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Climate forcing and shifts in water management on the Northwest Arabian Peninsula (mid-Holocene *Rasif* wetlands, Saudi Arabia)

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ABSTRACT

The mid-Holocene climate of Northwest Arabia is characterised by a significant increase in aridity which gave rise to changes in water management strategies including sophisticated techniques at later stages. The Rasif site, situated in Northwest Saudi Arabia, reveals a Late Neolithic society with multi-roomed domestic structures (**1st phase,** 6th millennium BCE, *before the current era*). At Rasif site the sediments of an endorheic basin (*qa*) show a minimum in salinity during this 1st phase. The **2nd phase** is characterised by a pastoral 'Chalcolithic' watering and 'Chalcolithic' burial location of the 5th millennium BCE with wells, complex trough systems, and initial, probably coexistent grave structures. During this 2nd phase the *qa* deposits show already a slight increase in salinity. We have evidence for a sub-surface water-rich sand layer within the *qa* that was exploited by shallow wells. During the subsequent **3rd phase** the number of pastoral 'Chalcolithic' D-shaped grave structures within the *qa* increased, probably co-existing with deepened wells and complex trough systems. At that time the *qa* is covered by an almost impermeable saline clay layer. The **4th phase** is characterised by a culturally yet to identify pastoral post-'Chalcolithic' watering location with single small troughs. The final **5th phase** represents a culturally unidentified pastoral post-'Chalcolithic' to sub-recent water harvesting location with complex dam systems, which were probably modified numerous times. The dam systems allowed to flooding the *qas* for several months, providing (sub-) surface water in the nowadays Northwest Arabian desert.

1. Introduction

Following an humid early Holocene climatic optimum (Engel et al., 2017), the relatively moist 6th–5th millennium BCE episodes of Arabia's mid-Holocene provided still extensive grazing land (Dinies et al., 2015, 2016) to hitherto unknown complex shepherd cultures, occupying many parts of the Arabian Peninsula (Gebel and Mahasneh, 2012, 2013, Gebel et al., 2016). These 'Chalcolithic to Early Bronze Age' cultures consisted of groups of mobile pastoralists who dug wells into wadi floors and near lake shores, collected runoff water in drainage systems, and fed their flocks at built watering places that were operated by wells and troughs (al-Ghazzi, 2004; Wellbrock et al., 2012; Gebel et al., 2016).

However, these predominantly mobile pastoralists remained aceramic and thus poor in their material inventory. Furthermore, they hardly left geoarchaeological archives in the today's deflated and arid desert landscape. Consequently, these cultures remained historically and archaeologically anonymous but most likely represent the origins of the Bedouin lifestyle that is the dominant cultural and economic tradition in the Arabian lands until today. Where local tabular bedrock sources allowed, their ritual and domestic architecture is executed by standing stones creating megalithic landscape sites (Gebel et al., 2016).

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Archaeological excavations in the greater Qulban Beni Murra region (Fig. 1) in Southeast Jordan (Gebel and Mahasneh, 2012, 2013) and at Rajajil (Fig. 1) in Northwest Saudi Arabia (Gebel et al., 2016) revealed that standing stone sites with certain grave types are characteristic for the hitherto unknown 5.0 to 4.0 ka BCE pastoral occupations of Arabia, which co-existed with sedentary Chalcolithic cultures in more water-rich regions of the *Fertile Crescent*. A radiocarbon date provided an age of 4459-4346 cal. BC (Gebel et al., 2016) for the pastoral 'Chalcolithic' well structure at Qulban Beni Murra. Two OSL ages (4800–4400 BCE and 5040–4500 BCE) confirmed the 5th millennium BCE age of the well (al Khasawneh et al., 2016). There is first evidence that standing stone sites were burial centres and locations of social identity and transaction in nowadays deserts, populated by mobile shepherds and characterised by watering places with wells and habitation structures. However, although standing stone cultures are widespread on the Arabian Peninsula (al-Ghazzi, 2004), the knowledge about their land use and water management strategies, ritual life and social interaction remains fragmentary so far. This is caused by several basic obstacles: hardly datable sedimentary archives are preserved so that a chronological framework does not exist so far, the sites' material culture is rather poor and insignificant, the horizontal stratigraphies of re-occupied sites are difficult to read, and many sites have been looted throughout all the periods including recent times.

