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INTERACTIONS BETWEEN GLACIERS AND LAKES IN THE DRY VALLEYS, ANTARCTICA indicated by multiparametric ice composition analyses

Abstract

Today, studying the Antarctic continent is essential for understanding and modeling the global climatic changes. Indeed, Antarctic ice not only contains precious paleoclimatic records but also plays a major role in the global warming mechanisms.

This work is part of a research program that aims to improve our understanding of the dynamic behaviour of the Antarctic ice sheet resulting from climatic change (AMICS*). For this purpose, it is essential to clarify the internal dynamics of the Antarctic ice sheet and to have a better assessment of the interactions of the ice sheet with its boundary conditions. This work focusses on this last aspect, specially on the processes acting at the ice-water interface. More specifically, it deals with the interactions between glaciers and lakes in the McMurdo Dry Valleys, on the basis of multiparametric ice composition analyses.

The **McMurdo Dry Valleys** (76°30' à 78°20'S – 160 à 164°E) are the largest ice free area of the Antarctic continent. The extreme aridity and low temperatures make these valleys one of the most hostile deserts of the planet. Mean annual temperature is close to –20°C and yearly precipitation reaches only 10mm 'water equivalent). Numerous glaciers flow in these valleys the soil of which is permanently frozen (permafrost). Their meltwater, only present during the summer months, gather into streams and feed permanently frozen lakes.

The **multiparametric approach** is a key tool to determine the origin of the studied ice. The ice composition analyses are: ice crystallography (texture and structure), major ions composition, stable water isotope composition, total gas content and gas composition. These different properties are analysed on the same or contiguous samples.

Three contact zones between cold glaciers (i.e. their whole ice mass being at a temperature lower than the melting point, all year round, even at the base) and

* Antarctic Ice Sheet Dynamics and Climatic Change: Modelisation and Ice Composition Studies, part of the second Belgian multiannual scientific support Plan for a Sustainable Development Policy (SPSD II). http://homepages.vub.ac.be/~fpattyn/amics/

permanently frozen lakes have been studied (see **figure 1** for localization). Among these three study sites, two are located in the contact zone of the same lake with the same glacier but present very different morphologies (**figure 2**). It is on the one hand a large area of totally clear ice (called blue ice) and on the other hand a complex ice-cored moraine, located between Wright Lower Glacier and Lake Brownworth (Wright Valley). The third site shows the influence of a frozen lake on a local glacier descending on the valley side and flowing across its floor (contact between Suess Glacier and Lake Popplewell – Taylor Valley). A slope, called apron, located at the base of the glacier ice cliff marks this contact (**figure 3**). The multiparametric analysis has been done not only on the ice of the contact zone itself, but also on basal ice upstream (sampled inside a tunnel dug at the glacier base) and on lake ice situated downstream. The study shows the following points.

At the first site, the lake plays a major role in the formation of the ice present in the contact zone. This ice has been formed by the slow progression of a freezing front into the free lake water. The evidence of this process is given by the isotopic and chemical compositions and by the total absence of bubbles in the studied ice. Crystallographic data combined with these compositional results allow to propose a model of ice cover formation in two phases in the contact zone.

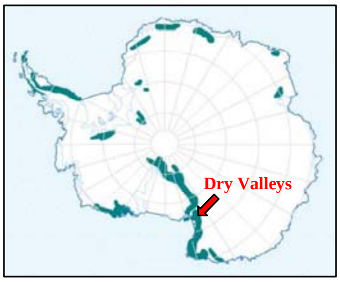
At the second site, the lake influence is also well marked, but not exclusive, in the formation of the ice-cored moraine. For most of the studied samples, the analytical results from isotopic analyses as well as from total gas content and gas composition clearly indicate that freezing of liquid water is a dominant process. The interbedding of clean ice and ice cemented sediments layers results from the progression of a freezing front from the glacier base to the lake bed. Besides the accreted ice at the glacier base, the moraine also contains ice similar to the one formed upstream, which has been partly influenced by liquid water. Complex deformations have led to the intercalation of both ice types

Finally, the third site is particular. Isotopic, ionic, crystallographic and gas analyses performed on lake ice have shown that Lake Popplewell is frozen to its base, contrary to Lake Brownworth. The glacier-lake interactions are therefore very different from those encountered at the two other sites. In its marginal zone, the glacier has nevertheless been influenced by the closeness of the lake. The glacier has indeed incorporated to its base lake sediments and ice formed by freezing of liquid water saturating seasonally the sediments of the lakeside. The ice formed by this mechanism is however more restricted to the contact zone by comparison with the other sites. Moreover, it does not form the largest part of the ice in the contact zone itself, which consist of ice originating directly from upstream and ice formed by freezing of surface water pockets.

