Journal of Human Evolution 64 (2013) 314–317

Contents lists available at SciVerse ScienceDirect

Journal of Human Evolution

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

News and views

How confident are we in the chronology of the transition between Howieson's Poort and Still Bay?

Guillaume Guérin [a,*], Andrew S. Murray [b], Mayank Jain [a], Kristina J. Thomsen [a], Norbert Mercier [c]

[a] Center for Nuclear Technologies, Technical University of Denmark, DTU Risø Campus, DK-4000 Roskilde, Denmark
[b] Nordic Laboratory for Luminescence Dating, Department of Geoscience, Aarhus University, DTU Nutech, Risø Campus, DK-4000 Roskilde, Denmark
[c] Institut de Recherche sur les Archéomatériaux, UMR 5060 CNRS – Université de Bordeaux, Centre de Recherche en Physique Appliquée à l'Archéologie (CRP2A), Maison de l'archéologie, 33607 Pessac cedex, France

ARTICLE INFO

Article history:
Received 23 November 2012
Accepted 17 January 2013
Available online 27 February 2013

Keywords:
OSL dating
Single grain
Dose rate modelling
Middle Stone Age

Introduction

We discuss here the derivation of the luminescence-based chronology for the Howieson's Poort (HP) and Still Bay (SB) techno-complexes (summarised in Jacobs et al., 2008a). It is demonstrated that (i) the manipulation of the luminescence data contains fundamental errors of both concept and implementation, and (ii) many of the uncertainties in the dose rates are significantly larger than stated. We conclude that the evidence for a detectable difference in the timing of the HP and SB techno-complexes does not stand close examination and that the overall uncertainties in the absolute chronology are significantly underestimated.

Dose and dose rate modelling

Jacobs et al. (2008a) published an optically stimulated luminescence (OSL)-based regional chronology for different Middle Stone Age (MSA) sites in South Africa and used this to address the question of potential chronological overlap between two different MSA techno-complexes, namely HP and SB. The authors concluded that, at the 95% confidence level, HP and SB did not overlap and that SB was ~7 ka (thousands of years) (~10%) older than HP. To derive their OSL ages, two different methods were used: (i) they divided a mean equivalent dose (D_e) as determined by the Central Age Model (CAM, Galbraith et al., 1999) by the measured average dose rate ($\bar{D}$) or (ii) they applied the Finite Mixture Model (FMM, Roberts et al., 2000) and divided the D_e from the main dose component by an assumed 'adjusted dose rate' (or in some circumstances by $\bar{D}$). The choice between method (i) or (ii) was determined by a potentially subjective 20% limit on the dose over-dispersion expected from 'well-bleached quartz grains' (Jacobs et al., 2008a). This limit was then used to constrain the use of the FMM in method (ii). The fundamental assumption in all of these analyses was that the over-dispersion in the D_e distributions does not arise from insufficient resetting of the luminescence signal before deposition, but rather from post-depositional mixing of sedimentary units and/or differences in beta dose rates received by different quartz grains after burial. This hypothesis was based on the observation that many of their dose distributions could best be represented as being made of two or more dose components. In 17 out of 48 samples, these were presumed to arise at least in part from two dose-rate components, which in turn were attributed to the presence of low-radioactivity minerals (as in Jacobs et al., 2008b) within an otherwise radioactive matrix. Although some samples contained three components, the extra component was apparently attributed to mixing and discarded (although without explicit justification). Furthermore, for 17 other samples the main dose component was associated with the average dose rate rather than an adjusted dose rate (again without explanation). This approach has since been applied to several other sites (Jacobs, 2010; Jacobs et al., 2011, 2012, 2013; Gliganic et al., 2012). These studies give the strong impression that bimodality arising from beta heterogeneity is a common occurrence, and can be addressed using this model.

