[Supplementary Material]

Neolithic pastoralism in marginal environments during the Holocene Humid Period, northern Saudi Arabia

Eleanor M.L. Scerri[1,2,*], Maria Guagnin[2,3], Huw S. Groucutt[1,2], Simon J. Armitage[4,5], Luke E. Parker[4], Nick Drake[6], Julien Louys[7], Paul S. Breeze[6], Muhammad Zahir[8], Abdullah Alsharekh[9] & Michael D. Petraglia[2]

[1] *School of Archaeology, 36 Beaumont Street, University of Oxford, Oxford OX1 2PG, UK*
[2] *Department of Archaeology, Max Planck Institute for the Science of Human History, Kahlaische Strasse 10, D-07745 Jena, Germany*
[3] *Freie Universität Berlin, TOPOI Excellence Cluster, Hittorfstraße 18, 14195 Berlin, Germany*
[4] *Centre for Quaternary Research, Department of Geography, Royal Holloway, University of London, Egham, Surrey TW20 0EX, UK*
[5] *SFF Centre for Early Sapiens Behaviour (SapienCE), University of Bergen, P.O. Box 7805, Bergen 5020, Norway*
[6] *Department of Geography, King's College London, The Strand, London WC2R 2LS, UK*
[7] *Australian Research Centre for Human Evolution, Environmental Futures Research Institute, Griffith University, 170 Kessels Road, Nathan, Brisbane, Qld 4111, Australia*
[8] *Department of Archaeology, Hazara University, Mansehra 21300, Pakistan*
[9] *Department of Archaeology, King Saud University, Riyadh, Saudi Arabia.*
[*] *Author for correspondence (Email: eleanor.scerri@rlaha.ox.ac.uk)*

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A. OSL dating methodology

The light exposed external surfaces of hearth ferricrete stones were removed using a chisel. A small portion of the remaining light-shielded material was homogenised using a Retsch Mixer Mill MM400. Fine grained (4-11µm) quartz extracted from the resulting powder via Stokes settling, a one week H2SiF6 etch followed by a 10M HCl rinse, and a second cycle of Stokes settling. Four of the seven samples analysed yielded sufficient quartz for dating.

Equivalent doses were measured using the single-aliquot regenerative dose method (Murray and Wintle 2000). Measurements were performed on a Risø TL/OSL-DA-20 automated dating system. Optical stimulation (60s at 125°C) was via blue light emitting diodes

(470±30nm, ~85mW) and the signal was measured using an Electron Tubes Ltd 9235QB photomultiplier shielded with 7.5mm of Hoya U-340 filter. Irradiation was carried out using a 40 mCi 90Sr/90Y beta source calibrated relative to the National Physical Laboratory, Teddington 60Co source (Armitage and Bailey 2005), yielding a dose rate of ~ 0.1Gy/s to 4–11µm quartz deposited on an aluminium disc. Dose recovery experiments (Roberts et al. 1999) performed on two samples, and yielded dose recovery ratios (recovered dose/known dose) consistent with unity when using PH1 (the preheat prior to measurement of the natural/regenerated dose OSL) temperatures ranging from 200–260°C, held for 10s, and a PH2 (the preheat prior to measurement of the test dose OSL) temperature of 160°C, held for 5s. A PH1 temperature of 240°C was adopted for equivalent dose measurements. Aliquots which yielded recycling ratios (Murray and Wintle, 2000) or OSL IR-depletion ratios (Duller 2003) differing from unity by more than two standard errors, or where recuperation is high (i.e. Lx/Tx for the 0 Gy regeneration point is greater than 5% of Ln/Tn) were rejected. Curve fitting and equivalent dose determination were performed using version 4.31.9 of the Luminescence Analyst software (Duller 2007). The Central Age Model (Roberts et al. 1999) was used to calculate the sample equivalent dose.

