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(ERASMUS MUNDUS MASTER IN ARCHaeological MATerials Science)

# Paleoecology of Equus africanus from the Late Pleistocene site of Jebel Gharbi; SJ-00-56 (Libya): insights from its dietary adaptations


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# Abstract

African wild ass is rara species in archaeological record of north Africa. Jebel Gharbi is one of the few sites representing this species in the archaeological record. This study used menswear and microwear data to analyse paleo ecology of the site. Mesowear and microwear analyses use data from worn tooth surfaces as proxies for feeding ecology. Both dental mesowear and microwear analysis use data from the "damaged" wear surface of a tooth as a proxy for feeding ecology in extant and extinct vertebrates. *Equus africanus* from Gebel Gharbi fall into grazing dietary group.



**Key word**: *Equus africanus*, mesowear, microwear, paleoecology

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# 1. Introduction

## 1.1. Introduction

African sites have provided immense paleontological and archaeological evidence that played a significant role in understanding mammalian and human biological and cultural evolution. Although the oldest sites have come to light in eastern and southern Africa, north Africa is also extremely rich in remains relating to all the phases of human occupation, from the early Stone Age to the Middle and Later Stone Age (or Epipalaeolithic) of the Final Pleistocene. A joint Italian Libyan archaeological research mission in Northern Libya, Jebel Gharbi area, have produced important evidence of early human occupation phases in the region by providing several faunal and artifactual remains including ESA (Acheulian), MSA (Levallois/Aterian) and Epipaleolithic industries (Barich, 2006; Barich and Garcea, 2008). The Jebel Gharbi or 'western mountain' in the local language is situated between the Gefara and the northern boundary of the Tripolitanian Plateau (Barich 2006).

Several important archaeological sites were discovered by the Italian-Libyan mission, among those the SJ-00-56 site. It is an interesting locality, near a permanent spring with a section made up of two layers belonging to a single occupation horizon dated to 20,140-19,510 calibrated BP (Beta-157689) based on radiocarbon dating from charcoal ash found in the horizon (Barich, 2006). The site has a great potential to understand late Pleistocene changes in human adaptation and represent the earliest example of microlithic technology in the Jebel Gharbi (Barich, 2006; Garcea and Giraudi, 2006). A preliminary zooarchaeological study at the SJ-00-56 site by Alhaique and Marshal (2009) suggests that the area was predominantly occupied during the arid phase of the Last Glacial Maximum (LGM) because of favourable conditions created by its location near a water source and the availability of wild ass which is more adaptable to arid environments than other African large mammals (Maloiy, 1971). Tsite has provided numerous cranial and post cranial skeletal elements dominated by wild equids. However, the degree of fragmentation is high in the post cranial skeletal elements which leaves the tooth remains which were collected as the main sources of paleoenvironmental data for the period and the site. In the present research I used these wild equid tooth remains to enrich our knowledge about the paleoenvironmental condition of the period through dental microwear and mesowear analysis.

Ancient terrestrial ecosystems cannot be observed directly but by using a variety of indirect approaches. Such ecosystems must be reconstructed from the physical evidence and chemical signatures left in the geological record by plants and animals. By integrating multiple lines of evidence about the climate, vegetation structure, and fauna of a given location at a particular time, a relatively complete paleoecological picture of a fossil locality can be generated (Croft et al., 2018). One of the many methods that are available for reconstructing aspects of an ancient ecosystem are the mesowear and microwear analyses of the tooth.

Both dental mesowear and microwear analyses use data from the "damaged" wear surface of a tooth as a proxy for feeding ecology in extant and extinct vertebrates (merc and Croft 2018). Dental microwear analysis studies microscopic wear patterns produced on the occlusal enamel surfaces of teeth during mastication. It is one of the most valuable methods to assess dietary preferences in vertebrate taxa. The abundance, morphology, size, distribution, and orientation of marks are a consequence of the mechanic abrasion produced by mastication and are distinctive between different diets, depending on the fracture properties of the food items (Strani et al., 2018). On the contrary, mesowear is based on gross dental wear (Green and Croft, 2018).

## 1.2. Objective of the study

The general objective of this research is reconstructing the palaeoecology of the late Pleistocene human occupation at site SJ-00-56 in the Shakshuk-Jebel Gharbi area depending on dental micro and meso wear analysis of wild ass (Equus africanus) tooth.

Specifically, this research focusses on answering two main questions; the first one is understanding the dietary adaption of the dominant species Equus africanus at SJ-00-56 and the second one is depending on the paleo-diet result, the paper will answer questions related to the environmental condition and to Equus africanus adaptive mechanisms to the extreme arid environment.

### 1.3. Significance of the study

According to DeSantis (2016), understanding the paleobiology and ecology of ancient mammals is critical to piecing together the context of their evolutionary history, including how they responded to environmental and climatic changes over deep time. Dental mesowear and dental microwear analysis are important to assess the dietary ecology of fossil mammals at a given place and time. It is also valuable to take advantage of the short-time window captured by dental microwear analyses. Dental microwear methods, provides a record of the dietary behaviour of an animal shortly before its death (i.e., over the past few days to some weeks) (DeSantis, 2016). As such these results will provide background information vital to understanding processes behind the domestication of the donkey (Alhaique and Marshal, 2009). Also assessing how mammals have altered their diet during periods of pronounced climate change may be able to answer questions regarding current biotic responses to climate change (DeSantis, 2016).

The methodology also has some significance. A major strength of mesowear and microwear as palaeodietary proxies is that only well-preserved teeth are required. Another major strength of this approach is that it appears to be non-destructive and relatively taxon-independent (Green and Croft, 2018).

The site was occupied during the arid phase of the last glaciation when sites are rare in much of northern Africa. The location of SJ-00-56 is on a plain adjacent to rocky slopes and close to a permanent spring. Hunter-gatherers who lived for periods of time at this site of Jebel Gharbi were able to take advantage of the lithic raw material and availability of wild ass near this site. Their familiarity with and dependence of the wild ass is clearly demonstrated as this site, which represents the first known so far with evidence of a specialized focus on the wild ass and one of a few in north Africa that preserve evidence for hunter-gatherer activity and hunting strategies during this phase elsewhere (Barich and Garcea, 2008; Alhaique and Marshall, 2009). This site is especially interesting in the context of the distribution of available large mammals and the behavioural characteristic of African wild ass.

