Temporal shifts in erosion provenance through multiple earthquake cycles

Jin Wang[1,2,] Jamie D. Howarth[3], Erin L. McClymont[2], Alexander L. Densmore[2],
Sean J. Fitzsimons[4], Thomas Croissant[2], Darren R. Gröcke[2], Martin D. West[2],
Erin L. Harvey[2], Nicole V. Frith[2], Mark H. Garnett[5], Robert G. Hilton[2]

1 Institute of Earth Environment, Chinese Academy of Sciences, Xi'an, China 2 Durham University, Durham, UK
3 Victoria University of Wellington, Wellington, New Zealand 4 University of Otago, Dunedin, New Zealand
5 NERC Radiocarbon Facility, , Glasgow, UK

Email：wangjin09@ieecas.cn

EGU2020-9817

1. Landsliding impacts on landscape evolution in active mountain belts

The steep topography of active mountain belts emerges from the interplay between tectonic uplift, river incision and bedrock landsliding. Widespread triggering of landslides by large storms or earthquakes is a dominant mechanism of erosion in mountain landscapes[1-3]. If landslides occur repeatedly in particular parts of a mountain range, then they will dominate the landscape evolution of that section and could leave a fingerprint in the topography. Despite this recognition, it has proved difficult toexamine shifts in the focus of landslide erosion through time, mainly because remote sensing approaches from single events to a few decades at most[1,3,4]. Here we turn to the depositional record of past erosion, attempting to track landslide occurrence and the provenance of eroded material using a novel combination of the isotopic and molecular composition of organic matter (bulk C and N isotopes, molecular abundance and isotopic composition) deposited in Lake Paringa, fed by catchments proximal to the Alpine Fault, New Zealand.

