Supplementary Material

Late Quaternary glacier advances in the Andes of Santiago, central Chile, and paleoclimatic implications

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Annex A - Optically-stimulated luminescence dating

Sediments targeted for optical dating are lenses and beds of well-sorted medium sands, reflecting infill of shallow channels by ripple bed accretion; lower energy sedimentary environments that enhance solar resetting (e.g. Schaetzl and Forman, 2008). Samples for optical dating were taken by hammering a 5-cm interior diameter and 10-15 cm length of copper tubing into profile walls. The outermost 1 cm of sediment inside the tube was removed, leaving an unlight-exposed sediment in the center of the tube for optical dating. Four Optical ages were determined by a multiple aliquot regenerative dose technique on the 425-500 μm and 150-100 μm quartz fractions (Jain et al, 2003). One OSL age was determined on quartz grains (150-100 μm by single aliquot regeneration (SAR) protocols (Wintle and Murray, 2006). The SAR protocols were selectively applied because of the paucity of quartz in these sediments, some quartz extracts lacked a dominant fast-component (Durcan and Duller, 2011); showed appreciable slow and medium components and often with low light levels (peak emissions of <1000 count/0.4 s). Noteworthy is that optical ages by these two different techniques overlap at one sigma errors and give added confidence in the resolved chronology.

Multiple-aliquot regeneration (MAR) procedures with component dose normalization (Jain et al., 2003) were used in this study to estimate the equivalent dose on coarse quartz fraction from sediments (**Table A1**). Initially, coarse grains (425-500 and 100-150 μm) were isolated by sieving, after organics and carbonate were removed with soaking in 30% H_2O_2 and in 11% HCl, respectively. The quartz fraction was isolated by density separations (2.62 and 2.55 g/cc) using the heavy liquid Na–polytungstate, and a 40-minute immersion in HF (40%) was applied to etch the outer ~10 μm of grains, which is affected by alpha radiation (Mejdahl and Christiansen, 1994). Quartz grains were rinsed finally in HCl (10%) to remove any insoluble fluorides. The purity of

quartz separate was evaluated by petrographic inspection and point counting of a representative aliquot. Samples that showed >1% of non-quartz minerals were retreated with HF and rechecked petrographically. Additional tests were performed on the spectral purity of quartz separates by exposing aliquots to infrared excitation (1.08 watts from a laser diode at 845 ± 4 nm), which preferentially excites feldspar minerals. Samples measured showed weak emissions (<200 counts/second), at or close to background counts with infrared excitation, and ratio of emissions from blue to infrared excitation of >20, indicating a spectrally pure quartz extract (Duller et al., 2003; Durcan and Duller, 2011).

The size of the quartz aliquot and number of grains measured can influence the resolved equivalent dose (e.g. Duller, 2008). The plate area for quartz grain was approximately a circular with a 2-mm diameter adhered to a 1-cm diameter aluminum disc. The maximum number of grains for in this plate area was approximately 20 and 400 for 455-500 μm and 150-100 μm. Approximately, 5-20% of quartz are luminescence, thus a maximum of 4 and 80 grains/disc for 455-500 μm and 150-100 μm were possibly luminescence (cf. Duller, 2008). This plate area (or grain number) was used because smaller masks were associated with low photon counts, <1000 counts/s for the natural and test dose at peak emission. Subsequent ages were only determined with peak emissions of >1000 photon counts/0.4s of the natural and lowest regenerative doses. Solar resetting of aliquots prior to MAR analysis was accomplished by 8 hr illumination from a 275W General Electric Mercury Vapor Sunlamp, removing any pre-existing electrons within accessible photosensitive traps while inducing minimal dose sensitivity changes (Richardson, 1994). Luminescence was measured using a Risø Model TL/luminescence-DA-15 System containing light emitting diodes capable of either infrared (875 ± 30) or blue (470 ± 20) excitation. The resulting luminescence passes through a Hoya U-340 filter (>10% transmission >380 nm) prior to detection within the system's Thorn-EMI 9235 QA photomultiplier tube.

