We calculated mean summer temperature lapse rates from 1971-2001 climate data (WRCC, 2005) for six sites in the central Cascade Range of Oregon between elevations of 451 and 1972 m. Because altitude and temperature are highly correlated, the six sites chosen for the mean summer temperature are selected according to their elevation and distance from Three Sisters. The calculated summer lapse rate is -0.53°C / 100 m, which is close to the wet adiabatic lapse rate (~ -0.60°C / 100 m). The mean summer temperature regression line accounts for 96% of the variance in temperature and is statistically significant at the $p = 0.01$ level. Because winter accumulation is sensitive to small changes in local topography and aspect, and not strictly changes in altitude, meteorological stations chosen for the accumulation gradient are east of the Cascade Range crest and within ~30 km of the Three Sisters and Broken Top to account for the prominent Cascade rain shadow effect. The winter accumulation gradient versus elevation is calculated using historical climate data from 1971-2000 (NRCS, 2005) from four SNOTEL and snow course sites between elevations of 1585 and 1951 m. The calculated winter accumulation gradient is 32 cm swe / 100 m similar to a more regional winter accumulation gradient of 20 cm swe / 100 m calculated by McDonald (1995) for mean April 1st snow depth. The winter accumulation regression line accounts for 96% of the variance in winter accumulation and is statistically significant at the $p = 0.025$ level. Because of the lack of detailed winter accumulation measurements at higher elevations in the Three Sisters area, it is difficult to assess if our winter accumulation gradient extrapolates to altitudes comparable to our estimated ELAs. However, from snow and mass balance measurements by McDonald (1995) as well as visual inspection during two winter coring expeditions, our winter accumulation lapse rate likely underestimates the true maximum winter accumulation at the ELAs.

Table S1.

Meteorological stations used to calculate linear regression line for mean summer temperature (1971-2001) (WRCC, 2005).

SNOTEL Name	Latitude and Longitude *(Degrees, Minutes)*	Elevation *(m)*	Average Summer Temperature *(°C)*
McKenzie	44º 11', 122º 07'	451	18.6
Belknap	44º 18', 122º 02'	655	17.1
Sisters	44º 17', 122º 33'	969	15.8
Bend	44º 04', (122º 17' & 122º 19')	1113	16.2
Santiam	44º 25', 122º 52'	1448	12.6
Crater Lake	42º 54', 122º 08'	1972	10.6

Table S2.

Meteorological stations used to calculate linear regression line for mean winter accumulation (1971-2000) (NRCS, 2005).

SNOTEL or Snow Course Name	Latitude and Longitude *(Degrees, Minutes)*	Elevation *(m)*	Highest Monthly Mean Snowpack *(cm swe)*
Three Creek Butte	44º 09', 121º 38'	1585	19.3
Tangent	44º 01', 121º 34'	1646	50.6
Three Creeks Meadow	44º 09', 121º 38'	1722	49.2
New Dutchman Flat #3	44º 00', 121º 42'	1951	140.7

Table S3.

Estimated modern climate conditions at present and past glacier equilibrium line altitudes at Three Sisters and Broken Top volcanoes using the BR method.

	Glacier	ELA	Mean Summer Temperature	Winter Accumulation
Modern Glaciers		*(m)*	*(°C)*	*(cm swe)*
	Diller	2580	7.3	340
	Hayden	2630	7.1	360
	Bend	2470	7.9	300
	Prouty	2670	6.8	370
	Lewis	2770	6.3	400
	Linn	2650	6.9	360
LIA Glaciers				
	Diller	2470	7.9	300
	Hayden	2540	7.5	330
	Bend	2430	8.1	290
	Prouty	2540	7.5	330
	Lewis	2650	6.9	360
	Linn	2480	7.8	310
Post-LGM				
	Diller	2290	8.9	250
	Hayden	2320	8.7	260
	Bend	2330	8.6	260
	Prouty	2360	8.5	270

Table S3.

Radiocarbon ages and methods.

