Paraglacial drivers of rockfall in the high mountains of the Pyrenees

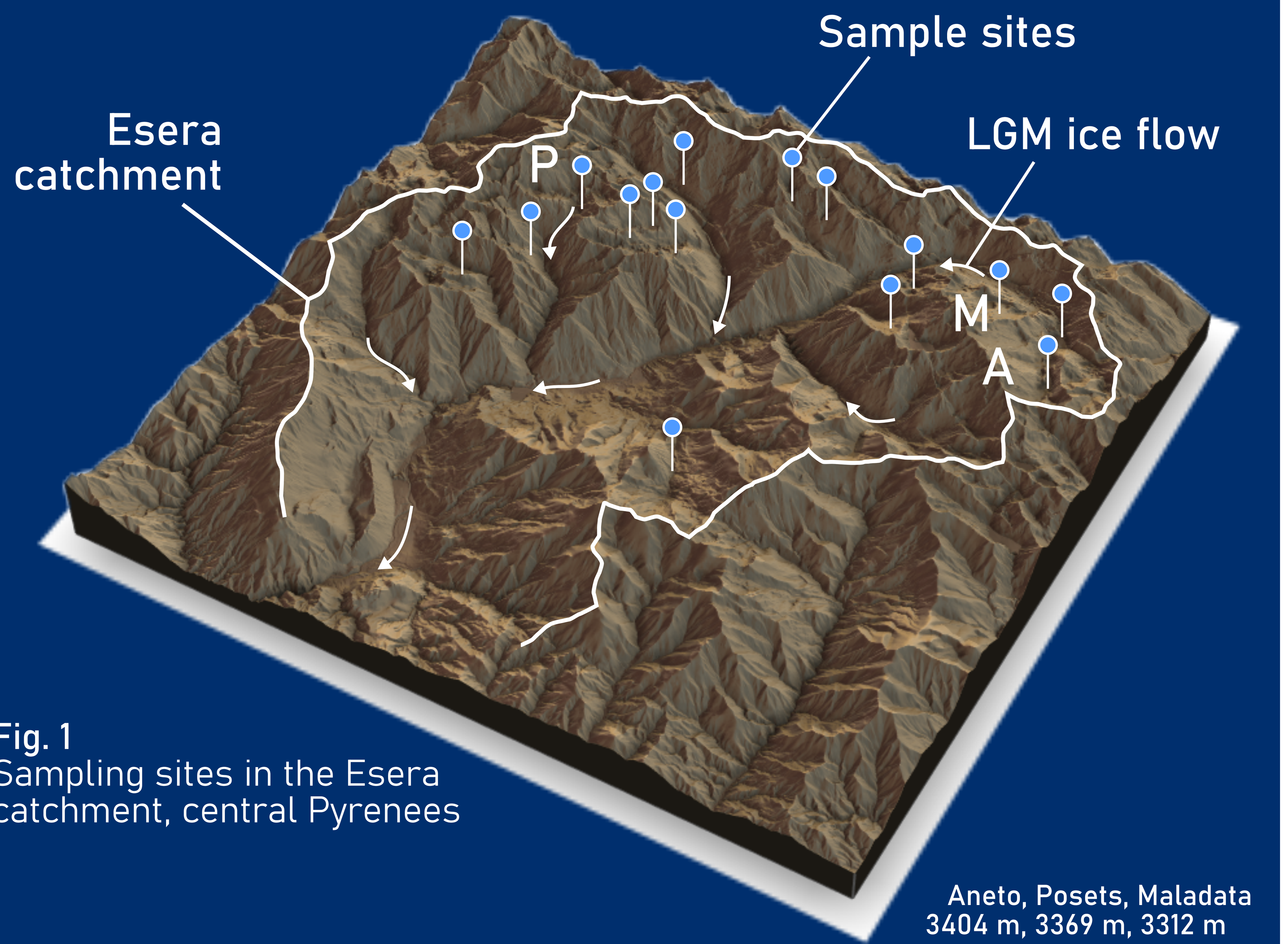

Fig. 1
Sampling sites in the Esera catchment, central Pyrenees

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A Context

- Understanding the mechanisms and drivers of rockfall and bedrock landsliding is critical to our understanding of their role in the evolution of mountainous topography.
- However, long-term records of rockfall activity are rare, in part due to the costs of terrestrial cosmogenic nuclide dating, and are typically focused on high-magnitude, low-frequency events (e.g. Dortch et al., 2009).
- We investigated rockfall activity in the Esera catchment, central Pyrenees, and in sub-catchments of the Maladeta-Posets massifs. The Esera was extensively glaciated during the Last Glacial Maximum but is now on the verge of total deglaciation (Chueca et al. 2007).
- Rockfall boulders were dated using Schmidt hammer exposure dating (SHED; Tomkins et al., 2018a); a cost- and time-effective technique which allows surface exposure ages to be estimated based on the degree of rock surface weathering.

