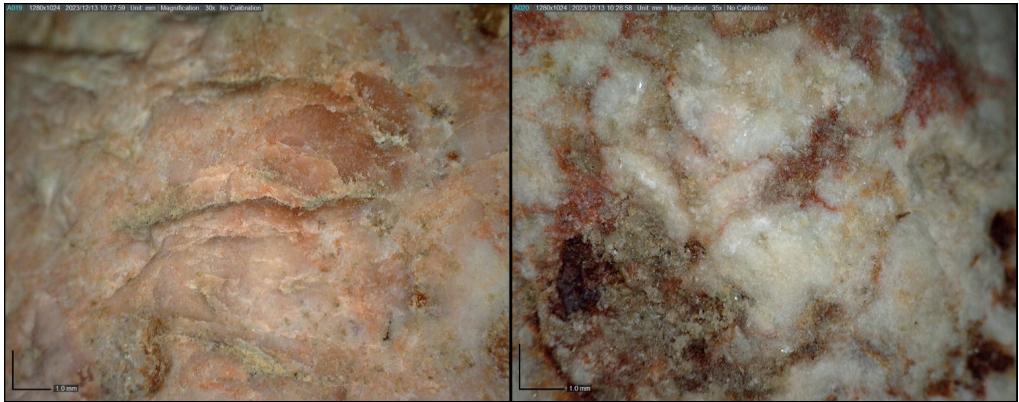


Fig. 8 – F87. Left: natural irregularities of the surface topography. Right: smooth, shiny area surrounded by rougher surfaces, located at a point of curvature. Scale: 1 mm; Magnification: 30x left, 35x right.

ic observations. Given the possibility to export only a very limited number of artefacts to Italy, these 6 were selected either for their relatively regular shape, their weight, or because they appeared more promising for the documentation of wear. Since it was not possible to carry out experimental archaeology specifically for this study, we relied on well established protocols and guidelines for ground stone tool analysis (e.g. Adams 1993, 2002, 2014; Hamon 2003; Adams *et al.* 2006; Dubreuil *et al.* 2015; Squitieri, Eitam 2016; Chondrou *et al.* 2022). The initial microscopic observations targeted the highest surface points, as these areas are most likely to represent the primary points of contact during tool use (Adams 2014: 134).

F87 (quartz/feldspatic vein)

Find 87 (fig. 8) shows no preferential support surface. Macroscopically, one surface is slightly smoother than the others. Under Dino-Lite observation, a slightly sheen area was identified at a point of curvature on the object's surface, surrounded by rougher areas. (fig. 8: right). On fig. 8: left is possible to appreciate the natural irregularities of the surface topography.

F161 (gabbro)

Find 161 has the most cubic shape among the finds discussed in this paragraph. Several parallel short striations are visible on one surface (fig. 13: left); on one edge, a couple of impact fractures were also documented (fig. 9: right). On what we considered the supporting surface, a general severe flattening of the grains⁴ and some sheen can be observed (fig. 9: left). By contrast, the remaining surfaces show a rougher micro-topography with more sharp-edged, less modified grains.

F272 (gabbro/diorite)

Find 272 has a smoothed surface with a worn-out edge, characterised by heavily flattened grains (fig. 10: right). On the opposite surface, the grains appear much more angular. Some striations (fig. 10: left) and a yellowish/orange patina are also visible on one surface.

F273 (peridotite)

A diffused pale yellowish patina covers much of the surface of this find. In some areas, a different type of orange patina

⁴ In this paper, “flattened grains” refers to a collapse of grain microrelief resulting in a locally smeared surface topography.

Is all that's ground a tool?