From basic dosimetric considerations, the presence of low-radioactivity 'coldspots' is very unlikely to cause such discrete dose-rate components (e.g., Brennan et al., 1997) and one would rather expect unimodal, skewed dose rate distributions in sedimentary media. Although they explicitly tried to reproduce bimodal dose-rate distributions by simulating such coldspots, Nathan et al. (2003) were unable to do so. Only a few specific and very unlikely distributions of grain to grain distances would result in such bimodal dose

* Corresponding author.
E-mail address: guillaumeguerin@ymail.com (G. Guérin).

http://dx.doi.org/10.1016/j.jhevol.2013.01.006

rate distributions. For instance, it would require one population of grains all to be shielded from beta particles to the same degree, and another population to be essentially unshielded. Most importantly, there must be no significant number of grains with intermediate degrees of shielding. This situation has never been observed or successfully simulated, and must be considered extremely unlikely.

Jacobs et al. (2008b) use an analytical model that invokes an assumed 'adjusted beta dose-rate,' which is then applied to a selected dose population. Independent of whether or not the dose-rate distribution is actually bimodal, we demonstrate first that their analysis is both flawed and unnecessary, and show that the best age estimate for such samples should be based on an average estimate (weighted or unweighted) of both dose and dose rate.

If one assumes that the only source of dispersion in single-grain doses is the dose rate (Jacobs et al., 2008b), then each grain has the same age OSL age 't', i.e.,

$$\frac{D_{e,1}}{\dot{D}_1} = \frac{D_{e,2}}{\dot{D}_2} = \ldots = \frac{D_{e,n}}{\dot{D}_n} = t \quad (1)$$

where $D_{e,i}$ is the equivalent dose recorded by the i-th grain, $\dot{D}_i$ is the corresponding dose rate, and n is the number of grains. This age t is arithmetically identical to the average equivalent dose $\overline{D_e}$ divided by the average dose rate $\bar{\dot{D}}$:

$$t = \frac{1}{n}\sum\frac{D_{e,i}}{\dot{D}_i} = \frac{\sum(D_{e,i}/n)}{\sum\left(\dot{D}_i/n\right)} = \frac{\overline{D}_e}{\bar{\dot{D}}} \quad (2)$$

This result is independent of the nature of the distribution of dose-rates to individual grains. Thus, if all grains have the same OSL age, then modelling of the dose-rate distribution is both unnecessary and undesirable; it cannot improve accuracy, and must introduce additional uncertainties. Clearly, any separation of the equivalent doses into two groups (e.g., the two first terms of Eq. (1)), arbitrary or otherwise, results in a unique solution for $\dot{D}_1$ and $\dot{D}_2$ because t is invariant. Thus, from first principles there is no extra information available as a result of splitting the average dose rate into two terms. On the other hand, any attempt to estimate ages based on selected dose populations and assumed dose rates (Jacobs et al., 2008b) will introduce significant additional, often unquantifiable, uncertainties, such as those arising in the accurate estimation of the number of grains in individual populations. According to Roberts et al. (2000), the use of the FMM on dose populations such as those presented by Jacobs et al. (2008b) should result in ~50% underestimation of the number of grains in the low dose component. We conclude that an average (or CAM) age is the best age estimate for well-bleached samples with beta dose rate heterogeneity.

