A SUMMARY OF SUBGLACIAL LAKES

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ABSTRACT Subglacial lakes are one of the final frontiers on the planet Earth. The inaccessibility of these geological formations makes them difficult to study and scientists know little about them. However, we already have an understanding of the geophysics involved in the formation of water under glaciers. The mapping of the Antarctic ice sheets has lead to the discovery of hundreds of subglacial lakes, the largest of which is Lake Vostok (Popov, 2007). The great size of Vostok makes it the center of attention for the study of subglacial lakes and the greatest source of information on this topic. But biological processes in these deep, supercooled waters hold secrets to the origin of life and the mechanism by which the microorganisms would have survived periods of global glaciations in the distant past.

1. Water and Supercooled Water

Water is not the first substance that an amateur geology student would expect to find in a glacier, which is considered a cold-climate formation. However, water occurs at all levels of a glacier for various reasons. But subglacial lakes occur specifically at the base of the glacier. Even in the coldest expanses of Antarctica, 4 km of ice is all that is necessary for the formation of large bodies of liquid water. Several complex factors contribute to the presence of subglacial lakes.

The melting point of water is not a fixed temperature and beneath a glacier but is dependent on the pressure of overlying ice. Thicker ice equates to greater pressures and a greater reduction in the melting temperature of water. The presence of 4 km of ice reduces the melting temperature to -3°C. The melting point under pressure is called the pressure-melting point (figure 1). Water that exists under these conditions is defined as supercooled and has special significance (Clarke, 2005). Supercooled water is more viscous, which leads to an increase in the deposition of sediments in subglacial lakes. If there is no water flowing out of the lake, it becomes a stagnant system with a complete, uninterrupted geologic history. Additionally, the pressure and cold conditions are ideal for the formation of gas hydrates – a necessity for life in this cold and dark environment (Seigert, 2001).

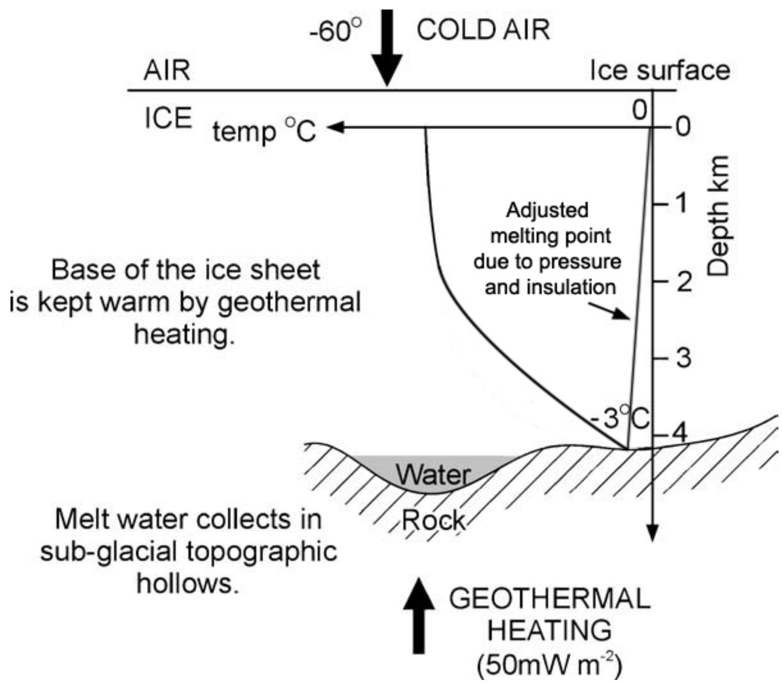

Figure 1 Pressure-melting point of ice within a glacier and influences of geothermal heating (Siegert, 2005)

Insulation is another factor that influences temperature at the base of a glacier. Even when surface temperatures average -60°C, the temperature of ice warms to near 0°C as depth increases. This is important for life within subglacial lakes because temperatures much colder than freezing will inhibit most organic processes (Siegert, 2005). Additionally, the deformation of ice as the glacier slides produces friction, which is transferred into heat. Deformation occurs at all levels of a glacier, but basal sliding along the bedrock is the primary source of heat from friction that contributes to subglacial lakes.

When the previous three factors are applied to basal ice the energy necessary for melting is approximately 50 mW/m^2, which is the same as the background geothermal radiation of the Earth's crust. Based on this set of principles, it is reasonable to conclude that subglacial lakes can form without the need for abnormal geothermal conditions. Taking all of these factors into account there are two locations that are most favorable for the formation of subglacial lakes. The first is under the thickest ice caps where pressure and insulation are greatest. The other location with ideal conditions for subglacial lakes is at the boundaries of collision zones between glaciers where friction and basal sliding are greatest (Siegert, 2005).