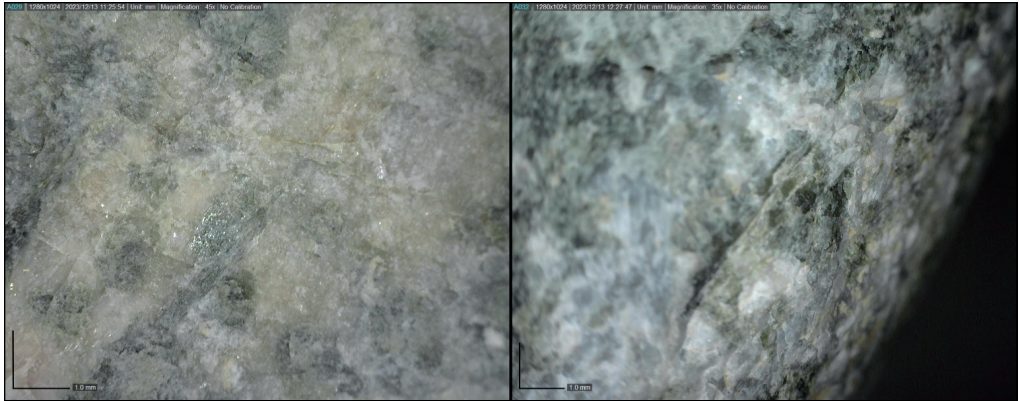


Fig. 9 - F161. Left: heavily flattened grains and some sheen. Right: impact fractures. Scale: 1 mm. Magnification: 45x left, 35x right.

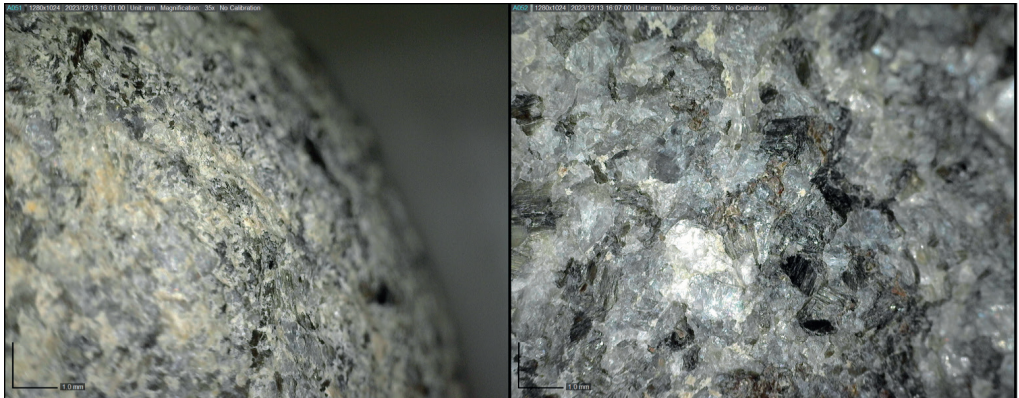


Fig. 10 - F272. Left: striations on one edge. Right: heavily flattened grains and sheen located on the smoothed edge of the object. Scale: 1 mm. Magnification: 35x both left and right.

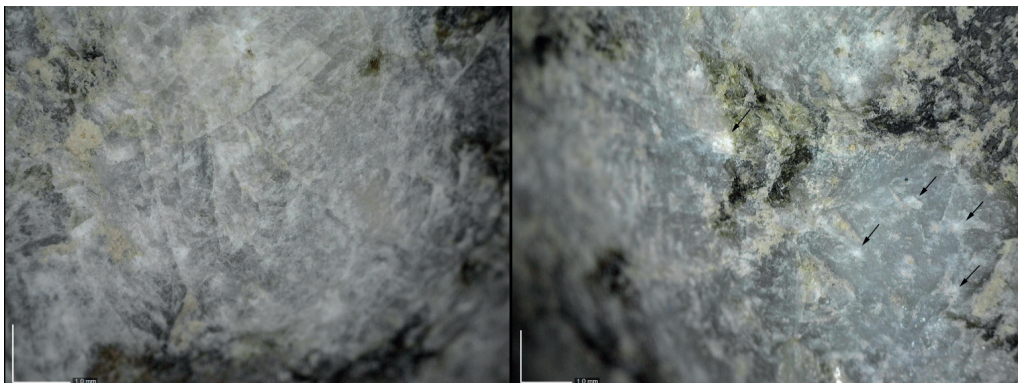


Fig. 11 - F308. Left: random and crossing striations. Right: impact fractures. Scale: 1 mm. Magnification: 45x left, 40x right.

