

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

Arbaz Pathan^{1,*}, Rabiul Haque Biswas^{1,*}, Devender Kumar^{2,3}

¹ Department of Earth Sciences, IIT Kanpur, Kanpur -208016, India

² CSIR-National Geophysical Research Institute (NGRI), Uppal Road, Hyderabad, Telangana 500007, India

³ Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, Uttar Pradesh 201002, India

*corresponding author email ID: akp20@iitk.ac.in, rabiul@iitk.ac.in

A. Research Question

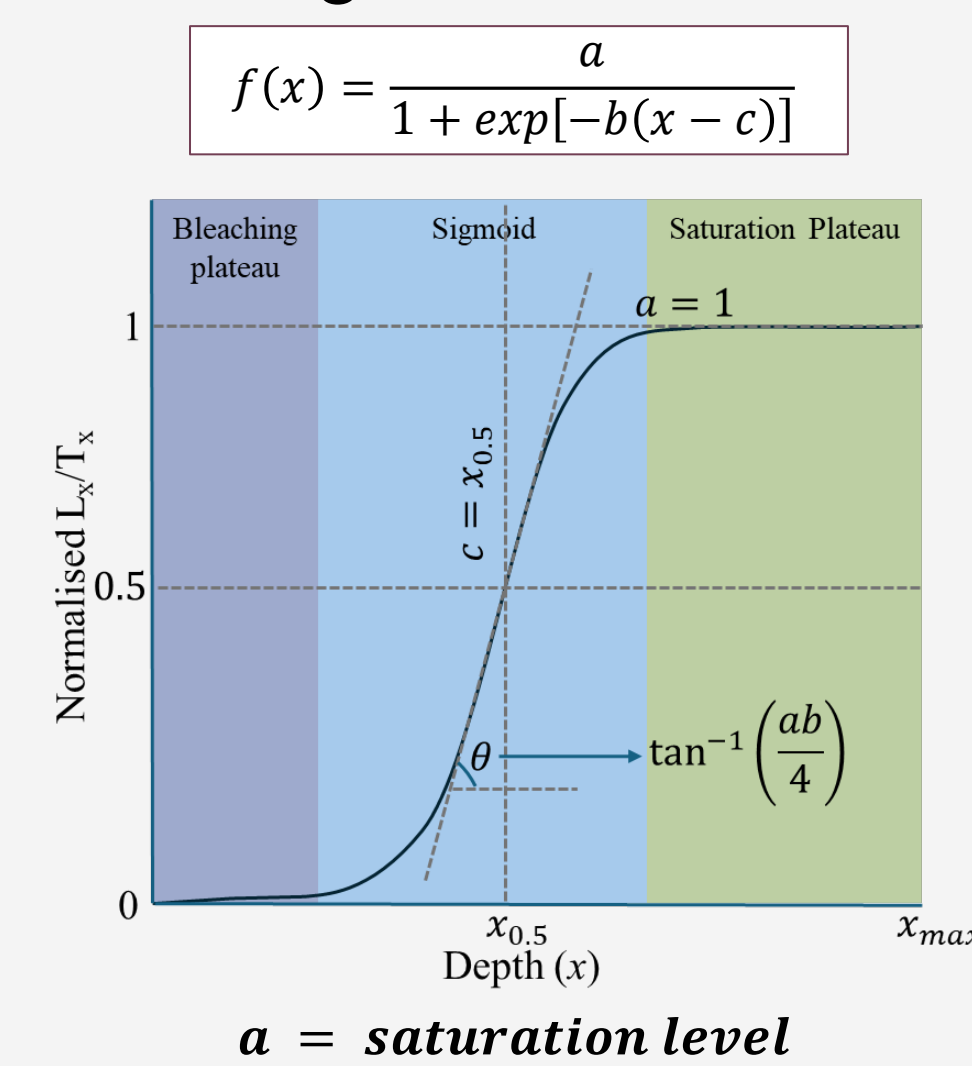
- Can LRSED be made more reproducible by: (a) replacing subjective profile normalisation and (ii) non-standard modelling with a unified inversion framework.
- Key Bottlenecks:
 - Manual deep-plateau selection introduces user bias
 - Inconsistent modelling strategies across studies
 - No Integrated workflow for calibration, age and erosion estimation with uncertainty.

