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Single-grain OSL chronologies for the Still Bay and Howieson's Poort industries and the transition between them: Further analyses and statistical modelling

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ABSTRACT

The chronology of the Still Bay (SB) and Howieson's Poort (HP) lithic industries remains an issue of keen interest because of the central role of these two phases of technological and behavioural innovation within the Middle Stone Age of southern Africa. Several dating studies have been conducted on SB and HP sites, including a pair published by the present authors and our colleagues in 2008 and 2013. These reported the results of systematically applying single-grain optically stimulated luminescence (OSL) dating procedures to 10 sites in South Africa, Lesotho and Namibia to constrain the timing of the start and end of the SB and HP and reveal the existence of a gap of several millennia between them. Alternative ages for these two industries have since been proposed by others for one of these South African sites (Diepkloof Rockshelter) and some concerns have been raised about the procedures used in our earlier studies to estimate the beta dose rates for a small number of samples. Here, we provide an update on our chronology for the SB and HP and address the issues raised about the methods that we used previously to estimate the beta dose rates and their associated uncertainties. To test the sensitivity of our new SB and HP ages to different underlying assumptions, we have run the same statistical model as that used in our 2008 and 2013 studies under three different scenarios. We show that the ages for the different samples are insensitive to how we analytically process or statistically model our data, and that our earlier conclusions about timing of the start and end of the SB and the HP and the probability of a gap between them remain true for two of the three scenarios. We conclude by bringing our study into the context of additional chronometric, stratigraphic and lithic technology studies that have been conducted in the intervening decade.

1. Introduction

The Still Bay (SB) and Howieson's Poort (HP) are two widely distributed Middle Stone Age (MSA) industries in southern Africa. Still Bay and HP artefacts have been recovered from sites spread across two million square kilometres of South Africa, Lesotho and Namibia. They exhibit a range of early technological and behavioural innovations, including the complex processing of ochre, the engraving of ochres and ostrich eggshells, the creation of decorative shell beads, and the production of multi-component tools that were hafted using compound adhesives (e.g., Henshilwood et al., 2002, 2004, 2014; Wadley et al., 2009; Texier et al., 2010, 2013; Vanhaeren et al., 2013). Other technological innovations also appear to originate at around the same time (e.g., Brown et al., 2009, 2012; Porraz et al., 2013).

In 2008, we proposed a chronology for the SB and HP, based on a systematic dating study of nine sites spanning a variety of climatic and ecological zones in southern Africa (Jacobs et al., 2008a). Age estimates for 54 sediment samples (and the associated artefacts) were obtained by optically stimulated luminescence (OSL) dating of individual grains of quartz sand, combined with statistical modelling to estimate the start and end dates of the SB and HP. Jacobs et al. (2013) re-examined the timing of the SB, based on the inclusion of 10 samples from Blombos Cave that had been analysed with the same instruments and experimental procedures as those used by Jacobs et al. (2008a).

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To discern small differences in age – such as the possible existence of a short time gap between the end of the SB and start of the HP – it is important to estimate ages with maximum precision. Resolving such events and their timing is easily obscured by the chronological 'haze' arising from different dating methods being applied to different sites and, in the case of OSL dating, from the use of different instruments, calibration standards and procedures for sample preparation, measurement and data analysis (Jacobs and Roberts, 2008; Jacobs et al., 2008a). Our published SB/HP chronology is more precise than most other OSL chronologies, because the same instruments and procedures were used to measure all of the samples. This systematic approach allowed several of the largest uncertainties attached to OSL ages to be removed when comparing our ages against each other, so that a more precise estimate could be made of the time span of the SB and HP industries and any gap between them (Jacobs and Roberts, 2008, 2009; Jacobs et al., 2008c, 2013). That is, the systematic error terms will be the same for each age, so it will not affect comparisons between estimates; only the random measurement errors, listed as the σ_1 values in Figure 2 of Jacobs et al. (2008a), will contribute to the uncertainty in age. However, when comparing our SB/HP chronology with independent ages – including OSL ages obtained in other laboratories and on other instruments – all of the systematic error terms (listed as the σ_2 values in Fig. 2 of Jacobs et al., 2008a) should be included in the age uncertainty. For readers unfamiliar with the treatment of errors in OSL dating, and in statistics more generally, we refer them to Appendix A in Galbraith and Roberts (2012).

