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## Foraging economies and population in the Middle Holocene highlands of southern Yemen

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with contributions by

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### Introduction

One of the most intriguing sets of questions about Arabia's ancient past still ponders the circumstances that led to the adoption of crop agriculture in oases, highland settlements, and ultimately in the desert-fringing polities that became southern Arabia's great ancient civilizations. Arabia lies at the centre of ancient and persistent contacts among different source regions for domesticated plants. The archaeological record shows ample evidence of contacts around water and sand seas connecting South Asia, Africa, and the Middle East, so one would expect crops were available early in Arabian pre-history. Domesticated animals appeared as early as 8,500 years ago from several regions.<sup>1</sup> Arabian foragers probably encountered domesticated plants at the same time as they encountered sheep and goat herders expanding from the Levant, sometime before 7800 years ago. But there remain puzzling questions about the Arabian foragers who adopted crops and seem to have done so relatively late (5200 cal. BP). Under what economic and social circumstances did foragers take up cultivation? New survey data from the [RASA] Archaeological Project in Ḥaḍramawt suggest that people in the southern highlands experienced regional population pressure by the Middle Holocene and managed their landscape with technologies which would prove critical in the later adoption of agriculture.<sup>2</sup>

The Arabian archaeological record provides some data for plausible scenarios of crop introductions. Charred remains and impressions of domesticated plants provide one line of evidence, but the incidences of specific crops are isolated and sometimes contested prior to about 5000 years ago. While we can continue searching, digging, and building better records, at present there is no indisputable archaeobotanical evidence for agricul-

ture much before 5000 years ago. By the third millennium BC cultivating and herding populations had established fortified settlements and anthropol sediments began accumulating in the farmlands of Marib, Bayḥān, and Wādī Markhah (e.g. Brunner 1997*a*; 1997*b*; Wilkinson, Edens & Barratt 2001). Agriculture had become an important occupation demanding the co-operative labour of closely-knit communities. But archaeology has provided little insight into how Arabian foragers developed these technologies and the communities that sustained them. Almost no forager-herder plant remains have been recovered and reported in Arabia, although not for lack of effort by researchers. In adjacent regions, charred archaeobotanical assemblages have allowed archaeologists to reconstruct plant components of forager economies (e.g. Hillman 2000; Kislev, Nadel & Carmi 1992; Hillman, Madeyska & Hathor 1989; Barakat & Fahmy 1999; Wasylikowa & Dahlberg 1999; Wasylikowa *et al.* 1997; Amblard 1996; Haaland 1995). But in Arabia, we still struggle to reconstruct the economies and societies into which agricultural crops were introduced.

### Human ecology, population pressure, and plant use

In ancient Arabia the success of early cultivation relied upon innovative techniques, which allowed crop survival in Arabia's unusually harsh environments. Middle Holocene climate changes, documented in ocean cores and terrestrial records (e.g. Overpeck *et al.* 1996; Sirocko *et al.* 1993) reduced rainfall and potentially heightened its seasonality across the Arabian Peninsula. That these environmental changes had significant impacts on the economic and social adaptations of foraging groups is indisputable. Some studies in lithic arte-