# 2. Research Background

## 2.1. Geological and Environmental context of the area

The Jebel Gharbi region is located in the subcoastal belt south-west of Tripoli, Libya. The area, also known as Jebel Nefusa, is a vast crescent-shaped area located on the boundary between two morphological elements: the northern part of the Tripolitanian Plateau to the south and the the Gefara coastal plain to the north. The Jebel Gharbi represents the most northern and highest part of the Plateau slopes down to Jefara by a steep escarpment and deep valleys. This mountain, made up of nearly horizontal limestone Cretaceous strata (Giraudi, 2005), has several water springs because of a deep cut network of valleys draining northwards into the Jefara plain. To a large extent, these springs were produced as a result of tectonic activity (Barich et al. 1996; 2003; 2006; Lucarini and Mutri, 2010).

According to Giraudi (2005), in the Jebel Gharbi the stratigraphic sequences and uninterrupted human occupation for the final millennia of the Pleistocene show how the paleoclimatic situation alternated in wet dry cycles, although within a context of considerable aridity. The presence of permanent springs guaranteed water supply even in periods of greater aridity, which is an element for a relatively stable occupation in the area during the final phase of the Pleistocene (Garcea and Giraudi, 2006; Lucarini and Mutri, 2010).

## 2.2. Research history and archaeology of Jebel Gharbi

Archaeological research in the Jebel Gharbi started in late 1980s by the Joint Libyan-Italian Archaeological Mission based on an official agreement between the University of Rome La Sapienza and the General Direction of Antiquities of Libya (Barich, 1996). The aim of the project was to reconstruct the development of human occupation in the Jebel from its earliest stages, with a particular focus on the transition from the predatory status of hunters to food production. Relationships between natural resources and human settlement during the Pleistocene and the Holocene have been highlighted through multidisciplinary study, investigating archaeology within its paleoenvironmental setting.

The Libyan-Italian Archaeological Mission has conducted geomorphological surveys and archaeological prospections along with systematic collections and test excavations. According to Barich (et al.1996) at the beginning the research focused on studying the geomorphology and sequences of cultural events. But later in 1997 the project was aimed to understand occupation patterns during the Pleistocene/ Holocene transitional time (Barich et al. 2006).

During a long research cycle (1989-2011) the Jebel Gharbi project directed by Barbara E. Barich from the University of Rome "La Sapienza" and Elena A.A. Garcea from the University of Cassino, recorded and documented nearly 100 prehistoric sites dating from Early Stone Age to Later Stone Age. as well as to the Neolithic time. Research conducted by the Italian team focused on two regions which showed intensive human occupation: the Wadi Ghan region near Gharian and the territory of Jado which is currently the administrative centre of Jebel Gharbi (Barich et al. 2003). Evidence of human occupation in both regions are in a dominating, short distance downhill position allowing to control the access to water resources. The two main water streams are, respectively, Wadi Ghan and Ain Zargha. Open-air sites are located on the hilly flanks currently covered by a sparse shrub vegetation, with numerous olive trees (Barich et al. 1996; 2003). Based on the archaeological evidence the earliest human occupation of the whole region goes back to the Early Stone Age/Upper Pleistocene. This very ancient inhabitation is attested by Acheulian bifacial handaxes and spheroids found on the Wadi Ain Zargha terraces at Ginnaun (Barich et al. 1996; 2006; Barich and Garcea, 2008).

Around 20,000 cal BP. the climate changed and to the South brought abandonment of the territories. On the coast, where the settlement took place without disruptions, human groups probably hunted Ammotragus, while in the areas that were closer to the desert, such as Hagfet et Tera, they hunted gazelle. equids (i.e., Equus zebra) cattle, rabbits while terrestrial molluscs were also collected (Barich et al. 2006). This region holds a great potential to understand late Pleistocene human adaptions and experiments in early food production after the early Holocene climatic amelioration.

### 2.3. Site SJ-00-56

During the 2000 field season a wide settlement area has been discovered at the foothills of the Jebel between the Jefara plain and the alluvial fan belt near the modern town of Shakshuk. The town is next to a series of perennial water sources flowing from the bedrock and this allowed the territory to be inhabited even in the most arid phases of the Pleistocene (Barich et al. 2006; Mutri and Lucarini, 2008; Lucarini and Mutri, 2010). The area is characterised by a lower terrace as well as by aeolian sediments (Barich et al. 2006). The geological setting and the characteristics of water-bearing strata of this territory, between the Jebel and the Jefara plain (Kruseman & Floeghel 1980; Singh, 1980 in Barich et al. 2006), show that such water sources could be connected to subterranean waters fed hundreds of kilometres south of the Jebel Gharbi (Barich et al. 2006). The importance of this area is due to its multiple human occupation layers and abundant archaeological finds scattered on the surface or found in situ at various sites (Lucarini and Mutri, 2010).

Investigation in the Shakshuk area brought about the important discovery of site SJ-00-56, located on the right bank of the Wadi Sel, a few meters south-west of the Ain Shakshuk perennial spring and near a series of permanent springs. The whole area contains a series of these perennial water sources connected to groundwaters located 2000km south of the Jebel Gharbi (Garcea and Giraudi, 2006) and it is thought likely to have been active during the arid period of the Last Glacial Maximum. As a result, the site must have benefited from a very favourable microclimate. According to Barich (et al. 2006) and Garcea and Giraudi (2006), the site function is not fully understood but the results from territorial investigation, the abundant stone implements along with fauna and charcoal remains suggest the site area could have been a hunting campsite which highlights the presence of hunters-gatherer settlements in the area after 20,000bp. The stratification of the site belongs to a single phase of occupation and the soil is made up of very dark organic sediments containing a large quantity of charcoals and ashes (Barich et al 2006).

The upper Later Stone Age Site SJ-00-56 shows an impressive archaeological record. During excavation a large number of lithic artifacts and many animals bone fragments were discovered. The southern edge of the site is deeply incised by the erosive gullies which which made it possible to assess from the very beginning both stratigraphy and distribution of finds by depth. The 60cm deep exposed sequence consists of three stratigraphic units belonging to yet a single occupation horizon (Lucarini and Mutri, 2010). The great amount of stone implements, fauna, charcoals and the prevalent presence of debitage products among the lithic artifacts could indicate either a specialized use of the site as a lithic workshop or a hunting campsite. The Upper and Final Later Stone Age sites at the foot of the Jebel and along the Wadi Ain Zargha represent a continuum, corresponding to different phases of occupation by groups of hunter-gatherers in their annual cycle (Barich and Garcea, 2008, Alhaique and Marshall, 2009).

