

1 Article type: Original article

2 Title:

3 **ROCK ART PROVIDES NEW EVIDENCE ON THE BIOGEOGRAPHY OF KUDU**  
4 **(*TRAGELAPHUS IMBERBIS*), WILD DROMEDARY, AUROCHS (*BOS PRIMIGENIUS*),**  
5 **AND AFRICAN WILD ASS (*EQUUS AFRICANUS*) IN THE EARLY AND MIDDLE**  
6 **HOLOCENE OF NORTH-WESTERN ARABIA**

7

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27 Word count (abstract): 237

28 Word count (main body of text incl. abstract, key words and references): 7570

29 Running Head: Rock art and biogeography in Saudi Arabia

30

### 31 **ACKNOWLEDGEMENTS**

32 We thank His Royal Highness Prince Sultan bin Salman, President of the Saudi  
33 Commission for Tourism and National Heritage (SCTH), and Prof. Ali Ghabban, Vice  
34 President, for permission to carry out this research. We also thank our Saudi  
35 colleagues from the SCTH, especially Jamal Omar, Abdulaziz al Omari, and Habeeb  
36 Turki for their support and assistance during fieldwork in Shuwaymis and Jubbah.

37 Financial support was provided by the SETH, the European Research Council (grant  
38 number 295719, to MDP), and the Max Planck Society.

39

## 40 ABSTRACT

41 **Aim:** Our knowledge of the prehistoric distribution of animal species is so far largely  
42 dependent on the location of excavated archaeological and palaeontological sites. In  
43 the absence of excavated faunal remains, many species that were present in the  
44 Levant and North Africa have been assumed to have been absent on the Arabian  
45 Peninsula. Here we explore representations of four species that were identifiable in  
46 the rock art, but had not previously been reported in north-western Arabia.

47 **Location:** Jubbah and Shuwaymis UNESCO world heritage rock art sites in Ha'il  
48 province, north-western Saudi Arabia

49 **Methods:** In total, the rock art panels surveyed and recorded in Jubbah and  
50 Shuwaymis contain 6618 individual animal depictions. Species were identified based  
51 on diagnostic features of the anatomy. The resulting dataset was then compared to  
52 the faunal spectrum reported in the (archaeo)zoological literature.

53 **Results:** The rock art dataset provides evidence that the distributions of lesser kudu  
54 (*Tragelaphus imberbis*), wild camel, and African wild ass (*Equus africanus*) extended  
55 into the north-west of Arabia, and that the engravers may have had knowledge of  
56 aurochs (*Bos primigenius*).

57 **Main conclusions:** The presence of previously undocumented mammal species in  
58 Arabia provides new information regarding their distribution, as well as the types of  
59 habitat and vegetation that were available in prehistoric landscapes. Moreover, the  
60 presence of kudu on the Arabian Peninsula indicates that the identification of  
61 palaeo-distributions based exclusively on faunal remains may miss key species in the  
62 Afro-Eurasian faunal exchange.

63

64 **Key words:** African wild ass, aurochs, camel, Holocene environment, kudu,  
65 palaeoenvironment, palaeo-distribution, rock art, wild dromedary

66

## 67 INTRODUCTION

68 The Holocene and terminal Pleistocene biogeography and faunal record of the  
69 Levant, Anatolia, and the Zagros have been researched intensively over the past  
70 century. Within archaeology, research has strongly focused on hunting strategies  
71 and species targeted by Epipalaeolithic and Neolithic hunters, and on the  
72 distribution of the wild ancestors of domesticates. This focus on the contrast  
73 between pre-agricultural and agricultural periods has led to a situation where the  
74 distribution of animal species in the Fertile Crescent area of domestication is  
75 relatively well understood (see for example Martin 2016; Moore et al. 2000;  
76 Uerpmann 1987). However, with the exception of a small number of sites in Yemen,  
77 and along the Gulf coast, the Holocene faunal record of the Arabian Peninsula

78 remains largely unknown (Fedele 2008; Harrison & Bates 1991; Uerpmann 1987;  
79 1991). This represents a substantial gap in our knowledge of the palaeo-distribution  
80 of taxa in the Middle East and limits our understanding of prehistoric habitats in the  
81 region.

82 In north-western Saudi Arabia, the lack of faunal remains is countered by a rich  
83 record of rock art, in which the prehistoric human populations of the area  
84 documented the fauna in their environment. Extensive rock art surveys carried out  
85 by the Palaeodeserts Project at the UNESCO world heritage rock art sites of Jubbah  
86 and Shuwaymis in Ha'il Province, Saudi Arabia, now provide a unique dataset with  
87 over 6000 animal depictions, which can be used in conjunction with the existing  
88 faunal record in Arabia to begin to close this gap.

89 While we can assume that the engravers and painters could only create naturalistic  
90 and anatomically accurate depictions of species they were familiar with, there are  
91 also a number of constraints that result from the 'artistic filter' that underlies the  
92 creation of these images. The frequency with which a particular species is depicted is  
93 culturally driven and probably relates to the symbolic value of the animal (Avner et  
94 al. 2016; Guagnin 2015; 2016; Rollefson et al. 2008). The rock art therefore allows a  
95 deduction of what species were present, but the frequency of the animal in the  
96 landscape and its economic importance can only be identified through skeletal  
97 remains of the animals themselves. Moreover, as we are dealing with mobile  
98 populations, we have to be able to show that the depicted species occurred locally,  
99 rather than reflecting animals seen elsewhere (see for example Masseti 2015).

100 To a large extent, these obvious limitations in the rock art can be countered by the  
101 use of large, systematic datasets, and by limiting the interpretation to those  
102 depictions that are clearly identifiable. Rock art also brings the additional benefit  
103 that patterns on the coat of the animals are often depicted and can be used to aid  
104 species identification. Similar approaches have successfully been used to identify  
105 animal species in the Sahara and in southern Africa (Gautier & Muzzolini 1991;  
106 Guagnin 2015; Loubser et al. 1990). Here we present compelling evidence from rock  
107 art for the identification of four novel large mammal species in the early and middle  
108 Holocene of north-western Arabia.

109

## 110 **BACKGROUND**

111 The oasis of Jubbah is located in the southern part of the Nefud desert, in the north-  
112 west of Saudi Arabia (Figure 1). Groundwater remains close to the surface and  
113 supports vegetation and irrigation agriculture today. During the Holocene humid  
114 period, increased precipitation and groundwater contributed to the formation of  
115 substantial palaeolakes in the Jubbah basin (Clark-Balzan et al. 2017; Engel et al.  
116 2017). Hilbert and colleagues report an early phase of lake formation at ca 10,000 BC

117 (Hilbert et al. 2014). Environmental evidence from the region suggests that the  
118 Holocene humid period peaked between 7000 and 6000 BC, when grasslands spread  
119 in the area and palaeolakes supported lush vegetation (Crassard et al. 2013; Dinies  
120 et al. 2015; Hilbert et al. 2014). Pollen records subsequently show a reduction in  
121 moisture availability; a more abrupt shift to aridity around 3900 BC is associated  
122 with changes in settlement patterns and an abandonment of landscapes in south-  
123 eastern Arabia (Dinies et al. 2015; Preston et al. 2012).

124 No palaeoenvironmental records are currently known for the region around  
125 Shuwaymis, a landscape of relict wadi courses, flanked by sandstone escarpments. In  
126 wetter periods, the watercourses along these wadis were active and would have  
127 supported vegetation. A climate model for the area shows that during the Holocene  
128 humid period Shuwaymis was situated on the northern extent of the African  
129 Summer Monsoon (Guagnin et al. 2016).