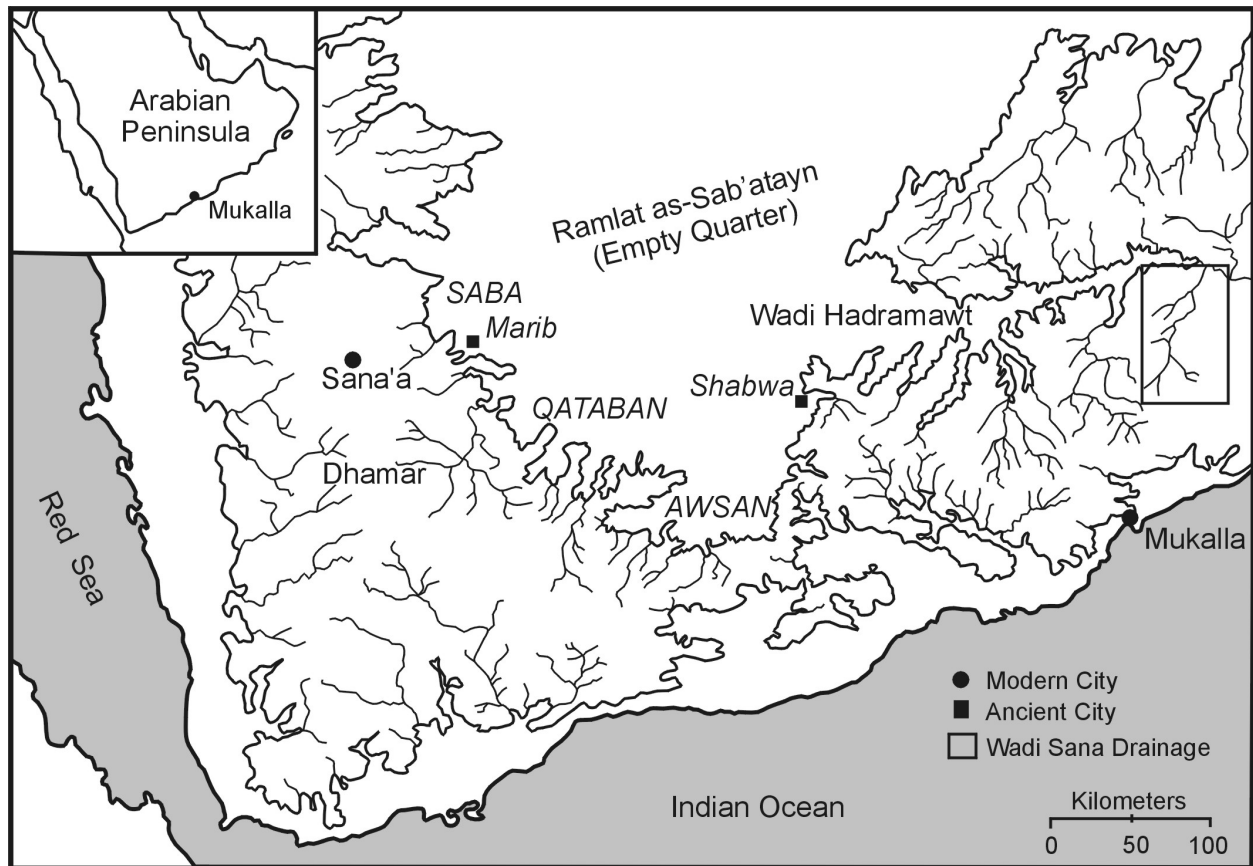


FIGURE 1. A map of south-west Arabia with the Wādī Ṣanā. Drainage indicated.

fact styles and distributions show Middle Holocene differentiation of facies (Spoor 1997; Fedele 1988: 36), which may indicate that foragers began to range less widely and identify more closely with territories and exclusive social groups, as in the Levant (e.g. Goring-Morris 1987; 1996; Henry 1989; 1996; cf. Neeley & Barton 1994; Clark 1996; Phillips 1996; Schuldenrein & Clark 2001). But current archaeological evidence for Southern Arabia, much of it from surveys using different sampling and collection techniques, at present allows little further elaboration of the social and economic practices of forager-hunter-herders in the Arabian interiors and much of its highlands. This paper employs principles of human behavioural ecology and ethnographic case-studies to suggest that techniques ultimately employed for crop-agriculture were first used by highland cultivators to enhance the productivity of wild plants. We believe that this best explains the archaeological record of check dams and burnt surfaces in the highland Jōl of southern Yemen (McCorrison & Oches

2001; McCorrison *et al.* 2002).