Based on Lucarini and Mutri (2010), the base layer of the site is a mixture of aeolian deposits and ashes. Organic sediment was sampled from this layer where large amount of lithic artifact and faunal remains were found and dated to 16,750+60BP (Sample BETA 157689: 20,140-19,510 CAL BP) This implies the exploitation of the site began during the Late Pleistocene arid phase.

### 2.4. African Wild Ass; *Equus africanus*

Ziccardi (1970a) on Bemmel (1972) suggested that the Wild Ass entered Africa from the northeast Asia and developed into a separate species about 500,000 years ago from the ancestral stock in Asia. Proceeding the migration, the species spread over the whole northern part of Africa. South of the Sahara, the forest belt acted as a natural border and in the east the Ethiopian mountains formed a barrier. As a result, the Wild Ass could only proceed along a narrow passage between these mountains and the Red Sea. According to Bemmel (1972), the Wild Ass once occurred in the whole of North Africa but today the African wild ass only found in the Horn of Africa critically threatened (Moehlman, 2002; Marshall and Asa, 2013). Fitzinger (1857) is the first to name the African wild ass, Equus africanus (Bemmel, 1972; Groves and Smeenk, 2007).

Historically, there were three recognised subspecies (Blench, 2012; Moehlman, 2002; Marshall and Asa, 2013). The Atlas wild ass, Equus africanus atlanticus, was found in the Atlas region of north-western Algeria, and adjacent parts of Morocco and Tunisia (Antonius, 1938 on Moehlman, 2002). The second one is the Nubian wild ass, Equus africanus africanus, lived in the Nubian desert of north-eastern Sudan, from east of the Nile River to the shores of the Red Sea, and south to the Atbara River into northern Eritrea (Watson, 1982 on Moehlman, 2002; Blench, 2012). The third one is the Somali wild ass, Equus africanus somaliensis, was found in the Denkelia region of Eritrea, the Danakil Desert and the Awash River Valley in the Afar region of north-eastern Ethiopia, Djibouti, and into the Ogadenn of eastern Ethiopia (Ansell, 1971 on Moehlman, 2002; Alhaique and Marshall, 2009). According to Moehlman and his colleagues (2008) the Somali is the only extant population living in the wild which is critically endangered.

The African Wild Ass (Equus africanus) is the wild ancestor of the donkey (Equus asinus) (Marshall and Asa, 2013). The earliest evidence of domesticated donkey is from Egypt. They were domesticated from resident Nubian wild ass (Equus africanus africanus) by villagers inhabiting the Egyptian Nile valley (Rossel et al. 2008). According to Marshall (2007), domestication of Donkeys about 6000 years ago transformed land-based transport leading to the development of mobile African pastoralism, land-based distribution of food within the early Egyptian state and long-distance trade in Africa and Asia.

The study of the social behaviour of African wild asses in captivity by Marshall and Asa (2013), provides insights into developments of donkey domestication in a process helping resolve apparent contradictions in the archaeological data. Except 16,000 years ago during arid conditions, Saharan foragers did not hunt African wild asses intensively. This wild asses and animals from multiple populations were brought into domestic herds in north-eastern Africa. Marshall and Asa (2013) stated African wild asses do not appear to fit the behavioural profile for an easy domestication. They suggested a closer examination of hunter-gatherer and pastoral Holocene open sites in the Sahara with a defined dating.

Ass specimens representation is rare in faunal collection from African hunter gatherer sites of the last 20,000 years. Nonetheless a few specimens were found at sites such as Hagfet et Tera, Haua Fteah or El Mouhaad (Alhaique and Marshall, 2009). According to Marshall (2007), Despite the suggestion African wild asses were hunted occasionally bones of the specimen are ubiquitous in northeast African sites but not common. Saharan foragers hunted African Wild Asses, but they were not an animal that people focused on or intensively exploit except in extreme desert condition 16,750+60BP years ago (Sample BETA 157689: 20,140-19,510 CAL BP) (Marshall and Asa, 2013). Because of its sensitivity the African wild ass is limited to the semi-arid regions and must have been very abundant species in hyper arid environments (Alhaique and Marshall, 2009; Blench, 2012).

Excavation at Shakshuk (SJ-00-56) in the Libyan desert, documents specialized hunting of African wild ass during hyper-arid period. Jebel Gharbi is the first site to be found with equid dominated faunal assemblage. The area is formerly occupied by the Nubian wild ass or on the boundary between the Atlas and Nubian will asses. It is striking those foragers only hunted wild asses in any numbers during the height of the last glaciation when the Sahara was greatly expanded (Alhaique and Marshall, 2009).

## 2.5. Mesowear and Microwear analysis

The two major proxies of dental wear analysis are mesowear (Fortelius and Solounias, 2000; Kaiser et al. 2000; Kaiser and Fortelius 2003; Kaiser and Solounias, 2003) and microwear signals (Solounias and Semprebon, 2002; Semprebon et al. 2004).

Mesowear and Microwear analysis uses data from worn tooth ("damaged" wear) surfaces of extant and extinct vertebrates as a proxy for feeding ecology. Both analytical approaches hold vital methods for paleo-ecological and environmental reconstruction but requires strict protocols (Green and Croft, 2018). Valli and his colleagues (2012) explained analysis of dental wear is among the most significant tools applied by palaeontologists to infer dietary behaviour and environmental context of extinct herbivore mammals. Both approaches are used to infer the dietary behaviour. Both methodologies applied by Fortelius and Solounias (2000) and Solunias and Semprebon (2002) proven to distinguish between browsing, grazing and mixed diets in a wide variety of extant and extinct herbivorous mammals.