To compensate for laboratory-induced sensitivity changes with the MAR approach, we used component specific normalization procedure (Jain et al., 2003; Waters et al. 2011). A normalization dose (~4 Gy β) was applied to all discs, either after the measurement of the natural luminescence signal or prior to the measurement of regenerative doses (**Table A1**). The ratio of secondary to initial luminescence response from the same test dose was used to derive a correction factor for sensitivity changes. The efficacy of the preheat treatment (160 °C for 1 hour) for the

normalization dose was evaluated by comparing curve shape (trap distribution) between the natural and subsequent dose (Bailey et al., 2003). A similar dose response was indicated by zero or low slope (<0.1) between the luminescence for initial and secondary dose, evaluated at one-second intervals. To eliminate any contributions to the luminescence signal from electrons residing within those traps that are thermally unstable over geologic time periods, two different heating treatments were employed: first, storage at 160°C for 1 hour immediately following each laboratory irradiation (Forman and Pierson, 2002; Wood et al., 2010; Waters et al., 2011), and second, measurement at elevated temperature 125°C during excitation (Wintle and Murray, 2000). The temperature and duration of the first heating treatment following the subsequent normalization dose was selected from a range of temperatures (140-200°C) to mirror the charge distribution exhibited by the natural luminescence emissions. Success was indicated by zero or low slope (<0.1) between the luminescence for initial and secondary dose, evaluated at one-second intervals, and by a uniform equivalent dose value across the shine down curve, also indicative of full solar resetting (Bailey et al., 2003). A sequential regenerative dose of up to 255 grays was applied to each sample that exceeded the corresponding natural luminescence and this dose response was unsaturated). Equivalent dose was calculated for at least the first 50 seconds of excitation, dependent on background counts, as a weighted mean (**Table A1**).

The MAR laboratory procedures accessed light-sensitive luminescence for quartz grains. The most photosensitive traps for quartz are reset within 5 seconds of high-intensity ($25mW/cm^2$) blue light ($470 \pm 20nm$) exposure (Agersnap-Larsen et al., 2000). These traps are linked to the 325°C thermal luminescence peak, suggesting that its parent traps are thermally stable over geologic timescales (lifetime $>3 \times 10^7$ years at 20°C) (Wintle and Murray, 2000; Bulur et al., 2000), and are thus suitable targets for luminescence geochronology. This study used the blue light emitting diode injection current that was limited to 10% of maximum, minimizing the photo-stimulation intensity and spreading the contributions from the various photosensitive traps over a longer time period (20 seconds) than Single Aliquot Measurements (Murray and Wintle, 2003), increasing component resolution. The resulting distributions of the natural luminescence response with increasing photo-stimulation time for these sediments suggested full solar resetting, with a preheat treatment of 160°C for 1 hour yielding a luminescence distribution most similar to the natural emissions.

Single aliquot regeneration (SAR) protocols (Wintle and Murray, 2006) were used in optical dating quartz separates (1 cm plate area) (**Table A1**). An Automated Risø TL/luminescence-DA-15 system was used for SAR analyses. Blue light excitation (470 ± 20 nm) was from an array of 30 light-emitting diodes that delivers ~15 mW/cm^2 to the sample position at 90% power. A Thorn EMI 9235 QA photomultiplier tube coupled with three 3 mm thick Hoya U-340 detection filters, transmitting between 290 and 370 nm, measured photon emissions. Laboratory irradiations used a calibrated ^{90}Sr/^{90}Y beta source coupled with the Risø Reader. The luminescence emissions for all quartz aliquots showed a clear dominance of a fast component with > 95% diminution of luminescence after four seconds of excitation with blue light. All SAR emissions were integrated over the first 0.8 s of stimulation out of 40 s of measurement, with background based on emissions for the last 30- to 40-s interval.