In a series of papers that collate, index, quantify, and codify the use of plant foods by nearly a hundred ethnographically and ethnohistorically-documented foraging and proto-agricultural groups, Lawrence Keeley concluded the following:

- a) Latitude is a major factor in accounting for degree of reliance on plant foods by foraging groups: higher latitudes are associated with less reliance on plants and vice versa (Keeley 1988: 393; 1992: 35).
- b) Plant foods are more important in regions with limited access to aquatic foods (Keeley 1988: 392; 1992: 35).
- c) "The proportion of plants in the diet will rise as precipitation declines" (Keeley 1992: 35).
- d) "The proportion of plants in the diet will rise as population density (i.e. population pressure) increases" (Keeley 1988: 393; 1992: 35).
- e) "As the proportion of plants in the diet increases ... as population pressure increases and rainfall de-

creases, the use of nuts and seeds will increase." (Keeley 1992: 36).

f) In a scale of increasing intensity, those groups relying most heavily on plant foods (seeds, nuts, and roots) and most constrained in mobility (by population pressure and decreasing precipitation) practise landscape burning (Keeley 1995: 248–255).

What do these generalizations, many of them derived from stepwise regression statistics on indexed variables, imply for the prehistory of Arabia? While the assumption central to optimal foraging theory and human behavioural ecology — that human choices can be modelled as rational decisions based on returns relative to energy expended — has been sharply criticized (Ingold 1996), this assumption has proved an enlightening basis for examining and modelling prehistoric foraging alternatives and subsistence transitions (e.g. Hawkes & O'Connell 1992; Russell 1988; Simms 1987; Simms & Russell 1997; Winterhalder 2002: 207–208; Winterhalder & Goland 1997). Arabia's foragers, like foragers everywhere, probably did not act with precise economic rationality, but neither optimal foraging models nor human behavioural ecology necessarily make or require this assumption. Optimal foraging models are just models — they establish generalized approximate parameters often based on quantitative evidence that help generate a better understanding of potential alternatives. Indeed, that humans in general do act with reference to the economic costs/benefits of their choices is reflected by Keeley's and others' ability quantitatively to demonstrate general patterns.

