# FINAL REPORT PROGRAM LEFE

| Program LEFE/ IMAGO | Project Title : CO2Role | Years 2017-2019 |
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*Context (2-3 lignes)*

*Building a chronology for ice cores is a complex task, since there is a lot of dating methods, with their advantages and drawbacks and domain of applicability. To optimize the chronology of ice cores, we must therefore combine these different sources of chronological information through a probabilistic dating model such as IceChrono (Parrenin et al., 2015).*

*Objectives / scientific questions (2-3 lignes)*

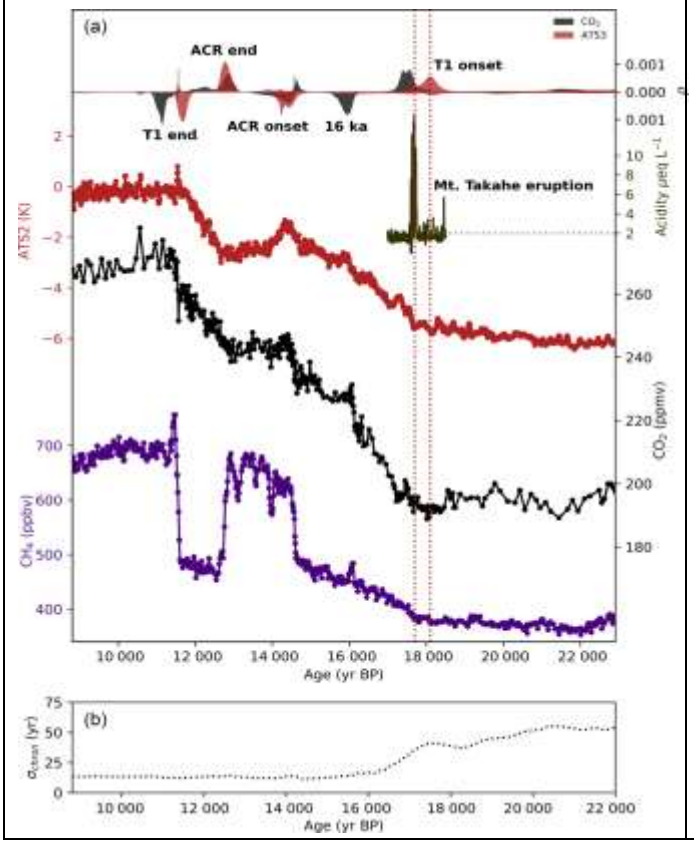
*The objectives have been: 1) to improve the probabilistic dating model IceChrono; 2) to apply IceChrono to the principal ice cores in Greenland and Antarctica; 3) to analyze the resulting dating in terms of climatic phasing.*

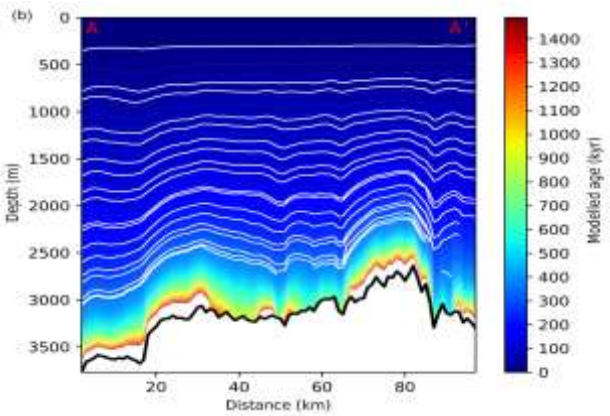
*Main results*

The probabilistic dating model IceChrono has been improved, expanded to other paleoclimatic archives and renamed Paleochrono. Thanks to its adjoint, it can now invert > 100,000 parameters.

A new estimate of the phasing between Antarctic temperature and $CO_2$ has been derived for the last deglaciation. It appears that Antarctic temperature leads at the onset and end of the deglaciation but that both proxies are in phase in the middle.

A new site in Antarctica where to drill a 1.5 Myr ice core has been located. This new ice core will be drilled in the frame of the European H2020 Beyond EPICA project (2019-2026, French PI: F. Parrenin).