130 Recent archaeological surveys and excavations in the Jubbah oasis have identified a  
131 number of sites that can be related to this emerging environmental record. An  
132 occupation site, dated to ca 8000 BC, was identified in the central part of the Jubbah  
133 oasis (Hilbert et al. 2014). El-Khiam and Helwan points, akin to those recorded in Pre-  
134 Pottery Neolithic (ca 9700-6250 BC) assemblages in the Levant (Crassard et al. 2013),  
135 and a large open-air site with artefacts relating to the Levantine Pottery Neolithic (ca  
136 6250-5300 BC) (Guagnin et al. 2017b) were discovered on the edges of two smaller  
137 palaeolakes. Although settlement sites dating to the Bronze Age (ca 3500/3300-1200  
138 BC) are not yet known from Jubbah, recent surveys have identified a body of Bronze  
139 Age rock art that is distinct from Neolithic and Iron Age imagery in stratigraphy, style  
140 and motif, and includes occasional representations of classic Bronze Age weaponry  
141 such as a double-convex bow and a lunate pommel sword (Figure 2; Guagnin et al.  
142 2017a; see also Anati 1968; Newton & Zarins 2000). Bronze Age occupation at  
143 Jubbah was also confirmed through artefacts recovered from disturbed burial cairns,  
144 which include a perforated shell pendant radiocarbon dated to  $2850 \pm 80$  calBC  
145 (Guagnin et al. 2017a). Although Iron Age settlements have yet to be identified in  
146 Jubbah, the rock art from this period is easily identifiable through the widespread  
147 use of so-called 'Thamudic' inscriptions, which accompany many figurative panels,  
148 and in the frequent depiction of domestic horse and camel (Figure 2; for a more  
149 detailed discussion of the rock art chronology see Guagnin et al. 2017a).

150 While direct absolute dating methods are not yet available for engraved rock art, it is  
151 possible to establish a relative chronology based on superimpositions, and changes  
152 in image content. Dated archaeological events such as the introduction of  
153 domesticated animal species, or the use of distinctive weapons are then used to  
154 correlate the rock art with dated archaeological contexts. We have consequently  
155 assigned the imagery discussed here to the early and middle Holocene (Figure 2). We  
156 cannot rule out that some engravings predate the Holocene. However, there is

157 currently no evidence in the archaeological record to suggest terminal Pleistocene  
158 occupation or rock art production.

159 In north-western Arabia cattle herding scenes are frequently superimposed on a  
160 body of earlier, “Pre-Neolithic” rock art that exclusively depicts wild animal species  
161 and hunting scenes with dogs (in the absence of established terminology we adopt  
162 Fedele’s (2008) term “Pre-Neolithic” here to describe the period preceding the  
163 adoption of food production). Since domestic cattle, sheep and goat were  
164 introduced before 6000 BC on the Arabian Peninsula (Drechsler 2007), the body of  
165 rock art that predates the presence of livestock must be older. Pre-Neolithic and  
166 Neolithic rock art also provide a reference to the landscapes of the Holocene humid  
167 period in representations of prey and carnivore species that are not supported in the  
168 current climatic regime (Guagnin et al 2015; 2016; 2017a; 2017c; see also Khan  
169 2007; 2011; Olsen & Bryant 2013). Of the surveyed areas in Jubbah, ca 40% of  
170 individual animal depictions can be associated with the Holocene humid period  
171 (Guagnin et al 2017a); and on the western escarpment at Shuwaymis ca 24%  
172 (Guagnin et al. 2015; 2016).

173

## 174 **MATERIALS AND METHODS**

175 Rock art data was collected between 2011 and 2016 in four survey seasons in  
176 Jubbah, and one in Shuwaymis (survey results and methodologies are reported in  
177 Guagnin et al. 2015; 2016; 2017a; Jennings et al. 2013; 2014). Specifically, the  
178 eastern escarpment at Shuwaymis, and 13 rocky hills (jebels) in the Jubbah oasis  
179 were systematically surveyed for rock art and associated archaeological sites (Figure  
180 1).

181 To date, a combined dataset of 1405 rock art panels has been recorded, containing a  
182 total of 6618 individual animal depictions. These were registered in a specially  
183 designed Microsoft Access database, that links photographs of each motif with  
184 individual characteristics such as the animal species, level of preservation, and any  
185 details in the representation such as coat markings or horn shapes.

186 The resulting dataset was then compared to the faunal spectrum reported in the  
187 (archaeo)zoological literature. In general, there is a very close match between animal  
188 species recorded in the rock art and faunal remains (Guagnin et al. 2016). Here we  
189 present four species that were identifiable in the rock art, but had previously not  
190 been reported in north-western Arabia.

191

## 192 **RESULTS**

### 193 **Lesser Kudu (*Tragelaphus imberbis*)**

194 The lesser kudu (*Tragelaphus imberbis* Blyth 1869) is a large antelope with a  
195 shoulder height of up to 110cm, large ears, and a grey-brown coat with a white  
196 longitudinal stripe along the spine and vertical stripes along the body. Only the  
197 males have horns, which are long and have a characteristic double spiral twist.  
198 Lesser kudu are browsers, feeding on shrubs and trees; they extract sufficient  
199 moisture from their food but rely on succulent plants in the dry season and drink  
200 water where they can (Kingdon 1997).

201 Today, the distribution of the lesser kudu is limited to the Somali-Maasai Arid Zone  
202 of north-eastern Africa (IUCN Red List 2016; Kingdon 1997). In Arabia the lesser kudu  
203 is only known from two sets of horns that were recovered from hunted specimens in  
204 the 1960s (Harrison & Bates 1991; Figure 3). One was reputedly shot in south  
205 Yemen, and another in the mountainous area of western Saudi Arabia (Büttiker  
206 1982). However, there is uncertainty as to whether the two Arabian specimens came  
207 from wild stock, because no other faunal remains or live animals of this species are  
208 known in Arabia (IUCN Red List 2016). Harrison and Bates (1991) suggest that the  
209 distance between the two locations in Arabia is larger than one would expect for  
210 introduced specimens.

211 In the rock art, representations of bovids with twisted horns were reported from the  
212 Yatib area near Hail, and from Jebel al Lawz north-west of Tabuk. However, in the  
213 absence of evidence for local bovid species with twisted horns, the representations  
214 were interpreted as stylized depictions of gazelles or cattle, rather than the  
215 representation of actual twisted horns (Khan 2007: 119pp). Animals with twisted  
216 horns were also reported from the eastern Badiah in Jordan, where they occur in  
217 small numbers in the rock art. Here, representations of addax (*Addax*  
218 *nasomaculatus*), greater kudu (*Tragelaphus strepsiceros*), and lesser kudu were  
219 considered (Rollefson et al. 2008). The addax is a large, white antelope with a  
220 shoulder height of 115cm, and long annulated horns that form loose spirals. In a  
221 stylized, two dimensional engraving addax are therefore indistinguishable from  
222 kudu, particularly where hide markings are omitted in favour of a fully pecked body,  
223 such as in the examples illustrated by Rollefson and colleagues (2008: 26).

