Exposure dating in the Central Andes: Quaternary glacier and climate reconstruction

Zech, R., *Kull, Ch. & Veit, H.

Institute of Geography, University of Bern, Switzerland

** PAGES IPO, Sulgeneckstrasse 38, 3007 Bern, Switzerland*

Glaciers sensitively record climate changes, because their mass balance depends on both temperature and precipitation. Moraines are therefore potentially valuable archives for Quaternary climate reconstructions. The possibility to determine the deposition age of moraines has, however, often been limited due to the lack of organic material for radiocarbon dating. This is especially true for arid high mountain areas, like e.g. the Central Andes. There, little is known about the glacial history, although the position between the tropical and extratropical circulation systems (westerlies vs. tropical influence) makes them a key area for studying Quaternary climate. Huge moraines north and south of the so-called 'Arid Diagonal', have been interpreted to document periods of substantially increased precipitation (Amman et al. 2001), but insufficient dating control prevented detailed interpretations.

Recent progress in developing surface exposure dating (SED) (Gosse & Phillips 2001) has provided a new tool, which now enables to address questions concerning

- the age of glacial advances north and south of the Arid Diagonal,
- their value as archive for shifting atmospheric circulation systems and concurrent precipitation changes, and
- their potential correlation with well-known northern hemispheric cold periods during deglaciation (e.g. the Oldest, Older and Younger Dryas).

So far, we have obtained first exposure ages from the Encierro Valley (~29°S), Northern Chile, just south of the Arid Diagonal (Zech et al., submitted) (Fig. 1). A very prominent moraine stage (M-II) documents an extensive glaciation, which reached an altitude of ~3500 m, resulting in an equilibrium line altitude (ELA) depression of ~1000 m. A large lateral moraine (LM in Fig. 1) corresponds to this advance and has also been sampled. Several recessional moraines (M-III, IV and V) can be found in the valley bottom and probably document climate fluctuations during deglaciation.

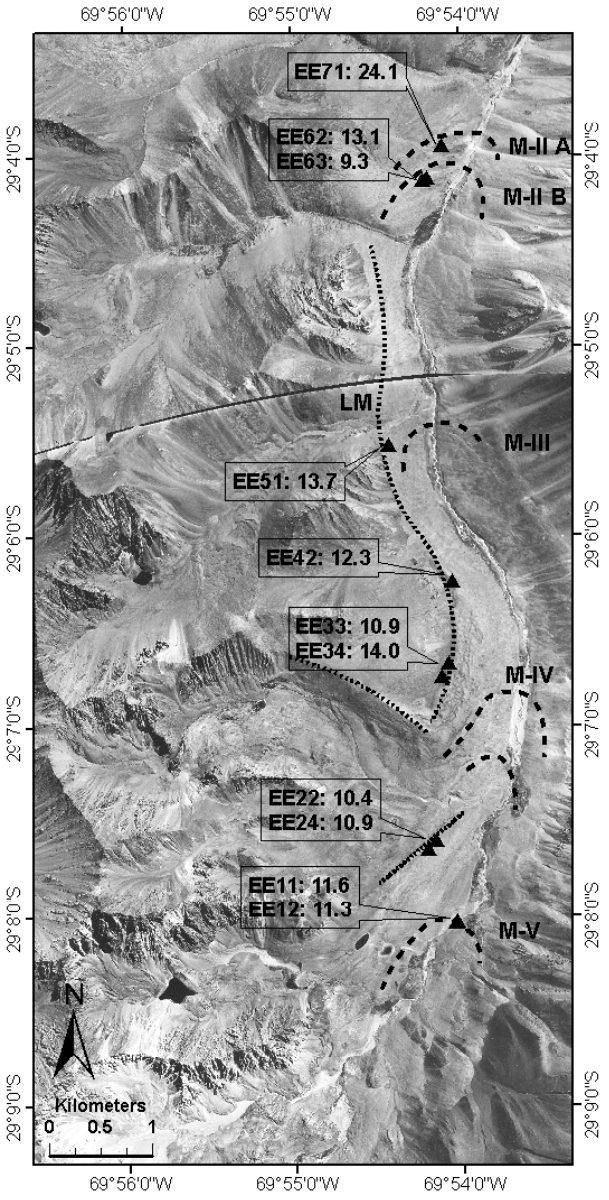

Figure 1: Geomorphological setting of the research location in the Encierro Valley. The dashed lines indicate terminal moraines, the dotted lines pronounced lateral moraines. Numbers behind sample labels are the exposure ages in ka.

The exposure ages from M-II B and LM indicate that the prominent glacial stage occurred at ~14.0 ± 1.4 ka BP. Too young exposure ages can be explained with post-depositional exhumation and instability of boulders, so that in the absence of obvious outliers the oldest exposure age should generally be considered the best estimate for the deposition age (Zech et al., in press). The oldest sample (EE71 on M-II A) may either be an outlier due to inheritance (pre-exposure) or, more likely, document a previous, more extensive glaciation than M-II B.
Deglaciation of the nowadays ice-free valley occurred after a final glacial advance at ~11.6 ± 1.2 ka BP.

Previous modeling has shown that a temperature depression of ~5.5°C and a precipitation increase of ~550 mm/a (presently: ~300 mm/a) has been necessary to create the most prominent moraine stage M-II B (Kull et al. 2002). Today, the study area is mainly influenced by the westerlies and winter precipitation. It has therefore been postulated that a glacial advance could have occurred synchronous with the temperature minimum during the last glacial maximum (LGM) at ~18-20 ka BP. Not only low temperatures, but also a northward shift of the westerlies, deduced from marine sediments off-shore Chile and pollen records, would have favored this scenario. However, the glacier-climate model could not determine any pronounced seasonality of the increased precipitation, and it can therefore not be excluded that austral summer advection of humid air masses from the Andean east-side might have played an important role for the observed glacial stages at ~14.0 and 11.6 ka BP. There is increasing evidence for major climatic changes in tropical and subtropical South American climate at these times (e.g. oxygen isotope records from stalagmites in SE-Brazil, from ice-cores on Vulcan Sajama and Illimani, from lake sediments on the Altiplano, etc.), but hitherto both proxy interpretation and correlation are a matter of ongoing debate.

We conclude that
- extensive glacial advances in the Encierro Valley occurred during the Lateglacial,
- these advances required substantially increased precipitation, which we speculate might originate from the tropical circulation system, and
- that the timing of glacial advances resembles the cold event stratigraphy in the northern hemisphere (Oldest Dryas, Younger Dryas), but that absolute uncertainties (~10%) need to be reduced for corroboration.

Further exposure age samples are currently being prepared and results are anticipated for October/November. These ongoing studies are focusing:
- on the refinement of the glacial chronology in a valley close to the presented Encierro Valley (at least six glacial stages),
- on the spatial extent of the identified glacial advances: Comparison with exposure age chronologies from Bolivia, as well as from south of the Encierro Valley are expected to yield further information on past precipitation changes and sources.

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