2. Study area and meterials

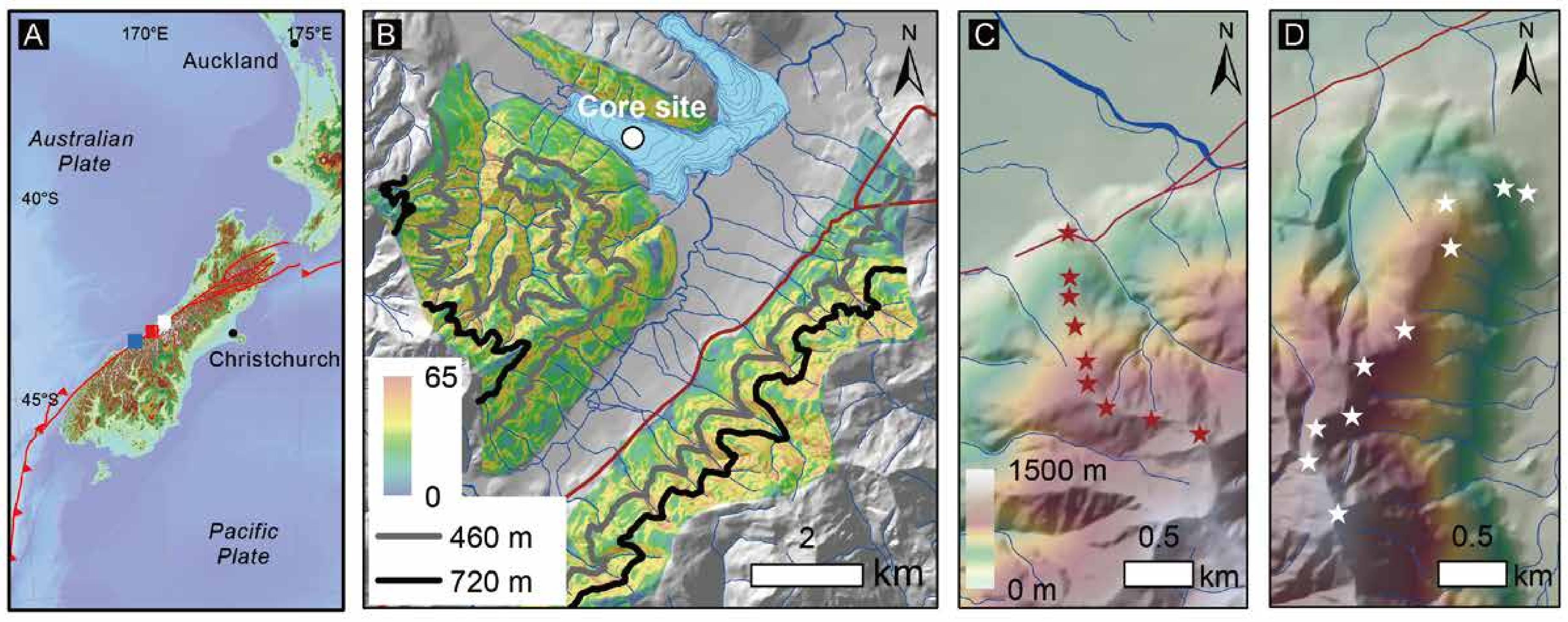

Fig.1 The study setting and topography of the Lake Paringa catchment and soil sample elevation transects

- ► A 6-metre sediment core (PA6m1) collected from Lake Paringa records four $M_w > 7.6$ earthquakes over the last ~1000 years[5].
