BIOLOGICAL PROPERTIES OF GLACIAL AND GROUND ICE

Yu.K. Vasil'chuk and **A.C. Vasil'chuk**
Departments of Geography and Geology, Lomonosov's Moscow State University, Moscow, Russia

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Summary

The main biologic property of the ice is the preserving of biologic subjects. Biologic properties of ice can be distinguished by inclusion of biologic subjects and biologically active substations. In the future glacier and ground ices might be used as a source preserving genetic material such as pollen and spores, seeds, microbes and also preserving carcasses of prehistoric animals. The ice subsurface constitutes special niche. Rich algae flora is growing at interface of snow and ice on broken and drifting ice floe in Antarctic and Arctic. Pollen and spores have been determined in number of key-cryospheric subjects, such as mountain glaciers, Arctic Ice caps in snow cover marine and river ice. Pollen and spores are relatively abundant in glacier ice, but in pollen concentration in polar snow cover is very low. Pollen and spores are common in ice bodies of different origin in permafrost areas. Enzymes may be classified as biologically active substance in the ice. Proteolytic activity is activity of albumen splitting; amylolytic activity is activity of starch splitting. These kinds of enzymatic activity may be determined in sea water, bay, rivers, season melted layer and also all variety of surface and ground ice, such as segregated ice, ice wedges, ice sheets, ice-floes, etc. Numerous and various viable microorganisms such as: prokaryotes, green algae, cyanobacteria, actinomicetes, fungi and yeast are found in the snow and pure marine, river, lake and ground ice. The findings of ancient people are very rare but of great interest because they give us the possibility to obtain valuable information about ancient people life. Mummies

were discovered in mountain glaciers of Alps, Andes and British Columbia. Mammoth fauna founds are also very informative and interesting. More than 10 findings of fossils mammoth's whole carcasses have been discovered in Siberian permafrost.

1. Plant Remains

Sometimes the plant macro-remains may be found in the ice in high concentration. About 4000 seeds of various species have been determined in Late Pleistocene ice–wedge ice in the exposure at the eastern coast of Anabar Gulf at the depth 11–23 m. Among them 88% of tundra plants and 12% of unclear ecology (Solov'yov, Stanishcheva, 1984) as follows: *Larix daurica Turcz, Poaceae, Eriophorum vaginatum L., Betula sect. Nanae, Alnuster sp., Oxiria digina (l) Hill., Cerastium arvense L., Minuartia rubella (Wahlenb)Hiern., M. sibirica (Sw.) Hiern., Stellaria sp., Papaver lapponicum (Tolm.) Nordh., Draba sp., Potentilla sp., Dryas punctata Yus*. The surrounding ice wedges sediments also enclosed similar plant remains and seeds. There are some attempts to use ancient material for germination "*in vitro*". Viable seeds of fossil plants have been found in frozen icy holes of fossil gophers referred to a species *Urocitellus suborder* in edoma sediments in Zelyony Mys cross-section, Lower Kolyma. The age of these holes is about 30–32 ka BP. The availability in the hole of transparent sublimation ice provides a good preservation of seeds, fruits, litter components, such as: hair, down, plant remains, and gives evidence that in the early stages of burial the holes were in relatively dry and cool conditions. Thus after burial and syngenetic freezing the bedrock layer was at negative temperature. In the holes the stores of seeds and fruits contain mostly bulbs of *Polygonum viviparum*, seeds of *Caryophyllaceae* and *Brassicaceae*, *Carex sp.,* small seeds of *Potentilla sp.,* R*anunculus* sp. (two species), *Draba cinerea Adam.,* and also *Poa sp., Bromus sp.* Seeds and fruits well preserved all peculiarities of their morphological and anatomical structure and sometimes their original color. Experiments of the seed germination using 'in vitro' methods after sterilization on agar media, the nutrient media with hormonal additives made it possible to induce germination of the germ rootlets from seeds of *Caryophyllaceae* and isolated fragment of sedge (Yashina et. al., 1997, 1998). Successfully has been germinated fossil seed of *Lupinus arcticus Wats* from the hole of lemming dated about 10 ka BP in Alaska.

Various species of plants and animals tolerate temperature lowering and preservation in the ice. The most tolerant organisms are microbes as cysts and also tardigrades, rotifers, roundworms. These organisms survive even their temperature close to –273^{o}C. Some other species are preserved in the ice in spite of considerable water content in them. For example, the mollusks and crustaceous which survived frozen into ice regularly in the inshore zone of Arctic seas, diving beetles, gnats, larva of gnats and moths, fishes and others. All of them are tolerant to low temperature because ice does not form in their cells. Their cells contain cryo-protectors i.e. the substances which lower freezing point such as: peptides, aminoacids, sugars, and glycerin. Cells of some species living in cold conditions are able to restore their structures injured by ice crystals.

Arctic and Antarctic ice acts as main limiting factor by inhibiting metabolic activities for 9–11 months in Arctic and more than 11 months in Antarctic and thus creates an ecological niche for cryobionts and organisms living in the melt water pools on the ice. Inhabited by Antarctic sea-ice microalgae environments are characterized by low ambient temperatures near –2^{o}C. These algae are psychrophiles, having growth temperatures below 15^{o}C, and maximum and minimum temperatures for growth at or below 20^{o}C and 0^{o}C respectively. The abundance of bacteria in the plankton under the annual sea ice in McMurdo Sound is low and increases slowly by five to tenfold over the austral spring. Bacteria growth may be limited by low temperatures, or by substrate availability.

