Composition and origin of basal ice in cold and polythermal glaciers

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INTRODUCTION

The study of ice composition sheds light on the thermal and mechanical processes operating at the ice-bedrock interface. By analysing the ice composition inferences can be made about ice formation and its origin. This project will compare the isotopic and solute composition of basal ice from the Suess, Rhone, and Taylor glaciers.

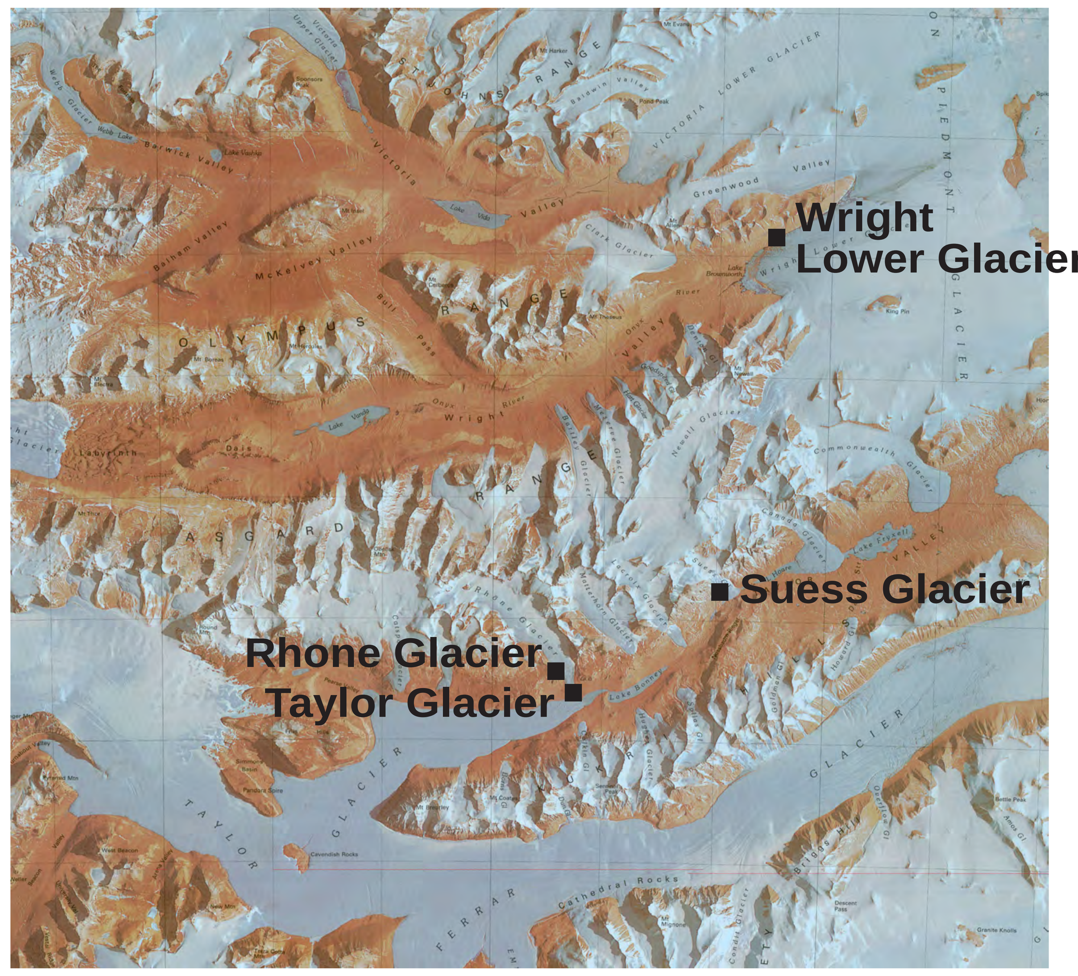

Figure 1: Aerial photograph of the Dry Valleys, Victoria Land, Antarctica.

STUDY AREA

The Rhone, Taylor and Suess glaciers are located in the Taylor Valley, South Victoria Land, Antarctica. Rhone Glacier is a small dry-based glacier with a basal ice temperature of -17ºC. Its basal zone is characterised by 3.5m thick basal sequences of stratified and amber ice that rest below 18m of clean englacial ice.