A gradation in the interactions between cold glacier and lake has been shown. This gradation is mainly based on the amount of liquid water present in the contact zone. The first site illustrates the case where a significant proportion of the glacier thickness is under water, the second site corresponds to the case of a glacier advancing into a lake containing a small water depth, and the last site is an example of a glacier flowing on water saturated lacustrine sediments without having direct contact with the lake itself.

In comparison with the models presented in the literature, this work brings new elements for a better understanding of the processes acting at the contact between a cold glacier and a liquid water mass. It also shows the complexity of these interactions. Further investigations (radar measurements, glacier movement surveys, temperature measurements) should complete those of the explanations that remain hypothetical. Numerical modeling developments taking all these parameters into account should moreover generalize the interpretations resulting from this work.

The diversity of glacier-lake contact conditions indicates that the ice encountered in Antarctic deep drilling ice cores can have multiple origins where the ice sheet flowed over subglacial lakes. This situation, that until now has only be studied at Vostok, is actually very frequent (more than 150 subglacial lakes have already been detected by radio echo sounding). We think our work should help to decipher the multiparametric analyses that would be conducted on ice samples from other cores that will penetrate lake ice.



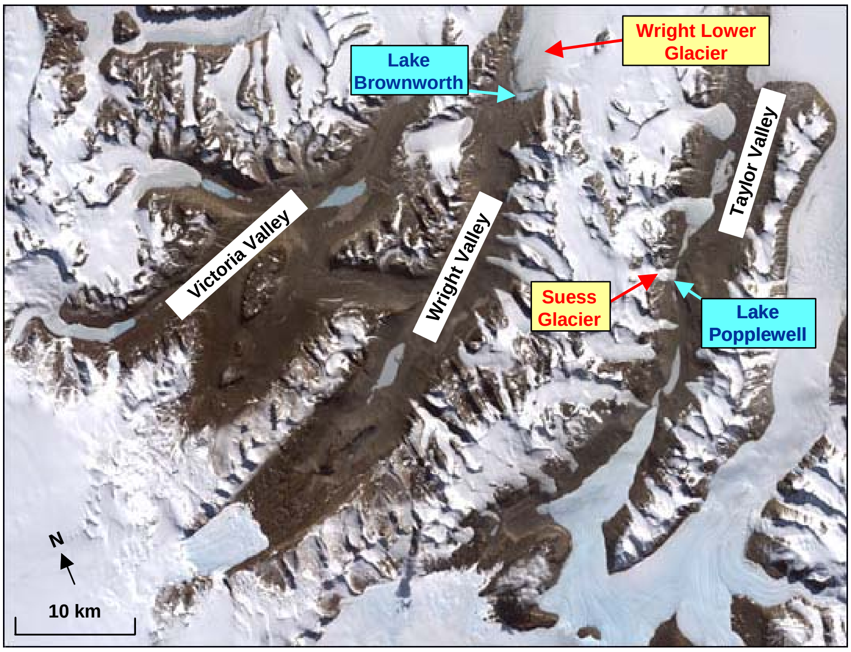


Figure 1: The McMurdo Dry Valleys in Antarctica and location of the study sites within these valleys (LANDSAT satellite image).