- ► Soils collected along two elevation transects on western flank of the Southern Alps - Mount Fox trail and Alex Knob track.

3. An empirical model of organic matter provenance

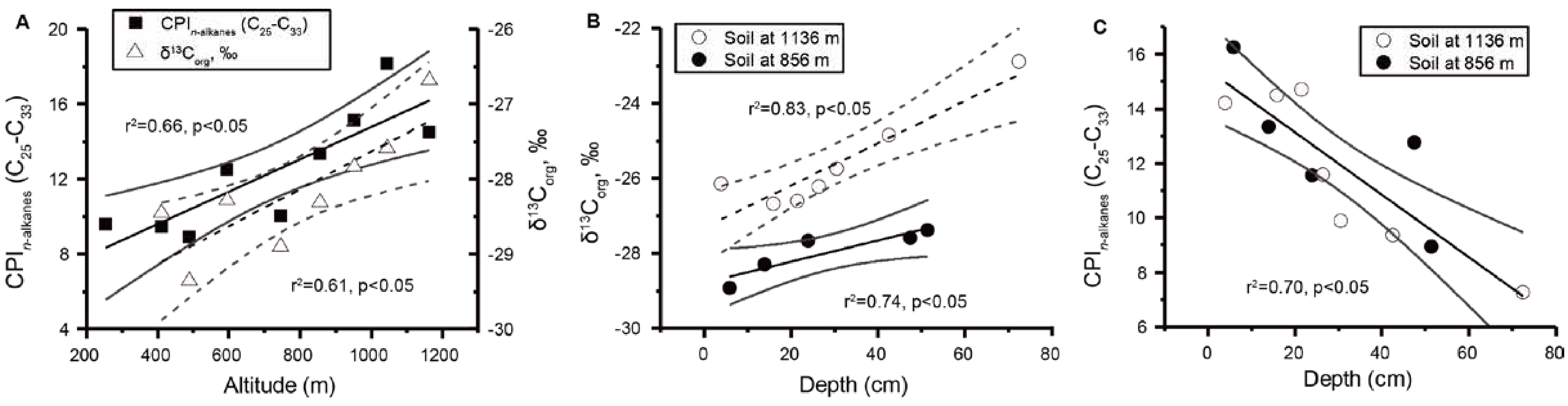

Fig.2 The relationship between $\delta^{13}C_{org}$ and $CPI_{n\text{-alkanes}}$ of organic matter in soils from Mount Fox as a function of elevation and soil depth

