Quaternary Geochronology 30 (2015) 90–99

Contents lists available at ScienceDirect

Quaternary Geochronology

journal homepage: www.elsevier.com/locate/quageo

Research paper

Age of a prehistoric "Rodedian" cult site constrained by sediment and rock surface luminescence dating techniques

R. Sohbati [a, b, *], A.S. Murray [a], N. Porat [c], M. Jain [b], U. Avner [d]

[a] Nordic Laboratory for Luminescence Dating, Department of Geoscience, Aarhus University, DTU Risø Campus, Roskilde 4000, Denmark
[b] Center for Nuclear Technologies, Technical University of Denmark, DTU Risø Campus, Roskilde 4000, Denmark
[c] Geological Survey of Israel, 30 Malkhe Israel Street, Jerusalem 95501, Israel
[d] Dead Sea-Arava Science Center, Patio 655, Eilat 88133, Israel

ARTICLE INFO

Article history:
Received 25 June 2015
Received in revised form
25 August 2015
Accepted 3 September 2015
Available online 8 September 2015

Keywords:
Quartz
Feldspar
OSL
IRSL
Rock surface dating
Luminescence-depth profile
Light attenuation

ABSTRACT

The construction age of a pavement in a "Rodedian" prehistoric cult site in Negev desert, Israel, is established by determining the burial age of (i) a cobble used in the pavement, and (ii) the underlying sediment. The quartz OSL age and the K-feldspar corrected IR_{50} age from the sediment and the corrected IR_{50} and $pIRIR_{225}$ ages from the cobble surface are all consistent, and give an average age of 4.22 ± 0.06 ka. Although the very similar ages indicate the reliability of the methods, these ages are ~3–4 ka younger than that expected for the Rodedian sites. The IR_{50} and $pIRIR_{225}$ luminescence-depth profiles from the cobble indicate multiple exposure and burial events in the depositional history. The apparently young ages may thus represent a later intervention in the site during the late 3rd millennium B.C. More sites need to be dated by the use of both rocks and sediments to confirm this suggestion. Important information on the bleaching history of the rock surfaces directly obtained from these luminescence-depth profiles is not available in the underlying unconsolidated sediments. This is a significant advantage of rock surface dating over more conventional sediment dating.

1. Introduction

The settlement history of the Negev desert, Israel, has been traditionally described as a series of short periods of settlement interrupted by longer gaps and archaeological sites were generally interpreted as temporary, seasonal and short-lived. However, with the advance of studies in the Negev, the settlement scenario is changing and gaps are shrinking (Avner, 2006). Of the Early Neolithic period (i.e. Pre-Pottery Neolithic periods B or PPNB, 8000–6400 BC) only about 30 habitation sites are currently known in the entire Negev (Barzilai and Goring-Morris, 2013) while almost no habitations are known from the Late Neolithic (LN, 6400–4600 BC). Nevertheless, during the last decade, 358 Neolithic cult sites have been identified in the mountains of southern Negev, presently dated to the 7th and 6th millennia BC (Avner et al., 2014). These sites drastically change our view of human presence in the desert during the Early and Late Neolithic, as well as our understanding of their spiritual culture (Avner et al., 2014). The sites are named here "Rodedian" following the name of Naḥal (Wadi) Roded in the Eilat Mountains (~5 km NW of the Gulf of Aqaba), where the highest density of cult sites was found, up to 42 sites on an area of 0.8 km^2 (Fig. 1).

Establishing an absolute chronology for these sites has usually relied on the ^{14}C dating of associated organic remains; such material is not always available, and when it is, the association cannot always be assumed to be secure. Optically stimulated luminescence dating of rock surfaces has attracted significant interest in the last few years (Vafiadou et al., 2007; Sohbati et al., 2011; Simms et al., 2011; Liritzis et al., 2013; Sohbati, 2015). The great advantage of this technique over the more conventional luminescence dating of buried sediments is that rock surfaces usually record their depositional history. Habermann et al. (2000), Polikreti et al. (2002), Liritzis et al. (2010) and Sohbati et al. (2011, 2012a) have all measured luminescence signal with depth into rock surfaces that were exposed to light immediately before measurement. However, by measuring such luminescence profiles into a buried rock surface, one can determine the degree to which the surface had been bleached prior to burial (Sohbati et al., 2012a,b; Chapot et al., 2012, Pederson et al., 2014) and even estimate, by using an appropriate calibration, how long the surface had been exposed before burial

* Corresponding author. Nordic Laboratory for Luminescence Dating, Department of Geoscience, Aarhus University, DTU Risø Campus, Roskilde 4000, Denmark.
E-mail address: resih@dtu.dk (R. Sohbati).