Consistent with the SAR protocols a series of experiments was performed to evaluate the effect of preheating at 180°, 200°, 220° and 240°C on thermal transfer of the regenerative signal. These experiments showed no preheat-based sensitivity changes and a preheat temperature of 240°C was used in SAR analyses (**Table A3**). A test for dose reproducibility was also performed with the initial and final regenerative dose of 7.4 or 21 Gy yielding concordant luminescence response (at 1-sigma error). Calculation of equivalent dose by the single aliquot protocols was straightforward with 30 aliquots measured for the equivalent dose determination (**Table A2**). The equivalent dose distribution is unimodal and the common age model (Galbraith and Roberts, 2012) was utilized for final equivalent dose calculation. Overdispersion values of $21 \pm 3\%$ for 28/30 aliquots for sample UIC2022 is indicative of single grain population, reflecting the time since solar resetting (Galbraith and Roberts, 2012).

An estimate of the environmental dose rate is needed to calculate an optical age. This value is determined from the U, Th and ^{40}K content and estimates on cosmic radiation components during the burial period (**Table A2**). The U and Th content of sediment assuming secular equilibrium in the decay series and ^{40}K were determined by inductively coupled plasma-mass spectrometry analysed by Activation Laboratory LTD, Ontario, Canada. A small cosmic ray component of 0.21 to 0.10 mGy/yr for the indicated depth was included in the estimated dose rate (Prescott and Hutton, 1994). Moisture content (by weight) for the dated sediment reflects current values at natural sections.

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Table A1 | Multiple Aliquot Regenerative Dose Procedure for Optical Dating.

Growth Curve

1. Optical bleaching 8 hr sunlamp
2. Test dose 4 grays
3. Preheat 160° C for 1 hr
4. Blue light stimulation and data collection @125°C
5. Optical bleaching 8 hr sunlamp
6. Regenerative doses (up to 290 grays)
7. Preheat 160° C for 1 h
8. Blue light stimulation and data collection @125°C

Natural

1. Stimulation with blue light and data collection
2. Optical bleaching 8 hr sunlamp
3. Test dose 4 Gy
4. Preheat 160° C for 1 hr
5. Blue light stimulation and data collection @125°C

Table A2 | Sampling sites and OSL age results from San Gabriel drift and Mapocho River catchment.

Sample/ Laboratory number and method[a]	Locality	Grain size analyzed (μm)	Equivalent dose (Grays)	U (ppm)[b]	Th (ppm)[b]	K₂O (%)[b]	Cosmic dose (Grays/ka) [c]	Dose Rate (Grays/ka) [d]	OSL age (yr)[e]
RM07-01/ UIC2037/MAR	Maipo, San Gabriel	425-500	109.91 ± 5.34	1.4 ± 0.1	4.8 ± 0.1	1.99 ± 0.02	0.21 ± 0.02	2.46 ± 0.14	44,715 ± 3670
RM07-02/ UIC2038/MAR	Maipo, San Gabriel	425-500	92.73 ± 4.65	1.6 ± 0.1	5.4 ± 0.1	2.00 ± 0.02	0.21 ± 0.02	2.55 ± 0.14	36,350 ± 2960
RM07-03/ UIC2039/MAR	Maipo, San Gabriel	425-500	117.60 ± 9.70	1.4 ± 0.1	5.3 ± 0.1	2.07 ± 0.02	0.21 ± 0.02	2.56 ± 0.14	45,985 ± 4705
RM07-15/ UIC2022/MAR	Mapocho, La Ermita	100-150	161.42 ± 7.87	2.0 ± 0.1	6.4 ± 0.1	1.99 ± 0.02	0.10 ± 0.01	2.67 ± 0.14	60,430 ± 5110
RM07-16/ UIC2022/SAR	Mapocho, La Ermita	100-150	143.96 ± 7.15	2.0 ± 0.1	6.4 ± 0.1	1.99 ± 0.02	0.10 ± 0.01	2.67 ± 0.14	53,920 ± 4990

[a]MAR= Multiple aliquot regenerative dose (Jain et al., 2003); SAR =Single aliquot regenerative dose (Murray and Wintle 2003) under blue light excitation
(470 ± 20 nm). Equivalent dose for sample UIC2022SAR was calculated with 28 out 30 aliquots, with an overdispersion value of 21 ±3, by the Central Age
Model (Galbraith and Roberts, 2012).
[b]U, Th and K content determined by ICP-MS by Activation Laboratory Inc. Ontario, Canada.
[c]From Prescott and Hutton (1994).
[d]Includes a moisture content estimate of 5 ± 2%.
[e]All ages are calculated from the datum year AD 2000 and errors include systematic and random errors in a quadrature.