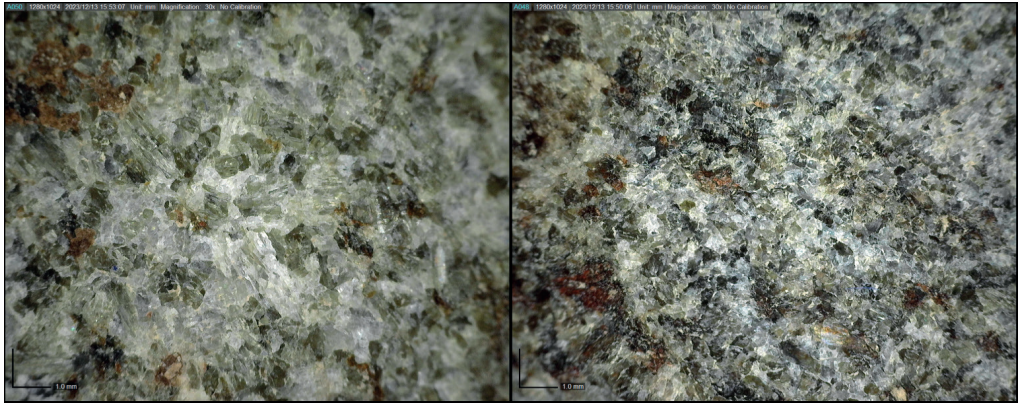


Fig. 12 – F309. Left: convex surface with more rounded grains. Right: inside the bigger concavity, the shape of the grains is more angular. Scale: 1 mm. Magnification: 30x both left and right.

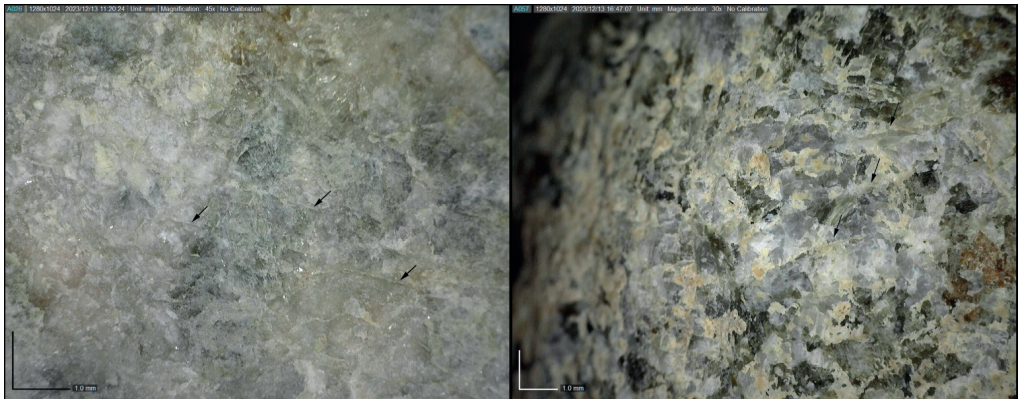


Fig. 13 – Left: F161 parallel striations. Right: F273 pale yellowish patina and 3 parallel striations. Scale: 1 mm. Magnification: 45x left, 30x right.

and a few rust-coloured spots – possibly iron oxidation – are visible. The pale yellowish patina obscures most of the object's surface, hindering the identification of potential use-wear traces. However, three parallel striations are visible on one edge. (fig. 13: right).

F308 (granodiorite)

Sheen is quite diffuse, as well as grain flattening. There is a flatter surface that is also rich in randomly oriented striations located on or near the edges (fig. 11: left), while they are absent in the centre of the

other surfaces. Several impact fractures are also visible (fig. 11: right).

F309 (peridotite)

Two opposing surfaces display shallow concave morphologies, while a third one shows signs of rough-hewing. No striations or minor impact fractures are visible.

Since the grains inside the two concave areas display comparatively sharper, more angular edges (fig. 12: right) than those outside them (fig. 12: left), some form of localised crushing is hypothesised (*fatigue wear*: Adams 2014: 133).

Summing up, no clear manufacturing traces⁵ are visible on any of the 6 objects. Indeed, the (few) traces and features described above are interpreted as relating to use (as in the case of the flattened grains, plausibly linked to handling) or, at most, to post-depositional modifications (impact fractures, which may derive either from use or, alternatively, from taphonomic processes).

