Antarctic Science Bursary Progress Report

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Project Title: Understanding processes of marine ice formation at the Southern McMurdo Ice Shelf, Antarctica

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Project aim: To determine processes of marine ice accretion investigating the chemical composition and crystallography of a ~7-m long marine ice core from the Southern McMurdo Ice Shelf.

Introduction

Marine ice forms from a mixture of sea water and glacial melt water at the base of ice shelves and is thought to enhance ice shelf stability by adding layers of dense ice mass and/or infilling structural weaknesses such as bottom crevasses or rifts. Marine ice is widespread in Antarctic ice shelves, which fringe 44% of the Antarctic continent and buffer glaciers and ice streams draining into the ocean. The physical and chemical properties of marine ice, however, remain poorly understood. The aim of this project is to understand processes of marine ice formation through the chemical and crystallographic investigation of a ~7-m long marine ice core extracted from the Southern McMurdo Ice Shelf in 2011. The main application of this new knowledge is understand the past present and future behavior of ice shelves formed partially by marine ice.

Achievements to date

1. **Ice core extraction and shipment to Brussels, Belgium**
   The ~7-m long marine ice core had been extracted in 2011 with a Kovacs corer by Inka Koch and her Ph.D. advisor Prof. Sean Fitzsimons from the surface Southern McMurdo Ice Shelf. The core was shipped to Brussels maintaining a temperature of -20^{o}C.

2. **Cold room and lab work in Brussels, Belgium**
   Vertical thin sections (of ~0.5 mm thickness) were prepared along the entire length of the ice core. Individual thin sections were ~9cm in length. Since the sediment content of the ice was very low (<1%), all samples could be prepared using the band saw and microtome in the cold room in Brussels. The ice crystal morphology was photographed in cross-polarized light. Selected thin sections were analyzed with an automatic fabric analyzer (G50 Russel-Head Instruments), which determines ice crystal orientation pixel by pixel.

   Total gas content was measured on selected crushed ice samples using Toepler extraction. The gas content was found to be too low to determine gas composition. In order to investigate ice composition, the ice core was cut at 10cm intervals. Samples were allowed to melt in sealed plastic containers. Melted samples were filtered with MF-Millipore 0.45 µm membrane cellulose acetate and cellulose nitrate filters. Water samples for isotopic analysis were bottled in airtight glass containers without headspace to avoid sample alternation as a result of evaporation. Water samples for analysis of major ions were bottled in plastic vials to avoid leaching of sodium (from glass).

3. **Lab work at the University of Otago, New Zealand**
   Water samples were analyzed for major ions and water isotopes at the University of Otago. A PICARRO Laser Spectrometer was used to determine $\delta^{18}O$ and δD concentration. Samples were repeat-injected eight times and the first three samples were rejected from the

analysis to avoid carry over. Measurements are accurate to 0.11‰ $\delta^{18}O$ and 0.75‰ δD with a precision of 0.07‰ and 0.40‰ respectively.

Samples were analyzed for major ions with an Ion Chromatograph, the Dionex ICS-3000 system. A method with a 16 molar potassium hydroxide eluent was used to determine the concentration of the cations Li^+, Na^+, Mg^{2+}, K^+, Ca^{2+}, NH^{4+} with an IonPac CS16 Cation-Exchange column. The concentration of the anions F^-, Cl^-, NO^{2-}, Br-, NO_3^{2-}, SO_4^{2-} was determined with an IonPac AS18 Anion-Exchange column using a method with 46 molar MSA eluent. Samples were repeat-injected and precision and accuracy was better than 5% for all concentrations. Carbonate content of all samples was measured by titration using sulfuric acid.

To be completed:

4. **Processing of ice crystal orientation data**
   Image data acquired by the automatic fabric analyzer needs to be processed using *Investigator* software. It allows determining crystal size and fabric from the pixel-by-pixel orientation data. Ice fabric data will be plotted on stereographic plots. Eigenvalues will be calculated to determine fabric strength (isotropy). The ice crystal morphology (focusing on shape) will be logged using the photographs of thin sections acquired along the length of the ice core. It is suggested that different marine ice accretion mechanism result in different ice crystals structures (orientation, size and shape). Crystal structures therefore help to establish whether the marine ice was formed from frazil, anchor or congelation ice.

5. **Processing chemistry data**
   Isotopic and ice chemistry data needs to be collated and analyzed. Water isotopic data will be plotted on co-isotopic diagrams. This will help to determine the freezing environment (open or closed system reservoir). Ion ratios and salinity (TDS) of the ice core samples will be compared to common seawater ratios, which will help to establish the rate of marine ice formation.

6. **Preparation of manuscript for *Antarctic Science***
   Upon completion of the data analysis a manuscript will be prepared for submission to *Antarctica Science*.

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I would like to thank Antarctic Science Ltd for providing me with the great opportunity to analyze this ice core at the Laboratoire de Glaciologie in Belgium. Not only did it allow me to process additional field data using state of the art instruments, but also to foster international collaboration working with researchers specializing in ice-ocean interface research. Thank you.