- ► At Mount Fox, the $\delta^{13}C_{org}$ values of soil A horizons are positively correlated with sample elevation; $\delta^{13}C_{org}$ is also positively correlated with the sampling depth of soil organic matter.
- ► The Carbon Preference Index, CPI, of the long-chain *n*-alkanes, of soil A horizons are positively correlated with the sample elevation; $CPI_{n\text{-alkanes}}$ of two soil profiles show a negative correlation with soil depth.
- ► An empirical model to predict elevation (Z) and depth (H) from paired $\delta^{13}C_{org}$ and $CPI_{n\text{-alkane}}$ values in the lake core:

$$\delta^{13}C_{org} = 3.9\pm0.8 \times 10^{-3} \cdot Z + 4.3\pm1.2 \times 10^{-2} \cdot H - 31.9\pm0.8 \quad r^2 = 0.75,\ p < 0.01$$

$$CPI_{n\text{-alkane}} = 5.3\pm2.1 \times 10^{-3} \cdot Z - 0.1\pm0.03 \cdot H + 9.8\pm1.8 \quad r^2 = 0.34,\ p < 0.01$$

4. Modelled elevation and depth of erosion for core PA6m1

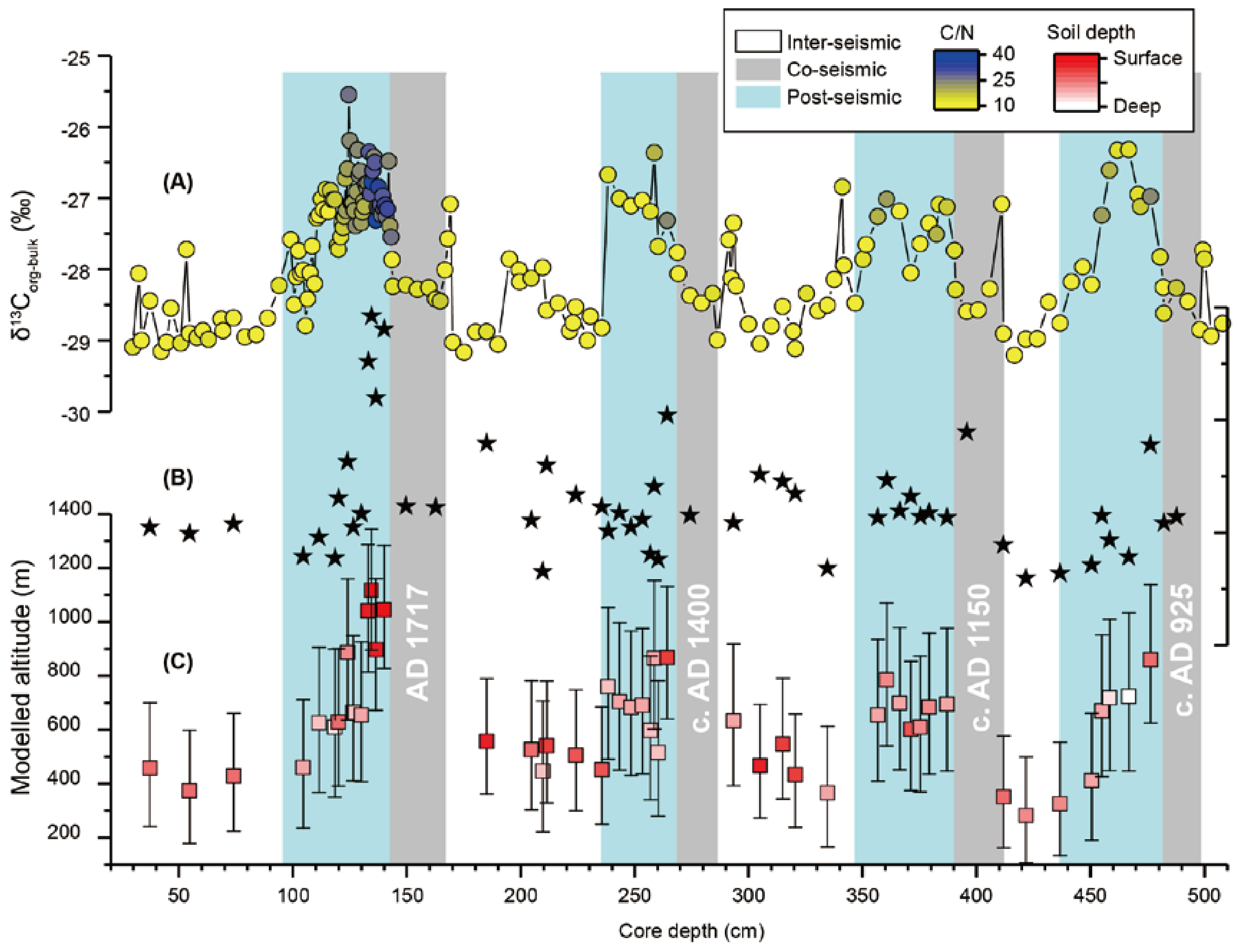

Fig.3 Geochemical analysis and modelled elevation and depth for core PA6m1

- ► Using the two equations, we predict the source elevation and soil profile depth of organic matter deposited in the lake sediment over four seismic cycles.
- ► The modelled elevation of erosion ranges from 283 ($^{+217}/_{-176}$) m to 1118 ($^{+225}/_{-222}$) m, while the depth ranges from 18 ($^{+18}/_{-12}$) cm to 63 ($^{+24}/_{-20}$) cm.