### 2.5.1. Mesowear analysis

Mesowear analysis is macroscopic wear study of occlusal surface on teeth, where futures are visible to the naked eye, which is a signature of long period, a lifespan of an individual (Fortelius and Solounias, 2000). The original method explained by Fortelius and Solounias, (2000), is based on the physical properties of ungulate food items as reflected in the relative amounts of attritive and abrasive wear that they cause on the dental enamel of occlusal surface. Such wear is known as facet. Mesowear analysis seeks to describe the degree to which such facets are developed on the teeth of herbivorous mammals and to correlate such patterns with diet. Based on Fortelius and Solounias (2000) the macroscopic wear of tooth cusps due to attritive tooth on tooth wear and abrasive food on tooth wear has the potential to differentiate between grazers and browsers in living and fossil mammals. The method assesses the dietary regime of herbivorous mammals based on the attrition/abrasion equilibrium of cheek tooth wear. The original method evaluates cusp shape and cusp relief of upper second molars and is able to correctly classify species into expected feeding groups.

As originally perceived by Fortelius and Solounias (2000), two qualitative variables of tooth are scored in lateral view for a mesowear analysis of an ungulate: occlusal relief and cusp shape. Tooth cusps are classified into shape: sharp, round, and blunt. Based on the standard definition by (Fortelius and Solounias, 2000; Kaiser and Fortelius, 2003) a sharp cusp terminates to a point and has practically no rounded area between the mesial and distal facets. A rounded cusp has a distinctly rounded tip without planar facet wear but retains facets on the lower slopes, while a blunt cusp lacks distinct facets altogether. Relief which is the height difference between the inter-cusp valleys and the tip of the cusp is classified in to high and low.

In the original methodology by Fortelius and Solounias (2000) occlusal relief and cusp shape are scored as two different variables. A study by Mihlbachler and his colleagues (2011) scored the two features of mesowear as a single variable. They concluded the two originally proposed measurements, cusp sharpness and relief, are not independent from each other. They integrate the shape and relief classification into numerical value. They enabled use of single, combinatorial variable for mesowear by using a mesowear "ruler" of tooth cusp casts illustrating the two endpoints and five intermediate stages in this categorial variable. The average number of mesowear values from the dentition of each taxon represents the mesowear score.

The 'original' mesowear method after Fortelius and Solounias (2000), mesowear is typically scored on an upper second molar in buccal view. Wear profile of the buccal enamel band of metacone and paracone is analysed. This methodology was employed to test if mesowear can indicate climate related habitat conditions such as humidity, evapotranspiration, and seasonality. While the "extended" mesowear method introduced by Kaiser and Solounias (2003) scores mesowear using the sharpest cusp of the tooth position P4, M1, M2 and M3. Kaiser and Solounias (2003) checked if the lower molars and premolars have consistency with the extended mesowear method and they concluded from their study that the upper premolars P2 and P3 have the most significant negative impact on consistency in the mesowear classification and therefore should be excluded.

Kaiser and Fortelius (2003) also tested if a consistent mesowear classification are obtainable from mandibular as well and from maxillary teeth. Based on their study applying the mesowear analysis to lower molars requires the adaption of the method and the definition of scoring convention. The entire surface of the lower teeth is affected by tooth wear as is the upper cheek teeth. As a matter of consistency with the scoring convention for upper teeth, the buccal edges of the enamel surfaces where the enamel ridge, bordering the protoconid and hypoconid buccally meets the occlusal plane was the reference scoring location for lower cheeks teeth (Kaiser and Fortelius, 2003).

Since the development of dental mesowear, the efficacy of the method has been demonstrated in extant ungulates with selenodont dentition (Kaiser and Fortelius 2003, Kaiser and Solounias 2003, Rivals et al 2007, Blondel et al 2010, Semprebon and Rivals 2010, Mihlbachler et al 2011, Louys et al 2012, Saarinen et al 2015).

Mesowear analysis has only been applied to herbivorous mammals. In herbivores that consume relatively soft foods, such as the leaves of dicotyledonous plants, twigs, buds, flowers, and fruits (i.e., browsers), the teeth working against one another is the primary cause of tooth wear; this type of wear is attrition. Attrition creates enamel surfaces that have sharp edges and well-developed facets. In grazing herbivores, which mainly consume grasses and other low-growing vegetation, the food consumed causes more tooth wear than the teeth themselves. This type of wear is termed abrasion, and it tends to obscure facets and round off enamel edges. (Green & Croft, 2018).

This is advantageous for fossil populations, where sample size can be a limitation factor.

Green and Croft (2018), recommend minimum 10 individuals if possible 20 individuals should be scored for both extant and extinct species. The percentages of specimens (individuals) of each species exhibiting high occlusal relief, blunt cusps, and sharp cusps are used for comparisons among species and for interpreting diets of extinct species.

Numerous research (Fortelius & Solounias, 2000; Kaiser & Fortelius, 2003; Kaiser & Solounias, 2003) confirmed the degree of attrition and abrasion evident in the cheek teeth varies among species depending on the consumed plant materials with different physical properties. Generally, species that eat leaves from trees and bushes shows the highest degree of attrition while species that eat grasses shows the highest degrees of abrasion. Browse leaves have high lignin contents and veins that block the propagation of fractures through the leaf tissue during mastication. Browser (intake >90% browse) teeth are therefore specialized for puncturing tough leaf tissue, which leads to mutual sharpening of opposing wear facets. Grazers ingest comparatively large amounts of exogenous grit that reduces the sharpness of wear facets

During the buccolingual chewing stroke, the cheek teeth experience both attrition: tooth on tooth wear and abrasion: food on tooth wear (fortelius and Solounias, 2000). Fraser and his? Colleagues (2014), explain attrition occurs during the interaction of opposing wear facets and results in mutual sharpening as the facets slide against one another. Abrasion occurs during the interaction of the teeth with plant-born abrasives or other ingested items and results in the dulling of the cusps.

Dental mesowear has a potential to differentiate between grazers and browsers in living and fossil mammals (fortelius and Solounias, 2000).

### 2.5.2. Microwear analysis

Microwear is the result of microscopic damage to the teeth: abrasion of teeth by food items during mastication process (Fortelius and Solounias, 2000). Differing to mesowear, microwear is not a long-term record of chewing, rather the patterns observed at the surface of teeth are constantly worn away and overprinted by new features as tooth wears down by each feeding event. Grine (1986) called this phenomenon the “last supper effect”. As a result, microwear reflect the last meal consumed by a species. The abundance, distributions, orientations, sizes, and shapes of microwear features have been used to interpret masticatory behaviours, diets, and other aspects of ecology for extinct and extant species (Green, 2009; Solounias et al. 2010; DeMiguel et al. 2011; Rivals and Semprebon, 2012; Teaford and Oyen, 1989; Solounias and semprbon, 2002). Each of these microwear features record unique chewing events and the food items associated with them (Teaford and Oyen,1989). Dental microwear analysis is an approach for characterizing diet of paleofauna and accordingly past environments (Hoffman, 1989).

