FINAL REPORT PROGRAM LEFE

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-CEREGE (Aix-en-Provence, France)

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Context :

Holocene glacier chronologies are necessary to assess spatial extent and magnitude of rapid climate changes having occurred during the current interglacial. Such chronologies are increasingly available worldwide but there is now a need to **improve their temporal resolution** to be able to answer questions related to distant teleconnections between northern and southern hemisphere climates for instance.

Objectives :

This project was designed to build new glacier chronologies in different regions of Patagonia along a latitudinal transect. Main questions are related to **the onset and timing of the Neoglacial period**. Emphasis was placed on the use of dendrochronology and wiggle matching techniques to constrain glacier variations with a decadal precision. For sites where dendrochronology was not applicable moraine chronologies were derived from surface exposure dating with ^{10}Be.

Main results :

The *PataGHol* project has allowed us to build glacier chronologies for four different glacier systems located in the Monte Tronador area (41°S) and around El Chaltén (49°S), Argentina. Investigated glaciers are of different types: small alpine glacier (Alerce, 2 km²) and medium-sized glacier with a regenerated debris-covered tongue (Ventisquero negro, 8 km²) at Monte Tronador; large land-terminating outlet of the Southern Patagonian Icefield (SPI) (Marconi, 50 km²) and the second largest glacier of south America, a freshwater calving glacier (Viedma, 977 km²).

The *PataGHol* project has established the **most complete and accurate Late Holocene glacial chronology to date in Patagonia at the Monte Tronador site** (Ventisquero Negro and Alerce glaciers). The ages obtained made it possible to precisely constrain the periods of tree burial by glaciofluvial sediments in proximal (lateral moraines) and distal (glaciofluvial outwash) environments – and thus the dates of glacier advances: around **150 CE**, **330 CE**, **550 CE**, **1030 CE**, **1220 CE** and **1350 CE** at Ventisquero Negro, and around **1600 CE** at Alerce glacier. At this latter site, cosmogenic dating of the outermost moraine identified confirmed the dendro-dating of the Little Ice Age (LIA) maximum. All these dates come from a precise chronological timing based on the wiggle-matching of subfossil wood floating chronologies, **which had never been used in Patagonia before**. However, we could not identify and date evidence for glacier advance that could have occurred before the Common Era in this area.

In the Chaltén area (Marconi and Viedma glaciers), our ^{10}Be-derived moraine chronologies highlight **a contemporary Neoglacial maximum at both sites around 7 ka** – despite two very different settings – and **two other advances**, quite similar in size, occurring **before 4 ka**. Then, two other Neoglacial stadials of decreasing magnitude occurred **around 2 ka, and during the LIA from 0.5 ka**. Our chronology is consistent with growing evidence of a prominent change in the regime of the Southern Westerly Winds (SWW) at 7 ka, as indicated by proxy records (Moreno et al, 2018). In this area, the magnitude of the reconstructed Neoglacial maxima are several kilometers downstream from the LIA positions.

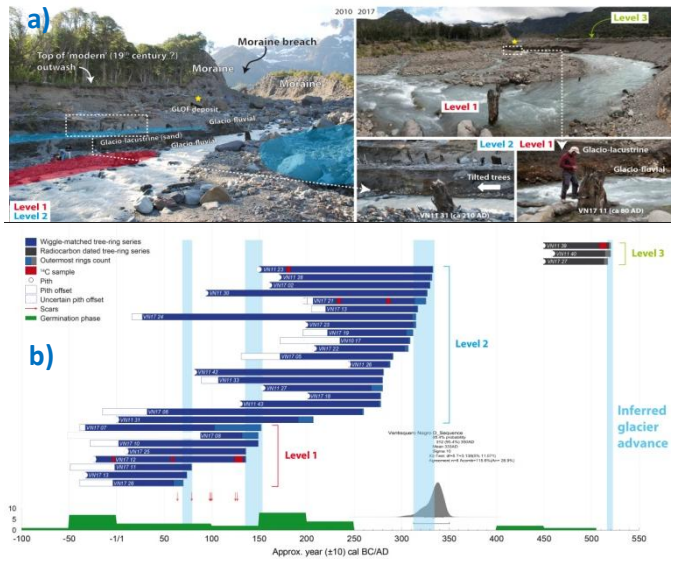

Fig. 1. *Results of the dendrochronological synchronizations of the* in situ *subfossil trees sampled in the glaciofluvial plain of the Ventisquero Negro glacier (floating chronologies are placed on a calendar scale based on the wiggle matching of the radiocarbon dates indicated in red).*