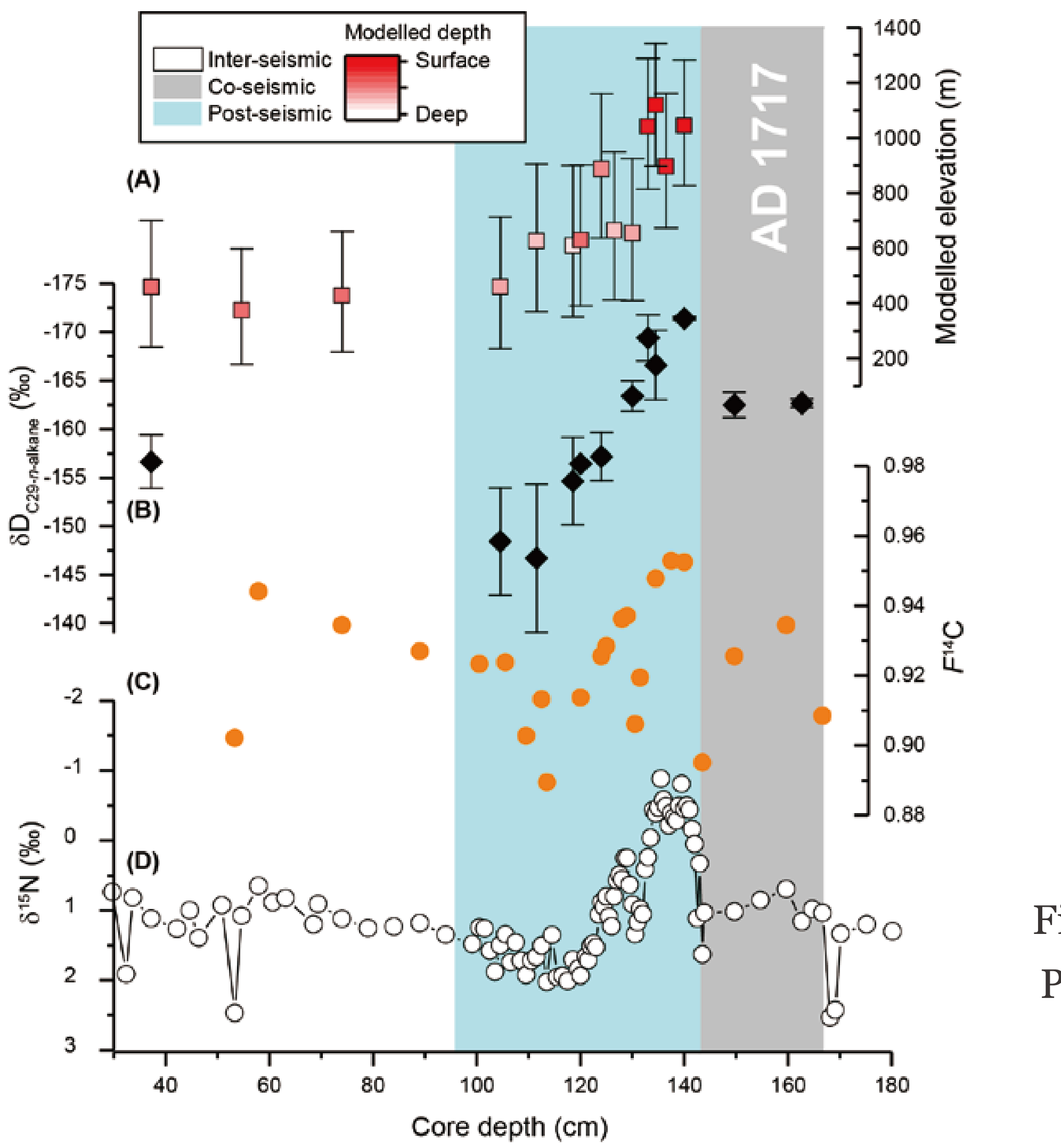

Fig.4 The evolution of predicted erosion provenance in Lake Paringa during the AD 1717 earthquake phase

- ► The modelled pattern of sediment mobilization following the AD 1717 earthquake is supported by the change in $\delta D_{C29\text{-}n\text{-alkane}}$ values, radiocarbon and nitrogen isotopes.