2. Finding Subglacial Lakes

The existence of subglacial lakes has been known since the 1960s when radio-echo sounding (RES) was used to map the internal structure of Antarctic ice sheets. The original goal of the mapping project was to detect the distinct contrast of layering within the glaciers. A large plane was flown over Antarctica, which contained transmitters and receiving equipment for the RES. Layer boundaries within the ice show up on the final scan because the differences in the dielectric constant between the ice layers reflect radio waves back to the receiver. At the base of the glacier, which is sometimes 4 km deep, bedrock reflects as parabolic interference because its properties are relatively indistinct from the basal ice. This bedrock layer is weak, useless background reflections resulting from small differences in the dielectric constant (the dielectric constant of ice is 3.2 and typical bedrock a dielectric constant of 5.5). However, when compared to ice, water has a much higher dielectric constant of 81. This large difference produces a distinct reflection to the receiver. These strong reflections are subglacial lakes shown in figure 2.

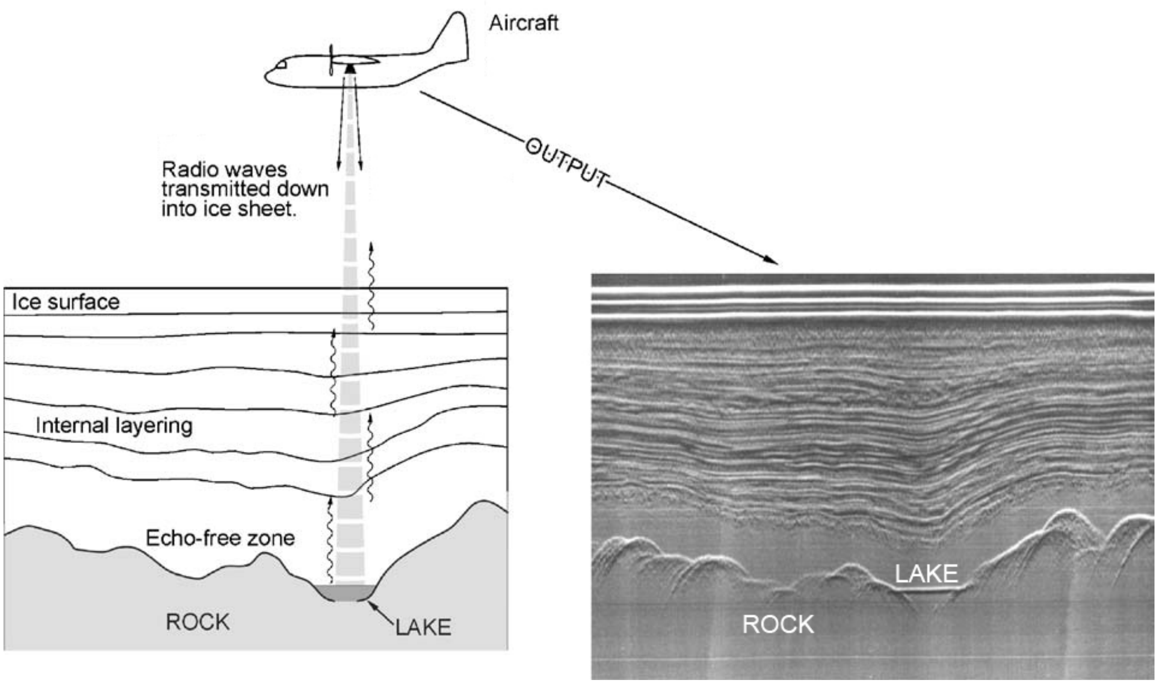

Figure 2 Radio-echo sounding (RES). Lakes show on the output scan as very distinct reflections near the bedrock. The echo-free zone is filled with interference from the indistinct layer between ice and bedrock (Siegert, 2005)

Glacial surface features can also be used to identify the presence of subglacial lakes. As the ice flows it adopts the contours of the basal topography. However, because ice is lighter than water, when a glacier flows over a subglacial lake it floats and stabilizes over this low-lying area. Above subglacial lakes there are areas of lower topography compared with the surrounding glacier.

3. Life in or near Subglacial Lakes

One of the greatest and most surprising discoveries to result from the study of subglacial lakes is the possibility of life in the form of microorganisms. Currently, a Russian team has drilled to within 150 ft of Lake Vostok (Popov, 2007). They have succeeded in identifying microbes in deep ice after taking careful precautions to keep the outer surface of ice core samples sterile. The presence of any life near a subglacial lake is unusual for several reasons. These environments are devoid of solar radiation for photosynthesis. Circulation of atmospheric oxygen with basal meltwater is not possible under several kilometers of ice. Finally, cold and pressure are unusually extreme to allow for the presence of life beneath a glacier. Given these circumstances, the life found in or near subglacial lakes provides us with evidence of surprising specialization. Instead of using photosynthesis, energy is generated by these microbes through oxidation of gas hydrates and sulfides. The long period of isolation of these microbes (approximately 33 million years since Antarctic glaciations started) suggests that a lack of equilibrium between consumption and replacement of resources from biological activity can continue for great lengths of time. This conclusion is important because it provides a mechanism for life to survive during periods of global glaciations in the distant past (Clarke, 2005).

For all of the attention that has been given to the study of subglacial lakes, there is still much to be discovered about these unusual systems. The future promises to continue seeking new information such as measuring lake depth and the diversity of microbes from each isolated lake system. Farther in the future, geologists have the goal of sampling sediments from subglacial lakebeds and analyzing the network of water flow beneath ice caps. However, technological and environmental difficulties will always be the limiting factor in this growing field of research.

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