B. Study System/ Context

- Compilation-based method paper
- CoRSEER Benchmarked by reanalysing published luminescence depth profile (LDP) dataset.
- Benchmark dataset:
 - 23 Calibration samples
 - 41 unknown-age samples
 - 11 steady-state erosion cases
- Literature sources: Smedley et al. (2021), Brill et al. (2021), Balco et al. (2023), Lehmann et al. (2018, 2019a, 2019b), Luo et al. (2018, 2022)

C. How CoRSEER Works ?

1) Luminescence Depth Profile Sigmoidal Model



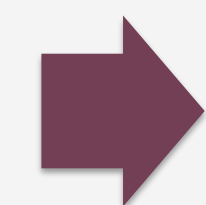
2) Forward Model (governing equation for signal evolution)

$$\frac{d\bar{n}}{dt} = \left\{ \frac{\dot{D}}{D_0} (1 - \bar{n}) \right\}_{growth} - \left\{ \bar{n}^r \bar{\sigma} \varphi_0 e^{-\mu x} \right\}_{decay} + \left\{ \varepsilon \frac{d\bar{n}}{dx} \right\}_{erosion}$$

Parameter	Description	Methodology
D_0 (Gy)	Characteristic Dose (~ dose that fills 63% of electron traps)	Dose-Response Curve (Wintle and Murray, 2006) [3]
$\dot{D}$ (Gy. kyr ⁻¹)	Ambient Dose Rate due to ⁴⁰ K, ²³⁸ U, ²³⁵ U, ²³² Th	ICPMS, Dose Rate calculator
r	Order of Kinetics of Feldspar IRSL decay	IRSL Decay with respect to time Fitting with decay term [2]
$\bar{\sigma} \varphi_0$ (kyr ⁻¹)	Wavelength dependent decay constant	Calibration with known age sample[1]
μ (mm ⁻¹)	Attenuation Coefficient of Rock	
ε (mm. kyr ⁻¹)	Rock surface Erosion Rates	Inverse Modelling

3) Inverse Modelling

$$\chi^2 = \sum_{i=1}^l \frac{(\bar{n}_{obs}^{(i)} - \bar{n}_{sim}^{(i)})^2}{\sigma^2}$$



Likelihood calculation and normalisation
 $likelihood = P = e^{-\chi^2/2}$



Monte Carlo Sampling to derive mean, median and $\pm 1\sigma$
 $P_{norm}^k > R$

4) CoRSEER Modules

CoRSEER-I: Calibration
Input: LDPs with known independent age
Output: Estimate Calibration parameters $\bar{\sigma} \varphi_0$ and μ



CoRSEER-II: Apparent Age
Input: LDPs with unknown-age surface
Output: Estimate apparent age t_{app} and chronometric limit t_{max} (no-erosion forward modelling)

