CoRSEER: The Calculator of Rock Surface Exposure Age and Erosion Rates for Rock Surface Luminescence dating

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Referee comments are in black.

The author's comments are in blue.

This is a well-written paper that provides valuable tools for luminescence-based exposure dating. The tests against previously published datasets are convincing and demonstrate that the tool produces reliable results consistent with the current state of the art. I have only a few minor comments, which are included in the annotated PDF.

We are happy to see the positive comments on our manuscript and on the tool's utility. Also, we are much obliged to the referee for their keen observations and constructive comments throughout this manuscript. Here, we provide point-by-point feedback for each comment.

L9: Rock surface dating is also used for burial dating. Not a part of this study, but I'd still call it rock-surface luminescence exposure dating for clarity's sake.

We agree that the previous nomenclature could be confusing. Therefore, we have revised the terminology to "luminescence rock surface exposure dating" (LRSED) and have implemented this change consistently throughout the manuscript.

L10: think this sentence needs rephrasing. 1) subjective plateau selection and different models are not "practical issues". Also, how have these issues limiting subsequent studies? 2) I think this phrasing overemphasise the challenges this study aims to correct in relation to other (in my opinion much larger) issues with exposure dating: e.g., finding good calibration samples, measuring representative depth-profiles, finding good lithologies that both bleach and have a signal, for eroding surfaces - what is the actual exposure age etc,..

Thanks for the thoughtful comment. We admit that this manuscript addresses mathematical analysis limitations rather than practical limitations.

We have made the necessary changes as shown in L10-12:

"The wider use of this method has been slowed by limitations in mathematical analysis, such as: the subjective selection of the deep plateau for profile normalisation, inconsistent modelling choices across studies, and the lack of a unified inverse-modelling workflow that delivers both parameter estimates and uncertainty bounds".

We also added this paragraph in the discussion section in L407-409 as:

"Although this method is affected by broader challenges such as availability of calibration samples, representative luminescence depth-profile selection, lithological suitability, and independent exposure-age constraints, additional methodological uncertainty can arise from subjective plateau selection and the use of non-standardised modelling approaches."

L42: This sentence reads very awkwardly.

The sentence has been changed and shown in L41-L45.

"Generally, there are two major reconstruction scenarios: (i) Establishing the exposure ages of host rocks (e.g., valley walls, bedrock, or strath surface) that can predict the age of the natural (e.g., deglaciation) and anthropogenic (e.g., stripping of regolith and quarrying) events that creates an freshly exposed surface (Owen and

Dortch, 2014; Gliganic et al., 2019). (ii) The transportation, deposition, and reworking histories of transportable clasts, such as cobbles and boulders (Luo et al., 2018)"

L46: "Furthermore"?

Complied

L68: Sohbati et al., 2018?

We have added the citation.

L90: Please elaborate on how this erosion model is different from Sohbati et al. 2018 and Freiesleben et al. 2023.

Both models, Sohbati et al. (2018), which was further incorporated into Freiesleben et al. (2023) and Lehman et al. (2019a), incorporate erosion into the exposure history, are mathematically correct, but their handling approaches differ. The Sohbati et al. (2018) model alters the depth term (based on erosion) in the equation, and the current model (Lehman et al., 2019) incorporates the erosion effect independently as advection. We find the current model is easier to solve numerically.

Lehman et al. (2019a) compared both approaches and found similar results.

L93: I'd definitely rephrase this to something softer than "far from accurate", especially since you demonstrate your tool further down using FOK.

We have softened the statement in L92-93 as:

"However, in the case of polymineral or feldspar samples, where the infrared stimulated luminescence (IRSL) of feldspar minerals exhibits non-first-order decay, the GOK model is more suitable for these samples."

L98: open parenthesis

Corrected

Section 2.4: I think this section would benefit from making crystal clear what improvement came from which study, elaborate on how these models are improvement over previous ones, and then give an overview on what will be included into Corseer.

Thanks for the suggestion. We have appended the paragraph in L108-114 and clearly stated the contribution, such as:

"Lehmann et al. (2019a) introduced the advection term in response to erosion as $\dot{\varepsilon}\frac{d\bar{n}}{dx}$ but for the FOK (r = 1) in addition to earlier models. This model can be solved with the finite-difference method with a second-order upwind scheme for the advection term rather than altering the depth term (Sohbati et al., 2018). Furthermore, Biswas et al. (2023) modified this model for a zero erosion scenario by incorporating GOK (r > 1) in the decay term and demonstrated the severe underestimation of the exposure age if FOK was used. Pathan et al. (2024) solved the GOK model (Eq. 15) for a non-zero erosion scenario and reported an overestimation of the erosion rate when FOK was used. Thus, we incorporate the most recent model, as in Eq. 15, into the mathematical framework of CoRSEER."

L104: "The modeling framework adopted in this study brings together key components that have not previously been combined within a single model."

