

Ancient TL

eM-Age (excel Macro for Age calculation), a new application for luminescence age calculation based on Dose Rate and Age Calculator (*DRAC*) and *Analyst*

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Abstract

eM-Age is a new program for calculating luminescence ages quickly and more easily. It allows the user to instantly check the impact of choosing different attenuation factors (dose rate parameters, grain size, water content, etc) on the final dose rate, and therefore also on the final age, calculation. Based on data collected by Durcan et al. (2015) in the *DRAC* program, *eM-Age* offers a graphical interface and also allows the calculation and selection of equivalent dose data from summaries generated by *Analyst*, as well as offering options for different age models for the loaded data.

Keywords: Quaternary, data treatment, data analysis, geochronology, luminescence dating, software

1. Introduction

Age calculation using dating techniques such as thermoluminescence (TL) or Optically Stimulated Luminescence (OSL) can be a challenge due to the large number of individual factors which need to be taken into account, such as grain size attenuation, etch depth attenuation, burial depth, water content, dose rates of the different radionuclides present in the sediment etc. In recent years, new applications and additions have emerged to help researchers in these processes, reducing the potential for miscalculations and providing useful tools for inter-laboratory comparisons and data sharing. Within this aim, specific programs have been developed for the different dating techniques, as well as additions such as *AGE* program (Grün, 2009), *ADELE* (Kulig, 2005), Dose Rate and Age Calculator, *DRAC* (Durcan et al., 2015), ‘Luminescence’ and ‘RLumShiny’ packages for **R**

(Kreutzer et al., 2012, 2019), *CRONUS* (Balco et al., 2008), *LDAC* (Liang & Forman, 2019), and the implementation of **R** features within *Analyst* (v4.57) (Duller, 2018).

Here I present a new program for luminescence age calculation based on *DRAC* datasets (Durcan et al., 2015), but with a simpler Graphical User Interface (GUI), for users with and without a high degree of knowledge of luminescence calculation programs like *Analyst* or **R** ‘Luminescence’ package, and are more familiar with commercial packages such as *Microsoft Office*[®].

2. Key features

eM-Age has been designed to be run on *Microsoft Excel*[®] (2007 and later) as a macro. For proper operation, users must have enabled macros in Excel. *eM-Age* is an easy and friendly way to perform most of the calculus and parameter evaluation involved in age calculation for luminescence dating techniques (especially OSL), both equivalent dose (D_e) and dose rate calculation. Users can input their data directly, and in addition, D_e data can be uploaded from *Analyst* .binx files.

One of the main features of *eM-Age* is to allow the user to check continuously (during the whole data input process) the effect of data changes on both the total dose rate and the final age calculation. This is an improvement with respect to other programs where the user needs to input all the data prior to obtaining a final result (e.g., *DRAC*, **R** ‘Luminescence’, *LDAC*), and provides a rapid way of sensitivity testing the impact of various different datasets on the final calculated dose rate.

Moreover, *eM-Age* offers the possibility of uploading data sets from *Analyst* (equivalent doses, recycling, test dose errors, palaeodose errors, recuperation %, reader dose rate if available, disc and grain position). Radionuclides (U,

Th, K and Rb) values can be input as either concentrations (ppm/%) or activities (Bq/kg) for dose rate calculation, offering more flexibility than other programs where the data input is restricted to a fixed format (e.g. radionuclide concentrations in ppm or weight percentage only). *eM-Age* avoids the use of complex syntaxes for equivalent dose calculation (e.g. from ‘Luminescence’, package for R: `calc_AverageDose[data, sigma_m = NULL, Nb_BE = 500, na.rm = TRUE, plot = TRUE, verbose = TRUE, ...]`), which requires a certain degree of knowledge of programming codes. In addition, the original data set often needs pre-treatment prior to use within R. The most recent enhancement of *Analyst* (Duller, 2018) includes the possibility of using the R ‘Luminescence’ package (Kreutzer et al., 2012, 2019), making it a powerful tool for researchers, and clearly enhances the use of advanced functions included in the ‘Luminescence’ package of R. Nonetheless, certain knowledge of R is required to obtain the desired results.

The aim of this program is to offer a straightforward, intuitive software, in which equivalent doses and dose rates can be calculated for luminescence dating. It is aimed at a broad range of researchers, without the requirement for coding skills. It is intended that this program will be developed in the future, with future versions having more capabilities. A repository in GitHub (<https://github.com/yomismovk/eM-Age-program>) has been created with this aim to house the original files and future updates.