224

#### 225 *Evidence for lesser kudu in the rock art*

226 The Jubbah rock art survey now provides sufficient data to address uncertainties  
227 about the prehistoric distribution of lesser kudu. Of 4715 individual animal  
228 depictions, 91 were identified as kudu. There are a number of factors that  
229 contributed to this identification: A total of 18 animals were depicted with striped  
230 coats (Figure 4), and one image clearly shows the modular pattern of the  
231 longitudinal stipe and the vertical stripes that spring from it. Most importantly, STH  
232 180 shows a herd of males on one face of a boulder and a herd of females with

233 calves and a single male on the adjacent face (Figure 5). This social organization of  
234 bachelor male groups and harem groups of females with offspring and a solitary  
235 male is typical of lesser kudu (Leuthold 1974). The females at this site are depicted  
236 without horns and show the large ears that are characteristic of this species.

237 The coat markings, social organization, and absence of horns in females all suggest a  
238 depiction of kudu, rather than addax. Owing to the fact that two specimens of lesser  
239 kudu were reported from Arabia in the 1960s (Harrison & Bates 1991), we consider  
240 the images to be representations of the former.

241 In our sample of the rock art of Jubbah, kudu appear to be exclusively depicted in  
242 the earlier periods of rock art production, which are concurrent with the Holocene  
243 humid period. However, engravings reported by Khan (2007) on panels at Jebel al  
244 Lawz and the Tabuk area that can also be identified as kudu, may be later in date.  
245 Differences in style, weathering, and stratigraphic position indicate that within the  
246 Jubbah oasis kudu were depicted over multiple phases of rock art production (Figure  
247 2), which suggests the portrayal of a local species.

248

#### 249 **Wild camel**

250 The wild ancestor of the domestic dromedary remains somewhat elusive. Over the  
251 last two decades, excavations in south-eastern Arabia, largely in the territory of the  
252 United Arab Emirates, have produced faunal remains of ancient camels (Figure 6;  
253 Beech et al. 2009; von den Driesch & Obermaier 2007; Uerpmann & Uerpmann  
254 2012). Based on osteological differences, principally a reduction in size and a change  
255 in the survival rates within dromedary populations, the shift from hunting to herding  
256 is dated to the transition between the Bronze and the Iron Age, between 1400 BC  
257 and 900 BC (Uerpmann & Uerpmann 2012). However, it remains unknown if the  
258 camel was domesticated locally. The rest of the Arabian Peninsula, where the  
259 dromedary could feasibly have been domesticated, remains poorly documented  
260 from an archaeozoological perspective, thus knowledge about the biogeographical  
261 history of wild camel is incomplete. Faunal remains from coastal Yemen did not yield  
262 wild camel remains, leading Almathen and colleagues (2016, supplementary  
263 information) to hypothesize that the wild ancestor of the dromedary may already  
264 have been limited to south-eastern Arabia at the time of its domestication at the end  
265 of the Bronze Age. A small number of rock art panels in south-western Saudi Arabia  
266 are reported to show the hunting of wild camels, with the images attributed to the  
267 Bronze Age based on the weapons depicted in their hunt (Anati 1968; Macdonald  
268 1990; Zarins et al. 1981). The wild dromedary likely became extinct towards the end  
269 of the Iron Age; excavations have so far not provided evidence for wild camels from  
270 younger sites (von den Driesch et al. 2008).

271 There is currently no valid scientific description of the wild dromedary, although  
272 *Camelus thomasi*, the extinct North African wild camel, and *Camelus "arabs"* have  
273 been proposed by various authors (von den Driesch & Obermaier 2007; Peters 1998;  
274 Uerpmann & Uerpmann 2012). Nothing is known about the diet or feeding behavior  
275 of wild camels (von den Driesch et al. 2008). Observations on free-grazing domestic  
276 dromedaries in the Sahara indicate that camels make periodic visits to areas with  
277 salty plants (halophytes) (Gauthier-Pilters & Dagg 1981). Likewise, veterinary studies  
278 on domestic camels suggest they require salt intake for their wellbeing, specifically  
279 for the prevention of diseases such as skin necrosis and arthritis (Peck 1939).

280

#### 281 *Evidence for wild camel in the rock art*

282 In Jubbah nine camel depictions and one engraving of a camel footprint could be  
283 attributed to the initial Holocene on account of advanced patina and weathering, the  
284 position of the engravings underneath later petroglyphs, and the naturalistic style of  
285 the images which distinguishes them even from Pre-Neolithic hunting scenes and  
286 Neolithic herding scenes. The engravings in Figures 7, 8, and 9 show a clear variation  
287 in patina. While late engravings of domestic camels appear freshly pecked and light  
288 in colour (Figure 7), the petroglyph in Figure 8 shows that dark patina has formed  
289 over the pecked lines and suggests a much older age. The panel in Figure 9c in  
290 particular illustrates the relative difference in patina and preservation in a direct  
291 superimposition; later engravings are also engraved over the camel in Figure 8 (for a  
292 more detailed photograph see Figure 10). There is also a pronounced difference in  
293 the representation of camels in early and late engravings. While the former are  
294 larger and naturalistic, the latter tend to be small (10-30 cm) and highly stylized.  
295 Heavily patinated, naturalistic engravings of camels are thus associated with a very  
296 early period of rock art production. Since the domestication of the camel is currently  
297 dated between 1400 and 900 BC (Uerpmann & Uerpmann 2012), the recorded early  
298 engravings of camels predate domestication by several thousand years, therefore  
299 representing wild species (Figure 2).

300

#### 301 **Aurochs (*Bos primigenius*)**

302 Similarities in osteomorphological features, in particular the post-crania, renders  
303 distinguishing between members of the tribe Bovini difficult. To date three species  
304 have been identified in the Middle East: Aurochs (*Bos primigenius* Bojanus 1827),  
305 wisent (*Bison bison*), and buffalo (*Bubalus* sp.) (Uerpmann 1987). While the buffalo  
306 was likely confined to the riverine habitats of the Mesopotamian lowlands, aurochs  
307 are well known across the Levant, Mesopotamia and beyond. On the Arabian  
308 Peninsula, evidence for the Holocene presence of aurochs was recently reported  
309 from eastern and southern Arabia (McCorriston & Martin 2009; see also Fedele

310 2008). Aurochs can survive in a wide range of habitats, from wooded environments  
311 to open steppe, but require access to drinking water every few days. There is some  
312 evidence from rock art that African buffalo (*Syncerus caffer*) may also have extended  
313 into southern Arabia, but has not yet been confirmed by faunal remains  
314 (McCorrison & Martin 2009).

315 Early evidence for the domestication of cattle in the middle Euphrates region and  
316 the southern Levant has been dated to the seventh millennium BC (summarized in  
317 Drechsler 2007). In Anatolia cattle herding appears to have been well established by  
318 the eighth millennium BC (Peters et al. 2013), while in southern Arabia domestic  
319 cattle are known from the late sixth millennium BC (McCorrison & Martin 2009). In  
320 the more arid regions of eastern and southern Jordan livestock was dominated by  
321 caprine herding (Martin & Edwards 2013; see also Henry et al. 2003; Rollefson et al.  
322 2014).

