Microbes eat rock under ice

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The deep cold biosphere[1] has a new noisy freshwater neighbour. Members of the WIZZARD team show, in this issue, that deep cold waters and sediments of the ocean are joined by cold waters under thick ice of the Antarctic Ice Sheet[2]. The paper is a landmark for polar sciences, demonstrating unequivocally for the first time by direct sampling that microbes are present in the waters and sediment of Subglacial Lake Whillans, located some 800m below the surface of the West Antarctic Ice Sheet and at a temperature of -0.17 ^{o}C. It completes a paradigm shift in our appreciation that glaciers and ice sheet beds are not sterile, but rather host to diverse microbial communities[3]. The beds of small valley glaciers were shown to be host to microbial communities only fifteen years ago[4], but these glaciers have much shallower ice and meltwaters export microorganisms, chemicals such as dissolved oxygen, nitrate and organic matter from the melting ice surface down to the bed, so it is easy to envisualise how microganisms, organic matter to consume and nutrients to enable growth are found at small valley glacier beds. This is not so for the Antarctic Ice Sheet, where there is little surface melt away from the ice margins, and evens less likelihood that this water can find a way through a kilometre or more of ice at temperatures well below freezing. Instead, water is produced from geothermal heating at the bed and frictional melting during ice flow[5], and so any microbial communities living in water that is present beneath about 55% of Antartica[5] has to exist on energy and nutrient sources that come from the melting ice, the rock and sediment beneath the ice, and recycling of materials from dead microorganisms[6]. The WIZZARD team's results give insight into how this may happen.

The most likely energy sources for microbes living in this deep cold freshwater biosphere differ from that of the deep ocean, where the remains of surface organisms rain down from above. Instead, microbes beneath Antarctica must utilise energy sources contained in the minerals crushed from the bedrock by the ice, such as sulphides (e.g. pyrite, found in many rock types) and reduced iron, Fe (II), found in many ferro-magnesium minerals, such as olivines and pyroxenes, and micas, such as biotite. These reduced Fe and S compounds, along with the bodies of dead microorganisms, can be oxidised with oxygen found in the water to liberate the energy necessary to drive the vital processes of the living microoorganisms that enable or catalyse the reactions[7]. In this sense, the microbes “eat rock”, although in practice, they sit attached to minerals particles and assist the particles to dissolve (Figure 1). The type of microbes needed to promote these types of reaction have been found by the WIZZARD team, in particular the Proteobacteria, making up ~53% of the gene sequences examined[2]. Glacier-crushed sediment is a ready source of phosphorous[8], a key nutrient for enabling microbial growth, but sources of the other key nutrient, dissolved nitrogen species, such as NO_3^- and NH_4^+, are harder to come by. They include a little from ice that melted to produce the water[7], and minor amounts in some feldspars and micas[6]. Any nitrogen scavenged from rock is hard won, and so must be preserved or tightly recycled to keep the microbial ecosystems viable (Figure 1). An intriguing feature of the WIZZARD team's data set is that NH_4^+, often liberated from decomposition of organic matter and consistent with the $\Delta^{17}O\text{-}NO_3^-$ values found, is the principal dissolved inorganic nitrogen species, and that there are significant numbers of nitrifying microorganism present in the water column[2]. This strongly suggests that hard won nitrogen is tightly recycled between dead and living microorganisms, and is a significant means of sustaining new microbial growth (chemoautotrophy).

The surface sediments beneath the water contain organic matter with lower higher C:N ratios than found in organic matter in the water column, suggesting that decomposition of organic matter in the sediments releases NH_4^+ and other dissolved N species back to the water column. Some of the carbon in the decomposing organic matter appears to be released back into the water column in the form of acetate and formate. The latter are forms of dissolved organic carbon that can readily be taken up by microbes in the water column. Hence, processes in the sediment, and recycling of materials between the sediment and the water column, are important to the longevity of the microbial ecosystem. In this respect, this deep cold freshwater ecosystem is similar to those in and overlying deep cold ocean sediments. The Antarctic Ice Sheet is draped over deep basins of former marine sediments, kilometres thick, which contain also organic matter[9]. Just how much influence this gradually decomposing organic matter has on surface sediments and the waters between the sediment and the ice bed remains to be seen, but beneath some parts of Antarctica, where water flow is slow, one can easily imagine how chemicals diffusing up from deeper sediment can enable microbial communities in shallower sediment to exist (Figure 1).

The WIZZARD Team have opened a tantalising window on microbial communities at the bed of the Antarctic Ice Sheet, and how they are maintained and how they self organise. It begs the question 'could microbes eat rock beneath the ice sheets on other extraterrestrial bodes', for example on Mars[10]? This is more of a possibility now.

Figure Caption

1. Cartoon depicting some of the microbial processes that operate beneath the Western Antarctic Ice Sheet. This is a trivialisation of the complex and multifaceted processes and interactions that occur within even the simplest of microbial ecosystems under ice.

References

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