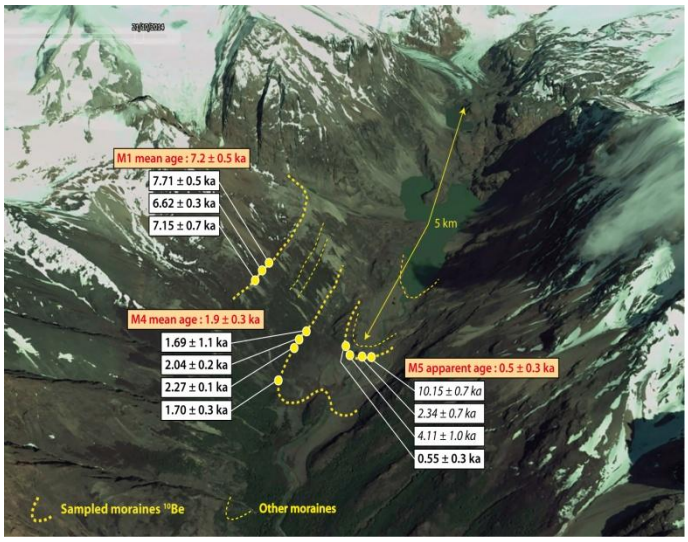

Fig. 2. *Results of the ^{10}Be surface exposure dating carried out on the Neoglacial moraines of the Rio Electrico valley (Marconi glacier can be seen in distant background; distance between present day front and LIA maximum position is 5 km).*

The major dated site during the course of the *PataGHol* project is the floodplain of the Ventisquero Negro glacier **[Fig. 1a]** where tens of *in situ* subfossil stumps belonging to different levels were recovered and crossdated. We hypothesized that each tree level was buried by flooplain aggradation due to sediment delivery by an advancing glacier (reaching a position close to the LIA maximum). This site is unique at the scale of South America because it is the only one to have delivered dendrochronological dating able to constrain glacier variations during the First Millennium CE with this degree of precision **[Fig. 1b]**.

Around El Chaltén, the Electrico valley provided a 'nearly complete' moraine record of Neoglacial glacier fluctuations **[Fig. 2]**. We targeted three of these moraines for ^{10}Be exposure dating and found they were deposited during the middle Holocene for the maximum and around 2 ka and 0.5 ka for inner moraines **[Fig. 2]**.

These two examples illustrate the complementarity of the used methods as well as the sites studied during the *PataGHol* project, which will allow establishing a new robust model of Neoglacial glacier fluctuations in Patagonia.

Future of the project :

The natural extension of this project is the increase of subfossil wood sampling in Patagonia in order to build millennial long chronologies for the tree species found in glacial sediments in this region (mainly *Nothofagus pumilio*). Unlike the Alps, long dendrochronological reference chronologies do not currently exist in Patagonia for species allowing to constrain glacier fluctuations. Yet, these long reference chronologies are an essential prerequisite for obtaining calendar-dated glacier chronologies over the Common Era – and beyond – in that key area. This will be the main objective to pursue in the next proposals submitted by our team.

Publications :

Le Roy M., Ruiz L., Schimmelpfennig I., Geiger A., Villalba R., Zorzut V., Ponce J.F., Deline P., ASTER Team, Xu S., Fabel D., 2019. Neoglacial fluctuations of two contrasting Southern Patagonian Icefield glaciers (49°S). In prep, to be submitted to *The Holocene*.

Conferences :

Le Roy M., Ruiz L., Schimmelpfennig I., Geiger A., Villalba R., Zorzut V., Ponce J.F., Deline P., ASTER Team, Xu S., Fabel D., 2019. Neoglacial fluctuations of two contrasting Southern Patagonian Icefield glaciers (49°S). 20th INQUA congress, 25-31 July 2019, Dublin.