A recognisable pattern is the presence of striations located on the rounded edges of the various surfaces (curvature points). Another pattern is the evidence of flattened grains and, in some cases, sheen (abrasion clue).⁶

5. DISCUSSION

5.1 *Raw materials procurement strategies*

Based on the hardness of the rocks, it is intuitively more likely that pebbles and cobbles with particular shapes and weights were collected from secondary deposits, such as riverbeds, fluvial and alluvial (WA, AFGO, AFGM) fans located at the foothills of the al-Hajar Mountains, rather than directly from the primary outcrops. This is further supported by the smooth and rounded shape of some specimens, which show little if any signs of human modification (e.g., F87) and could be explained by transport and erosion by water (Mueller *et al.* 2023) (figs. 2-3).

Considering the location of Tell Abraq relative to nearby wadis compared to the northern reaches of the al-Hajar mountain range – the al-Hajar al Gharbi, separated by the Ru'us al-Jibal (the mountains forming the Musandam Peninsula) by the Diba zone – the shorter distance to the wadis would further support the idea that the raw materials came from secondary deposits.

The remarkable amount of much larger (roughly 15 to 40 cm) wadi pebbles used in the construction of the main buildings of Tell Abraq, dated to the 3rd and 2nd millennium BC (e.g., Potts 1991; Degli Esposti *et al.* 2023) supports this interpretation and indicate the necessity to even venture further away to collect them.

The al-Hajar mountains offer a vast variety of rocks and minerals that have been used since prehistoric times and have fueled long-distance connections. Even if copper played the most important role (Weisgerber 1980; Weeks 2004), hard stones were also sought after (Maggie 2014: 16; Harrower *et al.* 2016). Recent studies have highlighted, for example, the procurement strategies implemented by the people living during the 3rd and 2nd millennia BC at Kalba 4, a sort of twin site to Tell Abraq located along the eastern coast of the UAE, to supply the production of stone artefacts (Schwall *et al.* 2023). The exploitation of semi-precious stone deposits was instead identified at Jebel al-Ma'taradh, located on the edge of the gravel plains that border the western foothills of the al-Hajar mountains (Charpentier *et al.* 2017). While objects allegedly made with the stones quarried at Jebel al-Ma'taradh are found some 300 km from their source (*ibid.*), the deposits tested to verify a possible correlation with Kalba 4 are comprised within a maximum distance of roughly 75 km from the site (Schwall *et al.* 2023: fig. 10). The distance between Tell Abraq and the same primary deposits would be consistent with this figure, around 70 km maximum⁷.

5.2 *The scale weight hypothesis*

Although this type of analysis yields more reliable results with a larger sample size,

⁵ By “*manufacturing traces*” we refer to clear evidence of rough shaping/chiselling intended to give the objects a cubic shape.

⁶ Tribochemical sheen develops on a surface when it becomes too smooth to be further abraded/be abraded (Adams 2014: 135).

⁷ The collection of lithological samples is among the future objectives of the IAMUQ.

the Frequency Distribution Analysis highlights a few weight clusters, the most consistent being the one around 135/155 g. Multiples can only be tentatively suggested, with specimens weighing around 210 g and 280/300 g (Tab. 1, column 7). Quoting Ialongo and Rahmstorf (2019: 117) «a relative standard deviation of ca. $\pm 5\%$ is generally accepted as a standard threshold (Ialongo 2018; Rahmstorf 2010), and there are cases where this value can be even higher (Hafford 2012)».

While the bigger sample size of Cluster 3 may be the reason for the exhibited lower variance, such lower variability could also be genuinely indicative of the fact that this group is the most conspicuous, the most standardised in terms of weight and shape, with one of the lowest and less variable specific weights.

The type of stones used could be an aspect to pay particular attention to: the selection of these very hard materials could be explained to avoid wear and subsequent weight loss as much as possible.

