Borehole Probe Study of Ice Stream C, West Antarctica (Drill Site 3), 01/23/00

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Note: Please refer to numbered pictures (i.e. #1, #2, # 3, etc.) on web page for images

Overview

The deployment of the borehole probe at Drill Site #3 revealed an unexpected, large water-filled cavity under the bottom of the ice.

Introduction

On the 7th dive done in Drill Site #3 we see clusters of sediments in the ice well above the transition from bubble-rich glacial ice to basal debris-rich ice. The transition between the glacial ice and the basal ice occurred ~ 15m above the base of the ice. The sediments incorporated in the glacial ice are present as fine and short bands of sediments or alignments of sediment aggregations. The sediment aggregations are in the size of 2 to 5 mm in diameter while the sediment itself is finer. Below the transition zone the amount of debris in the ice increases drastically. Within the debris-laden zone debris-rich bands of variable thickness alternate with bands of bubble free clear ice.

A layer of ~10cm crystal-clear basal ice forms the base of the ice sheet at 1063.30. Underneath the base 1.4m of slightly turbid water separates the base of the ice from the bed of the ice sheet, which is located at 1064.70. The horizontal dimension of this cavity is unknown.

The transition from glacier ice to debris laden basal ice

The first sign of reaching the bottom part of the ice are intrusions of sediments within the glacier ice. It is most likely that these sediments were picked up and incorporated into the ice by internal deformation at the beginning of the slow down of Ice Stream C, when partial freeze-on conditions existed. In the video the sediments appear as short alignments. It is also remarkable that these alignments are mostly curved and randomly oriented, which is also an indication of deformation of the ice as a cause for the transport of the sediments into the clean ice zone.

The direct transition from the glacier ice to the basal ice occurs over ~ 1m. In this zone we find bands of air bubbles in the otherwise clear ice. We also occasionally find alignments and cluster of sediments in the ice. Image 21 and 22 shows a part of the transition zone of an ice core taken in this borehole. Image 22 shows sediments and alignments of fine air bubbles in the otherwise clear ice. All the alignments of air bubbles and sediments are oriented. The angle, in which these alignments dip, was measured in the ice core and varied between 10° to 20°with extreme value of 30° and more. Image 19 shows the intersection of the borehole drilled to the bottom of the ice and a second hole caused by the ice corer. The ice cores were therefore taken within 15 and 25 meter above the base of the ice. In image 20 the second ice core hole appears as milky mist in the otherwise dark surrounding. This black and white appearance is a result of light reflection caused by turbid water in the adjacent borehole.

The zone of debris-laden ice

The basal zone of debris-laden ice is an alternation of bands of frozen debris, debris-rich ice and bands of clear ice. The alignment of these bands seems to be more horizontal than in the higher transition zone. The appearance of the debris in the ice varies from thin streaks of fine sediments over small thin alignments of sediment aggregations to thick bands of frozen till. Image 3, 4,7 & 8 show alignments of individual pieces of debris. In Image 5 a rock of about 1 cm in diameter appears in the debris layer. With the clear ice on top of this layer the picture looks similar to a picture taken from a riverbed. In image 7 and 8 are also finer sediments present. The images 2, 5, 6, 9 & 10, taken with the down looking camera, clearly show the alternation of debris rich layers with clear ice. In image 9 and 6 bigger rocks are sticking out of the borehole wall. The size of the stone seen in image 6 & 12 is in the order of a man's fist. The size of rocks found in the images vary from gravel to cobble. Image 18 shows streaks of fine sediments pointing away from the middle of the left side.

The ice – water interface

At the bottom of the debris-laden ice zone I will focus on a special feature, which might be a special case of the above described alternation of bands of debris-rich ice and thin bands of clear ice and might just exist under special circumstances, which are present in this location.

The feature is an unusual thick layer of very clear basal ice. This ~10cm thick layer is overlain by a 1cm thick layer of debris-rich ice and another 4 cm thick layer of very clear ice before the usual alternation of debris-laden ice begins.

This unusual thickness might be connected with the water filled cavity underneath it. The ice of this last layer is composed of ice crystals with a diameter up to centimeters in size. Image 11, 13, 14, 15 & 17 are taken within few centimeters at the base of the ice. In image 14 as better in the video from the base of the ice the outline of individual ice crystals is visible at the ice – water interface. The whole image shows about 3 to 5cm of the borehole wall. Image 13 and 15 shows clearly the transition from the ice (in the image dark) to the slightly turbid water in the cavity (in the image lighter). The turbidity in the water might be caused by the rush down of the water in the borehole during the violent breakthrough to the basal water system.

The water filled cavity

The depth of the water underneath the ice is 1.4m. In the video and in image 16 the bed of the cavity is covered with sediment aggregates. It is most likely that these sediments seen in the video were melted out of the debris-laden ice by the hot water drill during the drilling of the borehole and then deposited beneath the borehole after the breakthrough to the basal water system. The actual bed is most likely solid bedrock as attempts to take piston cores suggest.

Also of interest is the observation that debris, melted out of the borehole wall, does not fall straight through the water filled cavity to the ground. At the mouth of the borehole the particles get accelerated out of the hole in a distinct lateral direction (image 13). This indicates that some type of current is flowing across or around the mouth of the borehole and picking up the sinking debris. Variation in the direction of deflection over time further indicates turbulent flow within the cavity.

Search for a GPR Layer around 720m

Between 700m and 800m we searched for a distinct layer, which can be found on a ground penetrating radar profile at about 750m. As a preliminary result we can say that we found at a depth of 720 to 715 different layers containing impurities. In image 23 the impurities appear as black spots. The impurities with a size of about 1mm seem to be accumulated in different layers throughout the strata between 720 and 715. Further examination of the video and an ice core taken at ~750m as correlations with ice cores taken at Siple Dome (100km north of Ice Stream C) might reveal the nature of these impurities.