Sample Location	Sample Number (field label)	Material	Corrected conventional ^{14}C age BP ±1sigma [a,c]	Calibrated 2σ age range, in calendar years BP [b]	$^{13}C/^{12}C$ (‰)	Laboratory ID#
Site 16	15-MS	Wood	101.7 ± 0.5 pMC	post 0 BP	-23.3	Beta - 200871
Site 16	15-MS-2-0305	Wood	30 ± 40	220-260 and 20-140	-23.2	Beta - 203136
Site 32	58-MS	Plant Seed	111.3 ± 0.6 pMC	post 0 BP	-25.8	Beta - 200872
Site 43	72-BT	Plant Material	980 ± 40	790 – 960	-27.2	Beta - 200873
Site 43	72A-BT-0305	Plant Material	119.7 ± 0.5 pMC	post 0 BP	-26.2	Beta - 203137
Site 43	BT-01-03-05-10-397	Charcoal	7290 ± 35	8025 – 8175	-	WW5563

[a] Radiocarbon ages (in ^{14}C yr B.P.) are calculated on basis of Libby half-life for ^{14}C (5568 years). The error stated is ±1σ on basis of combined measurements of the sample, background, and modern reference standards. Age referenced to AD 1950. Where no measurements of $^{13}C/^{12}C$, a value of -25‰ assumed for determining corrected conventional age.

[b] Calibration on basis of INTCAL98 (Stuiver et al., 1998) and a laboratory error multiplier of 1, referenced to AD 1950. The 2σ range(s) encompass the intercept of the corrected conventional radiocarbon age ± 2σ with the calibrated calendar time-scale curve.

[c] "Results are reported in the pMC format when the analyzed material had more ^{14}C than did the modern (AD 1950) reference standard. The source of the "extra" ^{14}C in the atmosphere is from thermo-nuclear bomb testing which on-set in the 1950s." (Darden Hood, Beta Analytic Inc., written communication).

Table S4.

Glass shard chemistry from tephra layer at 329cm depth in sediment core from Broken Top (site 43).

Analysis was preformed by F.F. Foit, Jr. in 2006 at Washington State University, Microbeam Laboratories.

Sample	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Na_2O	K_2O	MgO	CaO	Cl
BT-01-329**	73.39 ±0.22*	14.50 ±0.16	2.11 ±0.04	0.43 ±0.02	4.63 ±0.12	2.75 ±0.05	0.45 ±0.03	1.63 ±0.03	0.12 ±0.01

Number of shards analyzed – 15
Probable Source - Mazama Climactic
Similarity Coefficient = 0.99

* Standard deviations of the analyses given as uncertainties
** Analyses normalized to 100 weight percent
*** (Borchardt et al., 1972)

