A 2.5 kyr luminescence date for a terminal moraine in the Leones valley, southern Chile

One of the problems for the construction of inter-hemispheric climate models is that in southern South America, an ideal location for supplying the Southern Hemisphere component, climate signals derived from glacier movements are often ambiguous, suggesting locally and regionally contrasting trends emphasizing climate variability rather than hemispheric changes (e.g. Luckman and Villalba, 2001). Most previous dating of terminal moraines in the region has relied on radiocarbon determinations. This technique is not without its problems, and confirmation through application of alternative dating techniques is required.

One possible alternative technique, optically stimulated luminescence (OSL), has so far received little attention in glaciofluvial environments (Krause and others, 1997). In turbid waters, there is a problem for optical resetting of the luminescent signal, known as bleaching, which typically requires several seconds of exposure to full daylight prior to deposition and burial (Wintle, 1997). Despite this problem, we decided to attempt OSL dating on deposits around Lago Leones on the east side of Hielo Patagónico Norte (HPN; northern Patagonia icefield).

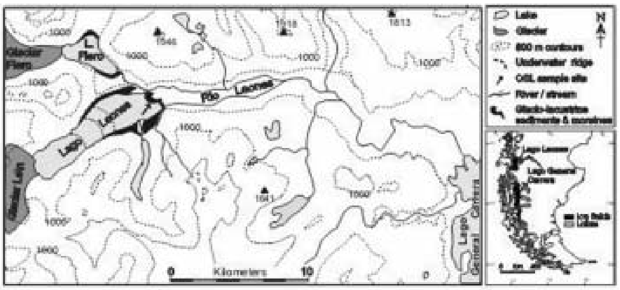

Fig. 1. Leones and Río Leones valleys with inset showing positions of HPN and HPS, Lago Leones and Lago General Carrera.

HPN and its partner, Hielo Patagónico Sur (HPS; southern Patagonia icefield), cover respectively ~4200 and 13 000 km^2. HPN has 16 major outlet glaciers and numerous smaller ones, with many on its eastern side ending in deep lakes. Of these, Glaciar León is a typical example, calving into Lago Leones, a 9.5 km long, 2.5 km wide proglacial lake terminating in a 125 m high moraine where the northeast-trending Lago Leones valley joins the east-trending Río Leones valley (46°46′ S, 73°13′ W). Río Leones empties into Lago General Carrera, a 1500 km^2 lake bisected by the Chilean/Argentinian frontier (Fig. 1).

We collected five samples, only one of which provided a successful date. This sample was taken from the proximal flank of the Leones terminal moraine where a small landslide has exposed finely laminated well-sorted sands and gravels (interpreted as glacio-lacustrine deposits) capped by a moraine. The sample was taken at a height of 100 m above lake level and 0.9 m below a boulder marking the base of the overlying moraine (Fig. 2a and b). The other four samples were taken from the lake's southern margin where similar sediments appear as lateral features (Fig. 3). These deposits, up to 110 m deep, suggest former high-lake levels, with the former lake contained by an enlarged version of the current terminal moraine whose upper slopes (those unprotected by the accumulated lake-floor sediments) were largely removed by an outburst flood shortly before the last glacier advance.

Standard luminescence methods (Murray and Wintle, 2000) were conducted, with the successful sample yielding average repeat-point ratios and thermal transfer ratios of 0.95 (±0.02) and 0.04 (±0.01) respectively. The dose rate was calculated using inductively coupled plasma mass spectrometry (ICP-MS; Bailey and others, 2003). Finally, the Minimum Age statistical model of Galbraith and others (1999) was applied, resulting in an OSL date

