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Research paper

Luminescence dating and associated analyses in transition landscapes of the Alto Ribatejo, central Portugal

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A B S T R A C T

Artefacts and regolith (soils, sediments, colluvia, *etc.*) from passage tombs, pit fills, stone scatter and clay structures, related to the transition to agro-pastoralism in the Alto Ribatejo, were analysed by optically stimulated luminescence, neutron activation analysis, field and high-resolution gamma spectrometry, and X-ray diffraction. Indications of anthropogenic, autogenic, and allogenic site formation and diagenetic processes, including radionuclide exchange, were applied to interpret 28 date estimates from the 9th to 1st millennia BC. Results from regolith samples relate to different phases of landscape activation and stability from the late 6th millennium BC to the Roman conquest. However, simple archaeological questions were best answered using heated materials, where present. Different chronological phases were often represented by different sample types in sites with multi-phase stratigraphies, indicating the importance of parallel analyses. Results from a fire pit coincide with the first indications of clearance in the regional pollen record (late 9th millennium BC): these features appear promising to map early Holocene human presence in the Alto Ribatejo landscape.

1. Introduction

The performance and interpretation of thermally or optically stimulated luminescence (TSL, OSL) dating analyses are interdependent with the archaeological, geochemical, mineralogical, geomorphological, and hydrological context of the samples being analysed (Aitken, 1985). In the dating of re-deposited mineral grains by OSL, the event of interest is their last exposure to light during transport. Chrono-stratigraphic points of view provided by the luminescence dating of heated artefacts include the direct dating of structures or typologies (e.g. Whittle and Arnaud, 1975), and the dating of undiagnostic sherds as geoarchaeological artefacts (e.g. Deckers et al., 2005). Questions of residuality, association, geometry, and alteration to be asked of the regolith are different to those of the heated artefact, so their parallel measurement using the same method can lend security to the dating of a context, while differences between results may be effectively applied to understand complex site-formation histories.

The presence of mineral fractions, and their luminescence behaviour, depends on geological source material, and the production technology of archaeological artefacts. Archaeological contexts are often subject to complex formation mechanisms and diagenetic changes. These may produce patterns of residuality in luminescence signals or samples (from transported grains or artefacts, Barnett, 2000; Burbidge et al., 2007), complex dosimetric geometries (Aitken, 1985), and changes in the geometry and radioisotope contents of a sample or its surroundings through time (Guibert et al., 2009; Zacharias et al., 2007). Instrumental neutron activation analysis (INAA) and X-ray diffraction (XRD) provide parent element concentrations and mineral concentrations, and are

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Table 1
Holocene environmental, climatic, and geomorphic context, summarized from van der Knaap and van Leeuwen (1995), Vis et al. (2010), Abrantes et al. (2005), and van der Schriek (2004). P = Palaeolithic, EP = Epipalaeolithic, M = Mesolithic, N = Neolithic, C = Chalcolithic, BA = Bronze Age, IA = Iron Age, R = Roman, Med = Mediaeval, PM = Post Mediaeval. 235 ^{14}C, 27 TSL/OSL and 7 U-series results from ascribed contexts, plus 'Me' from otherwise unascribed megalithic contexts were binned in each timeline division simply using each central estimate (from the database of Cardoso et al., 2012). The area 9–5 °W, 39–40 °N, was chosen to include Spanish Extremadura, the shell middens of the lower Tejo and Portuguese Estremadura, and the Alto Ribatejo, Uncalibrated ^{14}C data were converted using Reimer et al. (2009), other data are as reported. Problems of method, interpretation/association, and residual/intrusive materials/signals etc. produce tails in the distributions of dates for a given period, and of periods for a given date.

Timeline (BC/AD)	Vegetation	Climate	Sedimentation	Period	Extant dating results						
					P	EP	M	N	Me	C	BA
>10200	Forest colonization	Cold dry	Aeolian deposits	P	*46*		*3*	*2*			*2*
10200–9300	Forest development	Warmer and wetter			1		1				
9300–8300	Forest closure	Warm and wet		EP	4	1	1				
8300–7700	Possible lowland clearance/cultivation	Cycles of warm-dry/cool-wet			1		2		1		
7700–6700	Lowland anthropogenic clearance	of c. 500 year duration,			1		6	1			
6700–6500	Possible montane clearance/grazing	general trend to cool-wet					2				
6500–5500	Agriculture in lowlands (Cerealia)			M/N	1	1	35	3	1	1	
5500–4800					2		8	15	1		
4800–4500	Grazing			N			1	5			
4500–4000	Expansion of small scale deforestation	Drying following weakening	Alluvial accumulations				1	14			
4000–3600	Increased arable yields	of African monsoon					2	12			
3600–3300	Shift from cultivation to grazing. Reforestation						1	9	1	1	
3300–2600	Deforestation, overgrazing	Warm wet	Significant erosion: upland	N/C	3			2	9	10	
2600–2300	Reforestation	(strongly seasonal?)	Some colluviums and	C				2	3	8	2
2300–1900	Field cultivation		alluviums		1			2	2	3	2
1900–1500	Progressive deforestation			BA					1	2	14
1500–100	Contrasting phases: intensive field cultivation/pasture/ deforestation/stability/reforestation	Some indications of wetter climate		BA/IA	1				1		1
100BC–350AD	Reduced grazing and erosional pressure	Less wet		R					1		1
350–900	Valley deforestation, upland reforestation			Med				3			
900–1050	Large scale deforestation: valleys		Severe valley erosion								
1050–1250	Large scale deforestation: uplands	Warm dry	Severe erosion: upland						1		
1250–1450	Progressive severe soil erosion		and valley								
1450–1650	Permanent erosional degradation	Cold wet	Severe upland erosion:	PM							
1650–ca.1800	Forestry plantation	(Little ice age)	alluviums								

