Supplementary data to support the terrestrial cosmogenic nuclide exposure ages provided in *Evenson et al., 2009, GSA Today*.

In the past decade, there has been significant attention placed on the chronology of the ultimate and pre-ultimate drifts in southernmost South America. The most significant contribution to knowledge of the glacial history has been by researchers at University of Edinburgh (Kaplan *et al.*, 2007; 2008; and Glasser et al., 2008), who used combinations of radiocarbon (mostly on peat and lacustrine organics, and marine macrofossils), and terrestrial cosmogenic nuclide (TCN) exposure ages on boulders to date the ultimate and pre-ultimate glaciations.

To this foundation, we add the following: (i) nine TCN ages on the terminal moraine of the ultimate glaciation of the Bahia Inutil lobe, (ii) four TCN ages on a recessional moraine of the same lobe, but at an elevation below a post-glacial lake (and shoreline) so the ages reflect the time of glacial lake drainage; (iii) nine TCN ages on the BSS boulder train that reproduce problematic exposure ages reported by Kaplan et al. (2007), which were considered too young for the stratigraphic position of the moraine according to previous maps, and interpreted to be evidence of rapid exhumation of the drift; and (iv) other TCN ages to constrain the timing of the penultimate glaciation, which was tentatively correlated to marine oxygen isotope stage 6 (OIS-6) glaciation (Meglioli, 1992), but recently hypothesised to be between 35 and 50 ka by others with radiocarbon dates. Unlike the areas to the north, these TCN and radiocarbon ages indicate a significant OIS-4 ice expansion in southern Patagonia and Tierra del Fuego, which is consistent with ice extents in other parts of the mid latitude southern hemisphere (e.g. Barrows et al., 2001), where the OIS-4 paleo-margin extends beyond the last glacial maximum.

To facilitate comparison with other published ages on boulders in the vicinity of the two boulder trains, we have calculated all ages using lower-than-average barometric pressure at sea level (Stone, 2000; we adapted the values used by McCulloch *et al.*, 2005) and we have used the web-based Cronus Calculator (Balco *et al.*, 2008) v. 2.2 to calculate the appropriate production rates considering geomagnetic field influences and recent changes in the estimate of the half life of ^{10}Be and ^{26}Al and the consequent effects on AMS Be standards and production rates (see data repository for all data). Furthermore we have used CHLOE (v.3) (Phillips and Plummer, 1996) to calculate ages using ^{36}Cl.

Information (sample position, elevation and atmospheric pressure, shielding factors, sample thickness, AMS data and standards, carrier information, and chemical data) required for the interpretation of the TCN data are provided in Tables 1, 2a, 2b, and 3.

Table 1. Sample information for interpretation of cosmogenic nuclide ages (input data for CRONUS Calculator or CHLOE3)

Strat Pos or reference	Sample name	Lat	Long	Elev	Elev	Thick	Density	Shield	Erosion rate	[Be-10]	+/-	AMS	[Al-26]	+/-	AMS
		DD	DD	m	flag	cm	g cm^{-2}	factor	cm yr^{-1}	atoms g^{-1}	atoms g^{-1}	Std	atoms g^{-1}	atoms g^{-1}	Std
BI moraine	B1	53.50	69.25	80	std	1.0	2.7	0.96	0.00017	127868	16751	KNSTD	0	0	KNSTD
BI moraine	B2	53.50	69.23	75	std	1.0	2.7	0.96	0.00017	119923	15230	KNSTD	0	0	KNSTD
BI moraine	B3	53.51	69.25	85	std	1.0	2.7	0.96	0.00017	109517	11061	KNSTD	0	0	KNSTD
BI moraine	B4	53.51	69.25	80	std	1.0	2.7	0.95	0.00017	120969	16452	KNSTD	0	0	KNSTD
BI moraine	TF-04-04	53.49	69.22	90	std	2.5	2.7	1	0.00017	109000	12200	KNSTD	0	0	KNSTD
BI moraine	TF-04-04	53.49	69.22	90	std	2.5	2.7	1	0.00017	90400	4650	NIST_30600	0	0	KNSTD
BI moraine	TF-04-05	53.49	69.22	90	std	1.4	2.7	1	0.00017	107000	54300	NIST_30600	849400	18500	KNSTD
BI moraine	TF-04-06	53.49	69.22	101	std	1	2.7	1	0.00017	100000	42700	NIST_30600	0	0	KNSTD
BSS moraine	RC-04-01	53.40	68.08	16	std	1.5	2.7	1	0.00017	118000	32900	KNSTD	0	0	KNSTD
BSS moraine	RC-04-02	53.41	68.09	22	std	1.5	2.7	1	0.00017	145000	16500	KNSTD	0	0	KNSTD
BSS moraine	RC-04-03	53.41	68.09	21	std	1.5	2.7	1	0.00017	107000	14100	KNSTD	0	0	KNSTD
BSS moraine	RC-04-04	53.41	68.09	23	std	2.2	2.7	1	0.00017	145000	44700	KNSTD	0	0	KNSTD
BSS moraine	RC-04-05	53.40	68.08	17	std	1.9	2.7	1	0.00017	144000	33000	KNSTD	0	0	KNSTD
BSS moraine	RC-04-06	53.41	68.09	12	std	1.1	2.7	1	0.00017	73100	3860	KNSTD	0	0	KNSTD
BSS moraine	RC-04-07	53.41	68.12	21	std	1.2	2.7	1	0.00017	275000	58000	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-13	53.50	69.25	145	std	2	2.65	1	0.00017	101010	6427	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-14	53.50	69.25	145	std	2	2.65	1	0.00017	112971	6525	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-15	53.50	69.25	160	std	2	2.65	1	0.00017	98689	5883	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-16	53.50	69.25	160	std	2	2.65	1	0.00017	106896	4586	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-17	53.50	69.25	160	std	1	2.65	1	0.00017	123064	3493	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-18	53.50	69.25	160	std	4	2.65	1	0.00017	303471	7871	KNSTD	0	0	KNSTD