http://dx.doi.org/10.1016/j.quageo.2015.09.002
1871-1014/

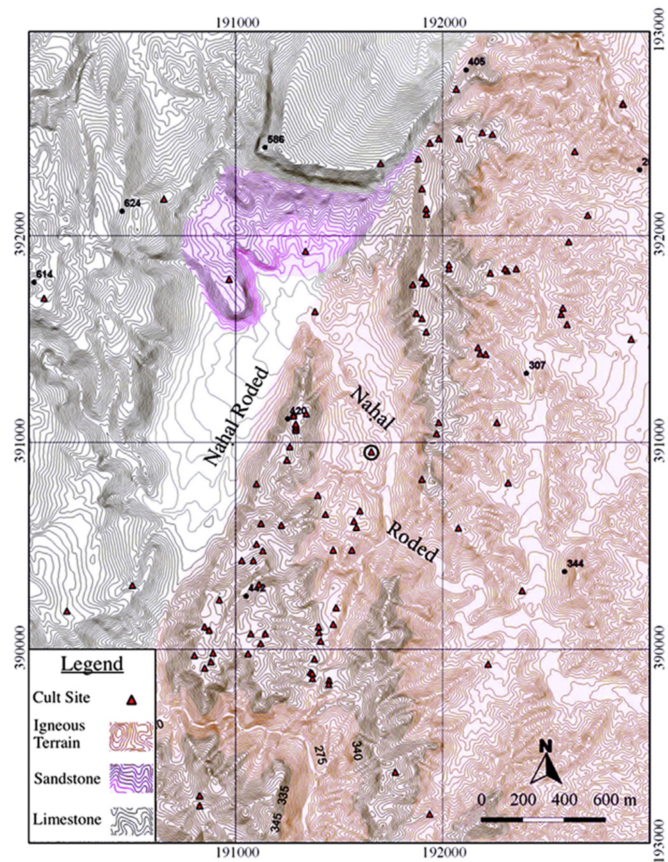

Fig. 1. Location of the cult sites distributed around Naḥal Roded in the Eilat Mountains, Israel.

(Sohbati et al., 2012a; Freiesleben et al., 2015).

In this study we report the dating of a cult site at Naḥal Roded, using optically stimulated luminescence (OSL) of quartz, and infrared stimulated luminescence (IRSL) of potassium-rich feldspar fractions from the dust accumulated in the sediment trapped underneath a stone pavement. We support the chronology of the sediment sample by IRSL dating of whole-rock slices from the buried surface of the rock.

2. The site and sampling

The site is located on a low Precambrian igneous ridge, formed by a quartz-porphyry dike. It contains several stone features, including a pavement, on which an anthropomorphic limestone image was found lying horizontally (Fig. 2). Flint flakes collected at the site suggest Late Neolithic date (i.e. 6th millennium BC). A small paving cobble (15 × 10 × 8 cm^3) and the dust accumulated underneath were collected under cover and placed in opaque plastic bags to prevent sample exposure to light. The light-protected sediment sample was accompanied by ~150 g of corresponding material for water content and dose rate measurements. The sediment sample is mixed with granite gruss; it is thus presumed that larger grain sizes are the product of local weathering and so not suitable for OSL dating, because of the expected low sensitivity and poor bleaching conditions.

3. Sample preparation and measurement facilities

The sediment sample was wet sieved into the size fraction

Fig. 2. A view of the cobble pavement. The white arrow shows the collected sample.

63–90 μm; this fraction is probably dominated by aeolian material, and presumed most likely to have been sufficiently bleached before deposition. The grains were treated with 10% HCl to remove carbonates and 10% H_2O_2 to dissolve any reactive organic material. They were then etched with 10% HF for 40 min to remove the alpha irradiated surface layer and weathering products and coatings, followed by 10% HCl for 20 min to remove any fluoride which may have precipitated. The K-rich feldspar fraction was then separated by floating in heavy liquid (ρ = 2.58 g cm^{-3}). Quartz grains (ρ > 2.58 g cm^{-3}) were further cleaned and etched using 40% HF for 1 h, followed by 10% HCl for 40 min. The resulting fractions were sieved again (dry) into the grain size range mentioned above. From the cobble sample, cores of ~10 mm diameter and various lengths (>20 mm) were drilled using a water-cooled diamond-tipped core drill. These cores were then cut into slices of ~1.5 mm thick by a water-cooled low-speed wafering saw equipped with a 0.3 mm thick diamond blade. The surface slices (<1.5 mm depth) were treated in a similar way to the K-rich feldspar grains (using 10% HF for 40 min and 10% HCl for 20 min) to ensure the removal of any surface weathering products. No acid treatment was done on inner slices.

All luminescence measurements were carried out using Risø OSL/TL reader (Model TL-DA 15). The blue (470 nm, 80 mW.cm^{-2}) stimulated signal from quartz grains was detected through a Hoya U-340 glass filter and the infrared (875 nm, 135 mW.cm^{-2}) stimulated signal from K-rich feldspar grains and intact cobble slices was measured through a Schott BG39/Corning 7-59 filter combination (2 and 4 mm, respectively). Beta irradiations used a $^{90}Sr/^{90}Y$ source mounted on the reader and calibrated for both disks and cups using 180–250 mm calibration quartz grains (Bøtter-Jensen et al., 2010; Hansen et al., 2015). To calibrate the source for rock slices, six slices cut from a quartzite cobble were sensitized and stabilized using successive cycles of dosing (~50 Gy) and heating (up to 450 °C). They were then given an accurately known dose of 4.81 Gy using a ^{137}Cs gamma source in a scatter free geometry and measured using a single-aliquot regenerative (SAR) protocol (Murray and Wintle, 2000). Slices were directly placed on the disk positions in the carousel, whereas quartz grains were mounted as large (8 mm) and K-rich feldspar grains as small (2 mm) aliquots in a monolayer using silicone oil on stainless steel disks (quartz) and cups (feldspar). The heating rate was 5 °C.s^{-1} throughout. All thermal treatments