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Research paper

# Optically stimulated luminescence dating of hearths from the Fazzan Basin, Libya: A tool for determining the timing and pattern of Holocene occupation of the Sahara

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ABSTRACT

Circular concentrations of burned stone fragments are widespread in the Sahara, and are generally interpreted as ancient hearths. These hearths provide a rich resource for reconstructing the pattern and timing of Holocene human occupation of North African drylands. However, this resource has not been fully exploited since only 5% of hearths contain dateable carbon, and collection of this carbon frequently results in the destruction of the hearth. Previous research indicates that anthropogenic firing empties the optically stimulated luminescence (OSL) source traps of quartz grains within hearth rocks. Consequently, the quartz OSL signal should provide a means for determining the time elapsed since last firing of Saharan hearths. To test the applicability of this approach to Saharan hearths, samples were collected from a site in the Fazzan Basin, and analysed using single-grain OSL. Equivalent dose–depth profiles through hearth rocks demonstrate that they are sufficiently opaque to preserve a record of ancient firing. Comparison with unfired parent material indicates that anthropogenic firing of hearth rocks was sufficient to empty the OSL source traps. The OSL ages for hearth rocks are internally consistent and suggest use around 8 ka. Our study demonstrates that OSL dating is a viable tool for determining the timing and pattern of Holocene occupation of the Sahara.

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## 1. Introduction

The abundant surface deposits of archaeological material found in the Sahara provide evidence for ancient human occupation over a variety of timescales (e.g. Mattingley et al., 2007). In the present day, this archaeological material is particularly conspicuous due to the near complete absence of vegetation, coupled with widespread deflation of sediment following mid-Holocene desiccation. Consequently, the surface archaeological record in the Sahara potentially represents an important resource for studying the timing and pattern of ancient human occupation of North Africa. However, the full potential of this resource is yet to be realised due to uncertainties regarding the taphonomy of surface deposits and the paucity of material suitable for radiometric dating.

Circular concentrations of apparently burnt rocks are found throughout the Sahara, and have been widely interpreted as hearths used by Neolithic cattle herders (e.g. Gabriel, 1987, 2002). Their distribution is inhomogeneous, with large clusters being found in shallow depressions and at the foot of escarpments. Similarly, hearths are usually found on fine grained alluvium rather than on the extensive rocky plains, leading Gabriel (1987) to postulate a connection with areas conducive to grass growth in more humid periods. The distribution of hearths does not appear to be dictated by wadis or obvious transport routes. Gabriel (1987) suggests that the hearths were produced by nomadic cattle herders since: (1) There is no apparent association between hearths and durable settlements; (2) The wide geographical distribution of hearths is suggestive of a population which is able to subsist from locally available resources, rather than one transiting between habitable areas; (3) While some hearth sites also contain occasional pottery and grinding stones, relatively few artefacts are found in the vicinity of hearths, suggesting brief periods of use; (4) Grooved rocks, interpreted as hobbling stones by Pachur (1982) are often found in association with hearths and (5) Radiocarbon ages from ash associated with hearths are similar to those for large-scale animal husbandry in North Africa.

A detailed investigation of the distribution and age of Saharan hearths could be of considerable interest since it would allow

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exploration of questions concerning the spatial and temporal patterns of Holocene occupation of North Africa, for example: (1) At what rate did nomadic pastoralism disperse across North Africa?; (2) How did ancient populations respond to climatic perturbations during the early Holocene? and (3) What is the pattern of human occupation of ecological niches in response to mid-Holocene desiccation? Questions 2 and 3 have recently been answered for Egypt and Northern Sudan by Kuper and Kröpelin (2006). They synthesised the radiocarbon data from 150 archaeological excavations to produce a model for the occupation and subsequent abandonment of the eastern Sahara in response to Holocene climatic change. However, Egypt has been far more intensively explored and excavated than any other North African country. Consequently, it is likely to be some time before sufficient excavations have been conducted to allow their approach to be applied elsewhere in the Sahara. Nonetheless, the growing realisation that populations did not respond to Holocene climatic changes in a uniform manner (e.g. Kuper and Kröpelin, 2006; Cremaschi and Zerboni, 2009) highlights the need for detailed chronologies for human occupation of central and western Sahara. Dating of Saharan hearths may expedite the production of these chronologies, since hearth fields are prominent landscape features and do not require time-consuming excavation. However, the potential for radiocarbon dating to provide a sufficiently detailed dataset is limited, since fewer than 5% of Saharan hearths contain sufficient charcoal for dating (Gabriel, 1987), and retrieval of this charcoal often results in the complete destruction of the hearth. In addition, charcoal preservation in hearths may be age dependent, thereby biasing radiocarbon based chronologies (Holdaway et al., 2008). Conversely, luminescence dating is potentially applicable to all Saharan hearths and only requires the destruction of a small number of hearth stones (Rhodes et al., 2009).