BI Terminal	CBI-T51-99-19	53.50	69.25	135	std	2	2.65	1	0.00017	111186	4324	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-20	53.50	69.25	140	std	6	2.65	1	0.00017	82817	4082	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-21	53.50	69.25	135	std	5	2.65	1	0.00017	104681	6420	KNSTD	0	0	KNSTD
BI Recessional	CBI-T52-99-10	53.50	69.30	65	std	3	2.65	1	0.00017	42024	2657	KNSTD	0	0	KNSTD
BI Recessional	CBI-T52-99-11	53.50	69.30	65	std	3	2.65	1	0.00017	47831	2825	KNSTD	0	0	KNSTD
BI Recessional	CBI-T52-99-12	53.50	69.30	65	std	2	2.65	1	0.00017	45843	3122	KNSTD	0	0	KNSTD
BI Recessional	CBI-T54-99-08	53.50	69.30	60	std	2	2.65	1	0.00017	72529	3798	KNSTD	0	0	KNSTD
Pre-Penultimate	CRG-T3-99-22	51.69	72.00	223	std	3	2.65	1	0.00017	318839	8514	KNSTD	0	0	KNSTD
Pre-Penultimate	CRG-T3-99-24	51.69	72.00	223	std	2	2.65	1	0.00017	323178	8318	KNSTD	0	0	KNSTD
[redacted]															
Using ATM pressure:									**Using zero erosion**						
BI moraine	B1	53.50	69.25	1010.5	pre	1.0	2.7	0.96	0	127868	16751	KNSTD	0	0	KNSTD
BI moraine	B2	53.50	69.23	1009.9	pre	1.0	2.7	0.96	0	119923	15230	KNSTD	0	0	KNSTD
BI moraine	B3	53.51	69.25	1011.1	pre	1.0	2.7	0.96	0	109517	11061	KNSTD	0	0	KNSTD
BI moraine	B4	53.51	69.25	1010.5	pre	1.0	2.7	0.95	0	120969	16452	KNSTD	0	0	KNSTD
BI moraine	TF-04-04	53.49	69.22	1011.7	pre	2.5	2.7	1	0	109000	12200	KNSTD	0	0	KNSTD
BI moraine	TF-04-04	53.49	69.22	1011.7	pre	2.5	2.7	1	0	90400	4650	NIST_30600	0	0	KNSTD
BI moraine	TF-04-05	53.49	69.22	1011.7	pre	1.4	2.7	1	0	107000	54300	NIST_30600	849400	18500	KNSTD
BI moraine	TF-04-06	53.49	69.22	1013.0	pre	1	2.7	1	0	100000	42700	NIST_30600	0	0	KNSTD
BSS moraine	RC-04-01	53.40	68.08	1003.6	pre	1.5	2.7	1	0	118000	32900	KNSTD	0	0	KNSTD
BSS moraine	RC-04-02	53.41	68.09	1004.3	pre	1.5	2.7	1	0	145000	16500	KNSTD	0	0	KNSTD
BSS moraine	RC-04-03	53.41	68.09	1004.2	pre	1.5	2.7	1	0	107000	14100	KNSTD	0	0	KNSTD
BSS moraine	RC-04-04	53.41	68.09	1004.4	pre	2.2	2.7	1	0	145000	44700	KNSTD	0	0	KNSTD