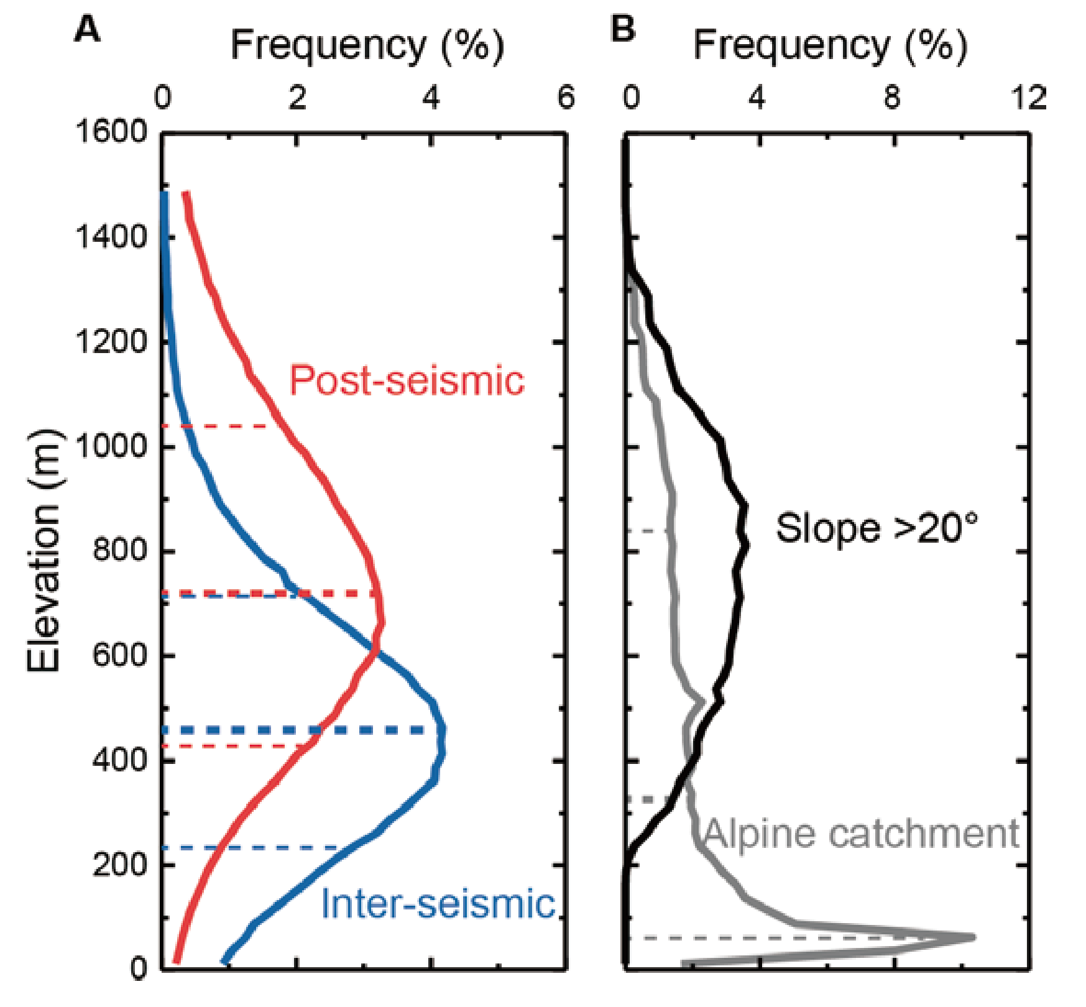

Fig.5 The elevation source of organic matter in Lake Paringa during the inter- and post-seismic periods.

- ► 43% of sediment flux from an average elevation of 722 ($^{+329}/_{-293}$) m during post-seismic phases, compared to 57% of the sediment flux from 459 ($^{+256}/_{-226}$) m during inter-seismic phases.

5. Conclusions and implications

- ► Our result suggests enhanced delivery of material eroded from high elevations following large earthquakes.
- ► Our results suggest that over the long-term, earthquakes can be the dominant process driving landsliding at drainage divide elevations, in consistence with the greater local relief as well as steeper channel profiles and hillslopes of west-flowing catchments .
- ► We find no significant difference in the predicted erosion depth of organic matter between the post- and inter-seismic phases of deposition.
- ► The mixture of surficial and deeper soil organic matter sources in both post-seismic and inter-seismic phases supports landsliding as the primary mechanism of erosion on hillslopes in the catchment.
- ► Our observations provide a test of the hypothesis that landslide trigger mechanisms influence the long-term spatial pattern of erosion on hillslopes in mountain belts[6].
- ► Over the long-term, earthquakes can be the dominant process driving landsliding at drainage divide elevations.