3. Quick guide and program structure

To run the program it is necessary to click on the button “Run eM-Age program” located in the main tab called “eM-Age program info”. In the first run, the program automatically uploads a default stored dataset (example data from SAR-2.bin file, *Analyst* (v4.57) - Duller 2018). The program window (Figure 1) is divided into two main sections; (1) an upper part with permanent (always visible) data (showing in green sample name, final age (in ka), equivalent dose (Gy) and total dose rate values (Gy/ka), and (2) a section with different tabs for data input (Data, Dosimetry, Results & Graphs and Summary). Listed below is a brief description of the different tabs and the required data.

3.1. “Data” tab

This tab is designed to introduce basic data information of the sample, such as name, project name, type of analysis (single aliquot, single grain), type of protocol (TL, OSL, VSL, TT-OSL), type of material (quartz, feldspars, others). Data included in this tab will be output in the user summary. Also, this tab allows the user to upload equivalent dose data from external sources (summaries from *Analyst* (v4.57) and later, exported as .anr files). The equivalent dose data (D_e in seconds and Gy) is shown, as well as different quality parameters like recycling ratio, test dose error, palaeodose error and recuperation % (for further information see *Analyst* (v4.57) manual).

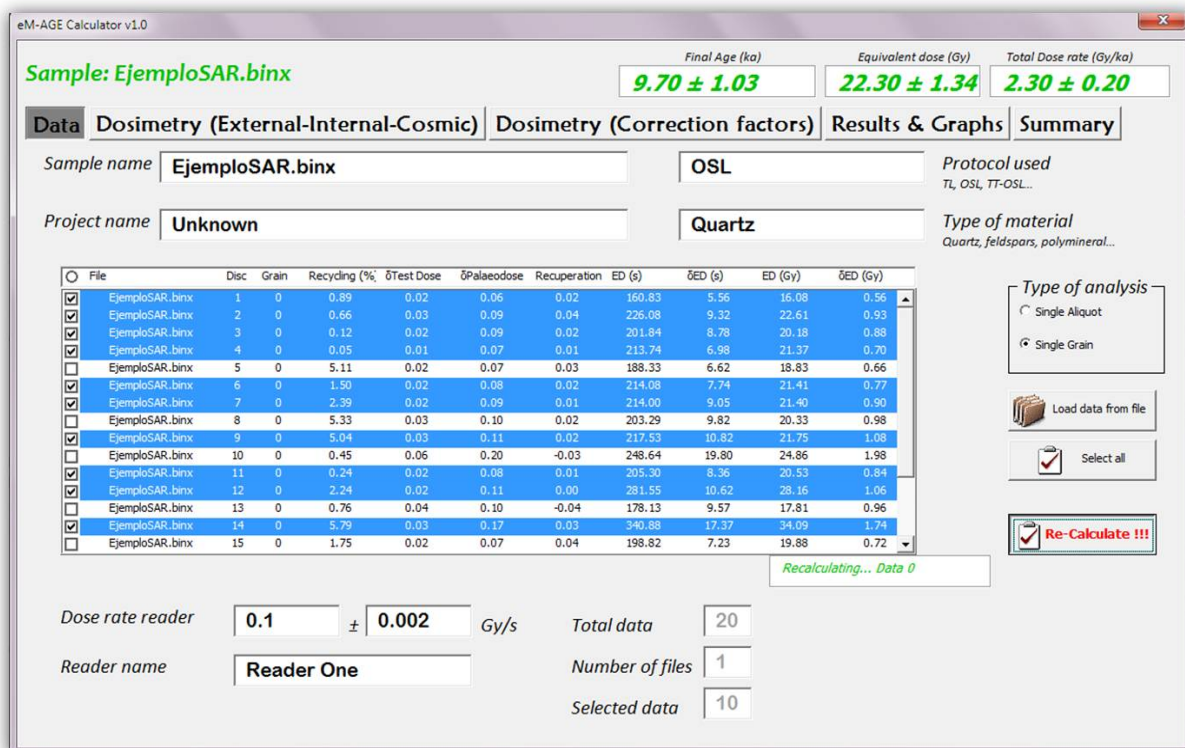


Figure 1. *eM-Age* main screen with an *Analyst* file uploaded

If the uploaded file contains data referring to the source dose rate from the luminescence reader, it will be shown and used for the calculations. If not, a “N.D.” (no data) caption will appear in the dose rate reader field, and a message will inform the user that an estimated dose rate of 0.100(2) Gy/s will be used. The user also has the option of manually inputting their source dose rate. Additionally, if the user does wish to import their equivalent dose data, it is possible to input an equivalent dose value for the sample in the “Results & Graphs” tab (User Equivalent Dose).

3.2. “Dosimetry” tabs

Dosimetry calculation is handled in the tabs “Dosimetry-Correction Factors”, for water content and correction factors of the infinite matrix alpha, beta and gamma doses calculated from the data input, and “Dosimetry-External-Internal-Cosmic”, that includes both external, internal and cosmic dosimetry parameters.