Tooth microwear method has been used in the past four decades to acquire information about the dietary traits of extant and extinct mammals such as ungulates and primates (Merceron et al. 2005a). Many of these studies applied different methods of observation and analysis and reported a correlation between tooth microwear patterns and the dietary traits of extant species (Solounias and Semprebon, 2002; Fraser er al. 2009). Each of these microwear features record unique chewing events and the food items associated with them (21-23).

The earlier method was using scanning electron microscope (SEM) at high magnification (Walker et al. 1978; Fraserf et al. 2009). It is a more traditional technique where an observer quantifies distinct events based on individual microwear features which are pits and scratches. The dental features are quantified from images taken by SEM at high magnification (eg. 500x). The futures are used to derive classification based on accepted relationships between the proportions of pits and scratches on teeth and the mechanical properties of feeds. This traditional technique has a shortcoming of being costly and nonrepeatable (Teaford, 1991; Fraserf et al. 2009; Mihlbachler and Beatty, 2012). Solounias and Semprebon (2002) adopted a lower-magnification (35x) dental microwear method (LDM) that similarly identifies and counts individual features via light microscope. Low magnification dental microwear method by (Solounias and Semprebon, 2002) identifies, counts, and sometimes measures individual features via a light microscope to categorize mammals as consuming grass, browse, fruit or some mixture of those food types. Microwear features: scratches and pits has been used to differentiate browsers, grazers, and mixed feeders in extant and extinct ungulates (Solounias and Moelleken, 1992a).

after the development of the new methodology multiple researches suggest the microwear features seen under the low-magnification light microscopy are a way to understand ecologically significant dietary variables, such as the percentages of browse, graze and fruit in the diet (Solounias and Semprebon, 2002; Semprebon et al. 2004; Nelson et al. 2005). For LDM according to Mihlbachler and Beatty (2012) magnification choice is largely arbitrary and typically determined by the resolution limits of the instrument used and the size of the animal being analysed. Lower magnification for larger species and higher magnification for smaller species. Stereoscopic LDM studies by Solounias and Semprebon (2002) and Semprebon et al. (2004) quantified microwear features through the eyepieces of the stereomicroscope with out digital photography. Later Merceron and his colleagues (2005a, 2005b) introduced a relatable method where microwear data are collected from digital micrographs taken through a light microscope and analysed on a computer display. It is the same basic methodology applied that involved identification and classification of irregularities on wear surfaces as different types of microwear scars.

The effectiveness of dental microwear analysis as a palaeoecological proxy is challenged by post-mortem dental wear processes, observer's error, and sensitivity to instrumentation variation (Fraser et al. 2009; Mihlbachler et al. 2012).

# 3. Material and Method

## 3.1. Material

The tooth samples are from the archeo-faunal collection of Jebel Gharbi Site Sj-00-56 (2000 and 2002 excavation). At first 25 good condition isolated tooth were selected. It includes 22 Equus africanus and 3 Alcelaphinae Out of the 25 specimens, based on the protocol of the methodology I used 16 were selected for mesowear analysis and 16 were selected for microwear analysis. It includes two 4th pre-molar, three 1st molar, four 2nd molar and six 3rd molar. From the 16 selected tooth 15 are Equus africanus and 1 is Alcelaphinae. The specimens are housed in Museo Delle Origini in the Sapienza university of Rome.

## 3.2. Method

### 3.2.1. Mesowear scoring method

Dental mesowear is based on the physical properties of food as reflected in the relative amounts of attritive and abrasive wear that they cause on the teeth throughout the lifetime of a species (Fortelius and Solounias. 2000). Mesowear study is implemented on a gross level with the naked eye, no special cleaning of specimens was required. The process of scoring proposed by Fortelius and Solounias (2000) is roughly quantifying the relative amounts of attrition and abrasion experienced by the cheek teeth by visually categorizing in to the two variables: occlusal relief (OR) and cusp shape (OS). Occlusal relief is classified as high (h) or low (l), depending on how high the cusps rise above the valley between them. The sharpest cusp on the buccal side of the tooth (anterior or posterior) was chosen. Teeth that had a broken paracone or metacone, or which were in very early or very late wear stage were excluded according to Fortelius and Solounias (2000).

The other mesowear variable, cusp shape, includes three scored attributes: sharp (s) round (r) and blunt (b) according to the degree of facet development. A sharp cusp terminates to a point and has practically no rounded area between the mesial and distal facets. A rounded cusp has a distinctly rounded tip without planar facet wear but retains facets on the lower slopes, while a blunt cusp lacks distinct facets altogether. The paracone and metacone of the upper molar and the metaconid and entoconid of the lower molar were examined with the naked eye and qualitatively scored. Specimens were observed using handheld x5 magnifier when needed. Since

In methodologies developed after the original one borderline case a quantitative index was clear for high/low occlusal relief. I applied the original approach of Fortelius and Solunias (2000) and the 'extended' method of Kaiser and Solounias (2003) to include lower molar I followed DeMiguel (et al. 2012). After scoring the variables the percentage of high and low cusps and cusp shape were calculated separately for the species Equus africanus. It is presented in table1 as the % high, % low % sharp; % round; and % blunt. Mesowear data were compared to a published database of 54 modern ungulate taxa with well-defined diets (Fortelius and Solounias, 2000).

### 3.2.2. Microwear scoring method

Microwear features of dental enamel were examined using a stereomicroscope on high-quality epoxy casts of teeth following the cleansing, moulding, and casting protocol developed by Solounias and Semprebon (2002) and Semprebon et al (2004). Very fragmented or immature individuals and specimens that has fresh break made during excavation or storage was eliminated at the biggening following King (et al. 1999).