In this paper, we take the opportunity to update our original SB/HP data set using recent updates in dose rate conversion factors and error estimation of beta dose rates (Jacobs and Roberts, 2015), and to then re-run the age model for further comparison. In doing so, we confirm the high likelihood of a gap of several millennia between the SB and HP for those samples reported by us in 2008, and demonstrate that the published single-grain OSL chronologies for these two industries (Jacobs et al., 2008a, 2013) are robust relative to a range of alternative assumptions and modelled ages. We also discuss the two aspects of our original analysis that were commented on by Guérin et al. (2013): (1) the small size of the uncertainties attached to the beta-particle contribution to the environmental dose rate, and (2) the details of implementation of a method proposed by Jacobs et al. (2008b) to adjust the beta dose rate in specific circumstances. The latter adjustment affected a subset of the samples from three of the nine sites reported in Jacobs et al. (2008a). We briefly discuss the first issue below (see section 4), but have addressed it in full in Jacobs and Roberts (2015), together with a new method that is now used in our laboratory to calculate beta dose rate errors when using our GM-25-5 beta counters. Here, we focus on the concept and implementation of the beta dose rate adjustment method of Jacobs et al. (2008b) to explore the effect of different approaches – including that advocated by Guérin et al. (2013) – on the ages calculated for the SB and HP samples. We also discuss the previously published data set from Pinnacle Point site 5–6 (PP5-6) that contains the HP, as well as evidence of a superficially similar microlithic industry earlier in time (Brown et al., 2012). The chronology of the latter is starting to fill the 'gap' between the SB and the HP, and, hence, directly address the question of the timing of the transition between the SB and the HP. This and other studies on lithic technology and chronology in this critical time period are currently stimulating a reassessment of the meaning of the HP (e.g., Mackay, 2011a,b; Porraz et al., 2013; Mackay et al., 2014; Conard and Porraz, 2015) and the SB (e.g., Archer et al., 2015, 2016) as homogeneous entities at different time scales.

2. Background

2.1. OSL dating and field context

There are two parts to the OSL dating equation; Jacobs and Roberts (2007), Duller (2008), Wintle (2014) and Roberts et al. (2015) provide overviews of OSL dating for non-specialists. The numerator is called the equivalent dose (usually denoted as D_e and expressed in grey, Gy), which represents the radiation energy absorbed by a mineral grain since it was last exposed to sunlight ('bleached') or heated to a high temperature. The D_e is estimated from measurements of the OSL signal emitted by individual grains or by single aliquots composed of multiple grains. The burial history of an individual grain is the smallest meaningful unit of analysis in OSL dating, so Jacobs et al. (2008c) obtained D_e estimates for all of the samples from OSL measurements of individual sand-sized grains of quartz.

The denominator in the OSL age equation is the environmental dose rate (Gy per unit time), which consists of four separate contributions: the beta-particle and gamma-ray dose rates from materials surrounding the quartz grains by up to ~3 mm and ~30 cm, respectively, and lesser contributions from cosmic rays and alpha particles (the latter emitted by radioactive inclusions internal to the quartz grains). Many archaeological deposits are heterogeneous in their composition and in the spatial distribution of the organic and inorganic constituents (e.g., Goldberg et al., 2009; Miller et al., 2013; Karkanas et al., 2015). Changes also commonly occur over time due to a variety of diagenetic, pedogenic and taphonomic processes. As a result, quartz grains deposited at the same time and situated within a few mm or cm of each other can have very different beta dose rates, depending on their relative proximity to materials of high or low radioactivity. Quartz itself typically has a very low dose rate, as do many secondary carbonates formed in archaeological sediments after deposition. By contrast, minerals such as zircon and potassium feldspar have much higher dose rates, so a quartz grain juxtaposed by a zircon grain will receive a much higher beta dose rate than a contemporaneous quartz grain coated in calcium carbonate, for example.

The differences in beta dose rate to individual quartz grains is difficult to model in a way that is both simple to implement and faithful to the field context of the sample, because each sample poses a unique set of circumstances that no single model can address without knowing the boundary conditions specific to that sample. Ideally, what is required is knowledge of the beta dose rate to each dated grain in its original, undisturbed burial position. Combining spatially resolved measurements of the OSL signal from individual grains with measurements of the dose rate at the single-grain scale of analysis is currently a research priority (e.g., Roberts et al., 2015; Martin et al., 2015a,b). At the present time, however, it is not feasible to model the beta dose rate to individual grains for each and every sample.

In practice, sediment samples are disaggregated in the laboratory and quartz grains are separated for OSL measurements. The dose rate is determined for the bulk sample (i.e., the sample as collected from the field) and D_e values are obtained from single grains or multi-grain aliquots composed of purified quartz grains. Based on the extent of scatter among these D_e values, and the existence of any patterns in the D_e distribution, some estimate is made of the overall D_e value that corresponds most closely to the last bleaching or heating event. Several well-established statistical models are widely used in OSL dating for combining independent D_e values appropriately, with the choice of model depending on sample context, among other things (Galbraith and Roberts, 2012). The D_e so obtained is representative of the values for the group of