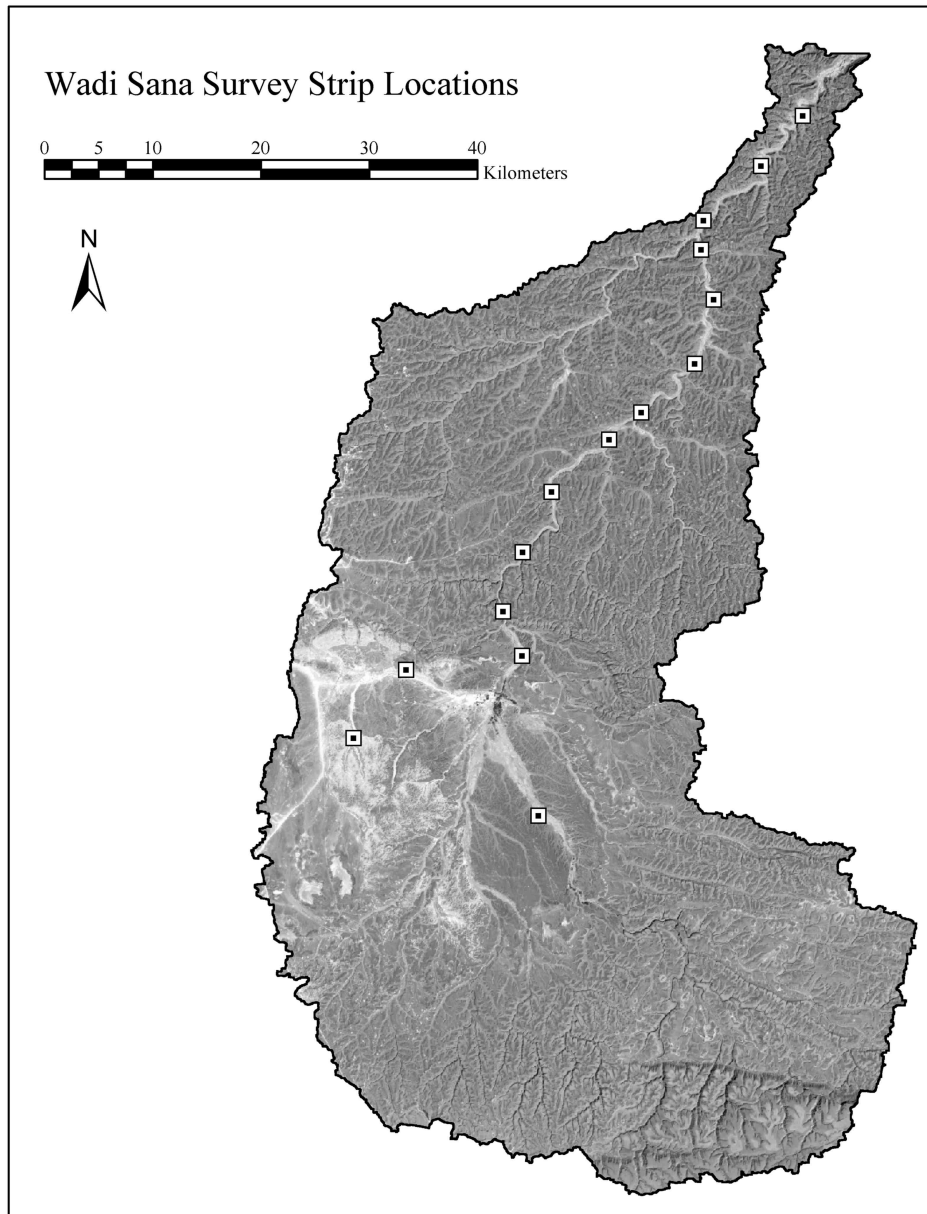
The complexity of these issues aside, Keeley's generalizations allow us to predict that where mobility was restricted in prehistoric Arabia, plant foods would have been an important dietary component. As precipitation declined throughout the Middle-Late Holocene, foraging groups in the highlands and desert interior would have been most likely to intensify their exploitation of plant foods, increasingly relying on seeds, nuts, and tubers as population densities increased near remaining water sources. If Middle Holocene change is implicated in human economic choices, one must remember with caution that the long time-frame of aridification suggests that human rational choices would have been responses to proximate causes rather than the ultimate cause of climate change. Such proximate causes could be people-packing near permanent water sources, a generational shift from predominantly dual-season to single-season precipitation, drying of specific springs and lakes, or the flip from negative to positive in evaporation to precipitation ratio. These are local events with local signatures in geo-archaeological records.

## RASA Archaeological Project Survey

Wādī Ṣanā is one of the major northward-draining tributaries of the Wādī Ḥaḍramawt, the major structural feature of southern Arabia (Cleuziou, Inizan & Marcolongo 1992) (Fig. 1). The deeply incised Tertiary course of Wādī Ṣanā extends some 80 km from the Ghayl Bin Yumayn basin to the Wādī Masīlah at the village of Ṣanā. The Wādī Ṣanā first forms a narrow course (about 500 m wide) at Ghayl Bin Yumayn, where perennial springs surface from the interface between the Jazā' formation (shale, limestone, and gypsum) and the harder Umm al-Raḍūmah limestone. Today there are few reliable sources of water — the springs at Ghayl Bin Yumayn have run dry, the modern wells depend on pumps that break down, and the traditional *krīf* and *qīr* reservoirs vary with uncertain rainfall. Vegetation cover is uneven with generally less than 1% cover of annuals, dwarf shrubs and spiny trees such as *Acacia* spp., *Lycium* spp., *Cadaba* spp., *Maerua oblongifolia*, and *Commiphora* spp. The modern population is exclusively pastoral (except for limited date and cereal farming in Ghayl Bin Yumayn) and very thinly scattered (fewer than two people per square kilometre).