After the qualified tooth ware laid down the primary steep was cleaning. First, I cleaned the surface of each tooth selected with cotton swabs moistened with acetone. Once the acetone drayed, I cleaned the remaining acetone with 95% ethanol. The next step is to make mould which is an impression of the tooth surface. After all tooth dried, I applied the polyvinylsiloxane compound (Elite HD+ Light Body) directly to the occlusal surface of the tooth using dispensing gun. Following, the drying for five minutes and the same volume of silicone and catalyst (Elite HD+ Putty Soft) were mixed manually until homogeneous colour appear then the mixture flattened on the negative impression and surrounding area of the tooth. While the silicone was soft the reference number of the sample was written on it. After the silicone was totally set, I carefully unattached the mould from the tooth. I applied more silicon and catalyst to form a containing wall that prevented liquid epoxy resin from spilling out when it was subsequently applied for the casting procedure. The epoxy and catalyst (Araldite LY 554 and Indurente HY 956) were mixed well with a ratio of 70ml:14ml. The prepared moulds were filled up with epoxy high enough to avoid the bottom surface of the resulting cast from being in proximity with the examining surface. During the casting process I attempted to orient the cast so that the wear surface of interest was horizontal when the specimen was placed on the microscope objective. Clear epoxy resin tooth casts were examined at 32x magnification using stereomicroscope and oblique lighting using the refractive properties of the transparent cast to reveal microfeatures on the enamel. Examination of microwear is done on the enamel band of paracone for upper molar and for lower molar on the enamel band of protoconid. I used classification of features defined by Solounias and Semprebon (2002) and Semprebon et al (2004) and quantified all categories of microwear features. These microware scars were counted on a standard 0.4 × 0.4 mm2 area of the enamel on digital image obtained by 32×magnification using the open-source image processing program ImageJ (Schenider et al. 2012).

Features were divided into five categories: small pits, large pits, fine scratches, coarse scratches and gouges. The presence of cross scratches was also recorded. Pits and scratches were identified based on their shapes and refraction properties. Pits are microwear scars that have approximately similar widths and lengths and circular or sub-circular in outline. Pits were classified as large or small. Small pits, by feature of their being relatively shallow, refract light easily and consequently appear bright and shiny. Large pits are deeper, wider, and consequently less refractive not shiny or white. Meanwhile scratches are elongated features with straight, parallel sides. By carefully adjusting the angle in which the light strikes the casts, pits and scratches become separable based on their refractive properties. Scratches within the counting area of the epoxy cast were scored as fine, coarse, or hyper-coarse. Fine scratches are narrow, and barely etched into the enamel surfaces. Coarse scratches are wider and more obviously etched into the enamel surface. Because neither fine nor coarse scratches are deep, they refract light well and are shiny and white under the light source. However, fine scratches are fainter than coarse scratches because they are very narrow. Hyper-coarse scratches are very deep and trenchlike, and they are wider than coarse or fine scratches. Consequently, they are not highly refractive and always appear dark under an oblique fibreoptic light source. Small pits, fine and coarse scratches have high refractivity, they can become relatively bright under certain lighting properties. However, large pits and hyper-coarse scratches are less refractive, they always remain darker.

Based on Semprebon (et al. 2004) protocol The dental microwear data of Equus africanus tooth facets from upper and lower molars are included in a single cluster because the dental microwear pattern of these facets is not significantly different.

The percentage of individuals with scratch numbers falling into a low scratch range (%0–17) defined in the 0.16 mm2 area can also separate mixed feeders from browsers and grazers as follows: grazers have 0.0–22.2% of individuals with scratches between 0 and 17; mixed feeders have 20.9–70.0%; and leaf-dominated browsers have 72.7–100.0% (Semprebon et al. 2016). Scratch textures were converted into a scratch width score (SWS) to simplify representation of the data by giving a score of ‘0' to teeth with predominantly fine scratches per tooth surface, ‘1' to those with a mixture of fine and coarse types of textures, and ‘2' to those with predominantly coarse scratches (Semprebon et al. 2016). Individual scores for a sample were then averaged to get the SWS of the taxa.

Those with badly preserved enamel or taphonomic alterations were removed from the analysis. M2 anterior lingual blade of the paracone and the m2 posterior buccal blade of the protoconid were selected as areas of study for artiodactyls, as these facets are in occlusion during mastication.

Features identified by their light refractive properties are easily and rapidly counted, allowing for the collection of large samples of individuals in a relatively short period of time. Using low magnification light microscopy, therefore, analysis of intraspecific (ontogenetic, geographic, and seasonal) variation in foods consumed becomes feasible. Secondly, because counting areas are six times larger than those typically employed in SEM studies, pit and scratch counts may be more representative of the whole and therefore robust to sampling error (Semprebon et al, 2004).

Fig. 1. Stereo microscope

# 4. Result

## 4.1. Mesowear analysis result

Teeth of African wild Ass from Jebel Gharbi indicated mesowear variable of low occlusal relief (87%) and blunt cusp shape (80%) followed by 13% sharp cusp and 7% round cusp. The only tooth of alcelaphins showed low relief and blunt cusp shape (Table 1). This shows abrasion (tooth-to-food) is dominated than attrition (tooth-to-tooth) in this species indicating abrasive dominated diets. Which is probably justifiably interpreted as proportion of grass in the food.

| population | n | l | h | s | r | b | %l | %h | %s | %r | %b |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Equus africanus | 15 | 13 | 2 | 2 | 1 | 12 | 87 | 13 | 13 | 7 | 80 |
| Alcelaphins | 1 | 1 | | | | 1 | 100 | | | | 100 |

Table 1. Mesowear result summery. n indicates number of specimens analysed; mesowear variables: l, absolute scorings low; h, absolute scorings high; s, absolute scorings sharp; r, absolute round; b, absolute scoring blunt; %l, percent low occlusal relief; %h, percent high occlusal relief; %s, percent sharp cusps; %r, percent rounded cusps; %b, percent blunt cusps.

When compared to living ungulates of the three dietary categories, the African wild ass shows similar pattern of mesowear to living grazer. In general, typical grazers have significantly lower relief and higher percentage of rounded and blunt cusps. Blunt cusps reflect that the diets include highly abrasive material such as phytoliths rich grasses (Demiguel et al. 2012). The alcelaphin sample size is not appropriate enough to offer well supported results.

According to DeSantis (2016) Specifically, teeth with blunter shapes and lower relief values are associated with abrasive food materials like grasses while teeth with sharper shapes and higher relief values are associated with browsing diets with teeth accumulating mesowear over the lifetime of the animal.