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B Approach

- Mapped rockfall deposits from sites with varying deglacial ages, ranging from the Last Glacial Maximum to the early Holocene (Fig. 1), and calculated their extents and volumes.
- Sampled 945 granitic rockfall boulders using the Schmidt hammer and calculated calibrated exposure ages using a ^{10}Be-SH calibration curve (Tomkins et al., 2018b).
- Analysed the distribution of calibrated exposure ages using a Monte Carlo style approach (Fig. 2; P-CAAT; Dortch et al., in prep) to isolate component normal distributions from a cumulative probability density estimate (PDE).

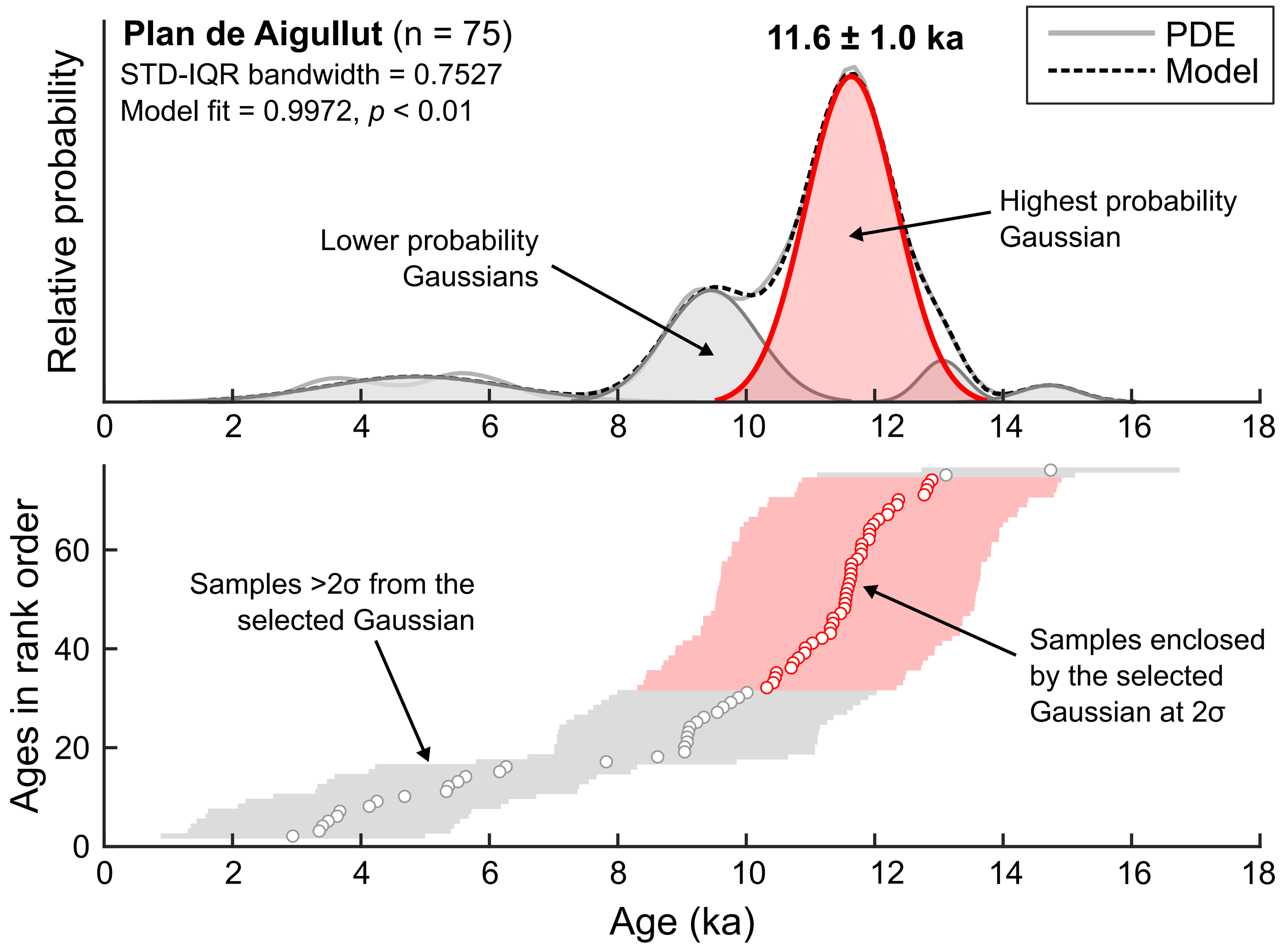

Fig. 2 Example of P-CAAT analysis of dated rockfall boulders

C Results

- Most rockfall occurred at sites deglaciated during the Late-glacial period (Fig. 3), with peak volume recorded in the first few thousand years following deglaciation (13 - 15 ka).