Taylor Glacier is a large, thick outlet glacier that flows from Taylor Dome, an independent dome within the East Antarctic ice sheet. At the terminus Taylor Glacier has a basal temperature of -18ºC but 8 km upstream it is believed to be at pressure melting point (Robinson, 1984). The Taylor basal zone consists of over 2.5m of debris-bearing ice that is overlain and underlain by clean englacial ice.

The Suess Glacier is a small dry-based glacier with a basal ice temperature of -18ºC. The basal zone is characterised by a 4m-thick sequence of stratified and amber ice beneath 20m of englacial ice.

RESULTS

Tunnels were excavated in both glaciers providing access to the basal ice and facilitated the extraction of samples for subsequent laboaratory analysis. The basal ice were mapped detailing sedimentary structure, and physical characteristics.

Ice blocks extracted from the tunnel were subsampled and the stable isotope signatures (δ18O and δD) and solutes were analysed.

Initial result suggest a strong contrast in physical and chemical properties between ice facies. There is a clear distinction between englacial ice, amber ice, and stratified ice facies (Figures 2 and 3).

Amber ice - distinct dicoloration (varying between yellow to green), low debris concentration and relatively high solute concentrations.

Stratified ice - characterised by layers of debris and clean ice and is characterised by high debris concentration and very high solute concentrations. Layers are dispersed with clear white bubbly ice.

Englacial ice - white, clear, bubbly ice, little or no debris, very low solute concentrations and isotopic values that plot on the local meteoric water line.

Figure 2: Photograph showing the different ice facies present in the Rhone Glacier. The englacial ice is clear, white and bubbly, whereas the amber ice is yellowy with dispersed debris.

(a) Englacial ice
average crystal size 7mm diameter

(b) Amber ice
average crystal size 1mm diameter

(c) Stratified ice
bimodal crystal size 5mm and 1mm in diameter. Small crystals associated with debris.

Figure 3: Thin sections from the different ice facies from the Rhone Glacier. The left photos show the ice under normal light, and the right photos show the ice crystals as reflected through polarised light. (a) Englacial ice (b) Amber ice (c) Stratified ice.