The RASA Archaeological Project selected this narrow course, limited adjacent terraces of the plateau, and drainages within the Ghayl Bin Yumayn basin for systematic archaeological survey beginning in 2000. We were building upon important pre-existing knowledge of the drainage, including the unpublished pipeline survey for Canadian Nexen Petroleum Ltd. (then CanOxy) (Vogt & Sedov, in press) and a reconnaissance survey in 1996 and 1998 (McCorrison 2000). In particular, over two field seasons we had focused survey and excavation on the landscape surrounding a prominent high butte of the middle Wādī Ṣanā, known to locals as the Khuzmat al-Shumliyah, and in antiquity as *ḥzmm* ("Khuzmum", from a graffito near an east-facing rock-shelter). In the vicinity lies what appeared to us to be a particularly concentrated array of structures, hearths, burnt surfaces, and water-management structures, described in greater detail elsewhere (McCorrison *et al.* 2002). We extended our survey to the rest of the Wādī Ṣanā to test our assumption that "Khuzmum" constitutes a "site" of particularly rich, concentrated, and hence important, ancient activities. We further expected that survey throughout the Wādī Ṣanā would reveal patterns of association between archaeological remains and different landforms and spatial distributions of archaeological remains.

Using methods that emphasize siteless survey and distributional archaeology (Cherry, Davis & Mant-



**FIGURE 2.** *The locations of a randomly-selected, stratified sample of survey strips across the Wādī Ṣanā. The area surveyed (2000 and 2004) is approximately 5% of the total Wādī Ṣanā between Ghayl Bin Yumayn and Wādī Masīlah.*

zourani 1991; Cherry *et al.* 1998; Dunnell 1992; Dunnell & Dancy 1983; Ebert 1992; Terrenato & Ammerman 1995), the RASA Project employed real-time differential correction GPS to map a quilt of different survey units, each defined by a single landform class (Harrower, McCorrison & Oches 2002). We conducted a

10 m-spaced transect walking survey within each unit, ensuring a complete sample of about 20% of the ground surface for the smallest artefacts and better visibility for more prominent remains such as structures, cairns, and water-management structures. About one half of our survey units were situated using targeted methods such

Land Class	Random	Targeted	Khuzmum	No. Sites	No. ha	Sites/ha
Wadi channel	16	11	10	130	46.6	2.8
Wadi silts	11	43	38	1207	78.5	15.4
Gravel terrace	7	4	5	95	10.0	9.5
Bedrock terrace	4	9	10	134	20.3	6.6
Bedrock slope	12	2	5	29	16.5	1.8
Scree slope	5	9	6	221	12.1	18.3
Plateau	16	18	10	564	64.5	8.7
<b>TOTALS</b>	<b>71</b>	<b>96</b>	<b>84</b>	<b>2380</b>	<b>--</b>	<b>--</b>

**FIGURE 3.** A summary table of Wādī Ṣanā survey units. Areas are given in hectares (ha). The term "site" has been used in this table to represent any locality in which a discrete human activity could be recognized.

	Density mean Khuzmum	Density mean Wadi Sana	Student's T	df	p value
All units, all remains	15.9 (n=84)	16.7 (n=83)	<b>.96</b>	165	.17
Random units, all remains	14.2 (n=16)	11.5 (n=32)	<b>.58</b>	67	.28
Targeted units, all remains	23.6 (n=68)	14.5 (n=31)	<b>.28</b>	98	.39
Wadi silts, all remains	18.1 (n=37)	30.8 (n=16)	<b>.35</b>	52	.36
Wadi silts, Burnt surfaces & water management structures	1.63 (n=37)	2.07 (n=16)	<b>.51</b>	52	.30

**FIGURE 4.** A student's t-test for selected means of "sites" recorded from survey units near "Khuzmum" compared to means from survey units in the rest of Wādī Ṣanā.