On the left figure (middle panel) are illustrated the Antarctic temperature (AT, red), the atmospheric $CO_2$ ($CO_2$, black) and the atmospheric methane (in pink). The top panel shows the probabilistic diagrams of the change of slope of the AT and $CO_2$ curves. The bottom panel shows for reference the relative uncertainty of the AT and $CO_2$ chronologies. From Beeman et al. (Climate of the Past, 2019).

On the right figure, is illustrated the age of the ice along the Dome C - Little Dome C profile. The white lines are the isochrones observed by radar. The modeled age is illustrated by the color code. A spot of ice > 1.5 Myr old seems to be located on a bedrock relief below the secondary Dome called Little Dome C. It is the place chosen by the European Beyond EPICA project for its next drilling in Antarctica. From Parrenin et al. (The Cryosphere, 2017).

*Future of the project :*
*A module to automatically synchronize paleoclimatic records within IceChrono has been developed and will soon be submitted (Beeman et al., in prep.).*
*IceChrono has been expanded to account for other type of climatic archives and renamed to Paleochrono. Paleochrono has been optimized in various ways (for example its adjoint has been derived), and it is now possible to invert >100,000 parameters. Moreover, Paleochrono has been made easier to use. A publication to describe Paleochrono will soon be submitted (Parrenin et al., in prep.).*
*Within the ERC project ICORDA (PI: A. Landais), it is planned to apply Paleochrono to the principal ice cores in Greenland and Antarctica and to derive an optimized chronology for these ice cores. This will be the subject of a PhD thesis which will start in September 2021.*
*Paleochrono is also used in various other projects, such as: 1) the dating of >100 marine records from the Mediterranean sea (Bazin et al., in prep.); 2) the dating of coastal ice cores in Antarctica (R. Mulvaney et al., in prep.); 3) an improved dating of the US GISP2 and WAIS ice cores (Martin, Buizert et al., in prep.); 4) the dating of the Dome Fuji ice core in Antarctica (Oyabu, Kawamura et al., in prep.).*
*The Paleochrono tool will also be used in the European H2020 project Beyond EPICA to establish the chronology of this future 1.5 Myr ice core.*

*Nombre de publications, de communications et de thèses*
*(citer au maximum 5 publications en lien direct avec le projet)*
*6 publications linked with the project, 12 communications, 1 PhD thesis.*


Parrenin, F., Bazin, L., Capron, É., Landais, A., Lemieux- Dudon, B. and Masson- Delmotte, V.: Icechrono1 : un modèle probabiliste pour calculer une chronologie commune et optimale pour plusieurs carottes de glace, Quaternaire, (vol. 28/2), 179–184, doi:10.4000/quaternaire.8121, 2017.

Passalacqua, O., Ritz, C., Parrenin, F., Urbini, S. and Frezzotti, M.: Geothermal flux and basal melt rate in the Dome C region inferred from radar reflectivity and heat modelling, The Cryosphere, 11(5), 2231–2246, doi:10.5194/tc-11-2231-2017, 2017.

Parrenin, F., Cavitte, M. G. P., Blankenship, D. D., Chappellaz, J., Fischer, H., Gagliardini, O., Masson-Delmotte, V., Passalacqua, O., Ritz, C., Roberts, J., Siegert, M. J. and Young, D. A.: Is there 1.5-million-year-old ice near Dome C, Antarctica?, The Cryosphere, 11(6), 2427–2437, doi:10.5194/tc-11-2427-2017, 2017.

Buizert, C., Sigl, M., Severi, M., Markle, B. R., Wettstein, J. J., McConnell, J. R., Pedro, J. B., Sodemann, H., Goto-Azuma, K., Kawamura, K., Fujita, S., Motoyama, H., Hirabayashi, M., Uemura, R., Stenni, B., Parrenin, F., He, F., Fudge, T. J. and Steig, E. J.: Abrupt ice-age shifts in southern westerly winds and Antarctic climate forced from the north, Nature, 563(7733), 681, doi:10.1038/s41586-018-0727-5, 2018.

Chowdhry Beeman, J., Gest, L., Parrenin, F., Raynaud, D., Fudge, T. J., Buizert, C. and Brook, E. J.: Antarctic temperature and CO2: near-synchrony yet variable phasing during the last deglaciation, Climate of the Past, 15(3), 913–926, doi:https://doi.org/10.5194/cp-15-913-2019, 2019.