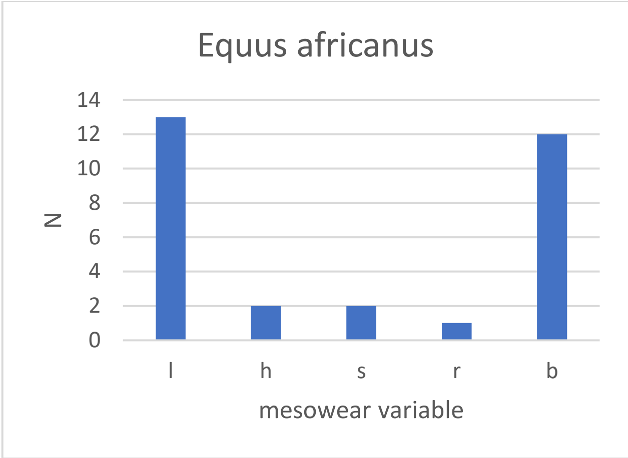


Fig. 2. Percentage of mesowear variable

In Fortelius and Solounias (2000) study Low relief and blunt cusps were found in 11 individuals of plains zebra. They conclude that the bluntness is genuinely present in early as well as late wear because the zebra are 2-13 years.

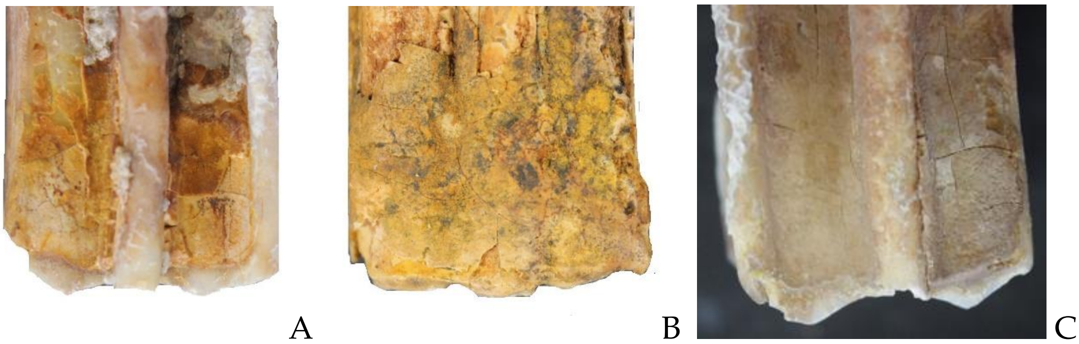


Fig 3. Selected specimens to show mesowear variables. A, sp. No. 8, 3rd upper molar bucual view shows blunt shape and low relief: B, sp. No. 191, 4th premolar lingual view shows blunt cusp and low relief; C, sp. No. 126, 3rd upper molar bucual shows sharp cusp and low relief.

### 4.2. Microwear analysis result

Microwear results for the Equus africanus shows high percentage of scratches than percentage of pits; 38 number of pit (Np) and 117 (Ns). The average number of scratches is 2.8 and % 0-17. SWS shows 0.2 which mostly dominated by fine scratch.

Table 2 summarizes the tooth microwear results (quantitative and qualitative) obtained from the African wild ass.

Based on the relative abundance of the microwear feature, in ungulates microwear patterns with a high incidence of pits usually points to a diet based on the consumption of soft plant material (eg. Foliage or fruits), while heavily scratched enamel surfaces are mostly linked to grazing behaviour (solounias and semprebon, 2002). According to Semprebon (et al. 2004) “use wear tropic triangle” ungulate that shows high scratch and pit counts are fruit-dominated browsers including *Cephalophus dorsalis*, *Moschus moschiferus*, *Cephalophus natalensis*, *Tragulus javanicus*, and *Tapirus bairdii*.

In herbivorous mammals, a high incidence of scratches relative to pits is interpreted as indicative of a diet of tougher food items, potentially with higher silica or grit content, these scars are caused by the high content of silicophytoliths presents in the walls of grasses, which are the main source of food for grazers (Solounias and Moelleken, 1993; Solounias and Semprebon, 2002). In contrast to surfaces with a higher frequency of pits that instead indicate the consumption of more brittle objects or delicate food consumption and potential seeds, whtich is characterizers a browser diet.  (Walker et al, 1978; Grine, 1986; Solounias and Semprebon, 2002). Unlike processing monocotyledons (grass), dicots have few silicophytoliths, whereby the browsers have proportionally few striations (Merceron et al. 2005b).

| taxa | N | AP | AS | SWS |
|---|---|---|---|---|
| E. africanus | 14 | 1.35 | 2.8 | 0.2 |
| Alcelaphin | 2 | 0.75 | 0.5 | 0 |

Table 2. Microwear result summery. N, number of specimens; AP, average number of pits; AS, average number of scratches; SWS, scratch width score.

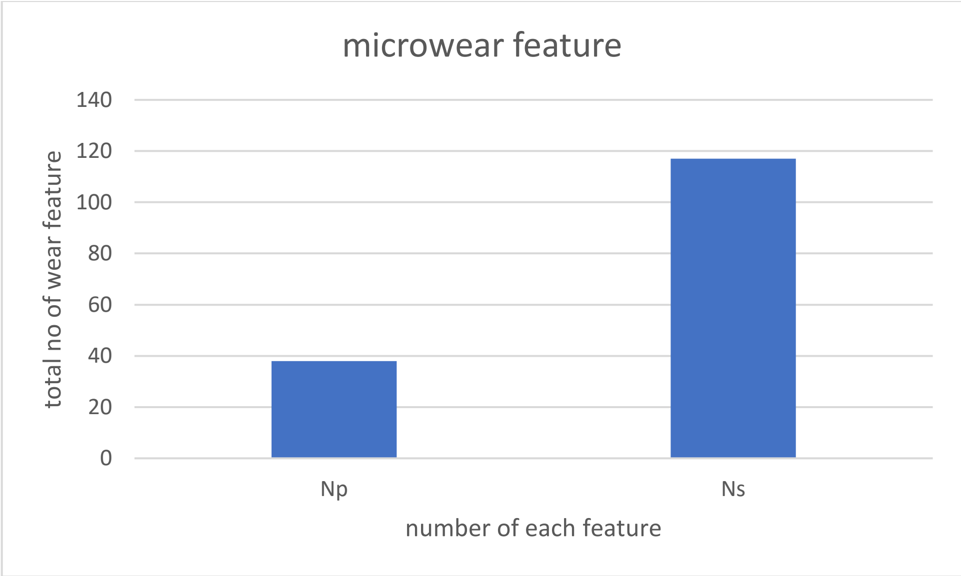


Fig 4. graph of microwear feature representation; Np, number of pits; Ns, number of scratch