Some of the finds may have served a secondary function as tools, as indicated by evidence of impact fractures, striations, polishing, and concavities (Tab. 1: column 11, and the descriptions in paragraph 4.3). However, none of these traces is unequivocally ascribable to a recognisable activity⁸. At the same time, certain items show no macro-traces at all (e.g., F87). Traces of secondary use are quite frequently documented on balance weights (Petruso 1992: 4; Rahmstorf 2016: 245-247; Eitam 2019: 182-185). Moreover, the possibility that some of these marks derive from an intentional reshaping and weight adjustment should also be considered.

Cuboid-spheroid stone objects with very similar characteristics were found in domestic contexts at several Iron Age sites in Israel (Eitam 2019: 185; Green-er et al. 2023: 60-61). According to D. Eitam

(2019), they were used as the common-market balance-weighing system.

5.3 Other hypotheses

In the classification of Squitieri, Herr and Amicone (2022: 9, 16), fist-sized pebbles with a maximum diameter of 5-7 cm can serve the function of polishers, adaptable to work with various types of materials (metal, stone, ceramic). Indeed, the authors explain that from an initial sub-spherical morphology, due to intense use, these objects can develop several flat and shiny surfaces, becoming almost cubic and thus strongly comparable with the items discussed here. On these flat surfaces, they identified tiny striations and sometimes a shiny patina. Noteworthy, most of the polishers found at the Iron Age site of Gird-i Bazar (Iraqi Kurdistan) are made of volcanic or metamorphic rocks (e.g. basalt or serpentinite): similarly to our considerations, the authors highlight the selection of lithotypes, justified by their hardness, which would enable a superior polishing effect compared to softer sedimentary rocks. At Gird-i Bazar, these polishers are considered to be used for the polishing and burnishing steps in the pottery *chaîne opératoire*.

In several European contexts, similar cuboid tools are known to have been employed in the metalworking process, to hammer copper alloy artefacts or smooth down metal objects (Drenth et al. 2013; Iaia 2014; Boutoille 2019; Caricola 2020). In some fortunate conservative cases, traces of copper were preserved and documented on some of these objects (Freudenberg 2006: 24-25).

A techno-functional analysis was conducted on five well-preserved objects from Eneolithic contexts from the area of Rome in Italy (observation of macro- and micro-traces using a binocular stereomicroscope and reflected light metallographic

⁸ Further use-wear analysis of a larger assemblage, together with targeted experimental work and/or systematic comparison with published experimental reference collections, would be required to interpret these use-wear patterns.

microscope) (Caricola 2020). By comparison with the type collection of wear patterns of the 'Museo delle Civiltà' in Rome, the traces identified on the archaeological objects were associated with those observed on replicas used for the abrasion/smoothing of objects made of "soft" metal (with a hardness similar to copper). The author proposes that the lack of evident manufacturing marks – connected to their initial shaping – on these cuboid objects may suggest their morphology resulted from prolonged use in smoothing or abrading activities. However, the possibility that use-wear may have entirely obscured any earlier manufacturing traces on the object surfaces is acknowledged.

Furthermore, this kind of objects may have been used interchangeably as either active or passive tools, but their small size makes them more practical in an active role, directly gripped without the mediation of a handle: surfaces which, when observed under the microscope, showed heavily flattened grains (as described in paragraph 4.3.), may be the result of the so-called prehensile wear/adhesive wear (Adams 2014: 132).

It can be noted here that indirect (non-metallic) evidence for secondary copper processing has been reported from Tell Abraç, including casting prills, crucible slags, anvils, and hammers. The latter stone tools, however, were not further described (Weeks 1997: 26-28). More in general, ground stone tools are often reported in connection with metallurgical activity at prehistoric sites in Southeast Arabia (e.g. Weisgerber 1981, 1987; Genchi, Giardino 2018; Valente 2023), consistent with the above-mentioned fundamental role of copper exchange in shaping long-distance connections since the 3rd millennium BC, although with a later decrease. This association was underlined in the early 3rd-millennium Buildings I and V at al-Khashbah, where some illustrated examples could indeed be comparable with

those examined here (Döpfer 2020: fig. 14/KSB17H-i7023).