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Supplemental Figure 1

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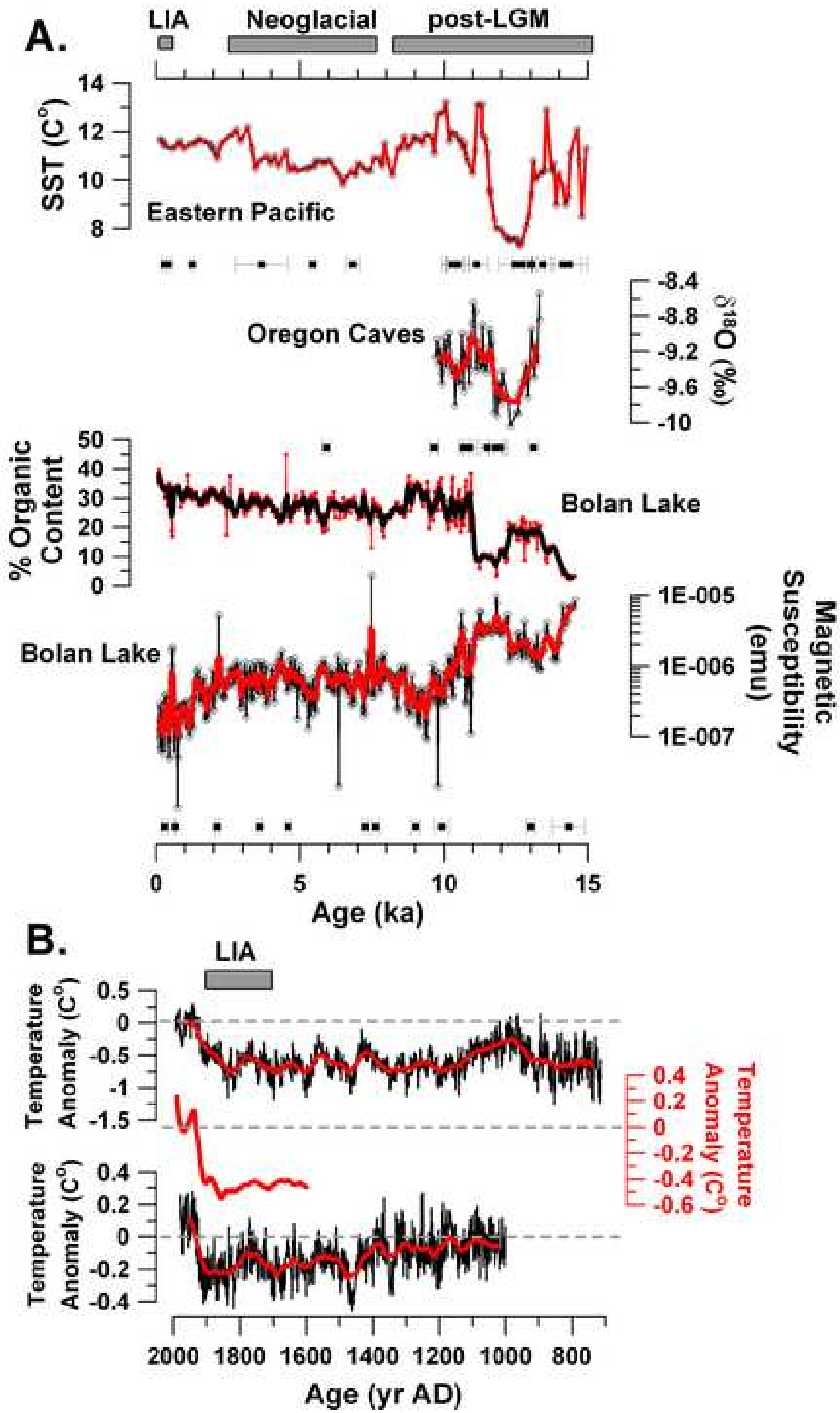