323

#### 324 *Evidence for aurochs in the rock art*

325 In our sample only a single engraving in Jubbah from the naturalistic earliest phase  
326 of rock art creation appears to represent a member of the tribe Bovini. Below the  
327 engraved outline of the camel in Figure 8 an earlier, completely internally pecked  
328 engraving can be seen (Figure 10). Unfortunately, the engraved horns have  
329 exfoliated and are no longer distinguishable. However, the outline of the body is  
330 clearly visible. The shape of the neck and back, as well as the environment of the  
331 Jubbah oasis, suggest a representation of *Bos* rather than buffalo or bison. The  
332 stratigraphic position of this engraving, and the degree of naturalism in the outline,  
333 suggest the image pre-dates the Neolithic and belongs to the earliest rock art in  
334 Jubbah (Figure 2). We therefore consider it likely to be a representation of wild  
335 rather than domestic cattle. The only other securely identified engraving of an  
336 aurochs on the Arabian Peninsula was found at Kilwa, on the other side of the Nefud  
337 desert, close to the Jordanian border (Guagnin et al. 2015). It therefore appears that  
338 at least some of the inhabitants of Jubbah and the wider region were familiar with  
339 wild cattle. However, in the absence of further aurochs engravings and skeletal  
340 remains, it is not yet possible to establish if aurochs occurred locally or were seen by  
341 the engravers some distance away.

342

#### 343 **African wild ass (*Equus africanus*)**

344 A small but growing body of data suggests the prehistoric presence of African wild  
345 ass (*Equus africanus* Heuglin & Fitzinger 1866) in the Levant and on the Arabian  
346 Peninsula (Cattani & Bökönyi 2002; Fedele 2008; Marshall 2007; Uerpmann 1991;  
347 Zarins 1986). At Ash Shumah in Yemen, 930 specimens of African wild ass were  
348 identified at a site radiocarbon dated to between 6684-6475 cal BC (Cattani &

349 Bökönyi 2002). At Ra's al-Hamra in Oman, a number of bones were assigned to  
350 African wild ass and at Ain Qannas in Saudi Arabia 20 specimens were identified;  
351 remains at both sites were dated to around 5500 BC (Uerpmann 1991; see also  
352 Marshall 2007). The only other dataset from the Arabian Peninsula comes from Hili 8  
353 in the United Arab Emirates, where 26 specimens were dated to the Bronze Age  
354 (3000 cal BC) (Uerpmann 1991; see also Marshall 2007; Figure 11).

355 The African wild ass is the ancestor of the domestic donkey (*Equus africanus asinus*),  
356 which was probably domesticated in north-east Africa (Beja-Pereira et al. 2004;  
357 Marshall & Weissbrod 2011; Rosenbom et al. 2015). There is some evidence that the  
358 morphology of early domestic donkeys remained undifferentiable from that of the  
359 wild ancestor for at least 1000 years (Marshall 2007; Marshall & Weissbrod 2011).  
360 Kimura and colleagues (2013) have therefore argued that the African wild ass  
361 remains in Arabia could be conflated with early domesticates (see also Marshall  
362 2007). The earliest domesticated donkeys in North Africa are currently dated to  
363 around 4000 BC (Marshall & Weissbrod 2011; see also Grinder et al. 2006), and they  
364 may have spread into Arabia fairly rapidly. The identification of African wild ass in  
365 Natufian and Chalcolithic layers at three sites in Jordan (Marshall 2007; Uerpmann  
366 1991), and a metatarsal dated to between 8000 and 7000 BC at Mureybit in Syria  
367 (Ducos 1986), confirms the presence of wild ass in southwest Asia. However, in the  
368 Levant the domestic donkey is not known before the Bronze Age. Here, the earliest  
369 evidence for the presence of domestic donkey currently dates to between 2800 and  
370 3000 BC, and to the late 3<sup>rd</sup> to early 2<sup>nd</sup> millennium BC in Oman, although a slow rate  
371 of morphological change may make it difficult to identify early domesticates in the  
372 archaeological record (Marshall 2007).

373 A range of subspecies are recognized among the wild asses and there is no  
374 consensus in their identification and naming (see for example Kingdon 1997;  
375 Marshall 2007; Uerpmann 1987; Zarins 1986). The most common distinction is  
376 between two North African subspecies: Somali wild ass (*E. a. somaliensis*) with  
377 transverse barring on the legs, and Nubian wild ass (*E. a. africanus*), the likely  
378 ancestor of the domestic donkey, which has a shoulder stripe (Grinder et al. 2006;  
379 Kingdon 1997; Marshall 2007). Shoulder stripes are also reported from North African  
380 wild asses depicted in the rock art of the Atlas Mountains (Kimura et al. 2013).

381

### 382 *African wild ass in the rock art of Jubbah and Shuwaymis*

383 At Shuwaymis 10 of 31 wild equid depictions suggested a possible depiction of  
384 African wild ass. On one panel, an equid was re-engraved to enlarge the head and  
385 ears in proportion to the body in a possible modification of the animal from onager  
386 to African wild ass (Figure 12). However, the engraved outline of two such similar  
387 animal species cannot be taken as conclusive evidence (Guagnin et al. 2016) and

388 subtle differences in the proportion of head and ears may reflect artistic license  
389 rather than anatomical accuracy.

390 A recent survey in the Jubbah oasis provided the first evidence for the depiction of  
391 African wild ass. On panel ORF 131A a large wild equid is clearly depicted with a  
392 shoulder stripe (Figure 13). Shoulder stripes are absent in onager and therefore  
393 serve as a secure distinction between both species. Moreover, the timing of the  
394 image is comparatively well secured. The animal is superimposed by the earliest  
395 known Chalcolithic or Bronze Age rock art in the Jubbah oasis. The fully patinated  
396 elongated human figures visible on the panel are typical for the Neolithic of the area  
397 (Khan 2007; 2011; Nayeem 2000; Olsen & Bryant 2013). However, the present panel  
398 is the first recorded example that was engraved using a metal tool, and depicts  
399 human figures with bronze or perhaps copper daggers. On the Arabian Peninsula the  
400 beginning of the Bronze Age dates to the late 4th millennium BC (Magee 2014); the  
401 earliest dates in the Levant are somewhat disputed but are thought to be between  
402 3500 and 3300 BC (Regev et al. 2012) with the Chalcolithic dating back to the end of  
403 the 5<sup>th</sup> millennium BC. If the engraved human figures with daggers date to the early  
404 Bronze Age then the depiction of the African wild ass itself must date to the early 4th  
405 millennium or earlier. On the other hand, if the human figures date to the  
406 Chalcolithic, then the underlying wild ass may even have been engraved as early as  
407 the 5<sup>th</sup> or 6<sup>th</sup> millennium BC. The engraving thus predates the earliest evidence for  
408 domestic donkeys in the Levant (Figure 2), and presumably represents a wild  
409 specimen. The presence of a shoulder stipe in the depicted individual indicates  
410 similarity to the Nubian wild ass, rather than the Somali wild ass.

411

## 412 **DISCUSSION**

413 Our research has shown that rock art studies provide information on species palaeo-  
414 distributions, particularly in areas where research on faunal remains is lacking. The  
415 rock art data also demonstrated that even in areas with comparatively rich datasets,  
416 such as in the archaeological and zoological records of the Levant, key species may  
417 be missing in faunal lists. Additionally, the representation of herd compositions, and  
418 coat markings in the rock art can provide information that is sometimes lacking in  
419 skeletal remains and help to distinguish the presence of morphologically similar  
420 species.

421 The relatively frequent depiction of bovids with twisted horns, often with vertical  
422 stripes, their social organization in bachelor groups and harems, and the  
423 representation of hornless females lead us to conclude that lesser kudu was present  
424 in Saudi Arabia during the Holocene humid period. If the two specimens hunted in  
425 the 1960s represent the last individuals of this population, kudu show remarkable  
426 resilience in the face of aridification, and illustrate the considerable effect habitat

427 destruction and hunting have had on the diversity of mammals in Arabia (see Tsahar  
428 et al. 2009 for similar observations in the southern Levant).