Environmental dose rates were calculated using the method of Armitage and King (2013). Alpha and beta dose rates were Daybreak Model 583 intelligent alpha counters and a Risø GM-25-5A beta counter respectively. Sediment gamma dose rates were measured using an EG&G Ortec digiDART-LF field gamma spectrometer with a 2” NaI crystal, and dose rates were calculated using the threshold method (Mercier & Falguères 2007). After removal of the sample rock, the gamma spectrometer crystal was placed as close as practicable to the sample’s original location, providing an estimate of the present-day gamma dose rate. The hearth rock gamma dose rate was calculated by multiplying the beta dose rate by 0.4959±0.0013 (Ankjaergaard & Murray 2007). The contribution of rock and sediment to the gamma dose rate experienced by the sample was calculated following Aitken (1985, his Appendix H) and Armitage and King (2013). Cosmic dose rates were calculated using the site location and mean depth of grains within a hearth rock of density 2.55g/cm3 (Prescott & Hutton 1994). The cosmic dose rate prior to deflation at 5ka (i.e. the end of the Holocene humid phase [e.g. Preston & Parker 2013]) was calculated assuming burial to 10cm depth in sediment of density 1.85g/cm3. Calculated ages change by <2% when varying burial depth from 0–50cm and varying the date of deflation between 3 and 7ka. Dose rates were corrected for water content (Aitken 1985) using values of 5±2% and 1±0.5% for sediment and rock respectively, following the calculations of Armitage and King (2013, their Supplementary

Material Section D).

B. Radiocarbon dating

Charcoal samples from Hearth 101 were extracted and sent to the Waikato Radiocarbon Dating Laboratory. Carbon-13 stable isotope values (δ13C) were measured on prepared graphite using an AMS spectrometer. The radiocarbon date has therefore been corrected for isotopic fractionation. Results of these dates are shown in Table 2 and Figure S4. Bone fragments recovered eroding from the surface near Hearth 101 were collected and submitted for dating at the Australian National University (lab code S-ANU-), with dates generated using an ultrafiltration protocol as described in Wood et al. (2014) and Fallon et al. (2010). Radiocarbon ages are presented in Table B1, and were calibrated using OxCal 4.3 (Bronk Ramsey (2009) and the IntCal13 calibration curve (Reimer et al. 2013).

<FIGURE S4, 13.5cm colour>

Table S1. Uncalibrated radiocarbon ages for Alshabah samples.

Context	Material	Lab code	Uncalibrated age (ka)	Calibrated age (ka cal BP)
Hearth 101	Charcoal	WK44320	6325±21	7.24±0.07
Surface	Uncalcined bone	S-ANU52619	5.356±0.027	6.14±0.13
Surface	Uncalcined bone	S-ANU52619	5.451±0.027	6.25±0.05

References

AITKEN, M.J. 1985. *Thermoluminescence dating*. London: Academic.

ARMITAGE, S.J. & R.M. BAILEY. 2005. The measured dependence of laboratory beta dose rates on sample grain size. *Radiation Measurements* 39: 123–27. https://doi.org/10.1016/j.radmeas.2004.06.008

ARMITAGE, S.J. & G.E. KING. 2013. 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. *Quaternary Geochronology* 15: 88–97. https://doi.org/10.1016/j.quageo.2012.10.002