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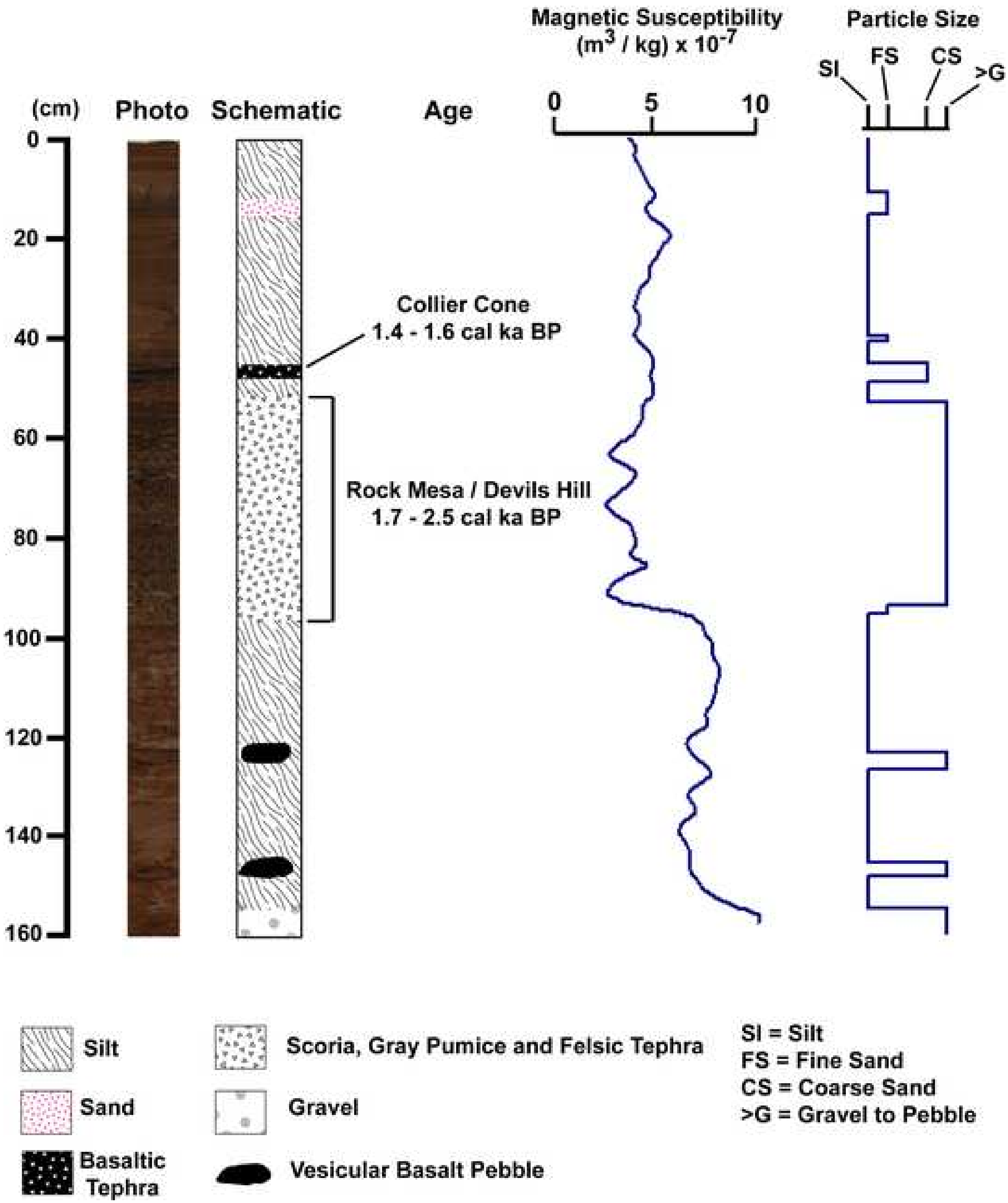