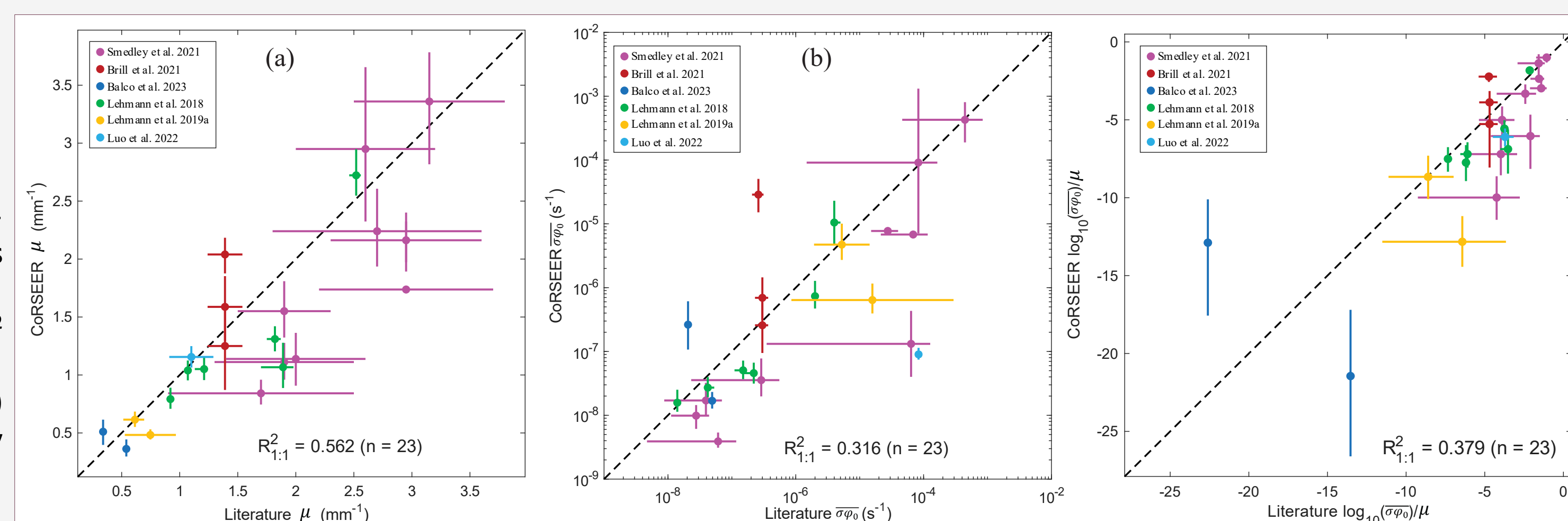


CoRSEER-III: Erosion Rate
Input: LDP + Independent age or t_{max}
Output: Estimate steady-state erosion rate ε_{ss} and onset time t_{ss}