ANKJAERGAARD, C. & A.S. MURRAY. 2007. Total beta and gamma dose rates in trapped charge dating based on beta counting. *Radiation Measurements* 42: 352–59. https://doi.org/10.1016/j.radmeas.2006.12.007
BRONK RAMSEY, C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51: 337–60. https://doi.org/10.1017/S0033822200033865
DULLER, G.A.T. 2003. Distinguishing quartz and feldspar in single grain luminescence measurements. *Radiation Measurements* 37: 161–65. https://doi.org/10.1016/S1350-4487(02)00170-1
– 2007. Assessing the error on equivalent dose estimates derived from single aliquot regenerative dose measurements. *Ancient TL* 25: 15–24.
FALLON, S.J., L.K. FIFIELD & J.M. CHAPPELL. 2010. The next chapter in radiocarbon dating at the Australian National University: status report on the single stage AMS. *Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms* 268: 898–901. https://doi.org/10.1016/j.nimb.2009.10.059
MERCIER, N. & C. FALGUÈRES. 2007. Field gamma dose-rate measurement with a NaI(Tl) detector: re-evaluation of the 'threshold' technique. *Ancient TL* 25: 1–4.
MURRAY, A.S. & J.M. OLLEY. 2002. Precision and accuracy in the optically stimulated luminescence dating of sedimentary quartz: a status review. *Geochronometria* 21: 1–16.
MURRAY, A.S. & A.G. WINTLE. 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements* 32: 57–73. https://doi.org/10.1016/S1350-4487(99)00253-X
PRESCOTT, J.R. & J.T. HUTTON. 1994. Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long-term time variations. *Radiation Measurements* 23: 497–500. https://doi.org/10.1016/1350-4487(94)90086-8
PRESTON, G.W. & A.G. PARKER. 2013. Understanding the evolution of the Holocene Pluvial Phase and its impact on Neolithic populations in South-east Arabia. *Arabian Archaeology and Epigraphy* 24: 87–94. https://doi.org/10.1111/aae.12006
REIMER, P.J., E. BARD, A. BAYLISS, J.W. BECK, P.G. BLACKWELL, C. BRONK RAMSEY, P.M. GROOTES, T.P. GUILDERSON, H. HAFLIDASON, I. HAJDAS, C. HATT, T.J. HEATON, D.L. HOFFMANN, A.G. HOGG, K.A. HUGHEN, K.F. KAISER, B. KROMER, S.W. MANNING, M. NIU, R.W. REIMER, D.A. RICHARDS, E.M. SCOTT, J.R. SOUTHON, R.A. STAFF, C.S.M. TURNEY & J. VAN DER PLICHT. 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0-50,000 years cal BP. Radiocarbon 55: 1869–87. https://doi.org/10.2458/azu_js_rc.55.16947
ROBERTS, R.G., R.F. GALBRAITH, J.M. OLLEY, H. YOSHIDA & G.M. LASLETT. 1999. Optical

dating of single and multiple grains of quartz from Jinmium rock shelter, northern Australia: part II, results and implications. *Archaeometry* 41: 365–95. https://doi.org/10.1111/j.1475-4754.1999.tb00988.x

STUIVER, M. & H.A. POLACH. 1977. Discussion reporting of 14C Data. *Radiocarbon* 19: 355–63.

WOOD, R.E., A. ARRIZABALAGA, M. CAMPS, S. FALLON, M.-J. IRIARTE-CHIAPUSSO, R. JONES, J. MAROTO, M. DE LA RASILLA, D. SANTAMARÍA, J. SOLER, N. SOLER, A. VILLALUENGA & T.F.G. HIGHAM. 2014. The chronology of the earliest Upper Palaeolithic in northern Iberia: new insights from L'Arbreda, Labeko Koba and La Viña. *Journal of Human Evolution* 69: 91–109. https://doi.org/10.1016/j.jhevol.2013.12.017

Figure captions

Figure S1. Grindstone axe fragment (length 140mm, width 20mm).

Figure S2. Tabular scraper fragment (length 70mm, width 7mm).

Figure S3. Fluted object (length 52mm, width 9mm).

Figure S4. AMS dating results for the charcoal sample from hearth 101. Explanation of the calibrated OxCal plots can be found at the Oxford Radiocarbon Accelerator Unit's calibration web pages (http://c14.arch.ox.ac.uk/embed.php?File=explanation.php). Result is conventional age or percent modern carbon (pMC) following Stuiver and Polach (1977). This is based on the Libby half-life of 5568yr with correction for isotopic fractionation applied. Quoted errors are 1 standard deviation due to counting statistics multiplied by an experimentally determined laboratory error multiplier. The isotopic fractionation, δ13C, is expressed as ‰ wrt PDB and is measured on sample CO2. F 14 C% is also known as pMC.