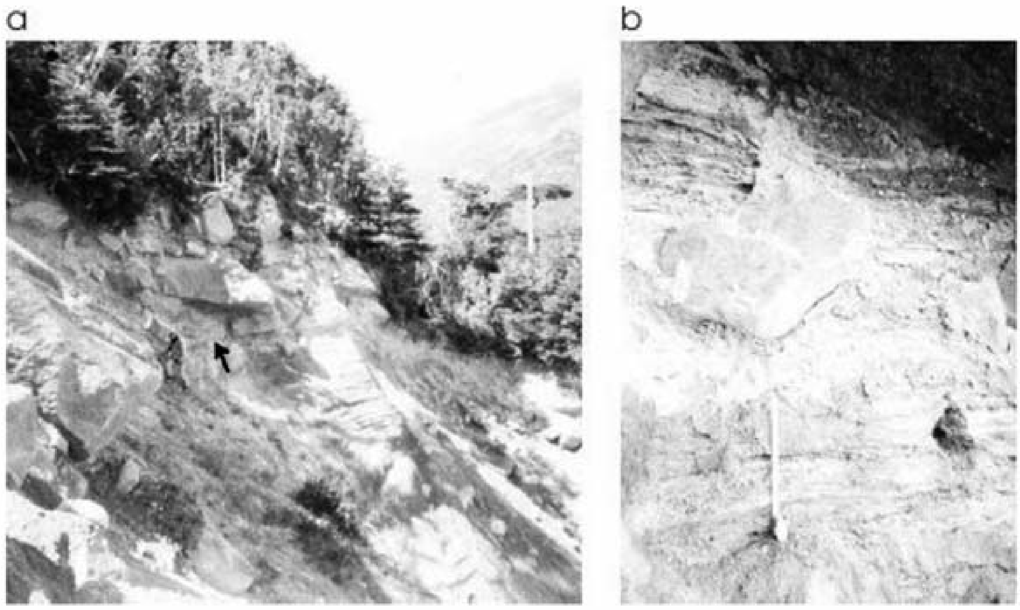

Fig. 2. (a) Sampling site (black arrow) on Leones terminal moraine showing moraine overlying glacio-lacustrine sediments (scale provided by S.H. standing left of arrow). (b) OSL sample site showing sand laminae with gravel lenses. Scale 30 cm.

Fig. 3. Panoramic view of Lago Leones and Río Leones valley showing OSL sample site, marked by terminal moraine asterisk, and LIA moraine.

of 2480 ± 130 years BP, equivalent to 2440 ^{14}C years BP. A summary of the dating results for sample Ch3b is given in Table 1.

PREVIOUS DATING AND DISCUSSION

Several Neoglacial cooling intervals, within the mid- to late Holocene period, have been identified in glacial deposits around the two icefields. Mercer (1976, 1982) established three cooling intervals: 4700–4200 and 2700–2200 ^{14}C years BP and the Little Ice Age (LIA). An alternative scheme (Aniya 1995) for Glaciares Tyndall and Upsala on the east side of HPS identified four glacial advances: 3600, 2300 and 1600–900 ^{14}C years BP and AD 1600–1750.

The 2440 ^{14}C years BP date for the last advance of Glaciar León to the foot of the Lago Leones valley is interesting because, on the radiocarbon calibration curve, the date falls roughly at midpoint on a plateau in the curve ranging from 2700 to 2350 cal. years BP (Stuiver and others, 1998). This adds a degree of precision to both Mercer's 2700–2200 ^{14}C year BP and Aniya's 2300 ^{14}C year BP minimum dates for Neoglacial II. The precise date, however, will be a little later than that of the sample since it must include the time taken for accumulation of 0.9 m of sediments. Three underwater ridges in Lago Leones, located during a bathymetric survey, suggest later Neoglacial advances or still-stands, with the youngest of these associated with a moraine-covered promontory 3 km from the icefield (see Fig. 1), dendrochronologically and lichenometrically dated to AD 1867 (Harrison and others, unpublished information), reflecting Glaciar León's maximum LIA position.

The achievement of an apparently successful OSL 2.5 kyr date for this sample is encouraging. As well as providing a more precise date for Neoglacial II, the date has implications for the size of the ice cap during the period. Multi-proxy dating of other terminal moraines at the ends of similar-sized lakes on the east side of the icefield (e.g. Lago Colonia) and on the west (e.g. the moraines encircling Laguna San Rafael) is needed to confirm this.

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Table 1. Summary of dating results. The *D*e estimate was obtained using the Minimum Age model of Galbraith and others (1999). All errors quoted are at 1σ

		Environmental dose rate				Absorbed dose		
U conc.	Th conc.	K conc.	Water	Cosmic dose rate	Total dose rate	*D*e	Overdispersion	Age
ppm	ppm	%	%	Gy kyr^{-1}	Gy kyr^{-1}	Gy	%	kyr
2.04 ± 0.02	6.24 ± 0.08	2.14 ± 0.01	3 ± 3	0.1 ± 0.02	3.04 ± 0.16	7.5 ± 0.23	123 ± 22	2.48 ± 0.13

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