as visual indications of archaeological remains and selecting land-cover from geo-rectified satellite imagery. The other half were units within randomly selected 100 m-wide transects across the Wādī Ṣanā course. These transects were stratified by latitude so that the twelve transects completed in 2000 and 2004 assured sample coverage (249 ha, or 2.49 km<sup>2</sup>) of the entire Wādī Ṣanā course from Ghayl Bin Yumayn to Ṣanā vilage (Fig. 2).<sup>4</sup>

Throughout the Wādī Ṣanā we found archaeological remains like those at Khuzmum. Our survey categories include hearths, burnt surfaces, artefact clusters, cairns, structures, rock-shelters, trackways, water-management structures, and rock-art. Within these categories we coded and described a number of different types. For the initial statistics presented here, we used the basic categories without exploring the spatial distributions of different types within them.

The results from survey units in a random stratified sample of the Wādī Ṣanā can be compared to results from the targeted and randomly-selected survey units around ancient Khuzmum, giving a clear indication that

the Khuzmum archaeological record is not significantly different from the rest of the Wādī Ṣanā. In total, the RASA Project has surveyed 169 survey units, of which 167 provide the sample base for statistical study (Fig. 3). Archaeological density, expressed as a number of individual features and artefact clusters divided by the unit area in hectares, was calculated for each survey unit. The density mean for all units around Khuzmum (15.9, n=84) and the density mean for all units in the rest of Wādī Ṣanā (16.7, n=83) are remarkably close (Fig. 4). Results of a student's t-tests ( $t=0.96$ ,  $df=165$ ) do not suggest a significant difference between the means even at 90% confidence interval. The test for significance at 90% confidence interval is also not met if one compares only the means of randomly selected units (14.2, n=16 Khuzmum; 11.5, n=52 Wādī Ṣanā,  $t=0.58$ ,  $df=67$ ) or the means of targeted units (23.6, n=68 Khuzmum; 14.5, n=31 Wādī Ṣanā,  $t=0.28$ ,  $df=98$ ). A number of other sample batches were also tried, including considering density means of all archaeological remains from the wadi silts land-cover class, which alone preserves stratified remains dated to the Early

Holocene period (18.1, n=37 Khuzmum; 30.8, n=16 Wādī Ṣanā,  $t=0.35$ ,  $df=52$ ). Wādī Ṣanā contains a rich array of archaeological materials, including structures, burnt surfaces, and water-management structures. Our attention to the documentation and dating of these at Khuzmum led us to the subjective impression that they were especially concentrated there, but the survey results suggest otherwise. A t-test of the density means for burnt surfaces plus water-management structures in wādī silts at Khuzmum (1.63, n=37) and Wādī Ṣanā (2.07, n=16) did not indicate significant differences at the 90% confidence interval ( $t=0.51$ ,  $df=52$ ). As best we can determine, all of Wādī Ṣanā accumulated remains come from human activities in prehistory. The densities of remains suggest that people occupied the entire drainage, perhaps because their populations were rather dense.

### Discussion

There are some problematic aspects to this pooling of archaeological remains for quantitative testing. First and most importantly, we have very poor chronological control on archaeological remains. There are almost no

stratified prehistoric sequences to give a good understanding of cultural history for Ḥaḍramawt. In 1998 and 2000, the RASA Project began test excavations with the expectation that these would provide chronological control for our systematic surface collections (McCorriston *et al.* 2002). Thus, we cannot yet differentiate easily among artefact scatters of differing dates (or multiple dates, in the case of surface scatters). Furthermore, many types of surface remains simply cannot be dated: a stone ring or deflated hearth on bedrock is unlikely ever to offer dating clues. Second, this first quantification of survey results has lumped together many remains that were separately tabulated and perhaps have significantly different spatial patterning. For example, structures were considered together, but the "structure" category includes a variety of different types, some of which should probably be considered separately. The same is true of "water-management structures". Further analysis may yet show significant differences between Khuzmum and the rest of Wādī Ṣanā, but it is striking that a variety of sample batches and categories of archaeological remains considered in this paper revealed none in density of remains.