429 Although kudu tend to maintain low population density, they must have been  
430 present in large enough numbers in the early Holocene to sustain their population  
431 longer term. The presence of palaeolakes is well attested at the oasis of Jubbah, with  
432 various lake phases dated to the early and middle Holocene, and palaeoecological  
433 reconstructions indicating well-vegetated environments (Hilbert et al. 2014; Crassard  
434 et al. 2013). Kudu are almost exclusively browsers (Estes 1991; Kingdon 1997),  
435 therefore there must have been trees and shrubs in the vegetation around the  
436 Jubbah palaeolakes.

437 It remains unclear when kudu arrived on the Arabian Peninsula and what route this  
438 dispersal followed. The complete lack of kudu identifications from Holocene faunal  
439 remains makes it difficult to trace any movements, although had they been common  
440 in the landscapes of North Africa and the Levant they would presumably have been  
441 noticed in the archaeological record. However, remains of *Tragelaphus* have been  
442 reported from the Middle Pleistocene site of Tighenif in northern Algeria (Geraads  
443 2010) and confirm their dispersal during periods of wetter climate. The presence of  
444 lesser kudu in Saudi Arabia therefore raises the question whether they arrived  
445 during the Pleistocene and survived the Last Glacial Maximum in small refugia, yet in  
446 large enough numbers to sustain populations over some millennia. Alternatively, a  
447 dispersal of kudu during the Holocene humid period via the Sinai and Levant or the  
448 Red Sea is a possibility, as has been surmised for Middle and Late Pleistocene  
449 movements of other species (Breeze et al. 2016; Stimpson et al. 2016).

450 The distribution of wild camel remains currently known gives the impression that  
451 they were attracted to coastal environments and lagoons (Uerpmann & Uerpmann  
452 2012). The presence of wild camel in the middle of the Nefud Desert confirms that  
453 their prehistoric distribution likely extended across all of the Arabian Peninsula, and  
454 that their habitat requirements, diet and feeding behavior may have been similar to  
455 those of the domestic camel. While domestic camel rely on humans to supply them  
456 with water (Gauthier-Pilters & Dagg 1981), wild camel would have been much more  
457 reliant on water sources in the form of springs and palaeolakes. Additionally,  
458 palaeolake deposits formed in multiple cycles of lake expansion and contraction  
459 (Hilbert et al. 2014; Crassard et al. 2013), may also have sustained the salty plants so  
460 sought after by camels (Gauthier-Pilters & Dagg 1981).

461 Although equid depictions are relatively common in Jubbah and Shuwaymis, only a  
462 single engraving had the body markings that enabled an attribution to *Equus*  
463 *africanus*. While the engravers and painters of Shuwaymis and Jubbah have so far  
464 been shown to depict local species (Guagnin et al. 2016), we cannot exclude the  
465 possibility that the African wild ass was seen somewhere else and then depicted in  
466 Jubbah. The archaeological record suggests wider reaching contacts (Crassard et al.

467 2013, Guagnin et al. 2017b; Hilbert et al. 2014) and at least some of the occupants of  
468 Jubbah would have been highly mobile.

469 Similarly, we cannot be certain whether the depiction of an aurochs at Jubbah is the  
470 result of human or animal mobility. Nevertheless, the presence of large and  
471 medium-sized ungulates, such as kudu, onager, African wild ass, and aurochs reflects  
472 the extent to which the vegetation and rainfall regimes of the Holocene humid  
473 period opened up corridors across northern Arabia that enabled the movement of  
474 humans and animals.

475 The presence of lesser kudu, wild camel, and African wild ass shows that the Jubbah  
476 oasis was a focal point for animals from different habitats. Carnivores identified in  
477 the rock art include lions, leopards, and hyaenas. These carnivores were likely  
478 attracted to the Jubbah oasis by the rich available prey biomass (Guagnin et al.  
479 2016). We note with interest that three of the previously undocumented species  
480 described here were present in Jubbah, but not in the Shuwaymis riverine zone. This  
481 opens up the possibility that oases like Jubbah may have provided refugia during  
482 periods of increased aridity, and provided stability and food security during episodes  
483 of drought. While we report four species that are identifiable in the rock art, our  
484 dataset also includes more ambiguous depictions. Engravings of mouflon or early  
485 domestic sheep are common and show horn shapes and hide markings. The  
486 distinction of wild and domestic sheep in the rock art requires more precise  
487 chronological controls than are currently available. However, in conjunction with the  
488 excavation and analysis of faunal remains, the rock art of north-western Saudi Arabia  
489 may provide further evidence on the palaeo-distribution of wild and early  
490 domesticated species in the future.

491 Prehistoric human populations documented many of the animals in their  
492 environments in paintings and engravings. Our data shows that faunal evidence from  
493 rock art contains valuable information that can be used to complement and  
494 strengthen datasets from skeletal remains. Rock art is found in most regions of the  
495 world and thus has an as of yet largely untapped potential to provide evidence on  
496 palaeo-distributions and biogeography.

497

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720

721 **FIGURE CAPTIONS**

722 **Figure 1** Satellite image of northern Saudi Arabia (top). White rectangles indicate the  
 723 location of Shuwaymis (bottom left) and Jubbah (bottom right). Dashed lines  
 724 indicate areas surveyed for rock art. All three satellite images are Google Earth,

725 Landsat / Copernicus. Top: Data SIO, NOAA, U.S. Navy, NGA, GEBCO. Bottom left:  
726 Image ©CNES / Astrium and © 2016 DigitalGlobe. Scales are in 1km units.

727 **Figure 2** Comparison of the chronology for rock art sites, individual engraved species,  
728 and archaeological contexts. Top: Darker shading represents more intensive rock art  
729 production. Representations of curvaceous women and of Bronze Age rock art were  
730 only identified in Jubbah (Guagnin et al. 2017a). Middle: Approximate timing of  
731 engraved species discussed in the text. Bottom: Domestic cattle and caprines were  
732 introduced to the Arabian Peninsula between 6,800 and 6,200 BC (Drechsler 2007);  
733 in the absence of dated early Neolithic sites in northwestern Saudi Arabia we have  
734 used 6,200 BC as a more conservative earliest date. Earliest evidence for domestic  
735 donkeys in the Levant currently dates to 3000 BC (Marshall 2007). Early dates for the  
736 presence of domestic camel and horse were documented in eastern Arabia (Magee  
737 2014; Uerpmann & Uerpmann 2012) and we assume similar timing in Jubbah and  
738 Shuwaymis.

739 **Figure 3** Current distribution of *Tragelaphus imberbis* (based on Kingdon 1997)  
740 shaded in grey. Locations of the two sets of horns found in Arabia indicated with  
741 stars (based on Harrison & Bates 1991). The hatched area indicates rock art  
742 representations of lesser kudu around the oasis of Jubbah.

743 **Figure 4** Engraved scene from Jebel Umm Sanman (Jubbah) with a hunter and two  
744 lesser kudu (Panel JSM 60A; bottom left: original; bottom right: tracing). Coat  
745 markings and twisted horns are clearly visible in both kudu engravings. The image on  
746 the top shows the engraved rock surface with two large, stylized camels  
747 superimposed over the scene, and a scale.