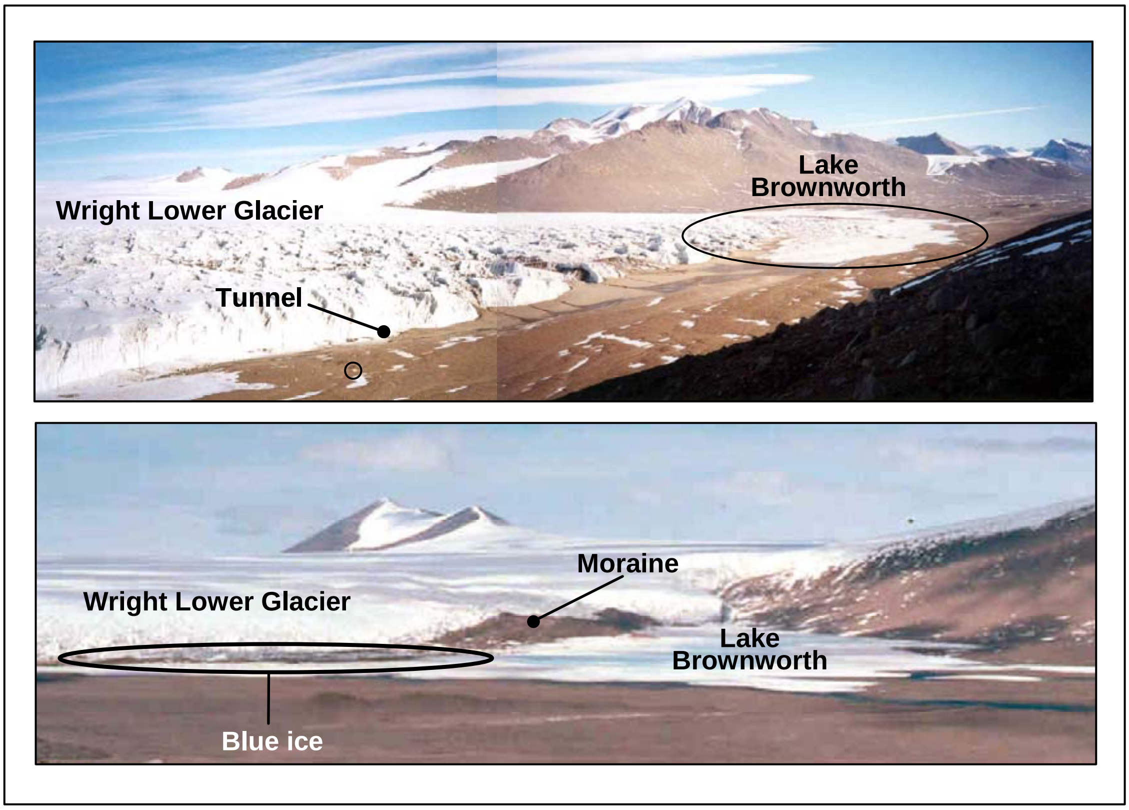


Figure 2 : Pictures showing the study sites of the contact zone between Wright Lower Glacier and Lake Brownworth (Wright Valley). Glacier scale is given on the upper picture by the tent encircled in black.
Pictures : S. Sleewaegen and R. Lorrain

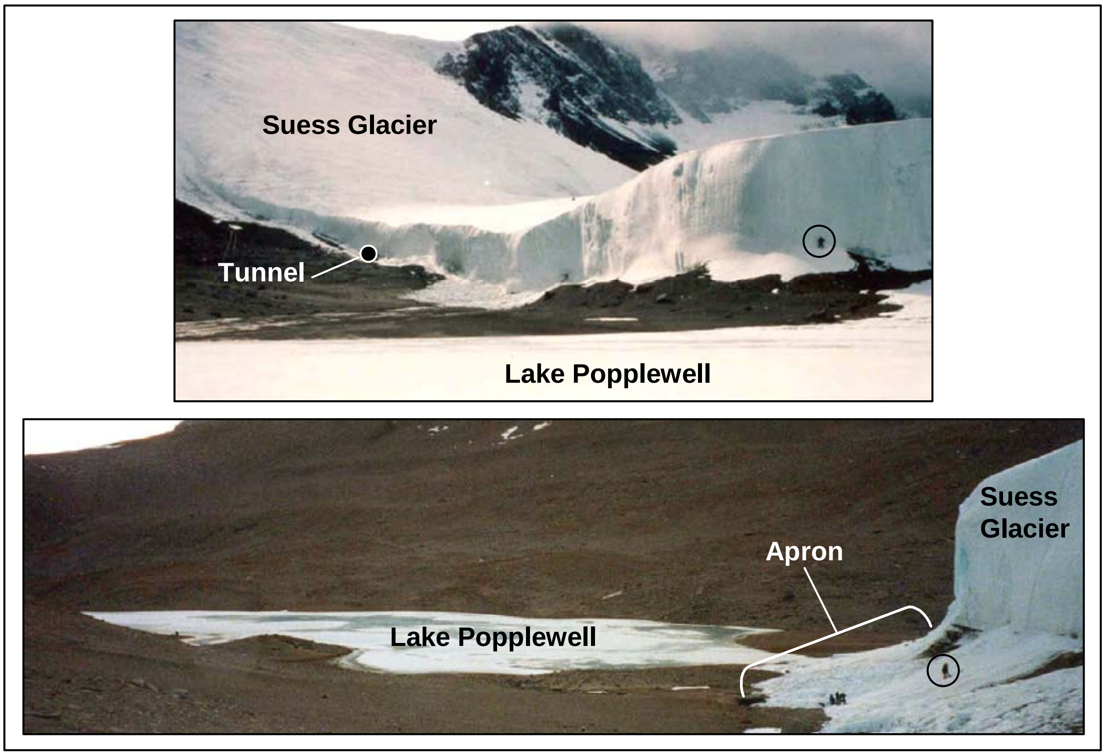


Figure 3 : Pictures showing the study sites of the contact zone between Suess Glacier and Lake Popplewell (Taylor Valley). Scale is given by men encircled in black.
Pictures : R. Lorrain