BSS moraine	RC-04-05	53.40	68.08	1003.7	pre	1.9	2.7	1	0	144000	33000	KNSTD	0	0	KNSTD
BSS moraine	RC-04-06	53.41	68.09	1003.1	pre	1.1	2.7	1	0	73100	3860	KNSTD	0	0	KNSTD
BSS moraine	RC-04-07	53.41	68.12	1004.2	pre	1.2	2.7	1	0	275000	58000	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-13	53.50	69.25	1018.3	pre	2	2.65	1	0	101010	6427	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-14	53.50	69.25	1018.3	pre	2	2.65	1	0	112971	6525	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-15	53.50	69.25	1020.1	pre	2	2.65	1	0	98689	5883	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-16	53.50	69.25	1020.1	pre	2	2.65	1	0	106896	4586	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-17	53.50	69.25	1020.1	pre	1	2.65	1	0	123064	3493	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-18	53.50	69.25	1020.1	pre	4	2.65	1	0	303471	7871	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-19	53.50	69.25	1017.1	pre	2	2.65	1	0	111186	4324	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-20	53.50	69.25	1017.7	pre	6	2.65	1	0	82817	4082	KNSTD	0	0	KNSTD
BI Terminal	CBI-T51-99-21	53.50	69.25	1017.1	pre	5	2.65	1	0	104681	6420	KNSTD	0	0	KNSTD
BI Recessional	CBI-T52-99-10	53.50	69.30	1008.7	pre	3	2.65	1	0	42024	2657	KNSTD	0	0	KNSTD
BI Recessional	CBI-T52-99-11	53.50	69.30	1008.7	pre	3	2.65	1	0	47831	2825	KNSTD	0	0	KNSTD
BI Recessional	CBI-T52-99-12	53.50	69.30	1008.7	pre	2	2.65	1	0	45843	3122	KNSTD	0	0	KNSTD
BI Recessional	CBI-T54-99-08	53.50	69.30	1008.1	pre	2	2.65	1	0	72529	3798	KNSTD	0	0	KNSTD
Pre-penultimate	CRG-T3-99-22	51.69	72.00	1028.6	pre	3	2.65	1	0	318839	8514	KNSTD	0	0	KNSTD
Pre-penultimate	CRG-T3-99-24	51.69	72.00	1028.6	pre	2	2.65	1	0	323178	8318	KNSTD	0	0	KNSTD

Table 2a. ^{36}Cl results from biotite separates at Bahia Inutil

Biotite sample	^{10}Be conc. (10^6 atom/g)	^{10}Be zero erosion age (kyr)	^{36}Cl conc. (atom/g)	^{36}Cl zero erosion age (kyr)
CBI-T5_1-99-15	0.09 ± 0.01	17.6 ± 1.1	0.25 ± 0.05	13.2 ± 2.5
CBI-T5_1-99-16	1.08 ± 0.04	19.1 ± 0.8	0.42 ± 0.03	21.1 ± 1.6

Note: The erosion rate required to equalize the ^{10}Be (quartz) and ^{36}Cl (biotite) ages in sample CBI-T51-99-16 is between 0.2 and 0.3 cm/ka. (see Jackofsky, 2002).

Biotite sample	SiO_2 (wt %)	TiO_2 (wt %)	Al_2O_3 (wt %)	Fe_2O_3 (wt %)	MgO (wt %)	CaO (wt %)	MnO (wt %)	Na_2O (wt %)	K_2O (wt %)	P_2O_3 (wt %)	Cl (ppm)	B (ppm)	Gd (ppm)
CBI-T5_1-99-15	48.60	0.38	14.70	0.45	11.80	10.90	0.16	1.35	0.38	0.04	223.12	0.50	6.50
CBI-T5_1-99-16	43.90	1.60	12.80	17.70	8.39	8.52	0.77	1.26	2.70	0.09	393.67	3.00	11.50

Major and Minor element composition measured at XRAL, Toronto Ontario. Sample error is 0.01for wt % and ppm. * Chlorine concentrations calculated from spike addition using CHLOE (Phillips and Plummer, 1996).