A completely different use was suggested for some of the small- to medium-sized ground stone tools discovered at Tell Abraç during the fieldworks of the Danish team that investigated the site between the late 1980s and the 1990s. D. Potts (1990: 124) compared several ground stone tools discovered at the site with shell crushers known from shell middens in the region as well as from one surveyed at the northern edge of Tell Abraç. Several such "shell crushers" are listed in the catalogues of small finds of the 1989 and 1990 field seasons (Potts 1990: 155-157; Potts 1991: 146-154). However, it is clear from the provided illustration of some of these items (Potts 1990: fig. 158) that they are not comparable with the cuboid-spheroid specimens considered here. At the same time, it is worth noting that in the same lists, four objects are termed "cube" and have comparable dimensions to those discussed here. Table S10 in the Appendix lists them together with a few other objects whose dimensions would also be consistent; lacking their illustration, it was, however, deemed not to add them to the statistical analyses performed here.

Finally, it can be mentioned that Böhme and Al Sabri (2011) suggested somewhat similar stone tools could have been used for trimming stones during Bronze Age tomb construction at the Bat site. Nevertheless, the morphology of those tools is not comparable to the ones under discussion (Böhme, Al Sabri 2011: fig. 23/165-166).

6. CONCLUDING REMARKS

Due to their shape and the material they are made of, the ground stone objects presented here initially made us think of scale weights. Of course, the interpretation remains in the realm of speculation in the absence of verified closed strati-

graphic contexts and a statistically relevant sample. Besides, it is not possible to rely on the presence of quantity marks (numerals) and textual sources about this issue are not known in the region.

Admittedly, almost anything can be used as a weight, as demonstrated by the often neglected category of natural pebbles (Petrucci 1992: 4; Roscio *et al.* 2011; also, ethnographic observations, pers. comm. Prof Maurizio Cattani). This makes their identification even more difficult (Ialongo, Rahmstorf 2019: 108).

Published parallels for Arabian regions are also scarce at best. Indeed, these items occur very frequently in excavations and surveys but are usually not separated from other general macro lithic tools and random occurrences of natural rocks. Nevertheless, the fact that a few similar objects were illustrated in the field reports from prehistoric sites such as the island of Umm an-Nar in Abu Dhabi, the towers of Bat and the copper production site of al-Khashbah in Oman (Costa 2016; Döpfer 2020; Al Meqbali, Eddisford 2023), triggers further interest in their study.

For a region about which still too little is known, this short contribution is certainly more an attempt to raise further interest and an invitation to include these objects in reports and final publications. Despite the challenges in definitively interpreting their function, incorporating these objects into the analysis would enlarge the known sample size and strengthen the statistical significance of tests aimed at determining their potential uses⁹. The combined application of geological and statistical analyses in this research has proven to be an effective approach for investigating this type of archaeological finds. Another key point is the replicability of this methodology, for which all relevant codes are provided in the Appendix (pp. 28-30).

The final point we wish to emphasize – although we are not the first to do so, yet it remains a challenge when navigating excavation reports and publications – is the inconsistent terminology used to refer to these objects, which are typically classified as *hammerstones*, *polishers*, or *pounders*, depending on the context. Perhaps, except cases involving ideal excavation contexts where the combination of topographical data, contextual information, and use-wear analysis allows for a secure interpretation, it would be useful to move away from terminologies that inherently convey an interpretative hypothesis. Instead, terms more closely related to the morphology of the objects, such as *cuboid-spheroidal stone objects*, could be preferred.

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DECLARATION OF COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the author(s) used ChatGPT exclusively to enhance English grammar. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

⁹ Ground stone objects were recorded from previous excavations at Tell Abraq whose measurements and descriptions are consistent with those considered here (Potts 1990: 152-157; Potts 1991: 145-155). These will hopefully allow a first enlargement of the sample.

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APPENDIX SUPPLEMENTARY DATA

	Test Statistic (W)	p-value
Cluster1	0.95266	0.7562
Cluster2	0.97417	0.6917
Cluster3	0.75711	0.0005
Cluster4	0.993	0.8428

Tab. S1 - Results of Shapiro-Wilk normality tests run on the distribution of the variable "Weight" within each identified cluster. Significant values for which the null hypothesis was rejected are indicated in bold.