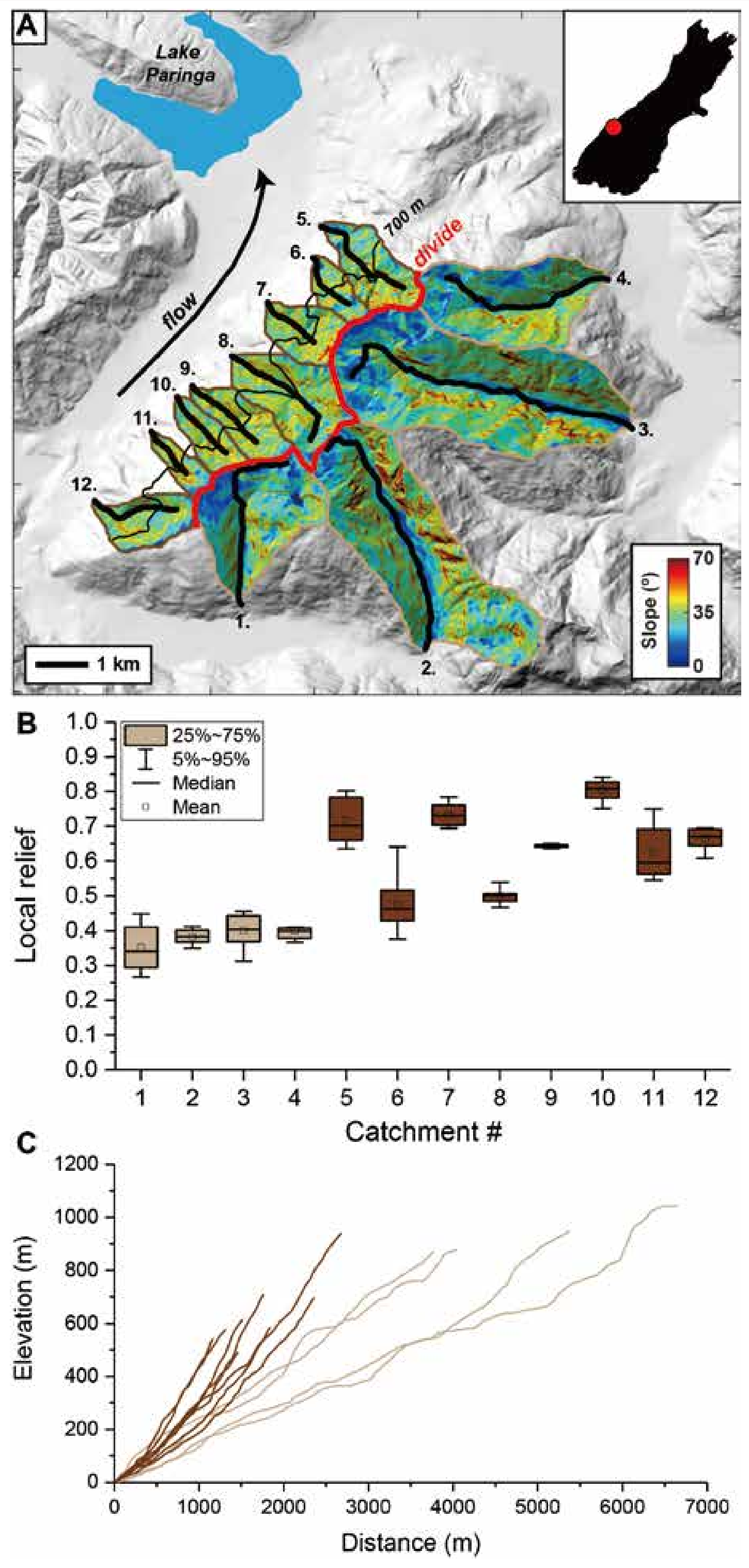

Fig.6 Topographic metrics for the Southern Alps range front that drains into the Windbag basin of Lake Paringa.

References and acknowledgment:

1. I. J. Larsen, D. R. Montgomery, Nat. Geosci. 5, 468-473 (2012).
2. D. L. Egholm, et al., Nature 498, 475-478 (2013).
3. N. Hovius, et al., Geology 25, 231-234 (1997).
4. C. Restrepo, N. Alvarez, Biotropica 38, 446-457 (2006).
5. N. V. Frith, et al., Nat. Geosci. 11, 772-776 (2018).
6. A. L. Densmore, N. Hovius, Geology 28, 371-374 (2000).

This work was funded by COFUND Junior Research Fellowship at Durham University and National Natural Science Foundation of China to J.W. and C, Natural Environment Research Council Standard Grant to R.G.H., A.L.D., E.L.M. and J.D.H. (NE/P013538/1), Rutherford Foundation Postdoctoral Fellowship to J.D.H. (RFTGNS1201-PD). The soil radiocarbon analysis was supported by NERC radiocarbon analysis allocation number 2170.1118. Samples were collected under Department of Conservation research licence. We thank for G. Soulet and A. Woolley for the field support and Dr. M. Sánchez Montes, E. Maddison, K. Melvin and A. George for laboratory support.