D. Key Quantitative Findings

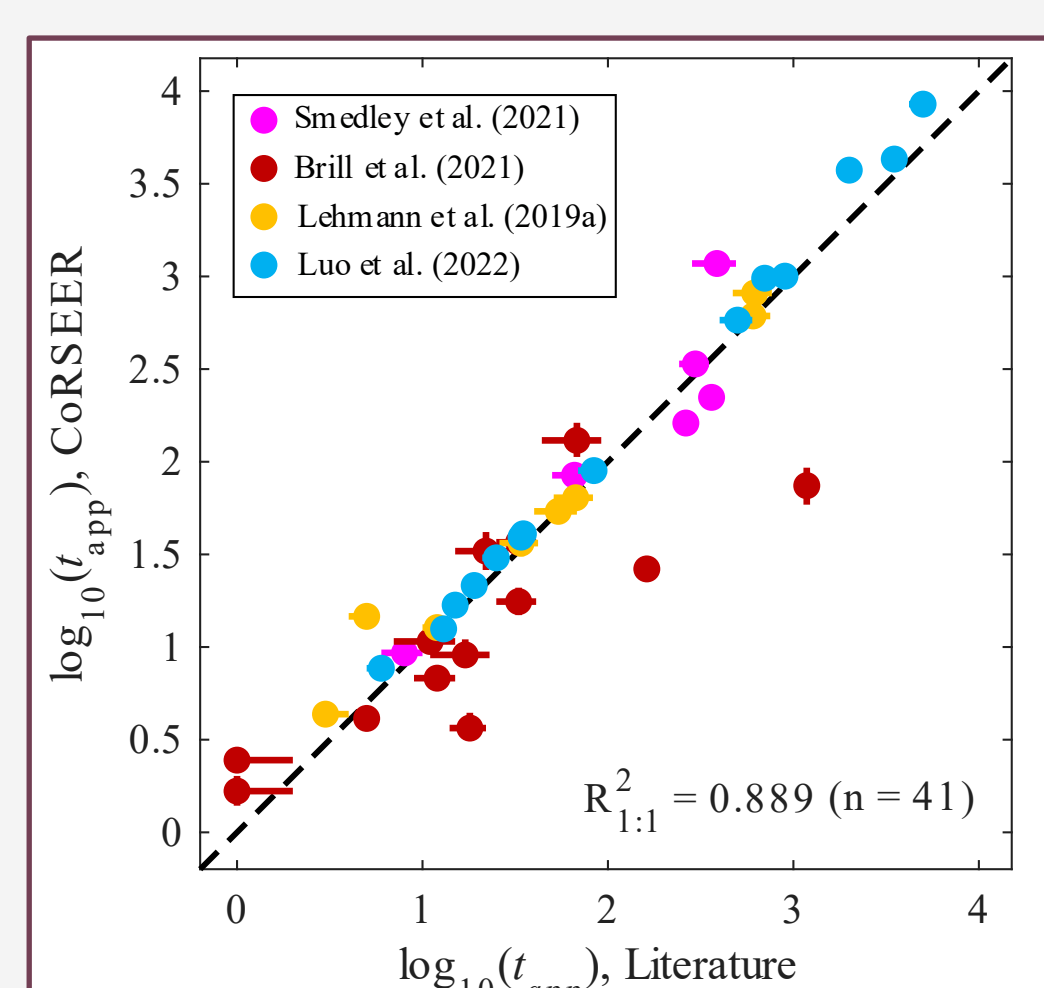
1) Calibration Performance

- ROAD02 test case (SCF normalisation):
 - $a = 1.085 \sim 8.5\%$ under-normalisation
 - $\pm 1\sigma$ range for $\bar{\sigma} \varphi_0$ is reduced from $1.27 \times 10^{-4} - 3.50 \times 10^{-7} \text{ s}^{-1}$ to $6.39 \times 10^{-8} - 3.11 \times 10^{-7} \text{ s}^{-1}$, and μ is reduced from 1.4 – 2.6 to 1.00 to 1.31 mm⁻¹
 - CoRSEER-I improved fit from $R^2 = 0.868$ TO $R^2 = 0.928$
- Across 23 Calibration samples (1:1 comparisons) The calibration parameters how offset mainly from normalisation and fitting strategy.
- Strong covariance between $\bar{\sigma} \varphi_0$ and μ