## 2. Optically stimulated luminescence dating of hearths

Optically stimulated luminescence dating (OSL) is a numerical dating technique which is conventionally used to determine the time elapsed since a sediment was last exposed to sunlight. However, the OSL source traps may also be emptied by heating, a property exploited by a number of recent studies aiming to date fired archaeological materials such as brick, pottery and hearths (e.g. Bailiff, 2007; Thomas et al., 2008; Rhodes et al., 2009, 2010). Gose (2000) used palaeomagnetic measurements to demonstrate that rocks at the centre of an ancient hearth attained maximum temperatures above 500 °C, while Backhouse and Johnson (2007) demonstrated that the core of rocks (10–15 cm diameter) in experimental hearths reached temperatures above 350 °C for 30–45 min. Since the lifetime of electrons in the OSL source traps at 350 °C is <1 s (Spooner and Questiaux, 2000), it is reasonable to assume that the OSL source traps are completely emptied by firing in antiquity. Consequently, OSL dating of hearths is potentially a powerful tool for investigating patterns of ancient landscape usage. At present, the Western New South Wales Archaeology Program (WNSWAP) is the only study to have applied this approach systematically. Initial work used OSL dating of sediments to provide a chronology for the creation of the "archaeological surfaces" upon which radiocarbon dated hearths had been constructed (Fanning et al., 2007, 2008; Holdaway et al., 2008). Subsequently, Rhodes et al. (2009, 2010) developed a rapid procedure for dating hearth stones using single-aliquot OSL methods. Of the 53 samples analysed by Rhodes et al. (2009), 60% yielded indistinguishable OSL and radiocarbon ages. However, where the two techniques yielded different ages, both OSL age underestimates and overestimates are present. Rhodes et al. (2009) proposed that age underestimates may be explained by daylight bleaching of grains within translucent lithologies, while age overestimates could be due to incomplete emptying of the OSL source traps during hearth firing. Since either mechanism would preclude the production of an OSL based chronology for Saharan hearths, we investigate both light penetration and the emptying of OSL source traps during firing, prior to calculating ages for a suite of hearths from the Fazzan Basin, Libya.

## 3. Site setting and context

The Fazzan Region is a large closed basin located in south-western Libya (Fig. 1). It was created by thermal uplift of the Al Haruj al Aswad from the Late Miocene onwards, which progressively diverted and finally blocked fluvial connections to the Mediterranean Sea, resulting in the creation of a large (~350,000 km$^2$) internally drained basin (Drake et al., 2008). During humid periods, this basin supported lakes as large as 135,000 km$^2$, which resulted in the widespread deposition of the Al Mahruqah formation, comprising lacustrine limestones/carbonate cemented sandstones intercalated with sands (Thiedig et al., 2000). The Al Wafa site (28°00′58.4″N, 10°47′52.3″E) is located in the north-western Fazzan and lies immediately north of the Awbari Sand Sea (Site NUS 1.8 of Mattingley et al., 2007). It consists of a gently sloping south-eastward draining basin perched ~10 m above the surrounding plain. The present day land surface is defined by resistant strata within the Al Mahruqah formation. Precipitation in the Fazzan region is presently less than 20 mm per year, resulting in a landscape devoid of vegetation. Al Wafa is characterised by shallow, ephemeral drainage channels cut into an extensively deflated surface consisting of unconsolidated sand protected by gravel-pebble sized carbonate clasts. As such, the land surface at Al Wafa is typical of much of the Fazzan Basin.

Despite the present-day hyper-arid climate, multiple phases of humidity are recorded in the Quaternary sediments of the Fazzan (Petit-Maire et al., 1980; Thiedig et al., 2000; Brooks et al., 2003; Drake et al., 2008), most recently during the early-mid Holocene (Armitage et al., 2007; Drake et al., 2011). Prehistoric human/hominin occupation of the Fazzan is attested to by the widespread occurrence of artefacts from the Acheulean through to the Neolithic. Al Wafa itself is archaeologically extremely rich, with Acheulean, Middle Stone Age, possibly Late Stone Age, Epi-palaeolithic and Neolithic artefacts present (Mattingley et al., 2007;

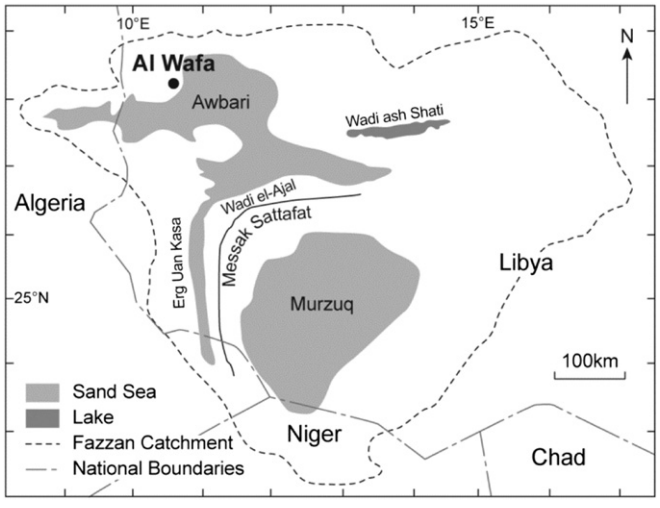


**Fig. 1.** Map of the Fazzan basin catchment, showing the location of the Al Wafa hearth field. The Wadi ash Shati lake existed ~110-100 ka (Armitage et al., 2007).

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