In this study we focus on Rasif site (Fig. 1, Northwest Arabian Peninsula, Saudi Arabia) that might become a key site for the 5th millennium BCE pastoral well cultures besides Rajajil and Qulban Beni Murra. All three sites are linked by the Wadi Sirhan drainage system and certainly were part of the complex pastoral networks in Arabia's 5th millennium BCE. In terms of geographical extension, variability of physiographic conditions, tasks and achievements of their long-distance exchange systems, etc., Arabia's crossroads followed historically different principles and dimensions than the confined Chalcolithic/Early Bronze Age regional centres of the *Fertile Crescent* or the Nile Valley.

1.1. Aims

Our study concentrates on the reconstruction of the Late Neolithic to Early Bronze Age palaeohydrological and archaeohydrological history of the Rasif site in Northwest Saudi Arabia. The study focuses on the unknown 5th to 4th millennium BCE mobile shepherd societies and shifts in their water management strategies. We distinguish between palaeohydrological and archaeohydrological approaches and arguments: palaeohydrology focuses on the supra-regional Holocene hydro-climatic history and its local hydrological impact while archaeohydrological research cares about water management techniques and strategies in the past.

With the focus on episodically flooded endorheic basins (local name: *qas*) and corresponding catchments at karstic Rasif site we aim to link archaeological (Gebel et al., 2016) and archaeohydrological survey data of burial fields, habitation and water management sites with geoarchaeological sounding data and palaeohydrological proxies. We aim to reconstruct changing water management strategies within the palaeohydrological transition from a mid-Holocene steppe landscape towards a late Holocene desert. Evidences of climate forcing and environmental changes will be detected by the interpretation of multi-proxy findings from *qa* deposits.

2. Geographical setting

Rasif (UTM 37N E633484 N3352570, 689.22 m above sea level [a.s.l.]) is located in the north-western part of the Arabian Peninsula at the edge of the greater Al Jouf oasis region (Fig. 1). The area is part of a nowadays arid environment which exhibits annual evaporation rates of more than 1.700 mm per year (Trabucco and Zomer, 2009) and mean annual precipitation are in a range of 80–90 mm per year (Hijmans et al., 2005; Almazroui et al., 2012). As a consequence, natural vegetation is sparse and concentrated on the sandy *wadi* fills and depressions. For the study area annual recharges rates of 3 mm per year are assumed for the phreatic *Saq* aquifer (BRGM, 2008: 93).

Extensive investigation and modelling of the *Saq* aquifer and adjacent aquifers suggested a water head to be at approx. 670–680 m a.s.l. within the Jauf formation (BRGM, 2008), i.e. only 10–20 m below Rasif area's surface (Fig. 1, Table 1). It is one particular unit of this formation, the Devonian Qasr limestone member (Wallace et al., 1997), which is supposed to be an aquifer of

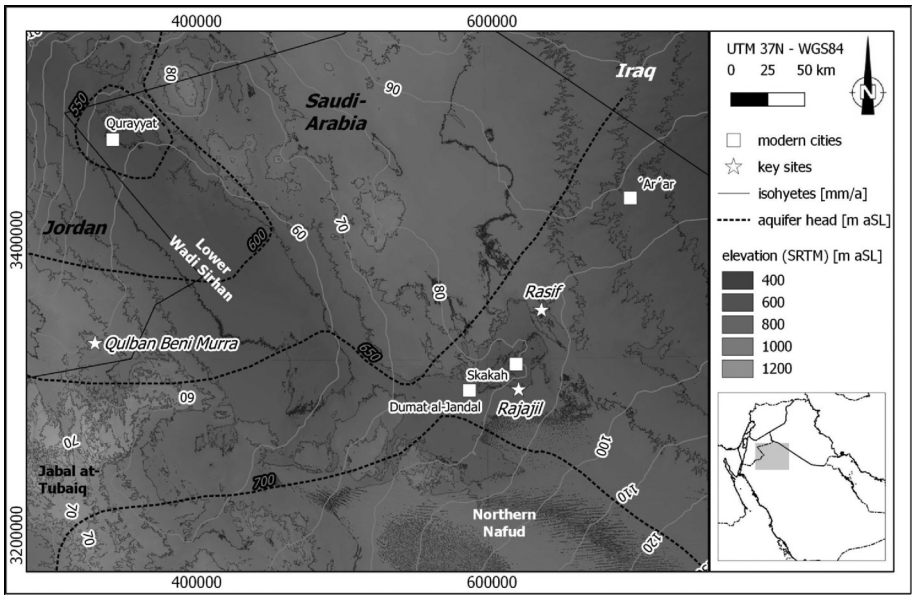

Fig. 1. North-western Arabia: Location of Chalcolithic key standing stone sites with present-day isohyets in south-eastern Jordan and north-western Saudi Arabia (aquifer head: BRGM, 2008; isohyetes: Hijmans et al., 2005; elevation data: SRTM3).

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