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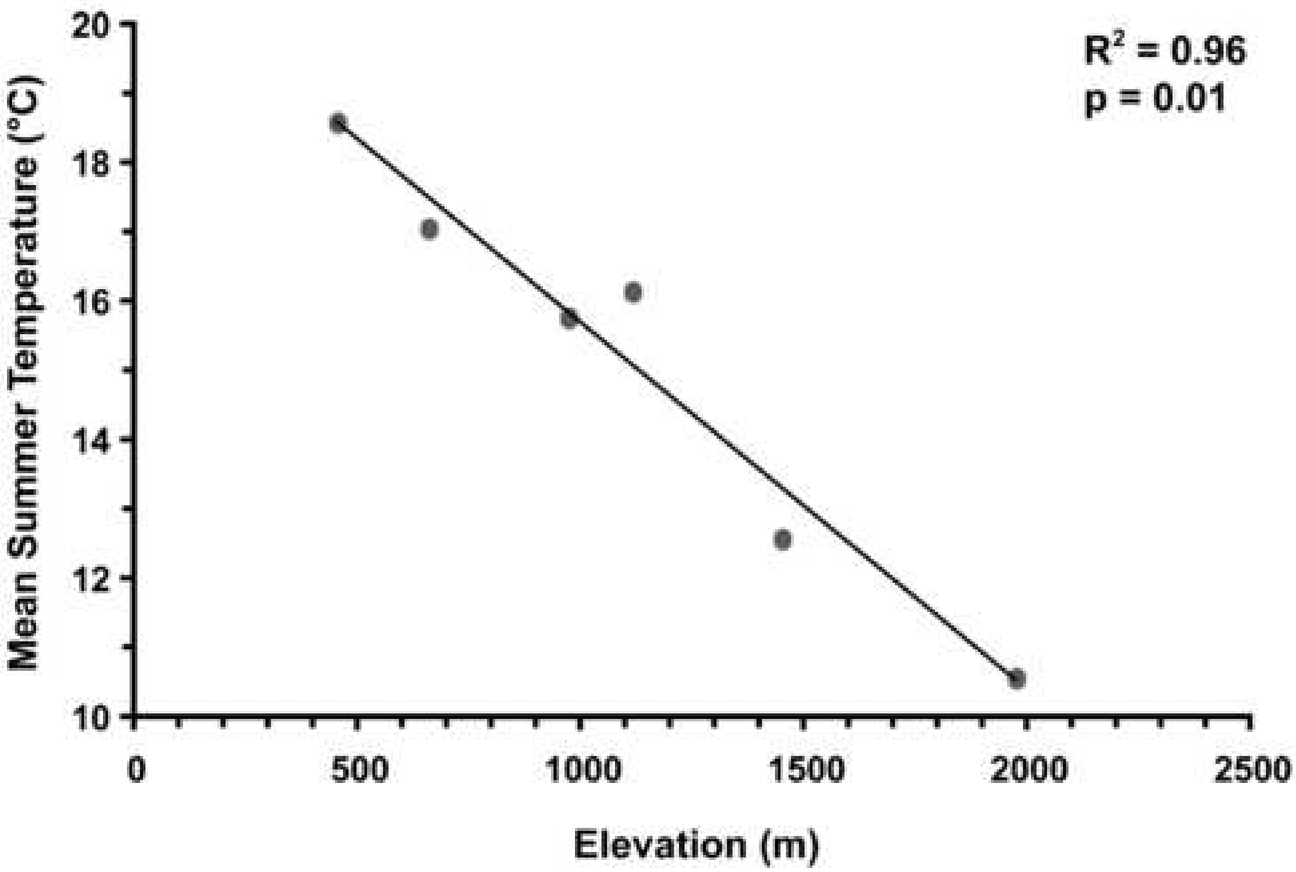

