doi.org/10.22498/pages.31.2.57

A European network of young ice-core scientists are developing new methods for the analysis of deep polar ice

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Ice cores are unique in that they are the only archives that enable direct measurement of gas composition of the past atmosphere. To date, the longest continuous ice-core record covers the last 800,000 years and was retrieved from the EPICA Dome C ice core (Jouzel et al. 2007). The next challenge is to understand the climatic transition from 41-kyr to 100-kyr glacial cycles which occurred between 1.2 to 0.7 Myr BP, known as the Mid-Pleistocene Transition (MPT) (Gunning et al. p. 58). The aim of the Beyond EPICA–Oldest Ice Core (BE-OIC) project is to drill an ice core as old as 1.5 Myr to obtain a continuous, high-resolution paleoclimatic record, including past greenhouse gas concentrations, which would cover the MPT. The BE-OIC project began in 2019 and drilling is scheduled to reach bedrock in 2026. The BE-OIC drill site (75.29°S, 122.44°E) on the East Antarctic Plateau was chosen for its low snow accumulation rate and topographic conditions, which are conducive to old ice (Chung et al. p. 60).

The oldest ice of the BE-OIC is characterized by very thin layers, which presents a major challenge to study. In preparation for the analysis and interpretation of the core, the DEEPICE Marie Sklodowska-Curie doctoral network was created to train the next generation of ice-core scientists. DEEPICE consists of 15 PhD students working at 10 institutions across Europe with 11 non-academic partner organizations.

This issue presents a selection of current research topics related to the DEEPICE PhD projects. Firstly, water isotope ($\delta^{18}O$ and δD) signals in ice cores are commonly interpreted as a temperature proxy, but they can be altered by surface processes (Ollivier et al. p. 62). Another challenge is to develop new techniques to measure and interpret these signals in the extremely thin layers of the deepest, oldest ice, which are discussed by Malegiannaki et al. (p. 64) and Shaw et al. (p. 66).

Impurities in ice can provide information about climatic changes. For example, mineral dust can tell us about atmospheric circulation changes and organic molecules can be used as tracers of past biospheres. Ongoing methodological developments enable the characterization of single dust particles (Lee et al. p. 68) and increase the number of detectable organic analytes (Notø p. 70). Laser ablation mass spectrometry shows that most impurities are located at grain boundaries between ice crystals (Larkman et al. p. 72). Moreno et al. (p. 74) explore the potential of large area scanning microscopy for the macro-scale analysis of the ice-crystal size.

The interpretation of climate data requires accurate dating, which becomes complicated for the deepest ice. This is why new dating methods using radionuclides (Kappelt et al. p. 76) and the gaseous O_2/N_2 ratio are under development (Harris Stuart et al. p. 78). The latter can also be used to reconstruct the atmospheric O_2 content. Past atmospheric concentrations of nitrous oxide are difficult to reconstruct because this greenhouse gas is produced in the ice. Soussaintjean et al. (p. 80) investigate this process to isolate the atmospheric signal of nitrous oxide.

The analysis and interpretation of gases in ice cores also requires an understanding of how air bubbles transform into air hydrates, which are ice "cages" filled with gas molecules (Painer et al. p. 82). At greater depths, the ice close to the bedrock contains debris and elevated gas concentrations, which could provide novel insights into the history of the ice sheet (Ardoin p. 84).

The developments in ice-core science from the DEEPICE project will enable us to study the only archive that combines continuous high-resolution climate signals with a direct record of the past atmospheric gas composition. A better understanding of past climate will help constrain models of ice-sheet and climate evolution (Gao et al. p. 86). The BE-OIC ice-core data will complement existing paleoclimatic records and assist in unraveling the mystery of the MPT.

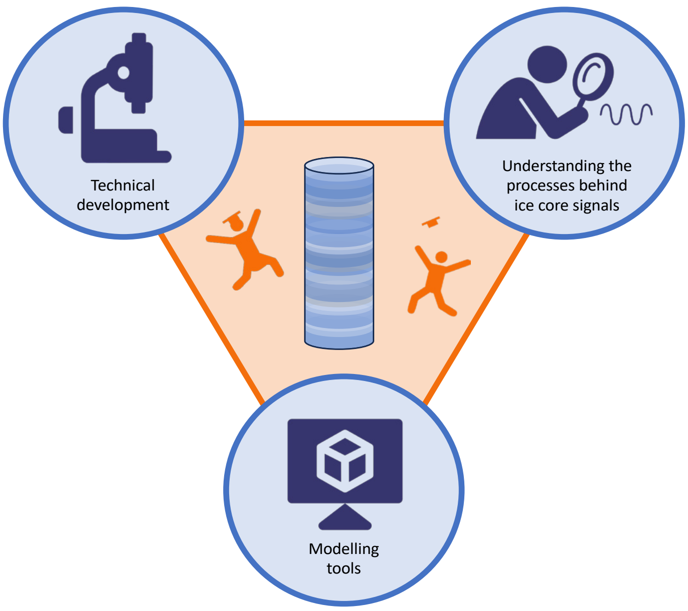

Figure 1: The three areas that the DEEPICE PhD students are working on to improve ice-core analysis and climate signal interpretation techniques for the BE-OIC project.

ACKNOWLEDGEMENTS

The articles of the DEEPICE special section of this magazine have received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955750.

The opinions expressed, and arguments employed herein, do not necessarily reflect the official views of the European Agency.

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