748 **Figure 5** Engraved boulder at Jebel Sateihah (Jubbah) with 12 male kudu on the west  
749 facing surface of the boulder (STH 180A, above) and one male, eight female and two  
750 young kudu on the south facing surface of the boulder (STH 180B, below). Engravings  
751 identifiable as kudu are traced in white, other engravings are traced in grey. A later  
752 engraving of a stylized camel and a wusum sign on panel STH 180A have not been  
753 traced. While the cellular markings on one of the females may represent a striped  
754 coat, this pattern is also frequently found on species that are not known to have coat  
755 markings, such as ibex.

756 **Figure 6** Currently known Holocene distribution of wild dromedary (based on  
757 Uerpmann & Uerpmann 2012) shaded in grey. The hatched area indicates rock art  
758 representations of wild dromedary around the oasis of Jubbah.

759 **Figure 7** Four late Holocene engravings of domestic camels from Jubbah. The  
760 engraving on the top left shows a saddle, while the engraving on the bottom left  
761 shows a rider. The camel on the bottom right is associated with an inscription.

762 **Figure 8** Engraving of a large camel at Jebel Umm Sanman (JSM50). The boulder is  
763 approximately 3m in height and appears to have fallen over from its original

764 position. The depictions are therefore in a vertical position today. A number of later  
765 engravings can be seen superimposed over the top of the camel.

766 **Figure 9** Engravings of wild camels at Jebel Umm Sanman in Jubbah. A: Detailed  
767 depiction of a camel's head (JSM193) on a boulder directly in front of JSM50 (Figure  
768 8). B: Eroded and patinated engraving of a camel footprint. C: Large and incomplete  
769 engraving of an almost live sized camel, superimposed by three engravings of later,  
770 domesticated camels (JSM211).

771 **Figure 10** Left: Engraving of an aurochs at Jebel Umm Sanman (JSM50). The outline  
772 of the aurochs is traced in white, the superimposed camel is traced in grey. Right:  
773 detailed photograph of the superimposition of the camel hump and neck over the  
774 back of the aurochs.

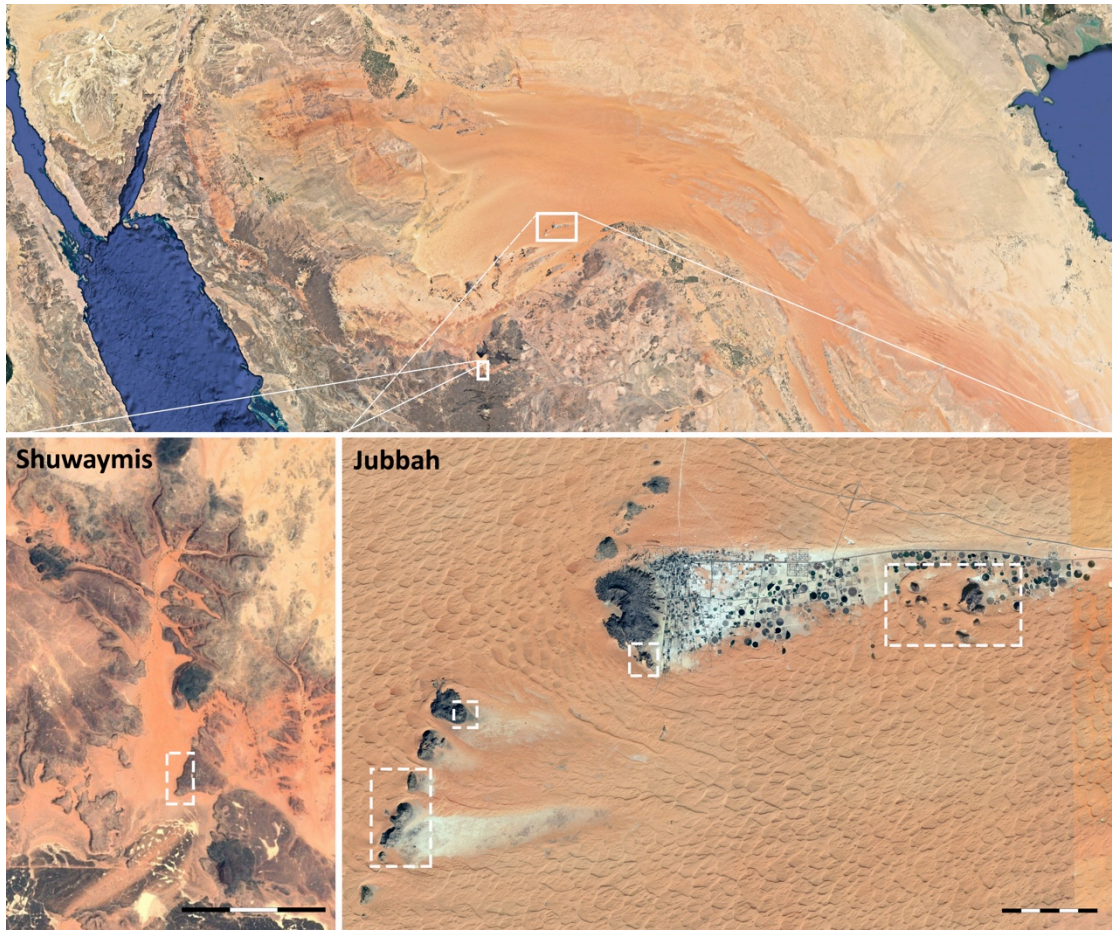
775 **Figure 11** Distribution of Somali wild ass (light grey) and Nubian/Saharan wild ass  
776 (dark grey) after Marshall (2007). Sites with faunal remains of African wild ass are  
777 marked with stars (after Marshall 2007; Uerpmann 1991). The hatched area  
778 indicates rock art representations of African wild ass at the sites of Jubbah and  
779 Shuwaymis.

780 **Figure 12** Panel 105A at Shuwaymis showing an equid with a young being attacked  
781 by hunting dogs. The head of the adult equid was modified in prehistory to increase  
782 its proportion relative to the body.

783 **Figure 13** Panel ORF 131A from Jebel Oraf in the jubbah oasis (above) and close up of  
784 the shoulder area of the equid (below). Pecked areas are traced in faded white. To  
785 the right of the equid three human figures are clearly visible. An additional figure is  
786 engraved on the belly of the animal, and a spear held by the figure is also  
787 superimposed on the animal. A fourth human figure can be seen to the left of the  
788 equid.