	Test Statistic (W)	p-value
Cluster1	0.83588	0.1538
Cluster2	0.95486	0.5911
Cluster3	0.83715	0.007
Cluster4	0.87537	0.3109

Tab. S2 - Results of Shapiro-Wilk normality tests run on the distribution of the variable "Specific weight" within each identified cluster. Significant values for which the null hypothesis was rejected are indicated in bold.

	Df	F Value	p-value
Group	3	0.6	0.62
Residual	24		

Tab. S3 - Levene's Test for homogeneity of variance across Clusters in the variable Weight (median used as center).

	Df	F Value	p-value
Group	3	1.3	0.3
Residual	24		

Tab. S4 - Levene's Test for homogeneity of variance across Clusters in the variable Specific weight (median used as center).

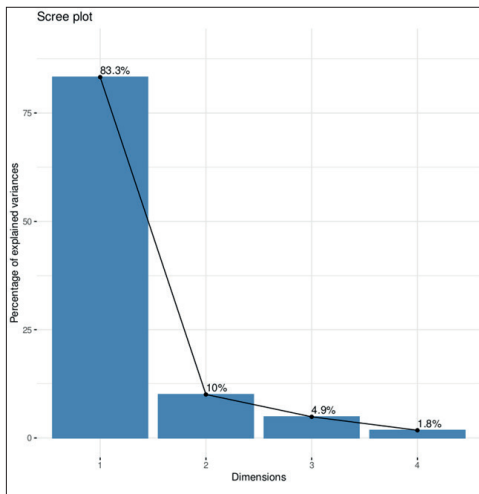


Fig. S1 - Variance explained by each of the four Principal Components emerged from the analysis (PCA) carried out on morphometric variables (D1, D2, D3, and Volume).

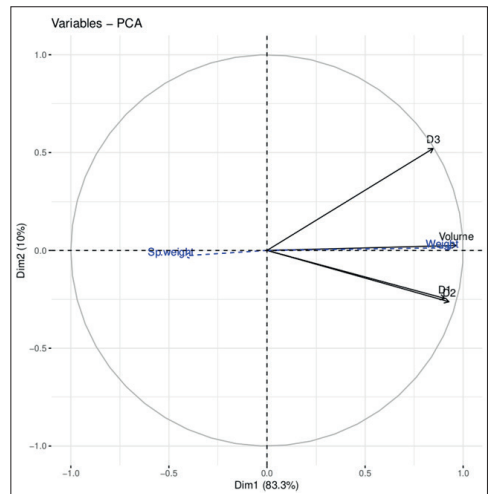


Fig. S2 - Correlation between the four morphometric variables and two supplementary qualitative variables (Weight and Specific weight).

	Shape	Weight	D1	D2	D3	Volume	Sp.weight	Cluster
62	Sub-spherical	219	5.7	5.4	4.8	79	2.77215189873418	1
66	Sub-spherical	226	5.5	4.8	4.4	59	3.83050847457627	3
80	Irregular	259	6	5.4	4.8	86	3.01162790697674	1
87	Cuboid	140	4.6	4.5	4.3	53	2.64150943396226	3
88	Sub-cubical	137	5	4.2	3.7	53	2.58490566037736	3
99	Sub-cubical	236	5.3	4.6	3.9	62	3.80645161290323	3
100	Flattened-sub-spherical	198	5.5	5.5	3.8	79	2.50632911392405	2
102	Sub-spherical	146	4.1	3.8	3.7	32	4.5625	3
111	Sub-spherical	140	4.7	4.4	4	52	2.69230769230769	3
112	Cuboid	155	4.6	4.3	4.2	59	2.6271186440678	3
130	Flattened-sub-spherical	226	5.8	5.6	3.6	66	3.42424242424242	2
131	Cuboid	177	4.6	4.6	4.3	59	3	3
141	Irregular	23	2.6	2.5	2.1	7	3.28571428571429	4
161	Cuboid	140	4.1	4	3.8	45	3.11111111111111	3
199	Sub-cubical	134	4.6	4.2	3.9	49	2.73469387755102	3
205	Semi-spheroid	72	4.1	3.8	2.7	20	3.6	4
272	Cuboid	192	5	4.9	4	59	3.25423728813559	3
273	Cuboid	294	5.9	4.8	5.1	99	2.96969696969697	1
274	Sub-spherical	161	5.4	4.5	4.3	50	3.22	3
308	Cuboid	155	4.4	4.3	4.3	53	2.92452830188679	3
309	Cuboid	138	4.1	4.1	4.4	36	3.83333333333333	3
311	Parallelepiped	373	5.4	7	5	126	2.96031746031746	1
335	Irregular-cuboid	51	3.5	3.2	3	10	5.1	4
465	Cuboid	153	4.4	4.3	4.1	53	2.88679245283019	3
468	Irregular	148	5.7	5.2	3.3	53	2.79245283018868	2
477	Sub-cubical	148	4.9	4.3	4.3	56	2.64285714285714	3
478	Cuboid	138	4.3	4.2	4.2	51	2.70588235294118	3
491	Cuboid	293	6.1	5.2	4.9	100	2.93	1