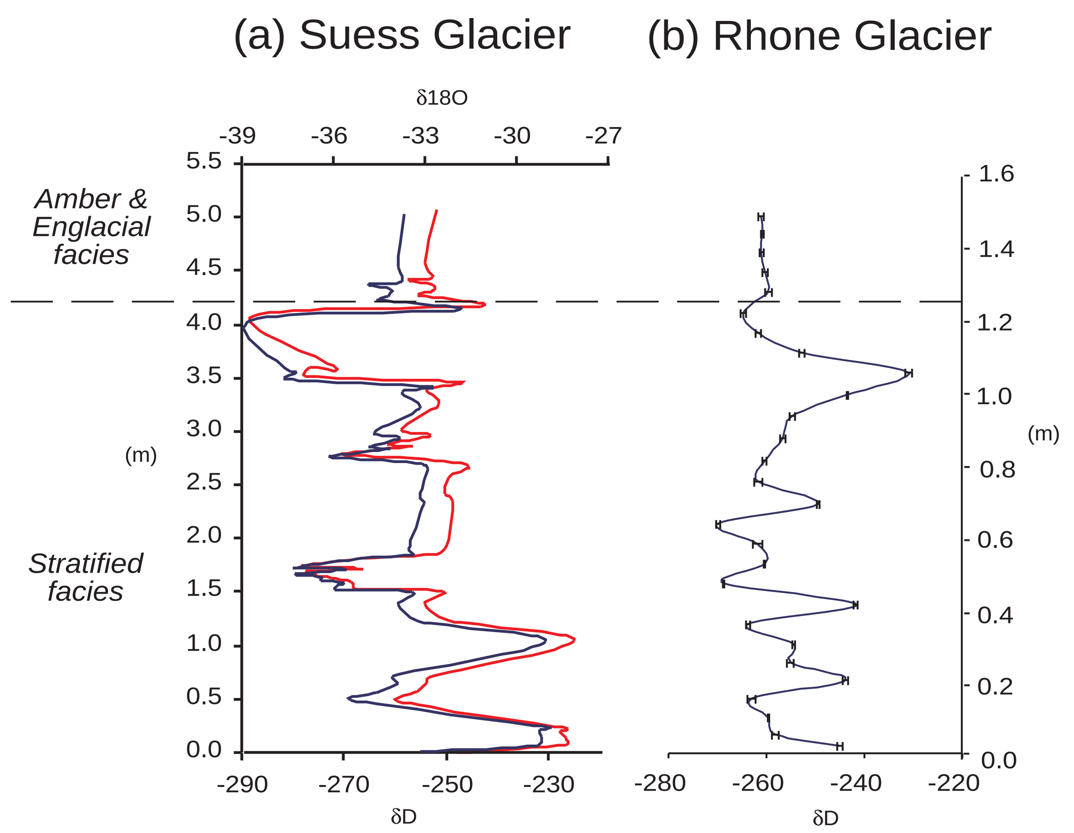

Figure 4: Plot of the isotopic composition of the (a) Suess and (b) Rhone Glaciers. Dashed line is the contact between the stratified and amber ice facies.

Figure 4 shows the variations in deuterium and 18-oxygen for the basal ice from the Suess and Rhone Glaciers. The bottom-most unit is the stratified ice which has debris-rich, dispersed, laminated, and debris-free layers. The variable isotopic values in the stratified ice broadly correlate to changes in the debris concentration and sub-facies. The overlying amber and englacial ice has an isotopic signature similar to the meteoric water (Figure 5).

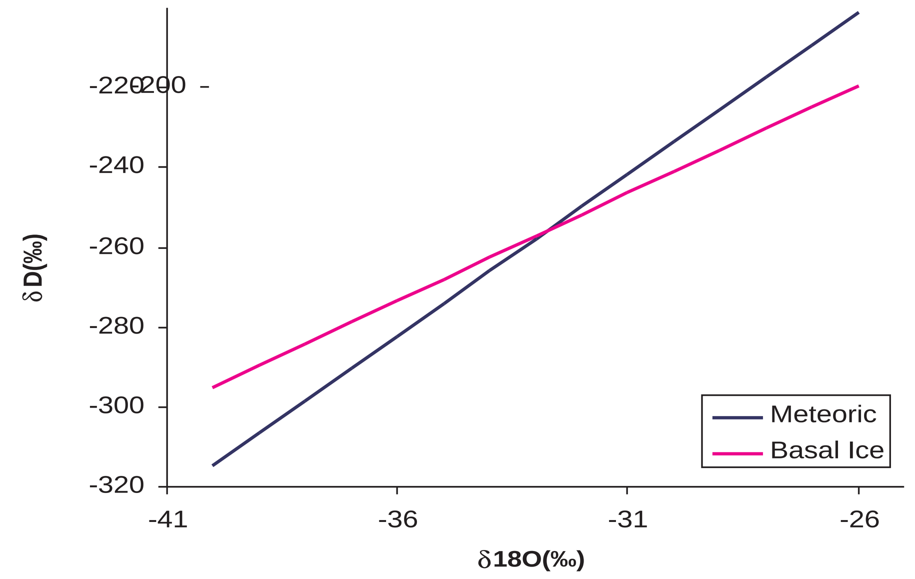

Figure 5: Co-isotopic plot for the Suess Glacier. The black line plots the local meteoric water line, the red plots the basal ice.

CONCLUSIONS

This project is presently in progress and will also analyse basal ice from the Taylor and Wright Lower glaciers. Preliminary results indicate that the differences in the physical and chemical signatures of the ice facies reflect different origins of the basal ice. The high solute concentrations and low slope of the isotopic values suggest that meltwater plays an important role in the formation of basal ice. Variations in isotopic contents are caused by water phase changes (fractionation) and not the product of metamorphism or tectonic processes.

The amber ice has a isotopic signature similar to the meteoric water line, suggesting its formation is a product of firnification processes, as is the englacial ice.

Reference:
Robinson, P.H. (1984) Ice dynamics and thermal regime of Taylor Glacier, South Victoria Land, Antarctica. *Journal of Glaciology 30*(105): 153-160.

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