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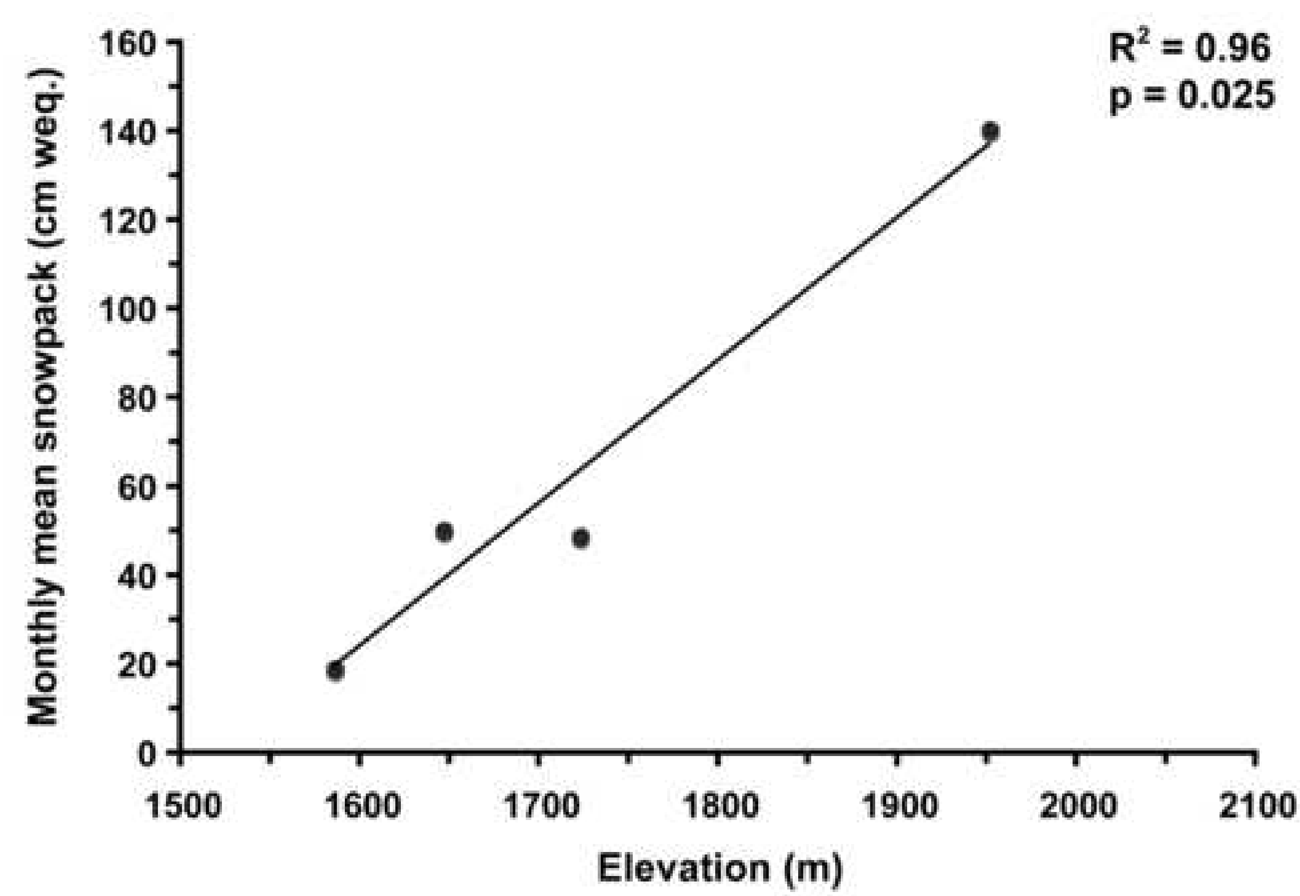

Figure S1. Comparison among timing of glacial stands at Three Sisters and Broken Top volcanoes (bars) and sea surface temperature reconstructions from the Pacific, oxygen isotopes from an Oregon speleothem, lake sediments from Oregon, tree ring analyses from the Northern Hemisphere, and glacier temperature reconstructions. A.) Reconstructed sea surface temperature (SST) from alkenones at Site 1019 in the Pacific Ocean just off the northern coast of California (top) (Barron et al., 2001), an oxygen isotope record (VPDB) from a speleothem (OCNM8-02A) collected from Oregon Caves National Monument in southwestern Oregon (middle) (Vacco et al., 2005), and percent organic materials and magnetic susceptibility from Bolan Lake in the Klamath Mountains, ~30 mi south of Oregon Caves National Monument (bottom two plots) (Briles et al., 2005). The bold line overlaying the speleothem and lake sediment records represents a 7-point running mean of the data. Small squares below each record represent age control points (i.e., ^{14}C, U/Th) with published uncertainties. B.) Tree ring temperature anomaly reconstructions from multiple sites in the Northern Hemisphere (top and bottom) (D'Arrigo et al., 2006; Mann et al., 1999), and temperature anomaly reconstructions from 169 glacier length records (middle) (Oerlemans, 2006). The bold lines overlaying the tree ring reconstructions represent a 51-point running mean of the data. See main text for full references.

Figure S2. Diagram of Camp Lake cores collected between Middle and South Sisters with magnetic susceptibility and generalized particle sizes. The Rock Mesa / Devils Hill tephra age is from Scott (1987) while the Collier Cone tephra age is from Scott et al. (1990). See main text for full references.

Figure S3. Linear regression line for mean summer temperature (°C) (June – August) versus elevation (m) for six meteorological stations near the Three Sisters volcanoes.

Figure S4. Linear regression line for highest monthly mean winter accumulation (cm swe) versus elevation (m) for four meteorological stations east of the Three Sisters volcanoes.