Tab. S5 – Each studied object was attributed to one of four clusters identified through Partitioning Around Medoids carried out on pairwise Euclidean distances calculated on PCA coordinates.

	Min.	1st Quartile	Median	Mean	3rd Quartile	Max.
Cluster1	219	259	293	287.6	294	373
Cluster2	148	173	198	190.7	212	226
Cluster3	134	140	148	159.8	161	236
Cluster4	23	37	51	48.67	61.5	72

Tab. S6 – Summary (minimum, mean, median, first and third quartiles, maximum) of values for the distribution of the variable Weight per each identified Cluster.

Comparison (Clusters)	Z	p-value	p-value (adjusted)
1-2	1.177616	0.39	1
1-3	3.008468	0.0026	0.0157
2-3	1.070767	0.28	1
1-4	3.899465	0.0000964	0.0006
2-4	2.434496	0.015	0.09
3-4	2.103427	0.0352	0.21

Tab. S7 – Results of Dunn Test for pairwise differences in the distribution of the variable Weight between all pairs of Clusters. Significant results after adjustment are highlighted in bold.

Is all that's ground a tool?

	Min.	1st Quartile	Median	Mean	3rd Quartile	Max.
Cluster1	2.772	2.93	2.96	2.93	2.97	3.012
Cluster2	2.506	2.649	2.792	2.908	3.108	3.424
Cluster3	2.585	2.692	2.925	3.121	3.254	4.562
Cluster4	3.286	3.443	3.6	3.995	4.350	5.1

Tab. S8 – Summary (minimum, mean, median, first and third quartiles, maximum) of values for the distribution of the variable Specific weight per each identified Cluster

	1	2	3	4	Sum
Cuboid	2	0	9	0	11
Flattened-sub-spherical	0	2	0	0	2
Irregular	1	1	0	1	3
Irregular-cuboid	0	0	0	1	1
Parallelepiped	1	0	0	0	1
Semi-spheroid	0	0	0	1	1
Sub-cubical	0	0	4	0	4
Sub-spherical	1	0	4	0	5
Total	5	3	17	3	28

Tab. S9 – Contingency table reporting the frequency of objects of each shape in each identified Cluster (columns).

Reg. No	Definition	Size (cms)		
43	Groundstone cube	4.1	4.2	4.2
52	Groundstone object	5.3	5.2	5
86	Groundstone cube	3.8	3.6	3.5
85	Groundstone cube	4.9	4.8	4.1
224	Hammerstone	4	4.5	3.5
325	Hammerstone	4.6	5.6	4.6
333	Hammerstone	3.1	3.5	2.9
416	Whetstone	2.4	2.6	2.2
511	Groundstone cube	3.5	3.6	2.9
539	Hammerstone	4.3	5.0	4.6

Tab. S10 – Cubic-shaped stone object listed in the catalogues of small finds of the 1989 and 1990 field seasons at Tell Abraq (Potts 1990; 1991), showing comparable dimensions with our finds.



Fig. S3. Photographs of the 6 objects chosen for more detailed microscopic observations. 1: F87. 2: F161. 3: F272. 4: F273. 5: F308. 6: F309.