Therefore, either the RASA Project has failed to col-



FIGURE 5. An overview of the "Khuzmum" outcrop taken from the north-west.

lect data that reflect different densities or, we believe, Khuzmum is not a "site" of unusually dense archaeological remains. Because the RASA team spent a high proportion of its time at Khuzmum, we gained a better understanding of human activities, archaeological density, and preservation around the Khuzmum outcrop (McCorrison *et al.* 2002), which led us to think it special (Fig. 5). We now propose that we can tentatively extend this understanding to the rest of the Wādī Ṣanā, giving a regional overview of human activities in prehistory.

There are several significant implications from the Wādī Ṣanā data. Our various surveys found no highland agricultural settlements like the late Neolithic and Bronze Age settlements in highland northern Yemen (de Maigret 1990; Breton 2000; Ghaleb 1990: 131–148). In 1996, McCorrison and Bin ‘Aqil's preliminary survey located several such settlements to the south of Wādī Ṣanā. These apparently post-date the Middle Holocene aridification, and they depended on orographic rainfall and the numerous springs in the uplifted and faulted escarpment. In Wādī Ṣanā, people remained relatively mobile throughout the Holocene. They used rock-shelters and by about 6500 calendar years ago, they built structures of dressed limestone uprights that appear to be scattered houses and house compounds. These structures are in a relatively good preservation environment, deserve further investigation, and will be the focus of future fieldwork.

The foragers and herders who built stone structures used water sources not available since the Middle Holocene, namely, the marshy basins left by annual floodwaters that backed up Wādī Ṣanā, leaving also thick deposits of late Pleistocene and Early Holocene alluvial sediments. At Khuzmum, we investigated a 1–2 m-thick deposit of dark, organic sediments containing the shells of wetland invertebrates (gastropods, ostracods) built up in uneven hummocks, as if over the rootlets and banks of tussock grasses and reeds. These types of deposit extend over 10 km<sup>2</sup> north of Ghayl Bin Yumayn, where there were springs into historical times and even within living memory. In the Early Holocene, greater precipitation and flooding meant that episodic marshes would have extended throughout much of the Wādī Ṣanā. Marshes would have drawn large animals, including cattle, and would have permitted relatively dense human populations dependent on both animal and plant foods. In sum, the Wādī Ṣanā was, at least seasonally, an oasis throughout its length in the Early Holocene.

Several lines of evidence suggest relatively dense human populations in the Early Holocene. For one, there are widespread indications of human-set fires, not

only in the vicinity of Khuzmum (McCorrison *et al.* 2002: 74–75), but layered in other sediment beds throughout Wādī Ṣanā. How frequently they were set and at what time of year would largely determine both short-term and long-term impact on vegetation (e.g. Aschmann 1977; Naveh 1974; 1975; Le Houérou 1979; Lewis 1973; Pyne 1991). From their magnetic impact on underlying sediments, we know that the Early Holocene Wādī Ṣanā fires were extremely hot, suggesting they cleared relatively dense woody vegetation to open a landscape to opportunistic plants — such as annual grasses and forbs — bunchgrass sprouts, and primary growth. Such plants afford better browse and graze for wild and domestic animals and they are also higher in seed yield. Once humans had cleared dense vegetation, landscape management would entail periodic refiring, the magnetic and archaeological signatures of which are much more difficult to detect.

People also began to manage water flow around 5100 years ago with the construction of check dams in tributaries to the main course of Wādī Ṣanā (McCorrison *et al.* 2002; McCorrison & Oches 2001; Harrower, in preparation). Using irrigation techniques somewhat similar in scale to those of the Owens Valley Paiute (Steward 1930; 1933; Smith 2001: 31–33), Wādī Ṣanā's Early Holocene inhabitants may never have become fully dependent on agriculture. Instead, they may be better characterized as low-level food producers (Smith 2001). Importantly, Wādī Ṣanā's inhabitants appear to have developed irrigation techniques that made it possible for later peoples to farm. We suspect that irrigation, like burning, developed an Early Holocene landscape into which territorially-inscribed clans of foragers and herders found themselves increasingly constricted before the onset of Middle Holocene aridification.

