Optical age constraints on decay of the last Cordilleran Ice Sheet:

applying an age range-finder method and standardized dose-response curves to efficiently date late-glacial, ice-marginal lake sediments

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Rationale

- Establishing chronological limits on decay of the last Cordilleran Ice Sheet in south-central BC has faced challenges largely based on a paucity of organic material in late-glacial sediments.
- Current age constraints loosely indicate retreat from the southern LGM began ~15.3 ± 1.3 ka cal BP(W-1644) and reached the southern Fraser Plateau by 10.5 ± 0.57 ka cal BP(GSC-511, Fig. 1).
- We apply an optical dating age-range finder method using standardized dose-response curves aimed at increasing efficiency in identifying a sample that is (i) most suitable for dating and (ii) applicable to refining the regional chronology.

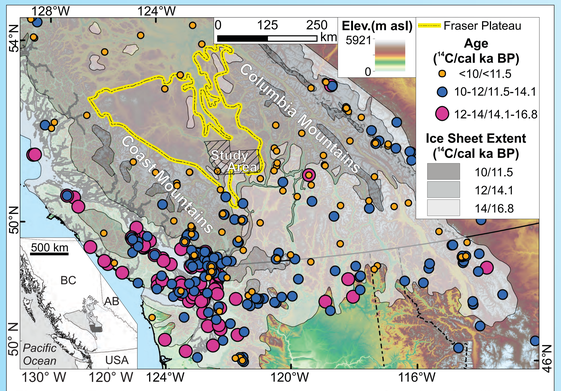


Figure 1: Existing chronological control on retreat of the last Cordilleran Ice Sheet. Ages and ice limit data from Dyke et al. 2003. Outline of Fraser Plateau from Holland (1976). DEM and hillshade produced from data available at Geobase®.

Objectives

1. Refine the chronology of ice-sheet decay over the southern Fraser Plateau through the addition of limiting optical ages on late-glacial, ice-marginal sediments.
2. Develop a laboratory routine for rapidly identifying the most well-bleached (apparently youngest) sample, from a set of samples collected from a lithostratigraphic unit, which is then used for a full optical dating experiment.

Study Area

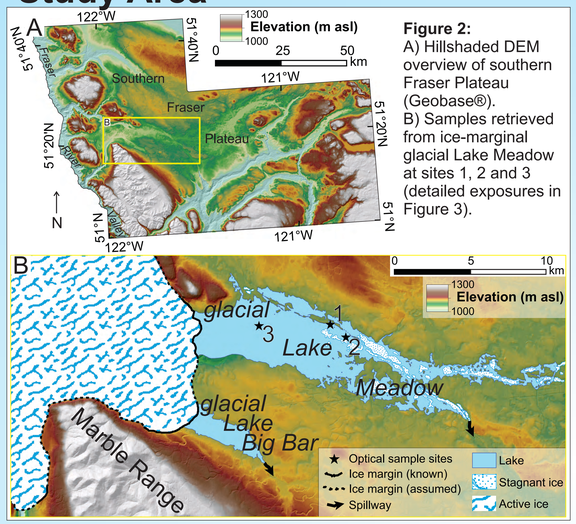
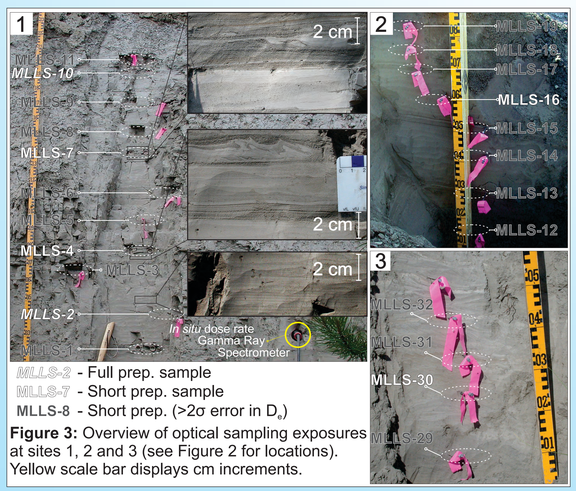


Figure 2: A) Hillshaded DEM overview of southern Fraser Plateau (Geobase®). B) Samples retrieved from ice-marginal glacial Lake Meadow at sites 1, 2 and 3 (detailed exposures in Figure 3).



MLLS-2 - Full prep. sample
MLLS-7 - Short prep. sample
MLLS-8 - Short prep. (>2σ error in D_e)

Figure 3: Overview of optical sampling exposures at sites 1, 2 and 3 (see Figure 2 for locations). Yellow scale bar displays cm increments.

Optical Dating

Methods

- To maximize the likelihood of sunlight exposure, samples were taken from the silt fraction of lake-bottom rhythmites.
- One sample was chosen to undergo full laboratory preparation (full prep) and measurement using a Multiple Aliquot Regeneration (MAR) technique (Fig. 4, Table 1).
- All other samples underwent a rudimentary, short laboratory prep and experimental results were compared to the dose-response curve generated for the full prep sample (Fig. 5, Table 1).
- The short prep sample with the greatest confidence of providing a limiting age (based on site location, sample depositional environment, short prep error, and fit with previous age estimates) was chosen to be run as a full experiment using the Single Aliquot Regeneration (SAR) technique (Fig. 6, Table 1).