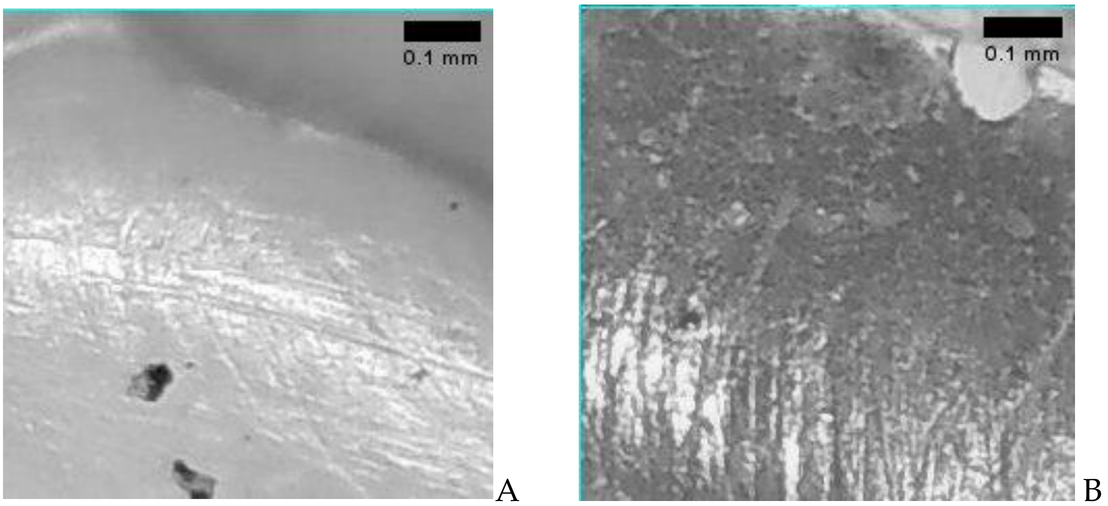


Fig 5. Photomicrographs of selected fossil tooth enamel by stereomicroscope 32x A, sp. No. 191 B, sp. No. 183 Stereomicroscope picture

# 5. Discussion and conclusion

## 5.1. Discussion

Browser, grazer, and mixed feeder are the three conventional dietary classes (Fortelius and Solounias,2000). Fortelius and Solounias (2000) work suggest grazers as a group have significantly lower relief than either browsers or mixed feeders; primarily the species of Equus and certain Alcelaphini. Cusp shape appears to be largely independent of hypsodonty, as all three cusp shapes occur in all crown height classes. Fossil equids are closest to the grazing end of the tree, with the less extreme grazers and grass-dominated mixed feeders

Based on the work of Schulz and Kaiser (2012) on feeding ecology of *Equus*, high ratios of sharp cusps (>28%) and high reliefs (>64%) occur in the species living in the most arid habitats (E. africanus and E. khur), while higher ratios of round cusps are more frequent in the more humid environments of all other equid species. Round cusps are frequent in E. quagga (%r = 80) and E. kiang (%r = 85), which are found in non-arid environments (Schulz and Kaiser, 2012).

Based on the mesowear and microwear result *Equus africanus* from site SJ-00-56 is a grazer species. Since the mesowear method evaluates a dietary mean signature, which is based on a stable wear equilibrium (Kaiser and Franz-Odendall, 2004), the dietary signal obtained for E. africanus from Jebel Gahrbi, Libya reflects the mean dietary regime of this animal rather than a temporary or seasonal extreme condition. The mesowear signature of a species is a robust characterization of the mechanical properties of the food that it eats, including whatever extraneous contamination the physical environment provides.

In herbivorous mammals, a high incidence of scratches relative to pits is interpreted as indicative of a diet of tougher food items, potentially with higher silica or grit content, in contrast to surfaces with a higher frequency of pits that instead indicate the consumption of more brittle objects including woody material, seeds, and/or fruit pits (Solounias and Semprebon 2002).

Grasses and related plants leave numerous scratches on the teeth because of the high concentration of silica phytoliths in their cell walls (Robert and Roland, 1998). These dental microwear variations can be correlated with seasonal or/and regional fluctuations of food availability. This relates with the stratification of the site belonging to a single phase of occupation. the final part of the Upper Pleistocene was a single phase extremely arid climate.

On the other hand, ungulates living in open and arid environments, such as the vicugna (*Llama vicugna*), show an intensive abrasion on molar facets due to the important intake of hard-food items such as exogenous grit particles (Solunias and Semprebon, 2002).

"This thesis of the mesowear in archeology cannot reveal all the potentials but I believe that mesowear will bring useful raw data for archeological interpretations."

Based on Giraudi (et al. 2012) pollen based Holocene paleoenvironmental inferences the open landscape is characterized by the prevalence of grasses (Poaceae) and sedges (Cyperaceae), and evidence of plants from the local wet environments is common. Raise a question how open the habitat was or how widespread were grasses. the area has several water springs because of a deep cut network of valleys draining northwards into the Jafara plain.

According to Giraudi (2005), in the Jebel Gharbi the stratigraphic sequences and uninterrupted human occupation for the final millennia of the Pleistocene show how the paleoclimatic situation alternated in wet dry cycles, although within a context of considerable aridity. The presence of permanent springs guaranteed water supply even in periods of greater aridity, which is an element for a relatively stable occupation in the area during the final phase of the Pleistocene (Garcea and Giraudi, 2006; Lucarini and Mutri, 2010). Shakshuk perennial spring and near a series of permanent springs (Garcea and Giraudi, 2006) and it is thought likely to have been active during the arid period of the Last Glacial Maximum. As a result, the site must have benefited from a very favourable microclimate. Scratches are related to seasonal changes in diet (Solounias and Semprebon, 2002; Rivals et al. 2009).

### 5.2. Conclusion

Palaeoecological data from Jebel Gharbi site SJ-00-56 provide a new information on the African wild ass feeding behaviour. The dietary adaptation of the species suggested the region was grassland. It also suggests the presence of abrasive materials. For the Alcelaphini the sample size is not sufficient to reach to a conclusion. In the future an isotope work is suggested to support the dietary data gained from the mesowear and microwear method.

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