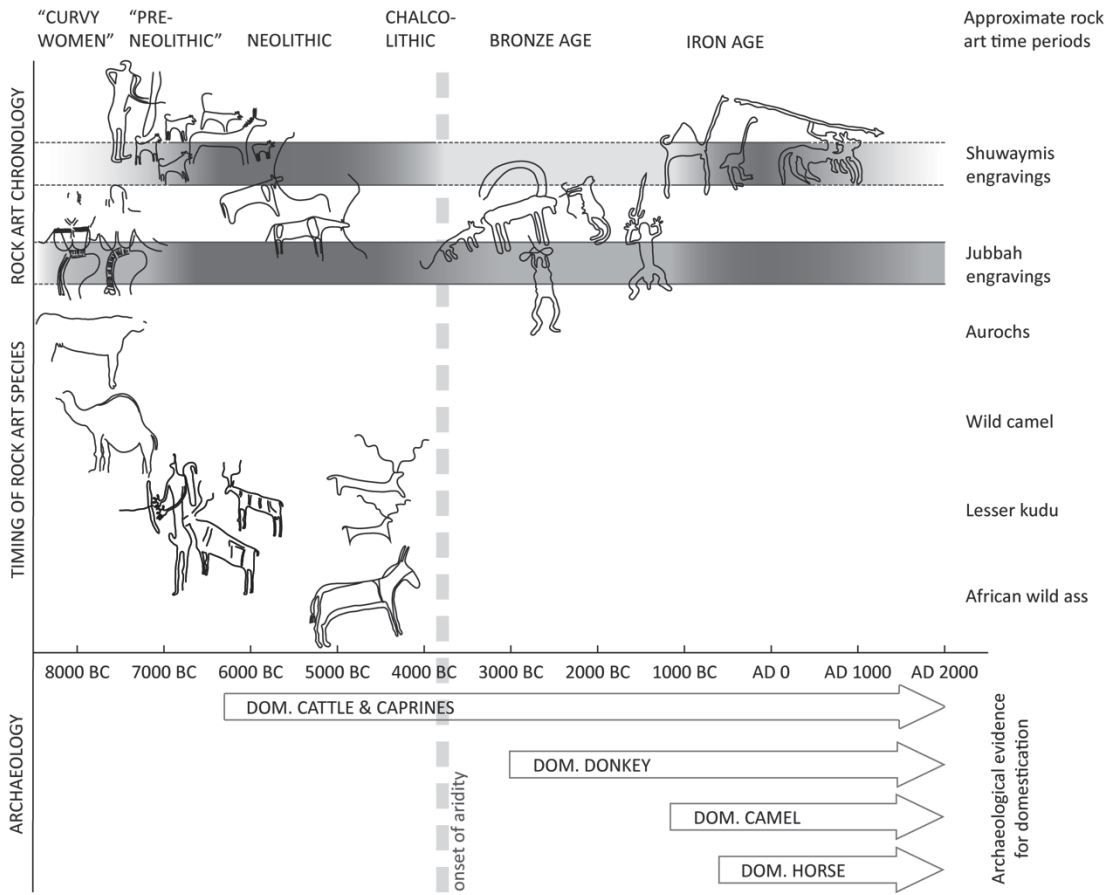
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790 **FIGURES**



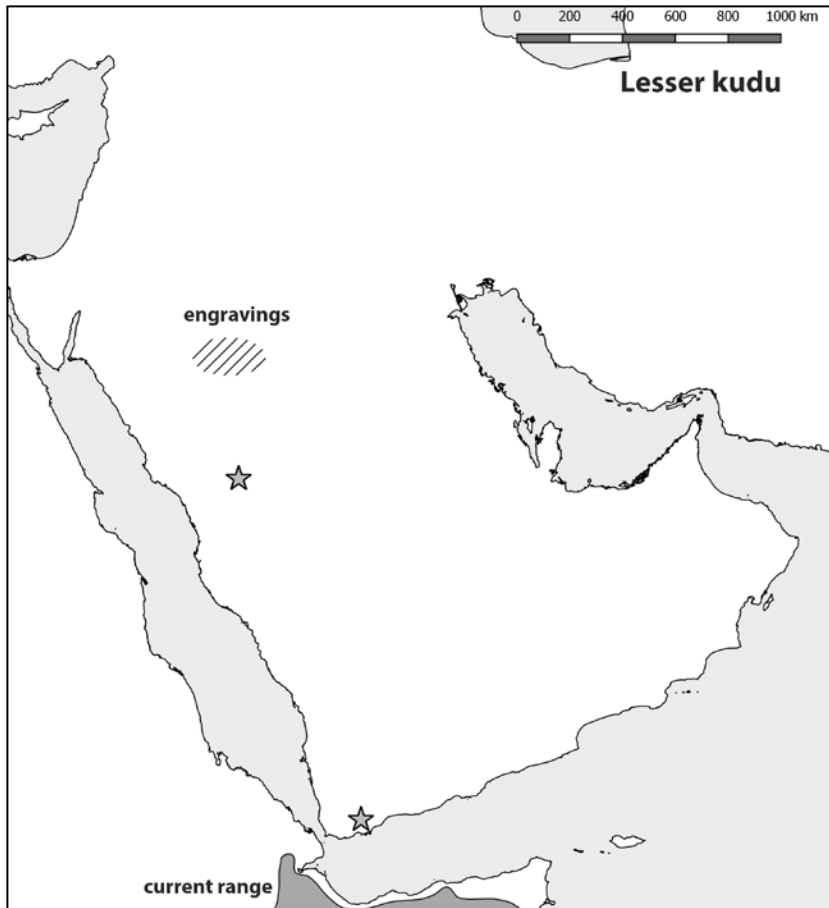
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792 Figure 1



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794 Figure 2



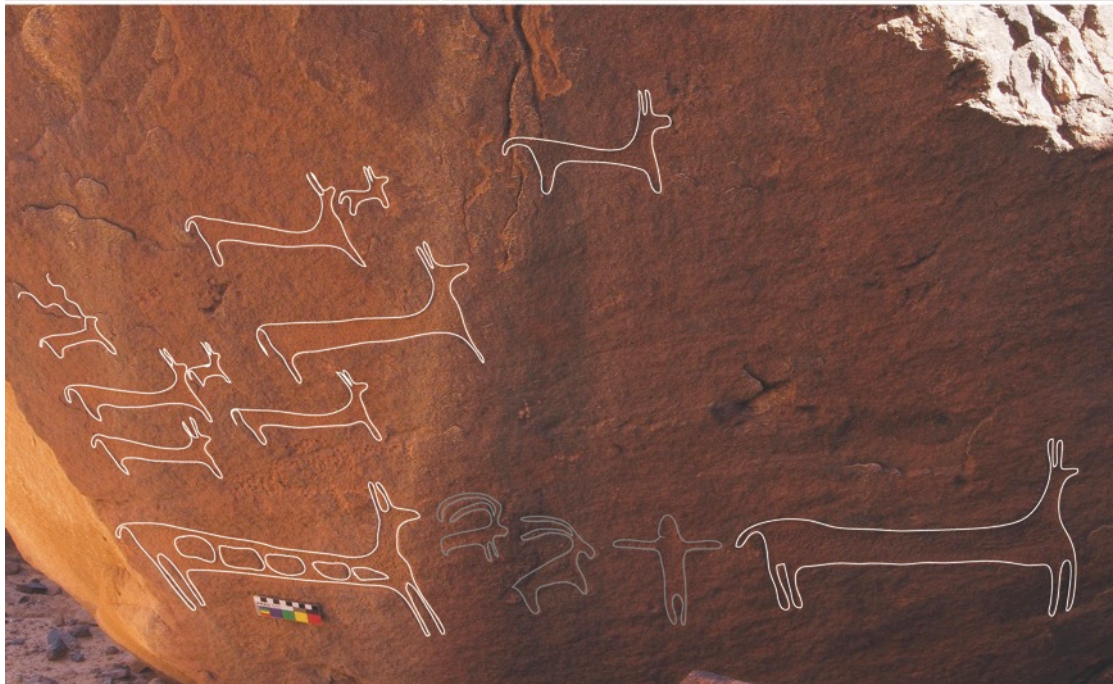
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796 Figure 3