Sample preparation

Step	Treatment
1	Remove sample exterior
2	HCl wash (carbonate removal)
3	Wet sieve (full prep only)
4	0.5 hr stokes settling
5	4 hr stokes settling (full prep only)
6	Acetone wash
7	Disc mounting

Measurement (MAR)

Step	Treatment
1	3 hour laboratory bleach(regen only)
2	Give dose, Di
3	Preheat for 4 hours at 160°C
4	Normalize with IR for 0.5s (880 nm, 1.4 eV)
5	Stimulate with IR for 100s (400 nm, 3.1 eV)

Measurement (SAR)

Step	Treatment
1	Give dose, Di
2	Preheat for 10s at 180°C
3	Stimulate with IR for 200s at 125°C
4	Give test dose, Dt
5	Cutheat at 160°C
6	Stimulate with IR for 200s at 125°C
7	Return to 1

Results

Transfer dose-response curve from full experiment to short prep experiments

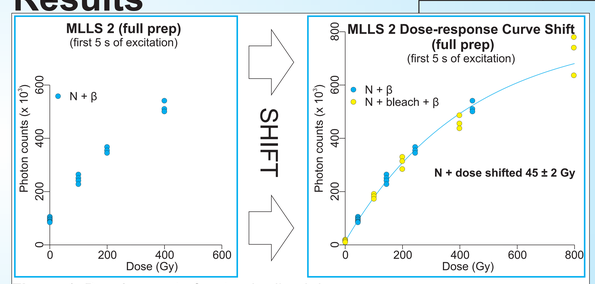


Figure 4: Development of a standardized dose-response curve.
- ~50 fine-grained silt aliquots (Naturals, "N") were prepared.
- 16 were exposed to light (bleached) to empty all optical traps (N+bleach).
- All aliquots were given various doses of laboratory beta (β) radiation forming two final sets, N+β and N+bleach+β.
- After a preheat, all aliquots were exposed to IR stimulation and the resulting luminescence intensity measured.
- The N+β data were horizontally shifted to overlay on the N+bleach+β data and a curve fitted, with the size of the shift proportional to the equivalent dose (D_e).

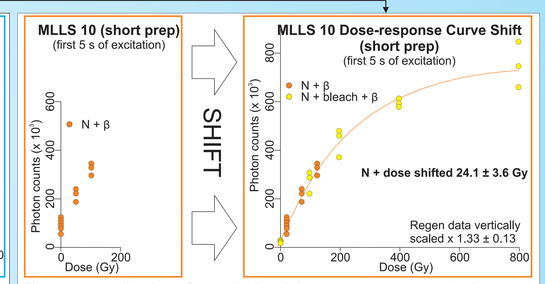


Figure 5: Application of standardized dose-response curve in short prep experiments.
- ~12 fine-grained silt aliquots (Naturals, "N") were prepared.
- Aliquots were given various doses of laboratory β-radiation (N+β).
- After a preheat, aliquots were exposed to IR stimulation and the resulting luminescence intensity measured.
- The N+β data was then shifted to align with the N+bleach+β data from the standardized dose-response curve.
- The size of the horizontal shift is proportional to the equivalent dose.

Table 1: Statistically significant results (2σ) of short and full prep experiments.

Sample	Prep	Type[a]	d (m)[b]	D_c (Gy/ka)[c]	D_T (Gy/ka)[d]	D_e(Gy)[e]	Optical age (ka)
MLLS-2	Full	MAR	2.20	0.144 ± 0.007	1.737 ± 0.112	45.0 ± 2.0	28.3 ± 2.2
MLLS-4	Short	MAR	1.70	0.157 ± 0.008	1.750 ± 0.113	22.6 ± 5.2	14.2 ± 3.4
MLLS-7	Short	MAR	1.20	0.170 ± 0.009	1.763 ± 0.114	35.8 ± 8.1	22.5 ± 5.3
MLLS-10	Short	MAR	0.60	0.189 ± 0.009	1.782 ± 0.115	24.1 ± 3.6	15.1 ± 2.5
MLLS-10	Full	SAR	0.60	0.189 ± 0.009	1.782 ± 0.115	26.7 ± 0.3	16.8 ± 1.1
MLLS-16	Short	MAR	0.50	0.192 ± 0.010	1.785 ± 0.115	65.4 ± 8.3	41.1 ± 5.8

[a]Type = experiment type; [b]d = depth; [c]D_c = cosmic dose-rate; [d]D_T = total dose-rate; [e]D_e = equivalent dose

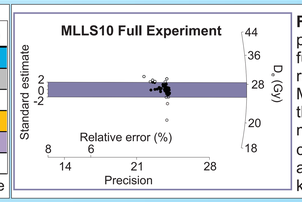


Figure 6: Radial plot showing SAR full experiment results for MLLS10. Using the central age model, the D_e corresponds to an age of 16.8 ± 1.1 ka BP.

Conclusions

1. Based on the youngest limiting ages from full experiments, ice-marginal lakes existed on the southern Fraser Plateau after 16.8 ± 1.1 ka BP confirming they existed during deglaciation of the last CIS.
2. Standardized dose-response curves and short prep experiments provide an efficient way to process many samples in order to quickly find the most well-bleached candidate.

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