The depositional flux of meteoric ^{10}Be derived from combined in situ and meteoric ^{10}Be analyses along a climate gradient (Chile)

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2. Citation

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3. Data Description

This dataset contains Beryllium isotope data, pH measurements, and calculations of surface process rates (denudation, weathering, erosion) from soil and drill core samples from the Coastal Cordillera, Chile. All drilling and soil sampling campaigns were conducted in the framework of the "EarthShape" project (DFG SPP1803). The drilling procedure and sampling strategy are described in (Krone et al., 2021a).

We measured the concentration of *in situ* ^{10}Be in quartz samples from soil samples and calculated denudation rates thereof. Furthermore, we applied a sequential extraction to analyse meteoric ^{10}Be and reactive ^{9}Be; we also measured residual ^{9}Be and parent bedrock ^{9}Be concentrations. Using the concentration of meteoric ^{10}Be, we calculated the inventory assuming exponential decrease with depth and calculated the depositional flux using the *in situ* ^{10}Be denudation rate and the ^{10}Be(meteoric)/^{9}Be isotope ratio. The detailed methods are given below.

3.1. In situ and meteoric ^{10}Be

For *in situ* ^{10}Be analyses, we collected additional soil samples below the respective soil mixing zone that was previously identified in the soil pits. For each soil pit ca. 3 kg sample material was cleaned, dried, and sieved. For quartz isolation, we used the grain-size fraction 0.25 – 1 mm and conducted standard physical and chemical separation methods. For ^{10}Be measurements, each sample was spiked with the same amount of ^{9}Be carrier for blank correction (blank ratio: 3.4 ± 0.8 x10^{-15}). After anion and cation column separation and alkaline precipitation of Be (von Blanckenburg et al., 2004), Be was oxidised and pressed into accelerator mass spectrometer (AMS) cathodes and measured at the AMS facility at the University of Cologne (Dewald et al., 2013). To determine denudation rates $D_{in\ situ}$, we used the CRONUS online exposure age calculator (Balco et al., 2008) using the time-dependent scaling scheme of Lal/Stone (St) (Lal, 1991; Stone, 2000) and a sea-level high latitude (SLHL) neutron spallation ^{10}Be production rate of 4.01 at g^{-1} yr^{-1} (Borchers et al., 2016). The denudation rate D_{insitu} (in g cm^{-2} yr^{-1}) can be calculated using equation 1 shown in a simplified form (Lal, 1991):

$$D_{in\ situ} = \left(\frac{P}{[^{10}Be]} - \lambda\right) \Lambda \qquad [1]$$

with the ^{10}Be nuclide concentration $[^{10}Be]$ (atoms g$_{(Quartz)}^{-1}$), the scaled ^{10}Be production rate P (atoms g$_{qtz}^{-1}$ yr^{-1}), λ as the decay constant of ^{10}Be (5 x10^{-7} yr^{-1}). Λ includes the e-folding absorption length for neutrons and muons, respectively.

For meteoric ^{10}Be analyses, we used ~1 g of powdered sample material (processed as described in (Wittmann et al., 2012); oven-dried for 72h at 60 °C) for sequential chemical extraction (Wittmann et al., 2012). We treated each sample with 0.5 M hydrochloric acid to extract amorphous oxyhydroxides (am-ox) followed by 1 M hydroxylamine-hydrochloride to extract crystalline oxyhydroxides (x-ox). After these steps, we decomposed the sample residue (min) with a combination of hydrofluoric acid and aqua regia; for organic-rich samples we also used hydrogen peroxide. Following matrix decomposition, we split the am-ox and x-ox fractions for ^{10}Be and ^{9}Be measurements. We measured ^{9}Be in the distinct am-ox, x-ox, and min fractions by Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES) and combined the measured concentrations to the reactive phase (reac) afterwards. For ^{10}Be measurements, the splits were combined to reac and processed the same way as described for *in situ* ^{10}Be measurements. For blank correction, we used a pooled blank from all (^{10}Be/^{9}Be) measurements of 6.5 ± 5.7 x10^{-15} (n=11).

3.2. pH measurements

The pH of all samples was determined following the procedure described in Uhlig and von Blanckenburg (2019). Approximately 1 g of sample material (oven-dried at 60°C, 24h) was used to measure pH in a suspension of the sample powder and 0.01 M $CaCl^2$. pH was measured with a WTW pH meter and Merck buffer solutions for calibration. We measured a reference material (IRMM-443-7, Cambisol, BCR/IRMM) and the pH 4 buffer solution every 10 samples to ensure stability, accuracy, and reproducibility. The relative uncertainty of the reference material measurements is 4%.