Complied.

We have made changes as shown in L104-106:

"The modelling framework adopted in this study brings together the current understanding of rock-surface luminescence signal evolution within a single computational framework. It includes: (1) general-order kinetics, (2) advection through the natural mechanism of erosion, and (3) ambient dose-rate-driven signal accumulation."

L105: You don't really explain why this erosion model is more realistic.

Please see the answer to the previous comment.

L105: I think it would make sense to elaborate here.

The sentence has been changed to

"The modelling framework adopted in this study brings together the current understanding of rock-surface luminescence signal evolution within a single computational framework. It includes: (1) general-order kinetics, (2) erosion through the natural mechanism of advection, and (3) dose-rate-driven signal accumulation."

L106: Please elaborate.

The sentence has been changed to

"The modelling framework adopted in this study brings together the current understanding of rock-surface luminescence signal evolution within a single computational framework. It includes: (1) general-order kinetics, (2) erosion through the natural mechanism of advection, and (3) dose-rate-driven signal accumulation. This formulation was required to simulate the luminescence-depth profile more accurately and builds upon earlier work by Lehmann et al. (2019a), Biswas et al. (2023), and Pathan et al. (2024). Lehmann et al. (2019a) introduced the advection term in response to erosion as $\dot{\varepsilon}\frac{d\bar{n}}{dx}$ for the FOK (r = 1) in addition to earlier models. This model can be solved with the finite-difference method with a second-order upwind scheme for the advection term rather than altering the depth term (Sohbati et al., 2018)."

L114: Did both studies provide separate improvements regarding the inclusion of GOK?

Biswas et al. (2023) applied the GOK model for a non-erosion scenario, whereas Pathan et al. (2024) applied the GOK model in the presence of an erosion scenario. We have modified the text at the beginning of Section 2.4.

L118: Maybe provide some examples from aforementioned studies of how it improved.

We have elaborated the section. Please see L104-L114.

Section 3.1: Could you please elaborate on why this logistic pre-fitting step is preferable to allowing the model to define the saturation limit directly? Is the normalisation to 1 really necessary?

Normalisation is necessary because the forward equation (Eq. 15) is solved on a relative luminescence scale, where the maximum field-saturated signal at depths beyond light penetration is set to 1. Experimentally, the test-dose-corrected luminescence intensity (L_x/T_x) at the saturation plateau may vary between samples and measurement conditions. Therefore, each LDP must be normalised to its plateau value before mathematical comparison and modelling.

In all previous studies, this plateau value was estimated subjectively by visually selecting the saturated region and taking its mean value, which can introduce user-dependent bias. Here, we provide an objective logistic pre-fitting approach to calculate the plateau vale, remove manual intervention, which improve the results, as shown in Fig. 2d and e.

L165: Meaning the normalised Lx/Tx points?

No, it's the simulated luminescence depth profile using best sigmoidal fitting, a, b and c parameters.

L188: Is this really fair to describe this as an error though? The kinetic parameter the normalisation is scaled to is the field-saturated, test-dose corrected luminescence intensity, correct? Does your SCF normalisation really accurately constrain this kinetic phenomenon? Isn't your argument that using the SCF that makes the modeling more reproducible and comparable, which ultimately makes comparing calibration profiles and their corresponding unknown age/erosion more accurate?

The SCF normalisation does not directly constrain the kinetic saturation process; rather, it provides an objective estimate of the field-saturated plateau value. By reducing user-dependent subjective plateau selection, this procedure improves the reproducibility and comparability of calibration and unknown-age luminescence-depth profiles, thereby supporting more consistent apparent-age and erosion-rate estimation.

Figure 2e: I'd include a legend here even if the colour coding conforms with Fig 2D

Thanks, the legend is added.

Figure 3: Is it just for me or does this figure look blurry? Please check.

The figure has been updated to a high-resolution format.

L272: This is sentence is awkward. Please rephrase.

Yes, we have changed it to in L283-286:

"If the t_{app} of a sample is much lower than the expected age as observed for IR50_BALL02, the LDP is in a steady state. To derive the erosion rates, the model should run for t_{max}. But, if the true exposure age is known by independent means, we suggest running the model for that exposure age."

L289: calibration

Complied

L290-293: "and and and" in Section 4

Corrected

L336-338: Is it corrected that Brill et al actually used Corseer for their own analysis or is this a typo?

Thank you for pointing it out. It was a typo.

We have corrected this in L351-354 as:

"For Brill et al. (2021), we use CoRSEER-I to evaluate the parameters of IR50_RAB 5-1 CAL for the samples of IR50_RAB 1-1, IR50_RAB 1-2, and IR50_RAB 5-1 (these samples were evaluated using IR50_HAR 1-1 CAL I in the literature due to the large uncertainty in IR50_RAB 5-1 CAL)."

L357: missing space

The paragraph is modified in revision.

L392: missing parenthesis

Corrected.