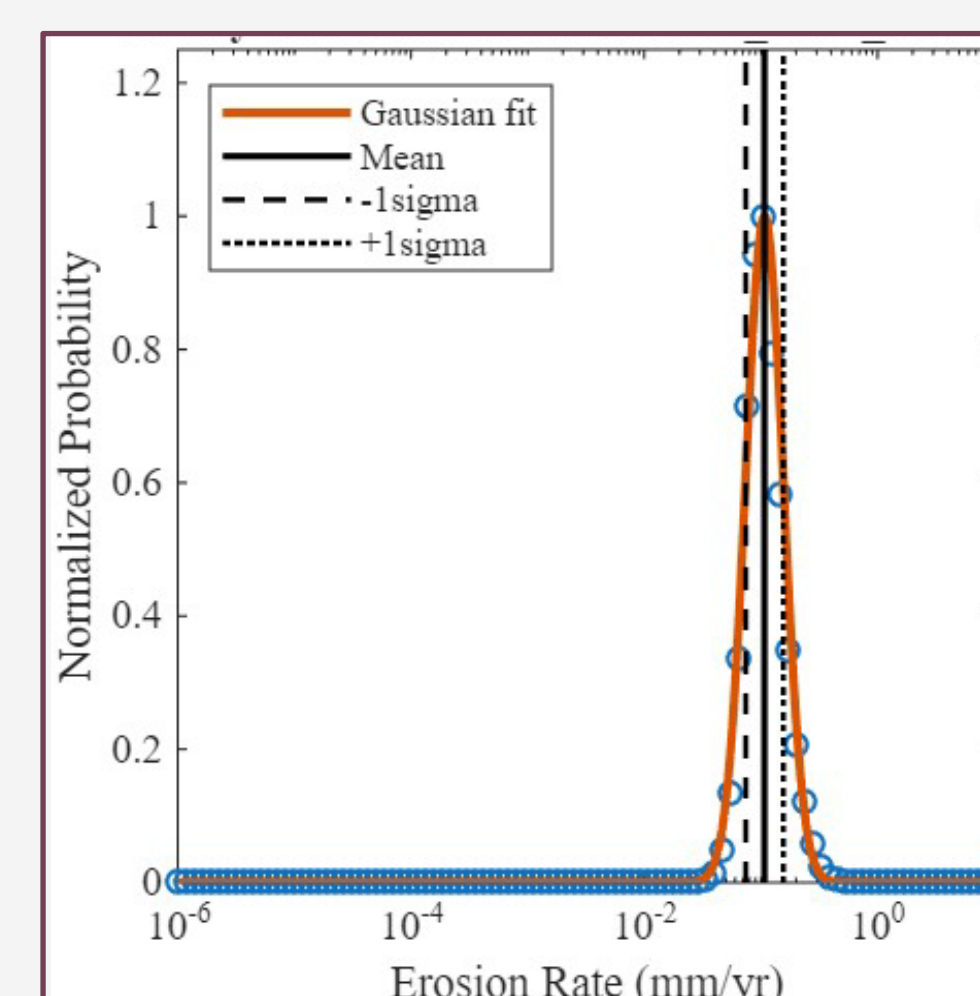
2) Apparent Exposure Ages

- For sample IR50_BALL02
 - CoRSEER-II: $t_{app} = 9 \pm 1 \text{ a}$ while literature: $9 \pm 1 \text{ a}$
 - Independent age of the boulder: $4.52 \pm 0.27 \text{ ka}$
 - No-erosion chronometric limit: $t_{max} \sim 52 \text{ ka}$
 - Since $t_{app} \ll$ independent age – erosion indicated.
- Across 41 samples (1:1 comparison with literature): $R^2 = 0.889$
- Predicted t_{app} span: 1a to 8.5ka.



3) Erosion-rate estimation

- For IR50_BALL02 (steady-state erosion case):
 - CoRSEER-III: ε_{ss} as $0.107^{+0.048}_{-0.033} \text{ mm/a}$ and t_{ss} as 38 a while literature estimate as 0.066 mm/a and 73 a
- Across 11 steady state case very mild insignificant offset between CoRSEER derived and literature erosion rates.
- Onset time differ strongly in few cases.
- CoRSEER introduces erosion rate error estimation algorithm using Gaussian distribution.



E. Process Contribution

- Objective Sigmoidal-curve-fit (SCF) normalisation
- Standardised inversion framework improves reproducibility while preserving physical interpretability
- Apparent ages remain robust even when calibrated $\bar{\sigma} \varphi_0$ and μ differ from literature values.
- Calibration offset mainly arise from normalisation and fitting strategies, with some covariance between $\bar{\sigma} \varphi_0$ and μ .

F. Limitation & Uncertainty

- Performance depends strongly on Lx/Tx data quality and Scatter.
- Dense sampling recommended; >50% of points should lie before the final plateau.
- Older calibration surfaces may already be affected by erosion
- Current release solves only single calibration sample.
- Transient-state erosion solutions remain mathematically difficult and partly user-guided.

G. Takeaway

- CoRSEER provides a reproducible, open-source end-to-end workflow for LRSED.
- It enables more consistent decadal-to-millennial exposure-age reconstructions and quantitative steady-state erosion-rate estimation with uncertainty.
- CoRSEER advances transparency and reproducibility in luminescence rock surface exposure dating.