3.3. Data processing

All equations used to derive metrics from measured data are contained in the corresponding paper Krone et al. (2024). The *in situ* ^{10}Be rates in Table S1 were calculated using the CRONUS online exposure age calculator (Balco et al., 2008) according to equation 1. The chemical weathering rate W is calculated using equation 5. The physical erosion rate E results from the subtraction $E = D - W$ (equation 6). The meteoric ^{10}Be denudation and weathering rates in Table S3 were calculated using equation 2; f_{reac}+f_{diss} was calculated according to equation 3.

4. File description

4.1. File inventory

The data is provided as a single file with 6 different tables in tabular form. Each table contains the sample name, depth below surface, IGSN, and the measured or calculated parameters. For each parameter, the unit is given in the heading.

4.2. File naming convention

The tables in the file are named:

2024-021_Krone-et-al_S1-In-situ-surface: In situ ^{10}Be: Sampling site properties, in situ Beryllium-10 concentration, calculated denudation, chemical weathering, and physical erosion rates.

2024-021_Krone-et-al_S2_9Be-parent: Bedrock^{9}Be-concentrations ($^{9}Be_{parent}$).

2024-021_Krone-et-al_S3_Meteoric-surface: Meteoric ^{10}Be: Sampling site properties, meteoric Beryllium-10, stable Beryllium-9, and calculated denudation, chemical weathering, and physical erosion rates for surface samples.

2024-021_Krone-et-al_S4_Meteoric-depth-profile: Meteoric ^{10}Be: Sampling site properties, meteoric Beryllium-10, stable Beryllium-9 (reactive phase, mineral-bound phase, parent) for depth profiles.

2024-021_Krone-et-al_S5_Depositional-flux-calc: Meteoric ^{10}Be depositional flux derived from GCM models and calculated using (^{10}Be/^{9}Be) and *in situ* ^{10}Be-derived denudation rate.

2024-021_Krone-et-al_S6_pH: pH measurements in soil, core and fracture samples.

4.3. Description of data tables

As the data is provided in a single file, the below description of the content refers to each table in the file.

2024-021_Krone-et-al_S1-In-situ-surface

Column header	unit	Description
Study site	-	Study site name and climate
Sample name	-	Sample Identifier
IGSN	-	Unique number to identify sample
Latitude	DD.dddd	Latitude in decimal degrees (WGS84)
Longitude	DD.dddd	Longitude in decimal degrees (WGS84)
altitude	m.a.s.l.	Height above sea level (in meter)
Sample depth	cm	Depth from where sample is taken below the surface
Density	g cm^{-3}	Sample density
Quartz mass	g	Mass taken for anaylsis
^{9}Be carrier mass	g	Mass of carrier taken for analysis and blank correction
($^{10}Be/^{9}Be$)	atoms $atoms^{-1}$	Measured isotope ratio of in situ ^{10}Be and stable ^{9}Be ± measurement uncertainty
$[^{10}Be]_{quartz}$	atoms g^{-1}	Measured concentration of in situ produced cosmogenic ^{10}Be ± measurement uncertainty
CDF	-	Chemical Depletion fraction: relative depletion of an immobile element (zirconium, niobium) compared to bedrock composition ± standard deviation (1SD)
Total denudation rate	t km^{-2} yr^{-1}	Mass removal from Earth's surface by chemical and physical processes ± calculated uncertainty
Chemical Weathering rate	t km^{-2} yr^{-1}	Mass removal by chemical weathering calculated with CDF ± calculated uncertainty
Physical Erosion rate	t km^{-2} yr^{-1}	Mass removal by physical erosion calculated with the total chemical weathering rate ± calculated uncertainty

2024-021_Krone-et-al_S2_9Be-parent

Column header	unit	Description
Study site	-	Study site name and climate
Sample name	-	Sample Identifier
IGSN	-	Unique number to identify sample
Depth	m	Sample depth below surface
[9Be]parent	µg g-1	Measured concentration of 9Be in parent bedrock ± measurement uncertainty
[9Be]parent	atoms g-1	Measured concentration of 9Be in parent bedrock ± standard deviation (1SD)