The “Dosimetry-Correction Factors” tab allows the user to input the information related to sample water content. This last point will define the percentage of water content used for age calculation (Zimmerman, 1971; Aitken & Xie, 1990). In this section, the user can input the “Saturation water content” (maximum percentage of water accepted by the sediment), organics content (estimated % of organic matter in the sample), and % saturation (estimated percentage of water during the burial time, 100% = sediment always saturated in water, 0% = sediment always dry). This tab enables the modification of parameters such as sample grain size, choose between different dose rate conversion factors (Adamiec & Aitken, 1998; Guérin et al., 2011; Liritzis et al., 2013), attenuation factors for grain size and etching (Bell & Zimmerman, 1978; Mejdahl, 1979; Bell, 1979, 1980; Brennan et al., 1991; Readhead, 2002a,b; Brennan, 2003; Guérin et al., 2012), shallow depth correction factor for samples with depth ≤ 30 cm (Aitken, 1985; Durcan et al., 2015), and the type of attenuation applied (independently from K, U and Th concentrations or using an average attenuation factor “MIX” calculated assuming the elemental ratios of Mejdahl 1979). Also shown in this tab, is a graphical presentation of the relative contribution (%) to the total dose of the different sources (alpha, beta, gamma, internal and cosmic doses).

The “Dosimetry-External-Internal-Cosmic” tab enables the input of parameters relevant to the cosmic dose rate, as well as the external and internal dosimetry. Several factors are taken into account for cosmic dose rate calculation such as altitude, burial depth, sediment density and sample coordinates (latitude and longitude). Geomagnetic corrections based on the workings of Prescott & Hutton (1988, 1994) are used.

External and internal dosimetry data can be inserted in two different ways: 1) as U, Th, Rb (ppm) and K (%) concentrations, or 2) as U, Th, K and Rb activities (Bq/kg). Also, this last method allows the users to use only ^{238}U , ^{232}Th and ^{40}K activities, if the user does not have data of the complete decay chain of ^{238}U and ^{232}Th .

3.3. “Results & Graphs” tab

This tab shows valuable information about the sample data set (if the data was uploaded from an external source, .anr files), including probability distribution and histogram plots for both raw uploaded data and selected equivalent dose data (“Raw data” and “Selected data” tabs).

Also, in the “Selected data” tab, users can compare different ages obtained by using different age models: Mean, Weight mean, Common age model and Central age model (Galbraith et al., 1999) and to choose between them. Moreover, for this last age model the overdispersion is calculated.

3.4. “Summary” tab

eM-Age allows the export of a .pdf file with all the information provided by the user and the main parameters used in the age calculation, such as alpha, beta, gamma, cosmic, internal dose rates, equivalent doses selected for the age calculation (if an *Analyst* file is uploaded) as well as a list of the different correction factors applied. This will help the researchers to organize their results and to compare different samples. Also, during the process of calculation the program generates (in the folder where it is located) a number of files with .gif format to be used in another programs or reports made by the user.

4. Conclusions

eM-Age offers a new opportunity for easily calculating luminescence ages. The simplicity of its interface together with the multiple data entry options offer researchers, and specifically the geochronologists, a fast and reliable tool for the basic calculation of luminescence ages. It is simple and intuitive enough for under- and postgraduate students to use, as they develop their skills and knowledge in luminescence dating. It can also serve to complement more advanced research in conjunction with existing programs.

The presentation of this calculator as a macro in Excel and the free access of the code used (<https://github.com/yomismovk/eM-Age-program>) offers the possibility of modification and improvement of the program’s capabilities by other users and the chance of adaptation to particular requirements.

5. Data Availability

Dose rate conversion factor data were obtained directly from the original works of: Adamiec & Aitken (1998); Guérin et al. (2011); Adamiec & Aitken (1998); Guérin et al. (2011); Liritzis et al. (2013). Grain size attenuation factors, etch depth attenuation factors, cosmic dose rate parameters (F, J and H) and gamma dose scaling factors were obtained and slightly modified (format only) from the supplementary information of Durcan et al. (2015) at <http://dx.doi.org/10.1016/j.quageo.2015.03.012>. All the datasets are visible in the background worksheets of the *eM-Age* calculator v1 Code Visible file.

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Appendix

The supplementary documents contain the following files: (1) program write-protected for general use (eM-AGE calculator v1.0 Protected) (2) program with visible code, spreadsheets, macro functions for advanced users (eM-AGE calculator v1.0 Visible Code) (3) Equivalent dose data file from Analyst summary (Example SAR-2.ANR) (4) Example of report (SAR-2.binx Report.pdf) (5) User Manual (eM-Age Manual v1.0). The Supplementary Documents are available as zip-file for download. A detailed description of the datasets used in the program can be found in the supplementary information of Durcan et al. (2015).

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Reviewer

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