Table 2b. ^{36}**Cl results from granite boulders on the Bahia San Sebastian boulder train**

Lab ID	SampleID	thickness	dissolution mass	Carrier mass	Carrier conc	36Cl/ total_Cl	1sig_err	35Cl/37Cl	1sigerr
	NA	cm	g	g	mg_35Cl/ g_Carr	Unitless (10E-15)	frac(10E-15)	unitless	frac
5070	aveblank	0	0	3.0963	1.2399	7.945	0.7912	194	3.597
5184M	ARG-00-Tdf-039	4	51.4779	1.6386		76.81	7.49	5.48	0.04
5185M	ARG-00-Tdf-043	4	51.0224	1.7446		125.10	5.25	5.75	0.12

Lab ID	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	Cr2O3	LOI	U	Th	Gd	Sm	Li	B
	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm
5070	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5184M	65.6	15	6.02	1.43	6.11	2.03	0.99	0.48	0.01	0.11	0.02	1.21	0.44	8	3.25	3.6	0	0
5185M	64.1	17	4.27	1.02	5.3	3.9	2.56	0.34	0.02	0.11	0.03	0.28	2.12	10	5.78	6.2	0	0

Major and minor elemental composition measured at MAXXAM Inc., Halifax Canada

Table 3. Additional sample information

Phases analysed	Quartz for all Be and Al samples, whole rock granitoid or biotite separates for Cl analysis
Targets	BeO, Al_2O_3, $AgCl_3$
Carriers	995 ppm ^{9}Be from beryl crystal from Homestake Goldmine; 1000 ppm ^{27}Al carrier from SPEX ICP.MS trace standards; ^{35}Cl spike from Oak Ridge National Lab
Sample chemistry	Be: Majority at University of Kansas (Jackofsky/Gosse); BSS samples were prepared at Dalhousie University (Yang/Gosse); Al: Prepared at Dalhousie University (Yang/Gosse); samples CBI-$T5_1$-99-15 and CBI-$T5_1$-99-15 for 36Cl prepared at NMT by T. Thomas, and were biotites extracted from samples with 10Be, to determine average erosion rate. Samples ARG-00-TdF-039 and 043 are samples of $AgCl_3$ prepared at Dalhousie University
AMS facility	CAMS-LLNL for all Be and Al measurements PRIME Lab for all Cl measurements
Chemical blank ratios	Average of 5 x 10^{-15} for $^{10}Be/^{9}Be$ chemical blank. Average of 9 x 10^{-15} for $^{26}Al/^{27}Al$ chemical blank. Average 8 x 10^{-15} for ^{36}Cl on Dalhousie samples using Oak Ridge National Lab spike
Calculators and version (version indicates the magnitude of all constants)	Chloe V3 (Phillips and Plummer, 1996) for ^{36}Cl CRONUS Calculator V2.2 (Balco et al., 2008) for ^{10}Be and ^{26}Al

The nine ages on the Bahia Inutil terminal moraine for the last glacial maximum are from 1.7 to 4 m high boulders situated above the highest known lake shoreline (~ 90 m, Meglioli, 1992). The ages range from 17.8 to 66.0 ka (see data repository) and there is no obvious trend in ages distributed from front (distal) to the back (proximal) parts of the moraine. We interpret the age for CBI-T51-99-18, (66.0 ka) as an outlier due to inheritance. The average of the other 8 boulders is 22.2 ± 0.9 ka (standard error). This mean age overlaps the 1 σ mean exposure ages from McCulloch *et al.* (2005) at 24.4 ± 0.9 ka (n=4) and Kaplan *et al.* (2007) at 20.4 ± 0.9 ka (n=3) and is consistent with radiocarbon chronologies and other dates in the vicinity as summarized by McCulloch *et al.* (2005) and Rabassa *et al.* (2007).

