Supplement 1: Overview of CRN methods and analysis for the Toro fans.

Boulder and depth profile sampling

Quartzite boulder samples were collected using a hammer and chisel. We reexcavated the depth profile pit that we resampled and carefully extracted pebble samples using a shovel, trowel, and chisel. The location of each sample was recorded using a handheld Garmin GPS unit (Table 1, Supplement 2). Samples were weighed and photographed in the field and laboratory (Supplement 3).

Sample preparation for CRN analysis

Sample were prepared for AMS measurement at the German Research Centre for Geosciences (GFZ-Potsdam) using the laboratory procedures outlined by Nishiizumi et al. (1989), von Blanckenburg, (2004) and Wittmann et al. (2016). Samples were crushed using a jaw crusher and disk mill and were then sieved using a sieve shaker. More than 50 g of the desired grainsize fraction was available for each sample (250–500 μm for boulder samples, 500–100 μm for pebble samples) (Supplement 2). Magnetic separation using a Franz Laboratory Separator was not necessary for these quartzite samples as the magnetic fraction was negligible.

Due to the abundance of quartz in each sample, only 30g of the reserved grainsize fraction was submitted for cleaning. All samples were subject to the same cleaning procedure. Organic and carbonate products were removed from the samples by heating them in a 9% HCl solution (HCl, H_2O_2) in an ultrasonic bath for 12 hours. Samples were then rinsed thoroughly before being subject to a 12-hour 2% HF (HF, HNO_3) leach in an ultrasonic bath. This procedural step dissolves any non-quartz minerals and removes meteoric ^{10}Be. Sample purity was confirmed using an ICP-OES. Clean quartz was achieved for all samples after three rounds of the 2% HF leach. A mean of 10 g of quartz per sample was subject to a final cleaning phase; one 7M HF leach (1 hour at 120°C) and Aqua Regia (14.4M HNO_3, 12M HCl) (1 hour at 120°C).

Extraction of ^{10}Be and AMS measurement

The Toro samples were processed in four batches of up to 8 samples, with at least one procedural blank per batch. 150 μg of ^{9}Be carrier was added to each sample before quartz digestion. Be-10 was isolated via column chemistry and was then oxidised. The sample targets were prepared for AMS measurement using an $AgNO_3$ matrix. Further details of the laboratory procedure are provided in von Blanckenburg et al. (2004) and Wittmann et al. (2016).

The CologneAMS facility at the University of Cologne conducted the AMS measurements. $^{10}Be/^{9}Be$ ratios were normalised to standards KN01-6-2 ($5.35x10^{-13}$) and KN01-5-3 ($6.320x10^{-12}$). Procedural blanks were subtracted from the sample ratios. When more than one blank was run per batch, a mean and standard deviation of the blanks was used. Supplement 2 summarises the AMS results.

Boulder exposure age calculation

Boulder exposure ages were calculated using the CREp online calculator (Martin et al., 2017). Corrections were made for sample thickness and topographic shielding. Shielding was measured using an inclinometer; we measured the angle from the boulder surface to the horizon at 10° increments. The basin's climate and our careful sampling strategy meant that corrections for snow cover and boulder erosion were not necessary (Schildgen et al., 2005, 2016; Tofelde et al., 2017).

The exposure ages were calculated using the LSD scaling scheme (Lifton et al., 2014), the ERA40 Atmosphere Model (Uppala et al., 2005), the LSD framework for geomagnetic correction (Lifton et al., 2014) and the reference (SLHL) production rate of 3.74 (±0.09) at g^{-1} yr^{-1} (Martin et al., 2015). Supplement 2 provides a copy of the CREp calculator input.

CRN depth profile

The Qf_1 CRN depth profile and exposure age were determined using the Hidy et al. (2010) Monte Carlo simulator with the ^{10}Be data from this study and the original profile (Tofelde et al., 2017). Building upon the approach of Tofelde et al. (2017), the model was set up with a sample density of 1.6 to 1.8 g cm^{-3}, a topographic shielding of 0.99, a neutron attenuation length of 160±5 g cm^{-2}, and a depth of muon fit of 5 m. The time-independent Lal/Stone scaling scheme (*St*) (Lal, 1991; Stone, 2000) and the reference production rate of 3.74 (±0.09) at/g yr (Martin et al., 2015) was used. The site-specific production rate was 30.36 at/g yr. The Monte Carlo parameters were a chi-squared value of 60 and 100,000 fitted curves per run. The erosion rate (cm/ka) was set to range between -0.2–0.2 and the total erosion threshold (cm) was set to -10–50. These negative values for erosion simulate inflation (Hidy et al., 2010).

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