Table A3 | Single Aliquot Regenerative Protocols for Optical Dating.

Step	Treatment
1	Natural dose or give beta dose
2	Preheat (240º C for 10s)
3	Stimulate with blue light (470 nm) for 40s at 125º C
4	Give beta test dose (e.g. 0.5 Gray)
5	Preheat as in step 2
6	Stimulate with blue light (470 nm) for 40s at 125º C
7	Stimulate with blue light for 40s at 260º C
8	Return to step 1

Annex B - ^{36}Cl cosmogenic geochronology from boulders

Geochronological determinations on morphostratigraphic units at La Engorda area were obtained by cosmogenic ^{36}Cl exposure dating from the top of boulders located at the surface of (ice-contact) moraines (**Table B1-B4)**. Samples were named with a prefix "ENG" in the field, then renamed to "E" in **Figures 10 and 11**, in the main text.

Sampled boulders were located on mounds corresponding to terminal moraines and in an intermorainic zone (**Table B3**; **Figures 6, 7, 10, 11** main text). Boulders were characterized by low degree of weathering, with flat and isolated surfaces (**Figure 11** main text) in all cases horizontal but one with a sloping surface with dip 194/32. The main lithology of the blocks corresponds to breccia and conglomerates in sandy matrix (**Figure 7** main text), associated with the Jurassic Río Damas Formation (Thiele, 1980). Hammer and chisel were used to extract about 1 kg of the most superficial layer (between 3 and 5 cm) from each boulder, with the aim to maximize the recovery of cosmogenic isotopes. Samples were then crushed and homogenized before splitting for chemistry (through ICP-MS multielemental analysis for major and trace elements) and isotope extraction. Multielemental analysis was performed at ALS-Chemex (as of 2023, ALS-Global) laboratories in Reno. Trace element data was obtained via ICP-MS, while major elements were measured via ICP-OES. Analytical chemistry data is reported in **Table B2**.

The isotopic extraction was carried out at the Desert Research Institute Soil Laboratory (https://www.dri.edu/labs/soils-lab/services/). Approximately 40 g of crushed, sieved (125-250 micron) and lightly etched (2M HNO_3) sample were spiked with about 1.2-1.3 g of Cl-35 enriched NaCl solution at 0.00142 g/g concentration (**Table B14**), prepared with 99.35% Cl-35 NaCl from Oak Ridge National Laboratories, and dissolved in concentrated HF for 3-4 days. After total dissolution, Cl was precipitated as AgCl in controlled light conditions, purified from isobaric interference ^{36}S using precipitation with $Ba(NO_3)_2$, then dissolved again and precipitated for a second time as AgCl, and rinsed for drying as pellets for further AMS measurements. Pellets were sent to the CAMS facility at Lawrence Livermore National Laboratory (https://cams.llnl.gov/cams-competencies/earth-system-processes) where steel cathodes were loaded with the AgCl precipitate. ^{36}Cl/^{35}Cl and ^{35}Cl/^{37}Cl ratios were measured by AMS at Lawrence Livermore National Laboratory CAMS facility. AgCl standards used (KNSTD1600; ^{36}Cl/^{35}Cl $= 2.112 \times 10^{-12}$, ^{35}Cl/^{37}Cl $= 3.127$; KNSTD5000, ^{36}Cl/Cl $= 5.000 \times 10^{-12}$, KNSTD500,

^{36}Cl/Cl =5.000 × 10^{-13}) were measured during runs (Sharma et al., 1990). The concentration of Cl in the samples was calculated using isotopic dilution (**Table B1**). Estimates for ENG-II-1 and ENG-M used an upper envelope value from from the remaining samples given the anomalous ratios of ENG-II-1 and ENG-M (^{35}Cl/^{37}Cl <3.127) given at the accelerator, which are attributed to a memory effect on the detection end of the AMS. After 2016 the memory effect has been addressed at CAMS by using a correction running zero-Cl matrix targets (Alan Hidy, written communication, 2023). [Cl] values are therefore in the range 800-1200 ppm. Lower [Cl] yields older ages, about 1 ka per 100 ppm, when all other parameters are held constant.