Despite the unavoidable consequences of Eqs. (1) and (2), the adjusted dose rate model has been used widely. In 113 out of 165 samples, the proponents argued that the adjusted dose rate model would give more credible age estimates (Jacobs et al., 2008a, b, 2011, 2012; 2013; Jacobs, 2010; Gliganic et al., 2012; see Table S1 in SOM for a summary of the samples for which adjusted dose rates appear to have been preferred). In particular, Jacobs et al. (2008b) report significant differences between CAM ages and dose-rate adjusted FMM ages for 13 out of 14 samples at Sibudu. Although we cannot test the generality of this observation on all data sets (the CAM data are not usually provided when adjusted dose rates are used), sufficient information is available to allow us to examine the Sibudu data set in some detail. Jacobs et al. (2008b) describe how the average of the lower dose-rate component is first guessed, and is assigned a (guessed) standard deviation sufficiently large to cover all likely possibilities. However, this guess is not optimised by iteration; in other words, there is no recalculation based on the initial assumption that the ages of the lower and larger dose components must be the same. The effect of this simplification can be examined using the data presented by Jacobs et al. (2012). There, the average ratio of the apparent age of the lower dose component to that of the higher dose is 0.76 ± 0.03 for the 'scattered' samples. This is clearly inconsistent with the authors' model assumption that these ages must be the same. Using their data, we fully implemented the adjusted dose rate model, i.e., we iterated the calculations until the age estimates for the two dose modes were indistinguishable. We find that the ages obtained with the FMM and adjusted dose-rates are, on average, ~1.5% lower than those resulting from the incomplete application of the model. In two cases (EH08-8 and EM10-1; Jacobs et al., 2012), this difference is as much as 4%. Nevertheless, even the fully iterated results are still, on average, ~3% larger than our (preferred) CAM results, and it seems that ages obtained with the FMM and adjusted dose rates systematically overestimate those from CAM. We attribute this difference to weighting effects when calculating the mean equivalent dose of different grain selections with different over-dispersion values (Galbraith and Roberts, 2012), and emphasise that the CAM ages must be regarded as the more accurate.

The strongest empirical argument in favour of the author's dosimetry model is that it apparently improves the stratigraphic consistency of the ages at Sibudu (Fig. 1; adapted from Fig. 6a, b in Jacobs et al., 2008b), especially for sample SIB2. If one ignores uncertainties, the CAM age–depth profile (after exclusion of intrusive grains using the FMM for a few samples, i.e., data summarised in Fig. 1, filled circles) appears to show an age inversion around this sample. After application of the adjusted dose-rate model the stratigraphic consistency does seem to improve, although it should be noted that the ages represented by open squares in Fig. 1 (samples SIB1, 2, 3, 4, 6, 9; Jacobs et al., 2008b, Fig. 6a in the original work) are under-dispersed, that is they lie closer together than would be expected from the uncertainties. On closer inspection of Tables 1 and 2 (Jacobs et al., 2008b), it becomes apparent that the equivalent doses used for the calculation of ages of samples SIB2 and SIB7 are smaller than the

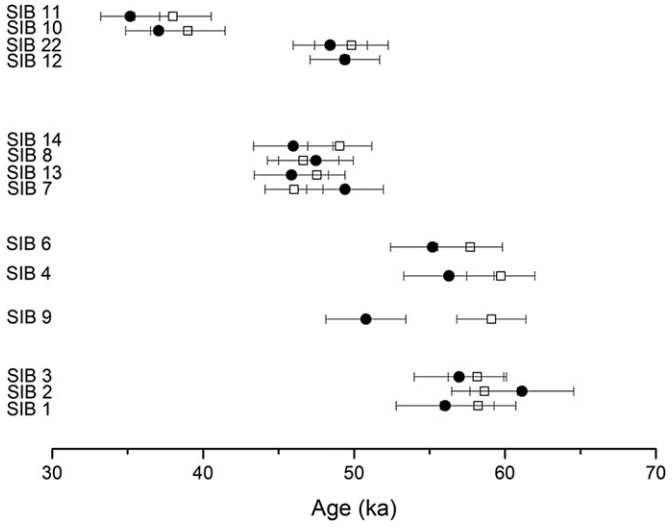

Figure 1. OSL ages for samples from Sibudu, based on Jacobs et al. (2008b). Open squares: their preferred ages, calculated by dividing a main dose component by an adjusted dose rates. Filled circles: our preferred ages based on their published data (CAM dose divided by average dose rate, and including a 7% uncertainty in beta dose rate). With three exceptions, all published modelled ages are overestimates (by up to 16% for SIB 9) of our preferred ages. The three exceptions are SIB 8, SIB 2 and SIB 7. However in the latter two cases the model does not appear to have been applied as described in the literature (see text).