Four boulders on recessional moraines below the highest shoreline yield much younger ages. The ages of 2.3 to 3 m high boulders (n=3) on the first recessional range from 8.3 to 9.4 ka, with mean age 8.9 ± 0.4 ka. Other chronology on a sequence of lateral moraines demonstrates that the lobe retreated from the terminus before 17 ka (McCulloch et al., 2005). Although the boulders exhibit deep (10 cm) gnammas and rillen, the excessive boulder erosion needed (>30 cm) to explain the factor of > 2 difference in age is not feasible for the top of these large boulders. Greater than 3 m of exhumation of till is also unlikely, particularly because none of the other moraines appear to have this problem. Furthermore, we observed no explanation for how these boulders were the only ones that were extensively eroded or exhumed while the remaining boulders of similar height and lithology were not. We completely re-measured the ^{10}Be concentration and reproduced the initial ages within 0.8 ka, so geochemistry and AMS error is precluded. The boulders are currently more than 50 meters above sea level. We cannot rule out the possibility that these boulders were exhumed by > 3 meters of wave erosion of the proximal side of the moraine, but we observed in natural exposures through the moraine ridges that no large boulders appear within the till (as observed at Bahia San Sabastian). Sea-ice push may have been extensive, considering the fetch of Bahia Inutil, so it is also possible that the ages mark the last time the boulders were pushed. However, there is no evidence for marine limit extending this far inland. A large lake, dammed from the sea by the glacier, and whose outlet was through the terminal moraines described above, persisted in Bahie Inutil between 17.0 and 12.2 ka (McCulloch *et al.*, 2005), The pro-glacial lake existed after the terminal moraine and first recessional moraines—and therefore the boulder train—were deposited. The most obvious explanation for the 8.9 ka age is a combination of factors including (1) the production rate of ^{10}Be in the boulders below the shoreline was reduced by a 5 ka-long partial shielding of cosmic radiation by lake water and possibly lake sediment on the boulders; and (2) some boulder erosion (few cm), as the boulders along the shoreline may have experienced relatively more weathering. The fourth age of 14.1 ± 1.7 ka (CBI-T54-99-08) is from the third recessional moraine and is consistent with exposure after lake level reached the elevation of this moraine (approximately 60 meters above sea level today). Its older age indicates that it may have been less eroded than the three younger boulders, or may have been equally eroded but carried a greater inherited signal. Nevertheless, its age is consistent with the age of the lake level dropping below this elevation. Cosmogenic ^{10}Be exposure ages on the BSS boulder train reported by Kaplan *et al.* (2007) range from 13 to 51 ka (n=7, mean 22.8 ± 1.2 ka excluding the statistical outlier of 51 ka) and have been problematic because the boulders sit on glacial drift mapped and interpreted by others to be greater than 1 Ma. Their interpretation was that the boulders are younger than expected because they have been exhumed in the last 50 ka. Although excessive boulder erosion could explain the ages, it is unlikely that all of the boulders would have eroded at the same excessive rate over the past 1 Ma to yield such a relatively tight cluster of ages. We reproduce their ages by dating two boulders with cosmogenic ^{36}Cl, yielding ages of 18.7 and 27.9 ka. Kaplan *et al.* (2007) consider many reasons for such exceptional erosion on the drift. We also consider that the surface may have been wave-washed when it was isostatically-depressed during transgression after OIS-4, which could explain the lack of any boulders older than 51 ka on such an old moraine.

Cosmogenic ^{10}Be and ^{36}Cl exposure ages on boulders beyond the last glacial maximum moraines, on drifts T3 and T4 of Meglioli (1992) range from 74.4 to 38.1 ka (n=5). The oldest ages are on the T3 pre-penultimate drift (74.2 ka, n=2), a T3 recessional moraine dates at 55 ka, and the penultimate terminal dates at 39.0 ka (n=2). At face value, these ages would imply that the T4 and T3 correlated with OIS-3 and OIS-4 cool periods. However, even low rates of boulder erosion or exhumation (1.7 mm/ka) will significantly increase the ages of the penultimate moraine to >50 ka. Considering snow cover, boulder exhumation, and boulder erosion, it is therefore likely that T4 represents the OIS-4 and that T3 represents OIS-5 glaciation, possibly OIS-6. A significant (extending beyond OIS-2 ice limits) OIS-4 glaciation in the high latitudes of the southern hemisphere has been identified in regional glacial moraine records elsewhere (e.g. Barrows, 2001), but OIS-4 is missing in other records, such as the global-averaging ice volume records in marine sediments. A significant OIS-4 advance has also been recognized in high latitude North America (e.g. Ward *et al.*, 2007). Some combination of polar sea ice, regional atmospheric anomalies, and orbitally-controlled solar insolation patterns may explain why the high latitudes experienced greater glaciation during OIS-4. Better documentation of the distribution and timing of OIS-4 glacial limits worldwide, however, is needed to completely understand high latitude climates.

Overall, our new ages generally confirm earlier work of Kaplan et al. (2007, 2008), McCulloch et al (2005a,b) and others in documenting a rich but sometimes puzzling glacial history in the vicinity of Darwin's Boulders and the Bahia Inutil Boulder Train. The combined data set is most consistent with an LGM age for deposition of the Bahia Inutil Boulder Train, and a much older age for deposition of Darwin's Boulders (MIS 6 or older). The cosmogenic exposure ages also reveal important geomorphic as well as chronologic information, with burial and exhumation especially important for many samples.

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