The isotopic data (**Table B1**), plus the elemental concentration data (**Table B2**) and the position and shielding information (**Table B3**) were ingested into the online CREp calculator (https://crep.otelo.univ-lorraine.fr; Martin et al., 2017). Ages were computed using the Lal/Stone time dependent scaling scheme (Balco et al., 2008; Lal, 1991; Stone, 2000), with the ERA-40 atmosphere database (Uppala et al., 2005), and the atmospheric ^{10}Be-based VDM geomagnetic record of Muscheler, et al. (2005) as implemented in CREp. Spallation ^{36}Cl production rates are Schimmelpfennig et al. (2011) for Ca, Schimmelpfennig et al. (2014) for K, Moore and Granger (2019) for Fe and Marrero et al. (2016) for Ti. Ages are presented in **Table B4** (columns A, B) and **Figure 11** (main text), where the set of production rates mentioned above was chosen to display. Spallation Ca and K production rates from Marrero et al. (2016) were also input into the CREp model, for comparison (**Table B4**, columns C, D) given that these production rates incorporate a similar Lm scaling method than the scaling scheme used for the model run. Both production rates yield however similar results under 1-sigma uncertainty, which is attributed to the relatively large contribution to the production rate from thermal and epithermal neutron pathways.

Table B1 | Isotopic data for boulders samples dated with the ^{36}Cl method in La Engorda drift. All uncertainties are at 1-sigma.

Field ID	Sample mass dissolved [g]	Carrier (2) mass added [g]	^{36}Cl/^{35}Cl ratio [10^{-15}]	Uncertainty in ratio ^{36}Cl/Cl [10^{-15}]	^{35}Cl/^{37}Cl ratio	Uncertainty in ^{35}Cl/^{37}Cl ratio	[Cl] (3) [ppm]	Uncertainty [Cl] [ppm]
ENG-I-1	42.1682	1.0692	90.48	2.19	3.328	0.008	925	90
ENG-I-2	40.3926	1.053	139.1	4.38	3.337	0.011	750	70
ENG-II-1	40.014	1.3271	187.4	3.69	3.05(4)	0.046	1000	200
ENG-II-2	40.0275	1.253	164.3	4.48	3.469	0.025	525	50
ENG-M	40.3941	1.2541	201.59	3.11	3.085(4)	0.039	1000	200

Notes. (1) Rocks samples were crushed completely under 250 microns; the 150–250-micron fraction was used for subsequent dissolution and analysis. (2) Carrier concentration: 0.00142 g Cl /g solution. (3) [Cl] was obtained directly from isotope dilution calculations, except for ENG-II-1 and ENG-M which used an upper bound estimate from the rest of the batch (1000±200 ppm). (4) Anomalous ratios, possibly arising from AMS memory effects; the data is shown uncorrected here, not used for further calculations (see note (3)).

Table B2 | Chemistry data for production rate calculations used in [36]Cl dating of boulders dated in La Engorda drift.

Field ID	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	MnO	LOI	U	Th	Sm	B	Gd	S [%]
ENG-I-1	61	16.9	6.87	3.26	4.4	4.61	1.47	0.78	0.11	0.4	1.52	5.13	3.11	0	3.11	0.01
ENG-I-2	57.4	17.85	7.42	2.51	3.62	7.28	0.51	0.78	0.12	2.42	0.65	2.26	3.07	0	2.67	0.01
ENG-II-1	56.8	18.2	9.57	2.94	1.86	6.69	2.03	0.73	0.07	0.95	1.14	4.43	2.82	0	2.48	0.01
ENG-II-2	55.8	17.9	8.1	2.91	4.05	5.45	2.76	0.73	0.13	1.94	0.69	2.33	2.84	0	2.71	0.01
ENG-M	55.1	17.1	13.2	2.54	1.73	6.79	1.63	0.99	0.07	0.72	1.38	4.95	3.02	0	2.75	0.00

Table B3 | Sampling sites of boulders dated with the [36]Cl method in La Engorda drift. Location data for production rate calculation.