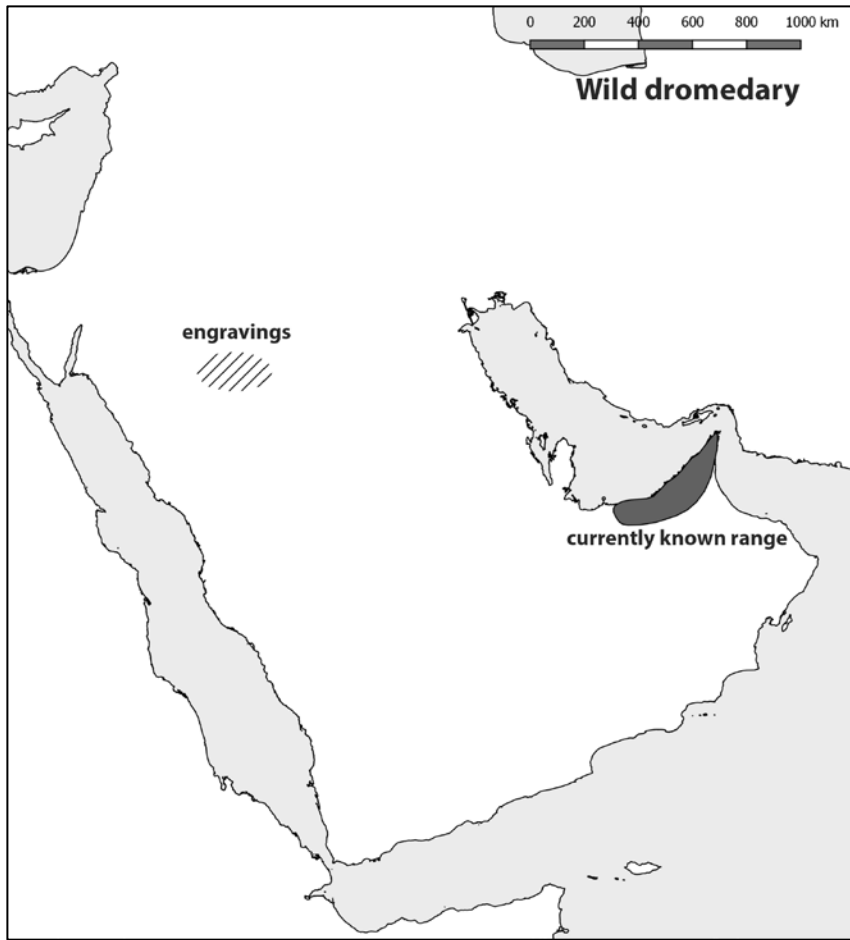
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798 Figure 4



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800 Figure 5



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802 Figure 6



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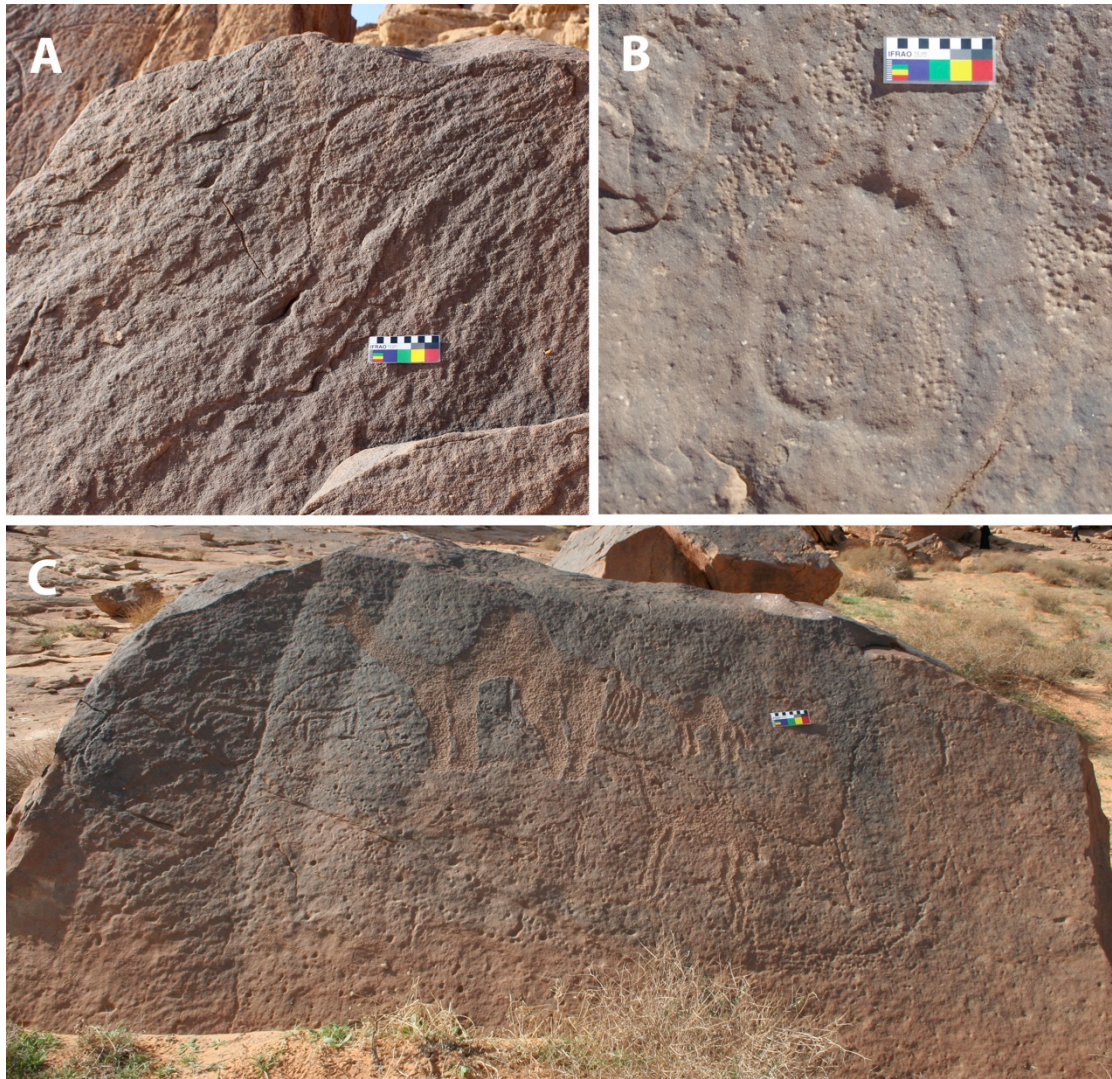
804 Figure 7



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Figure 8



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808 Figure 9



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810 Figure 10



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812 Figure 11



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814 Figure 12



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816 Figure 13

817 **BIOSKETCH**

818 Maria Guagnin is an archaeologist specialising in rock art research, with a particular  
819 focus on the relationship between the depicted animal species and the prehistoric  
820 environment and landscape. This study was carried out as part of her postdoctoral  
821 position with the Palaeodeserts project ([www.palaeodeserts.com](http://www.palaeodeserts.com)), a  
822 multidisciplinary team that examines the effect of environmental change on  
823 prehistoric human and animal populations in the Arabian Desert.

824

#### 825 **STATEMENT OF AUTHOR CONTRIBUTIONS**

826 M.G. performed the analyses and wrote the manuscript with contributions from C.S.,  
827 M.S., F.O. and M.D.P. All authors collected data in the field. A.A. facilitated  
828 collaboration with King Saud University and support in the field, and S.D. contributed  
829 panel identifications from her PhD research in Jubbah. M.D.P is the grant holder and  
830 PI of the ERC funded Palaeodeserts project and secured research permits and  
831 collaboration with the Saudi Commission for Tourism and National Heritage.

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