2024-021_Krone-et-al_S3_Meteoric-surface

Column header	unit	Description
Study site	-	Study site name and climate
Sample name	-	Sample Identifier
IGSN	-	Unique number to identify sample
Latitude	DD.dddd	Latitude in decimal degrees (WGS84)
Longitude	DD.dddd	Longitude in decimal degrees (WGS84)
Altitude	m.a.s.l.	Height above sea level (in meter)
Sample depth	cm	Depth from where sample is taken below the surface
Sample interval	cm	Length interval of analysed sample
$(^{10}Be/^{9}Be)$	atoms atoms^{-1}	Measured isotope ratio of meteoric ^{10}Be and stable ^{9}Be ± calculated uncertainty
$[^{10}Be]_{reac}$	atoms g^{-1}	Measured concentration of meteoric cosmogenic ^{10}Be ± measurement uncertainty
Inventory $[^{10}Be]_{reac}$	atoms cm^{-2}	Inventory of all meteoric ^{10}Be to a certain depth ± calculated uncertainty
$[^{9}Be]_{reac}$	atoms g^{-1}	Measured concentration of ^{9}Be in reactive phase ± measurement uncertainty
$[^{9}Be]_{min}$	atoms g^{-1}	Measured concentration of ^{9}Be in residual mineral-bound phase ± measurement uncertainty
^{9}Be $(f_{reac}+f_{diss})$	-	Fraction of ^{9}Be in reactive and dissolved phase as weathering indicator
$[^{9}Be]_{parent}$	atoms g^{-1}	Measured concentration of ^{9}Be in parent bedrock ± standard deviation (1SD)
Depositional flux ^{10}Be	atoms cm^{-2} yr^{-1}	Flux of meteoric ^{10}Be deposition to Earth's surface, derived from a coupled climate and Be production model ± calculated uncertainty
Total denudation rate	t km^{-2} yr^{-1}	Mass removal from Earth's surface by chemical and physical processes ± calculated uncertainty
Chemical Weathering rate	t km^{-2} yr^{-1}	Mass removal by chemical weathering calculated with CDF ± calculated uncertainty

2024-021_Krone-et-al_S4_Meteoric-depth-profile

Column header	unit	Description
Study site	-	Study site name and climate
Sample name	-	Sample Identifier
IGSN	-	Unique number to identify sample
Sample type	-	Description of sample type (soil or core)
Sample depth	m	Depth from where sample is taken below the surface
$(^{10}Be/^{9}Be)$	atoms atoms^{-1}	Measured isotope ratio of meteoric ^{10}Be and stable ^{9}Be ± calculated uncertainty
$[^{10}Be]_{reac}$	atoms g^{-1}	Measured concentration of meteoric cosmogenic ^{10}Be ± measurement uncertainty
$[^{9}Be]_{reac}$	atoms g^{-1}	Measured concentration of ^{9}Be in reactive phase ± measurement uncertainty
$[^{9}Be]_{min}$	atoms g^{-1}	Measured concentration of ^{9}Be in residual mineral-bound phase ± measurement uncertainty
$[^{9}Be]_{parent}$	atoms g^{-1}	Measured concentration of ^{9}Be in parent bedrock ± standard deviation (1SD)

2024-021_Krone-et-al_S5_Depositional-flux-calc

Column header	unit	Description
Study site	-	Study site name and climate
GCM-model flux	atoms cm^{-2} yr^{-1}	Flux of meteoric ^{10}Be deposition to Earth's surface, derived from a coupled climate and Be production model (Heikkilä and von Blanckenburg, 2015) ± difference between Holocene and pre-industrial model
Precipitation-derived flux	atoms cm^{-2} yr^{-1}	Flux of meteoric ^{10}Be deposition to Earth's surface, derived from an empirical equation from precipitation collections (Graly et al., 2011) ± calculated uncertainty
(^{10}Be/^{9}Be)-derived flux	atoms cm^{-2} yr^{-1}	Flux of meteoric ^{10}Be deposition to Earth's surface, derived from *in situ* ^{10}Be denudation rate, ^{10}Be(meteoric)/^{9}Be at the surface and ^{9}Be concentrations ± calculated uncertainty

2024-021_Krone-et-al_S6_pH

Column header	unit	Description
Study site	-	Study site name and climate
Sample name	-	Sample Identifier
Sample type	-	Description of sample type (soil or core)
IGSN	-	Unique number to identify sample
Sample depth	m	Depth from where sample is taken below the surface
1. pH	-	First pH measurement
2. pH	-	Second pH measurement
3. pH	-	Third pH measurement
mean pH	-	Average pH from all 3 measurements
2SD	-	Uncertainty of pH given as 2x standard deviation (SD)

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