Field ID	Latitude (south)	Longitude (west)	Elevation meters above sea level (m. a.s.l)	Shielding correction Factor (unitless)	Thickness of sample (cm)
ENG-I-1	-33.80131052	-70.007269	2520	0.98036	3.5
ENG-I-2	-33.80132441	-70.00777	2516	0.962126	5
ENG-II-1	-33.80080483	-70.00845	2511	0.98036	5
ENG-II-2	-33.80094797	-70.0085938	2514	0.98036	5
ENG-M	-33.80093391	-70.0081075	2513	0.98036	3.5

Table B4 | [36]Cl sample concentration and age data for two different production data sets, highlighting differences in Ca, K, Fe rates: columns A, B refers to the set of production rates in Schimmelpfennig et al. (2011; 2014), and the data in columns C, D was calculated in reference to the Marrero et al. (2016) set.

Field ID	[36]Cl Concentration [10^6 atom/g]	Uncertainty in concentration [10^6 atom/g]	Age (A) [ka]	Uncertainty in age (B) [ka]	Age (C) [ka]	Uncertainty in age (D) [ka]
ENG-I-1	1.064	0.035	5.43	1.19	5.38	1.12
ENG-I-2	1.385	0.056	10.04	2.16	9.95	2.08
ENG-II-1	2.631	0.068	14.77	2.76	13.96	2.40
ENG-II-2	1.334	0.044	11.88	2.04	11.69	1.99
ENG-M	2.651	0.073	14.96	3.16	14.73	2.92

Notes. Age was obtained by ingestion of data in **Tables B1-B3** into the CREp model (Martin et al., 2017).

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Annex C – Mineral concentration and quantification of quartz

The analysis of mineral concentrations in the samples obtained at the sites of interest aims to quantify the amount of quartz present in the samples. Quantification of the quartz content is fundamental to establish the feasibility of applying cosmogenic dating methods such as ^{10}Be.

The quartz content exceeds 50% in only 3 samples, which are associated with the sieves 140 (op. 106 µm) and 140 (op. 106 µm). In general, the quartz content is in the order of 10% in the samples obtained both in rocks and sediments (**Table C1**).

Table C1 | Sampling sites and mineral concentration according to sieve size selection.

Sample	Sieve 35 (opening 500 μm)			Sieve 60 (op. 250 μm)			Sieve 140 (op. 106 μm)			Sieve 270 (op. 53 μm)		
	Quartz-Feldspar % (Qz % approx.)	% Lithic fragments	Other minerals or particles in order of importance	Quartz-Feldspar % (Qz % approx.)	% Lithic fragments	Other minerals or particles in order of importance	Quartz-Feldspar % (Qz % approx.)	% Lithic fragments	Other minerals or particles in order of importance	Quartz-Feldspar % (Qz % approx.)	% Lithic fragments	Other minerals or particles in order of importance
M1-C14-20	10 (7)	85	Vegetal (Carbón?), Bt, Mgt,	15 (10)	80	Mgt, Bt, Amp	65 (35)	25	Mgt, Glass, Bt, Amp	80 (55)	10	Mgt, Glass, Bt, Amp
M2-1-30	30 (20)	50	Mgt, Glass, Bt, Amp	70 (50)	10	Mgt, Glass, Bt, Amp	80 (60)	10	Mgt, Bt, Amp	85 (60)	5	Mgt, Bt, Amp
M2-C14-40	15 (10)	80	Bt, Mgt, Glass	15 (7)	80	Bt, Mgt, Glass	20 (10)	75	Bt, Mgt, Glass, Amp	70 (50)	15	Bt, Glass, Mgt, Amp
M2-C14-165	10 (7)	75	Mgt, Glass, Hmt	15 (10)	80	Mgt, Glass, Hmt. Bt	60 (45)	30	Mgt, Glass, Bt	70 (50)	15	Bt, Glass, Mgt, Amp. Ep
RM07-01	15 (10)	75	Amphibole-Piroxene (Amp-Prx); Pumice; Biotite (Bt)	20 (15)	70	Amp-Prx; Bt;Epidote (Ep); Magnetite (Mt)						
RM07-04	15 (10)	75	Pumice; Glass; Amp-Prx; Bt	15 (8)	80	Glass; Amp-Prx	20 (10 - 15)	70	Bt; Glass; Amp-Prx			
RM07-05	10 (7)	85	Bt: Epi; Amp-Prx	12 (6)	85	Bt; Amp - Prx	10 (6)	85	Bt; Amp-Prx			

