LAKE ICE GROWTH AND CONDUCTIVITY

By

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Exsolution of solids and gases occurs as water freezes. In general, the exsolution is more efficient where the rate of freezing is slow. When the surface water of a lake freezes, producing a layer of columnar "black" ice, exsolution into the decreasing lake body has considerable significance in terms of such parameters as dissolved oxygen, nutrients and dissolved solids in general. Black ice is a particularly 'pure' form of ice with relatively few inclusions--notably in bubble layers, zones of rapid growth, and at crystal and grain interfaces.

Where ice growth is associated with a substantial snowcover, the rate of black ice growth is slowed (and exsolution presumably made more efficient) but growth of the ice sheet as a whole is promoted where the flooding of the lake snowcover occurs. The resulting ice, "white ice", is granular in structure and composed of crystals which are small relative to black ice crystals. It is usually the product of a rapid freezing process--the freezing of a slush layer, part ice, part water, which has many freezing nuclei and which is poorly insulated from the cold atmosphere. The lake water portion of the white ice, being derived from immediately below the black ice, is relatively rich in exsolution products and the snow portion contains the products of dry and wet fallout from the atmosphere.

The new layer of ice forms on top of the original ice cover, the freezing interface moves downwards through the slush until a bond is established at the black ice/white ice interface. In terms of exsolution, this suggests that there is a relatively inefficient exsolution process (rapid freezing, small grains) of a high (relative to lake water) concentration solution. As freezing proceeds, the concentration of remaining slush will increase so that highest concentrations might be expected at the black ice/white ice interface. As the exsolution process is relatively inefficient in this case, the concentrating effect should not be as marked as might be expected. It is possible that, under some circumstances, there is a loss of slush water, back into the unfrozen lake body, via the crack which caused the slushing.

This white ice forming process may occur several times during a winter, producing successive layers of white ice. In each case, ideally, an increase in concentration of total dissolved solids might be anticipated at the contact interface between white ice layers as well as at the white ice/black ice interface.

Thus, analysis of the ice cover of a lake might be expected to show relatively low concentrations of dissolved solids in black ice except in bubble layers. In the white ice layer, generally higher concentrations would be expected but with variations, reflecting differences in snow and lake water from which the ice was formed and rates of freezing, and with marked peaks denoting individual slushing events and freezing interfaces. This preliminary study was undertaken to examine, in the light of the above scenario, the vertical variation of the distribution of the concentration of major ions in blocks of white ice and black ice from a subarctic and a temperate lake.

Ice blocks from Elizabeth Lake, Labrador and from Lake St. George, Southern Ontario were examined. Conductivity ($\mu\ cm^{-1}$) was used as a measure of ion concentration. Specific conductance of bicarbonate-type lake water is closely proportional to the concentration of major ions. Data from the Elizabeth Lake block are presented here, diagrams of the blocks and other data were displayed at the conference.

In both blocks the conductivity of the black ice was low, indicating a relatively efficient freeze-out process. The most striking feature is the marked vertical variation observed in the total ion content of the white ice layers. In Lake St. George, the concentration of ions decreases from the white ice surface to the black ice/white ice interface. In the Elizabeth Lake block, there is also a trend towards decreasing conductivity with depth in the white ice but superimposed on this trend are three peaks (Figure).

The decrease in conductivity with depth may be the result of one or several interacting factors. The efficient freeze-out of ions from the black ice would result in high conductivity in the unfrozen water immediately under the ice. A slushing event would

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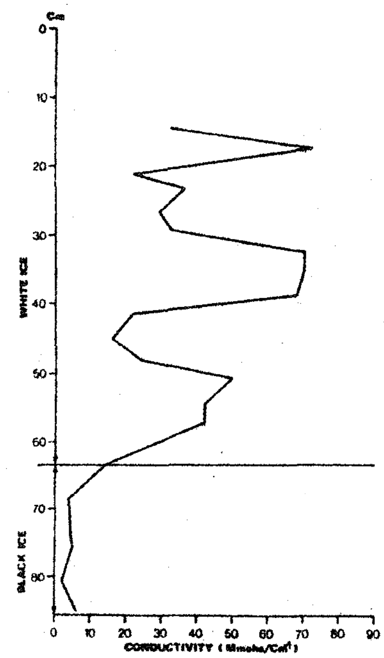
result in the redistribution of this water on the white ice surface. As the winter proceeds and black ice growth continues, conductivity under the ice increases from freeze-out and the last slushing event would produce the highest conductivity zone in the white ice. The rate of decrease in conductivity with depth in the white ice would depend on such factors as the amount of lake water distributed on the ice and where slush water came from in the lake. The three separate peaks in the diagram probably represent three separate slushing events. Of particular interest was the close relationship between the bubble zones and the high conductivity peaks, further evidence that rapid freezing (inefficient freeze-out) produces high concentrations of ions.



VERTICAL DISTRIBUTION OF CONDUCTIVITY IN ELIZABETH LAKE ICE BLOCK

We suggest that the peaks represent the bottom of slush layers, this being the last place to freeze. Thus <u>within</u> white ice layers, the pattern is low conductivity at the top and high conductivity at the bottom. The bubble layers have the effect of reducing the expected gradient. A high concentration from beneath a water lens in the Lake St. George block suggests that concentration of ions does begin while the slush water is unfrozen.

An ice block from a lake, at peak ice, should ideally contain a historical record of limno-climatic events which occurred in the region from the time of ice formation up to the time of sampling. Lake ice can be viewed as a sample of the chemical composition of the winter air masses and precipitation which may prove to be of considerable value once the processes of ice formation are understood. As well, since nutrient release at time of thawing may be an important component of lake nutrient budgets it is important that we understand the mechanisms of ice formation which result in the observed distribution patterns of nutrients in lake ice. This study can be viewed as an initial investigation of these problems.

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