While Keeley's cross-cultural comparisons do not include groups primarily practising pastoralism and do not specifically address the merits of small-seed plant exploitation, optimal foraging research on these topics also has important relevance for understanding ancient Arabia. Russell's estimates (1988: 101 figs 8–9, 103 figs 10–11) suggest that cattle pastoralism offers higher caloric return rates than ovicaprid husbandry, and estimates of return rates for small-seeded plants suggest comparatively modest returns (e.g. Simms 1987). While this optimal foraging approach begs more detailed consideration than is possible here, these measures may indeed help to explain why Wādī Ṣanā's inhabitants first adopted cattle and only later intensified exploitation of indigenous wild plants. In addition we know that some prehistoric Arabian groups — perhaps most — adopted domesticated animals and practised mobile pastoralism



in combination with hunting and fishing (Uerpmann H-P, Uerpmann M & Jasim 2000; Cleuziou & Tosi 1997: 127–128). Keeley's generalizations predict that the proportion of (hunted) animal foods in the diet will also decline given aridification (Keeley 1988: 292; 1992: 32; 1995: 249), but in the case of Arabia, some have argued persuasively that the adoption of domestic animals served as mobile desalinizers (Lancaster W & Lancaster F 1999a; 1999b: 112; Cleuziou & Tosi 1997: 126; cf. Close & Wendorf 1992: 68). Milk harvests may have required hunter-forager-pastoralists to maintain their mobility and access to wild game (populations that thinned and dispersed among more widely scattered water sources), but it must also be remembered that milk flows from herded animals in sharply seasonal coincidence with calving and spring/wet season growth. Thus during most of the year, herders would have been confined to permanent water sources or to tracts accessible between them. Ultimately the adoption of pastoralism may explain why many groups apparently did not adopt domesticated crops, but it does not explain the circumstances in which some did.

### Conclusions

What we have learned in Wādī Ṣanā informs us about foraging behaviour in the wider highland southern Jōl where foragers and herders constricted into territories had little access to aquatic resources or to the expansive interior grazing lands that lacked year-round water. Although we cannot exclude irrigation-based cultivation of domesticated crops in Wādī Ṣanā 5000 years ago, we consider it unlikely. We suggest that irrigation technologies first emerged in highland wadis such as Wādī Ṣanā, where irrigation enhanced animal browse and the seed-yield of perennial bunchgrasses naturally adapted to summer rainfall regimes. Moreover we believe that simple check-dam and hill-slope (*šrūj*) water diversion technologies such as we have identified in Wādī Ṣanā were probably an important technical and socio-organizational precursor to subsequent, much larger-scale irrigation schemes supporting Arabia's great civilizations. Middle Holocene aridification connected to the weakening of the south-west monsoon was devastating for the forager-herder economies of Wādī Ṣanā. Already packed into territories around the receding floodwaters

and periodically inundated portions of the silty wadi-bottom, emerging clans were stressed by the failure of floodwaters and adopted an array of responses. These included, (a) convergence on the remaining springs and basins and (b) the adoption of caprine pastoralism (and later camels), which afford a wider range than cattle.

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### Notes

- <sup>1</sup> All dates in this paper will be reported as calendar years ago to avoid the confusion of uncalibrated radiocarbon dates juxtaposed with dates BC.
- <sup>2</sup> By "landscape" we mean the physical manifestation of a historical dynamic between humans and their environment.
- <sup>3</sup> Keeley's cases were drawn principally but not exclusively from the Human Resource Area Files (HRAF). This paper is not intended as a critique of Keeley's work or methods; therefore no comment is offered on the data and its use in his original studies.
- <sup>4</sup> The total area surveyed includes several transects in the Ghayl Bin Yumayn basin, bringing the total to 248.5 ha as in Table 1.

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