used to address questions of provenance, technology, use, and alteration/degradation/weathering (Dias and Prudêncio, 2007). Field- and high resolution- gamma spectrometry (FGS, HRGS) provide daughter radioisotope activities for different sample geometries and are used to evaluate spatial and temporal variability of dose rate (e.g. Trindade et al., 2013).

The Alto Ribatejo is a region of diverse geology, located on the faulting between the Central Iberian Zone (CIZ) and the Ossa Morena Zone (OMZ). River valleys are deeply incised into the Mesozoic Lusitanian Basin and the Lower Tejo Cenozoic Basin (Oliveira et al., 1992), through a partial coverage of Mio-Pliocene fluvial clayey sands (Pais et al., 2012; Ch 5.5). The study region is delimited to the South by the valley of the modern Tejo, and transition to the plains of Alto Alentejo. The present and recent climate is warm-temperate with dry, warm-hot summers, and hence highly seasonal in terms of wetness and moderately seasonal in temperature (codes Csa-Csb according to Köppen-Geiger climate classification, Rubel and Kottek, 2010). Regolith is commonly acidic and highly weathered. Indications from a high altitude lake core *ca.* 80 km to the North (van der Knaap and van Leeuwen, 1995), are of a fluctuating Holocene climate with phases of landscape activation and stability (Table 1), which was on average rather wetter than present from *ca.* 9000–3000 BC and slightly wetter than present since *ca.* 3000 BC. Charred particle analysis has highlighted palaeoclimatic/autogenic changes (Connor et al., 2012), but indicates potential for human impact from *ca.* 8000 BC. Anthropogenic (local) factors came to dominate climatic (regional) in its pollen assemblages from around the onset of megalithic construction in Iberia at the end of the 5th millennium BC. Substantial landscape clearance is only indicated from the 3rd millennium BC onwards, when the chrono-sequence may become less precisely relatable to the Alto Ribatejo, but the relationship is renewed with the rapid and regional Roman conquest, indicated by *Castanea Sativa* pollen.

The transition from the Mesolithic to Neolithic and the earliest agriculture near the Iberian Coast has been placed 5600–5400 BC, that for the interior 4900 BC; while the onset of megalithic construction is placed around 4200–4000 BC (Carvalho, 2010; Rowley-Conwy, 2011; Zapata et al., 2004). Archaeologically the Alto Ribatejo region has produced variants on the paradigms of Neolithization. Important among these is a drawing away from focus on coastal spread followed by inland dispersal of people ("cardial model", Zilhão, 1997), towards the possibility of overland spread along river valleys and a balance between the movement of people (replacement) and that of technology/ideas (integration) (Oosterbeek, 2001). The apparently lengthy Mesolithic–Neolithic co-occupation or transition in the coastal regions of Portugal has led to increasing emphasis on Epipalaeolithic communities as the precursors for integrative Neolithization (Carvalho, 2010; Scarre et al., 2003, Table 1), unlike other regions of Atlantic Europe (Scarre, 2007). Radiocarbon and luminescence dates as early as *ca.* 4000 BC have been reported for megaliths in the Tejo valley and various parts of Portugal (Scarre et al., 2003, Table 2; Scarre and Oosterbeek, 2010; Cruz, 2007, Table 1). How agro-pastoralism in the upper reaches of the Portuguese Tejo valley relates chronologically to evidence from on one hand coastal Portugal, and on the other to central and ultimately eastern Iberia, is important to distinguish between different models (Oosterbeek, 2001). However, there is a preponderance of absolute dating evidence from non-megalithic littoral sites and the nature of the sites and records changes with the landscape: shell middens are absent in-land and early megalithic contexts in this region tend to be aceramic. Despite