- No clear pulse in rockfall activity associated with Younger Dryas deglaciation.
- Low rockfall volumes after the LGM (≥ 20 ka) likely reflects a sampling bias due to the spatial distribution of lithologies suitable for SHED (granites).
- Sustained rockfall activity throughout the Holocene likely accounted for by permafrost degradation, seismicity or thermal stressing.

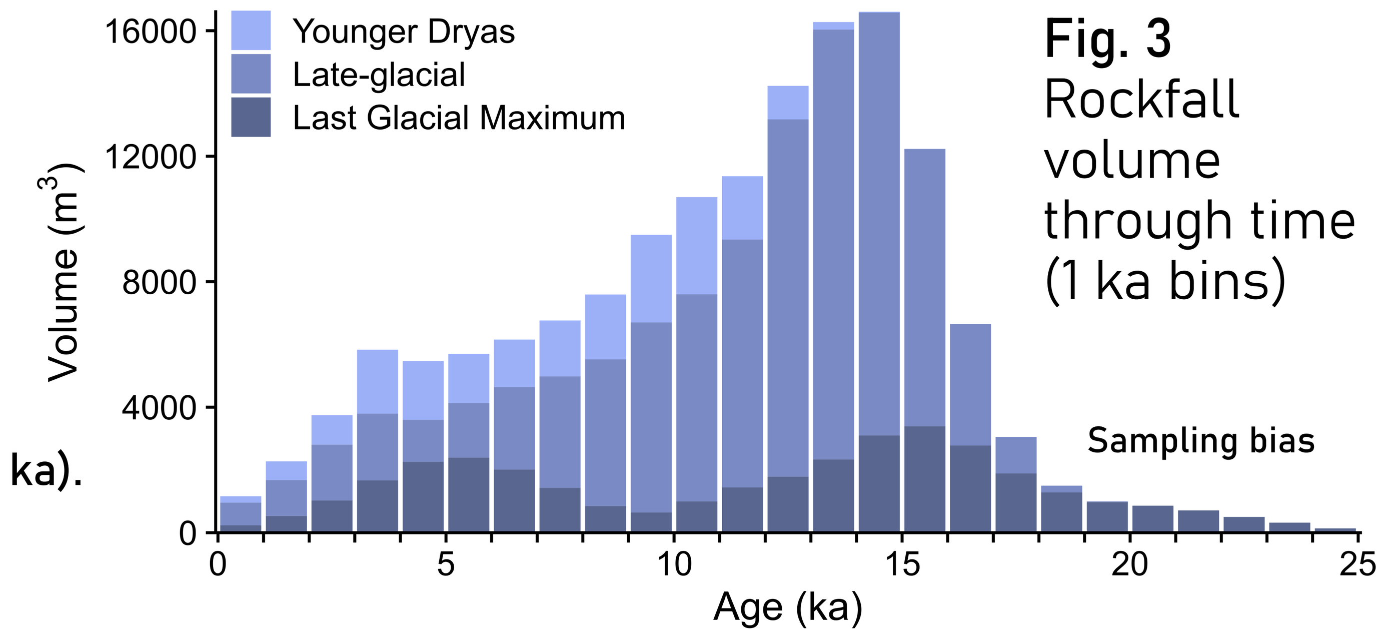

Fig. 3 Rockfall volume through time (1 ka bins)

- The highest probability component Gaussian is correlated with the site deglaciation age in many cases (Fig. 4), indicative of a paraglacial response.
- However, while some site deglaciation ages are constrained by independent dating evidence (e.g. Plan de Aigullut; Crest et al., 2017), most are morpho-stratigraphic, which may account for apparent lags in the paraglacial response (e.g. Molseret).