Sample	Sieve 35 (opening 500 μm)			Sieve 60 (op. 250 μm)			Sieve 140 (op. 106 μm)			Sieve 270 (op. 53 μm)		
	Quartz-Feldspar % (Qz % approx.)	% Lithic fragments	Other minerals or particles in order of importance	Quartz-Feldspar % (Qz % approx.)	% Lithic fragments	Other minerals or particles in order of importance	Quartz-Feldspar % (Qz % approx.)	% Lithic fragments	Other minerals or particles in order of importance	Quartz-Feldspar % (Qz % approx.)	% Lithic fragments	Other minerals or particles in order of importance
RM07-07				15 (10)	70	Amp-Prx; Epi; Bt; Glass	15 (12)	70	Amp-Prx; Glass; Epi	20 (10)	70	Amp-Px; Mt; Bt; Epi
RM07-08				18 (10)	65	Amp-Prx; Bt; Epi	15 (7)	70	Bt; Amp-Prx; Epi	15 (10)	70	Bio; Epi; Amp-Prx
RM07-11				10 (5)	75	Pumice; Glass; Amp-Prx	15 (7)	75	Pumice; Glass; Amp-Prx	15 (10)	70	Amp-Prx; Glass; Epi
RM07-14				15 (10)	75	Amp-Prx; Mica; Glass; Epi	20 (10)	70	Amp-Prx; Micas; Epi			
RM07-15							40 (25)	40	Micas	50 (30)	30	Micas; Amp-Prx; Epi

Annex D – Radiocarbon ages

Table D1 | Sampling sites and ^{14}C ages. Calibration according Stuiver and Reimer (1993), and Hogg et al. (2020).

Sample Name Field (Ref.)	Coordinate North (meters)	Coordinate Este (meters)	Altitude (m a.s.l.)	Sample Code Lab	Service	Material Pre-treatment	d^{13}C (‰)	Conventional Age (yrs BP)	2 sigma calibration age range, (Prob.), and mean value (Cal yrs BP)	Geomorphological context
M2-C14-165/ (This work)	6259391	406643	2512	Beta 304734	AMS-Standard delivery	Organic sediment: acid washes	-24.2	7900 ± 40	8543 – 8783 (0.88) 8663 ± 120	Fine grained sediment overlaying moraine 2
M2-C14-85 (This work)	6259391	406643	2512	Beta 304733	AMS-Standard delivery	Organic sediment: acid washes	-23.6	4030 ± 30	4400 – 4573 (0.97) 4487 ± 87	Fine grained sediment overlaying moraine 2
M2-C14-40 (This work)	6259391	406643	2512	Beta 304732	AMS-Standard delivery	Organic sediment: acid washes	-22.8	1260 ± 30	1060 – 1178 (0.90) 1119 ± 59	Fine grained sediment overlaying moraine 2
M1-C14-49 (This work)	6259433	406761	2525	Beta 304731	AMS-Standard delivery	Organic sediment: acid washes	-23.0	2990 ± 30	2992 – 3227 (0.98) 3110 ± 118	Fine grained sediment overlaying moraine 1
M1-C14-15 (This work)	6259433	406761	2525	Beta 304730	AMS-Standard delivery	Organic sediment: acid washes	-23.3	2730 ± 30	2747 – 2864 (1) 2806 ± 59	Fine grained organic facies overlaying moraine 1
LE-7 (This work)	6259385	406900	2504	Beta 304729	AMS-Standard delivery	Organic sediment: acid washes	-25.6	1060 ± 30	899 – 961 (0.77) 930 ± 31	Fine grained to sandy organic facies in fluvioglacial plain upstream the moraine

