熱水掘削による南極氷床底面の観測

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Exploring Antarctic subglacial environment using hot water drilling

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Subglacial environment of the Antarctic ice sheet is one of the least explored part on the planet. This is because direct observations are hampered by thick ice cover and surface measurements provide only limited information of the bed. Accordingly, numbers of questions posed on the subglacial environment have been left unsolved. One such example is basal ice motion of outlet glaciers. Fast flowing glaciers take a key role in the ice sheet mass budget, because they transport ice to the ocean where it calves and melting into the ocean. Outlet glaciers flow fast because ice bed is lubricated by high water pressure and/or a deformable sediment layer. Nevertheless, direct evidence for fast flowing mechanisms are very few. Another long-standing unsolved issue is the subglacial lake. Life is expected in lakes beneath several thousand meters of ice thickness, and they are believed to be connected by channels (Fricker and others, 2007). However, in-situ studies on biological and hydrological lake conditions have just initiated for the last several years. Moreover, ice shelves along the Antarctic coast pose important subglacial problems, such as ice shelf basal melting (Rignot and others, 2013), subshelf ocean conditions (Stanton and others, 2013), biological activities under the ice shelf (Domack and others, 2005), and ocean bed geometry. Subshelf processes are drawing attention particularly because the interaction of ice shelves and warming ocean is a likely driver of recent mass loss of the Antarctic ice sheet (Hellmer and others, 2012).

Direct observations are required to understand these subglacial processes, but they are possible only with an access to the ice sheet bottom. Hot water drilling is a fast and efficient mean to excavate a borehole for subglacial measurements and sampling. Institute of Low Temperature Science, Hokkaido University, developed a light-weight portable hot water system in 2007 for drilling mountain glaciers. The system was used in the Alps (Tsutaki and others, 2013), and then updated to drill a thick calving glacier in Patagonia (Sugiyama and others, 201), and a cold outlet glacier in Antarctica. In this contribution, we introduce our hot water system and drilling activities performed in the past to propose a future research activity in Antarctica. We show how we drill ice through to the ice-bed and ice-ocean boundaries, and discuss what to be explored using the borehole as an access to the subglacial environment.

As an example of subglacial investigations using hot water drilling, we present the results of a field campaign carried out at Langhovde Glacier, 20 km south to the Syowa Station. In January 2012 as a part of the JARE 53 research program, four boreholes were drilled at two locations, 2.5 and 3.0 km from the glacier calving front. Borehole inspection revealed that the drilling sites were located on the floating tongue close to the grounding line. The boreholes were used for CTD and current measurements, water sampling, and borehole video camera observations in the subshelf cavity. Water temperature was 0.7°C above the freezing temperature and the salinity was 34.25 PSU. These properties are very similar to the values measured in the ocean in front of the glacier. This observation suggests that innermost part of the cavity is connected with the ocean through active water transport by subshelf water current. It implies that ocean warming would immediately affect the melting rate underneath the floating part of Langhovde Glacier. Water samples contained phytoplankton and video image captured a crustacean on the sea floor, indicating biological activities in the cold and dark subglacial cavity. These results provide clues to understand the ice-ocean interaction and biodiversity beneath the ice shelf. Further field activities in the future, e.g. longer-term measurements, biological sampling, drilling in the grounded part of the glacier, would provide us more detailed data set and new findings on the subglacial environment and processes at the Antarctic coastal margins.

Figure 1. Hot water drilling on Langhovde Glacier, Antarctica.

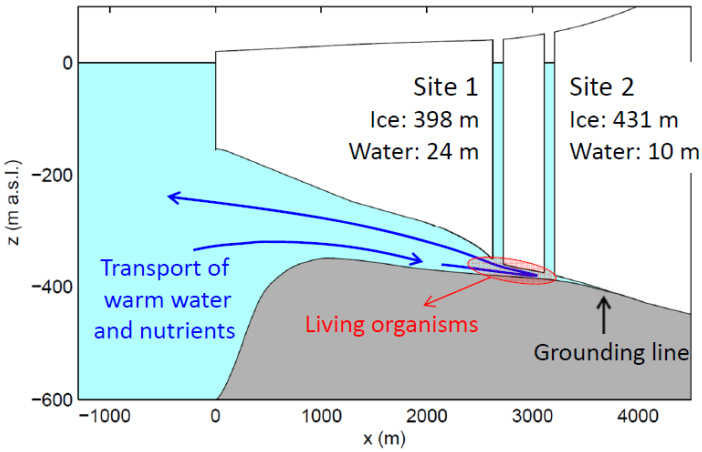

Figure 2. Cross section of Langhovde Glacier as revealed by the drilling.

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