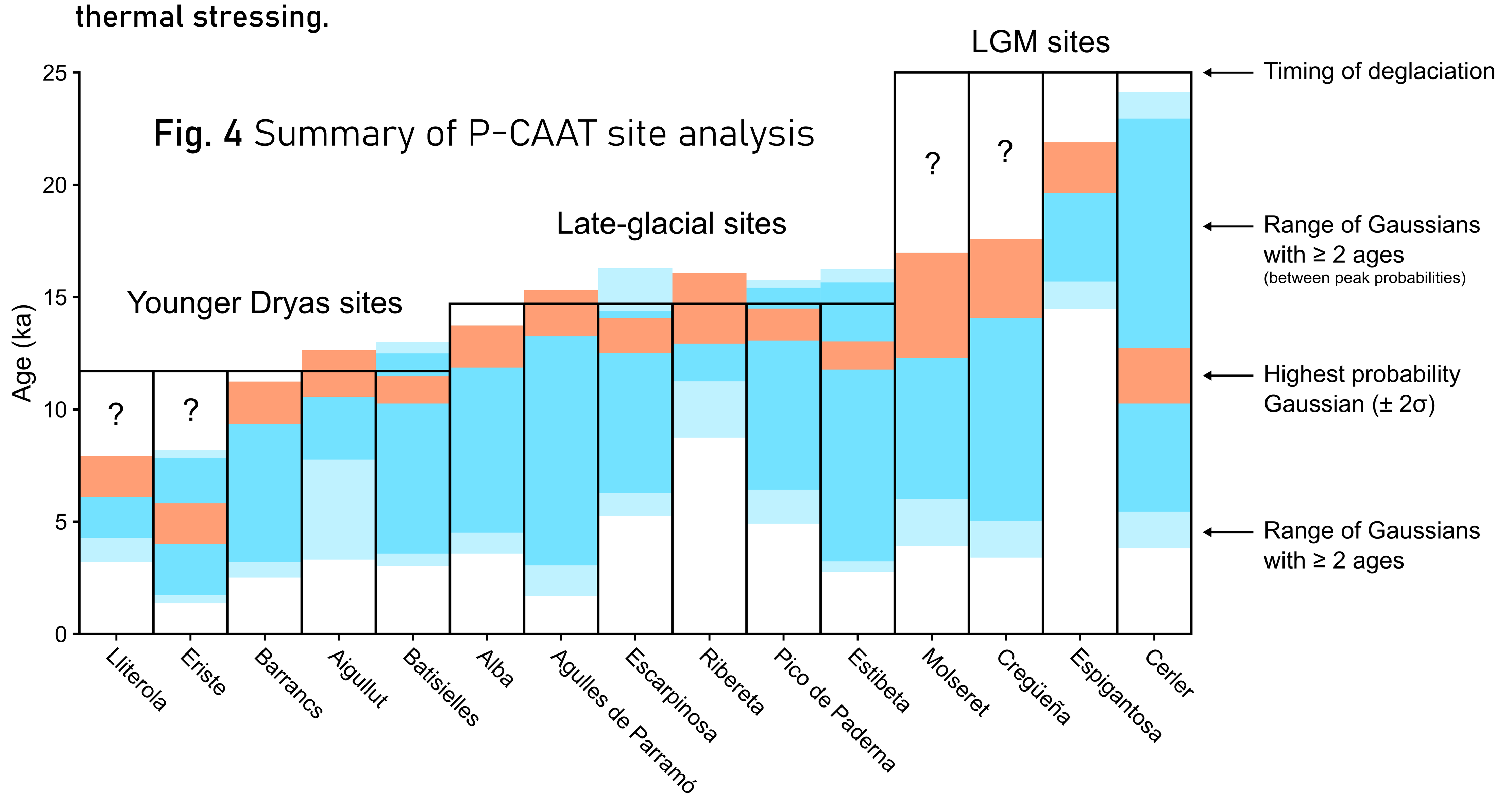

Fig. 4 Summary of P-CAAT site analysis

D Conclusions

Many rockfall deposits are primarily paraglacial in origin. → Paraglacial effects most pronounced during the Late-glacial → Most cliffs are still geomorphically active, with evidence of contemporary rockfall

References

Chueca et al. 2007. Journal of Glaciology 53(183), 547-557; Crest et al. 2017. Geomorphology 278, 60-77; Dortch et al. 2013. Quaternary Science Review 28, 1037-1054; Tomkins et al. 2018a. Quaternary Geochronology 44, 55-62; Tomkins et al. 2018b. Quaternary Research 90(1), 26-37