Sample Name Field (Ref.)	Coordinate North (meters)	Coordinate Este (meters)	Altitude (m a.s.l.)	Sample Code Lab	Service	Material Pre-treatment	$d^{13}C$ (‰)	Conventional Age (yrs BP)	2 sigma calibration age range, (Prob.), and mean value (Cal yrs BP)	Geomorphological context
LE-6 (This work)	6259385	406900	2504	Beta 304728	AMS-Standard delivery	Organic sediment: acid washes	-26.5	2020 ± 30	1874 – 2002 (0.98) 1938 ± 64	Fine grained to sandy organic facies in fluvioglacial plain upstream the moraine
LE-5 (This work)	6259385	406900	2504	Beta 304727	AMS-Standard delivery	Organic sediment: acid washes	-24.0	1960 ± 30	1812 – 1930 (0.88) 1871 ± 59	Fine grained to sandy organic facies in fluvioglacial plain upstream the moraine
LE-4 (This work)	6259385	406900	2504	Beta 304726	AMS-Standard delivery	Organic sediment: acid washes	-23.4	1730 ± 30	1532 – 1629 (0.75) 1581 ± 49	Fine grained lacustrine facies in fluvioglacial plain upstream the moraine
LE-3 (This work)	6259385	406900	2504	Beta 304725	AMS-Standard delivery	Organic sediment: acid washes	-25.0	2220 ± 30	2219 – 2324 (0.54) 2272 ± 53	Fine grained organic facies in fluvioglacial plain upstream the moraine
LE-2 (This work)	6259385	406900	2504	Beta 304724	AMS-Standard delivery	Organic sediment: acid washes	-22.9	5780 ± 30	6443 – 6651 (0.99) 6547 ± 10	Fine-grained and sandy facies in fluvioglacial plain upstream the moraine
LE-1 (This work)	6259385	406900	2504	Beta 304723	AMS-Standard delivery	Organic sediment: acid washes	-23.7	8940 ± 40	9890– 10197 (0.98) 10044 ± 15	Lacustrine fine-grained facies in fluvioglacial plain upstream the moraine

Sample Name Field (Ref.)	Coordinate North (meters)	Coordinate Este (meters)	Altitude (m a.s.l.)	Sample Code Lab	Service	Material Pre-treatment	$d^{13}C$ (‰)	Conventional Age (yrs BP)	2 sigma calibration age range, (Prob.), and mean value (Cal yrs BP)	Geomorphological context
RC2303 (This work)	6257690	406621	2350	Beta 665614	AMS-Priority	Organic sediment: acid washes	-25.9	31440 ± 210	35346– 36184 (1) 35765 ± 419	Lacustrine fine-grained sediment, glacio-fluvial terrace
RC2302 (This work)	6257690	406621	2350	Beta 665613	AMS-Priority	Organic sediment: acid washes	-26.4	28400 ± 150	31942–33071 (1) 32507 ± 565	Lacustrine fine-grained sediment, glacio-fluvial terrace
RC2301 (This work)	6257690	406621	2350	Beta 665612	AMS-Priority	Organic sediment: acid washes	-26.4	29520 ± 170	33678–34409 (1) 34044± 366	Lacustrine fine-grained sediment, glacio-fluvial terrace
(Moreno et al., 1991)								24500 ± 400	27776–29551 (1) 28664 ± 888	Lacustrine fine-grained sediment, glacio-fluvial terrace
Espizúa (2004)			2170			Peat		13560 ± 90	16018-16603 (1) 16311 ± 293	Hermoso II
Espizúa (2004)			2170			Peat		15920 ± 100	18929-19446 (1) 19188 ± 259	Hermoso II
Espizúa (2004)			2600			Peat		10560 ± 140	11966-12737 (1) 12352 ± 386	Hermoso III

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