Rich algae flora is growing at the interface of snow and ice on broken and drifting ice floe in Antarctic and Arctic. It was found that the ratio of chlorophyll concentrations greatly exceeds those normally found in marine phytoplankton populations. If 16 millions km^2 of sea ice exist each year in Northern Hemisphere, it can be estimated that a standing crop of at least 10–12 mg/m^2 or 25×10^6 kg chlorophyll *a* exists during about two months.

The ice subsurface constitutes another typical arctic niche. It serves as a second sea floor for attachment of many endemic arctic diatoms, mainly pennate forms and some extent *Centricae* from benthos and plankton. The biogeographical distribution, duration and alternation of planktonic diatoms determine by ice conditions. In the Arctic Ocean different interlocking ecological niches and cycles each containing a well– defined population can be distinguished (Bursa, 1963). Phytoplankton also can be surviving below the ice. At point Barrow, Alaska, close to the ice found mainly *Chlorella salina, Chlorella sp., Oocystis sp., Cryptomonas sp., and Scendesmus bijugatus*. At a depth of 6 m under the ice there were mostly brackish diatoms, *Navicula sp., Nitzchia so., Synedra sp., Grammatophora sp*., and very numerous *Chrysomonadineae*. Low salinity during the time of ice melting favors growth of fresh water and brackish forms. The microflora of the melt water pools consists mainly of the fresh water green algae (*Chlorella salina, Oocystis sp., Uothrix sp.*) and flagellates, fungi and dispersed patches of bacteria initially found on the ice surface (cryibionts) as conspicuous brown green patches. When the ice breaks the microflora of the pools is mixed with marine waters and plankton. The microflora of the off shore pack ice continued its activities until the first autumn frost. The nutritional requirements of the ice flora are probably supported mainly by nutrients derived from detritus from the tundra and bird and animals faeces. The sand gravel and silt in the ice and on its surface hasten melting of the ice by absorbing more heat than the surrounding ice itself. The ecosystem of the arctic ice represents the poorest oligohaline type of short duration. Owing to physic-chemical continuity of snow and ice, the microflora has cosmopolitan features probably found in any geographical latitudes. Sometimes abundance of *Clamidomonas nivalis* may produce of red colored snow.

The studies on sea ice in the Antarctic have indicated that the nutrient concentrations in the sea ice can differ considerably from the underlying water column. One reason for this may be restricted exchange between sea ice and seawater, concomitant with enhanced biological activity.

The bottom 20 cm of congelation ice and platelet layer, which underlies a large portion of the fast ice of McMurdo Sound in spring and summer, has been observed to harbor sea–ice microbial communities of exceptional biomass (Palmisano, Sullivan, 1983). Nutrients in congelation ice were studied in ice core near McMurdo Station (Arrigo et al., 1990). The ice cover consisted of 2–year–old congelation ice 2.5-m thick underlying roughly 65 cm of platelet ice. Chlorophyll profiles indicate that when present, microalgae biomass was concentrated in the upper 20 cm of the platelet ice layer throughout spring bloom, with the highest concentration (70 percent of total biomass) found immediately beneath the congelation ice. Chlorophyll concentrations in the upper 2m of the water column were less than1 mg per cubic meter. Judging from spectral irradiance and from chlorophyll and inorganic nutrient profiles the distribution of algae is controlled by light. Conversely, community is rapidly attenuated by snow, sea ice, and particulates present in the congelation ice, including microalgae because surface irradiance potentially available to the platelet ice. Irradiance at the top of the platelet layer is usually quite low from 0 to 50 microeinsteins per square meter per second depending upon congelation ice thickness, snow cover and particle concentration. A steep light gradient exists in the platelet ice due to high concentration of algae (2–5 g chlorophyll) (Arrigo et al., 1990).

In land–fast ice as found in McMurdo Sound there is high salinity (150%) in the upper 20–25 cm of the approximately 175 cm of annual ice. Unique flagellate and ciliate–dominated sea-ice microbial communities are found in the brine channels and pockets of the upper congelation ice during the late austral spring and early summer. Hypersaline conditions were most pronounced early, but as the ice began to melt, salinity below 34‰ was also observed. Chlorophyll values decreased in the brine as ice began to melt and tended to be low in samples collected near the ice edge. Diatoms were rare (generally less than 2×10^3 per liter) in the upper ice although these are the dominant forms in lower ice sea–ice microbial communities. Autotrophic nanoflagellates, autotrophic athecate dinoflagellates and ciliates dominated in the upper ice assemblages. These microbial assemblages are close to communities described from Antarctic pack ice.

Living organisms are preserved in the ice because they have some adaptation for low temperatures. Particularly, Antarctic fishes contain antifreeze glycopeptides which protect them from freezing also inhibit recrystallization and grain boundary migration in the ice, even at concentrations as low as $10^{-7}g^{-1}$.

Living organisms have been found in the ice of Baikal Lake, which are frozen in the ice in winter and begin to be active in spring in narrow channels in the ice. They are rotifers, fungi and bacteria.

2. Diatoms

It is well known that diatoms live on, in and under the sea ice in the Arctic and Antarctic waters. A rich diatom flora was found in continuous permafrost area in ice wedges in the northernmost Ungava Peninsula on the floodplain terrace of River Deception about 50 m above see level (A.S.L.), and 35 km from the present of Hudson Strait. Two hundred diatom frustules were counted (Koivo and Seppälä, 1994). Two species, *Cymbella aequalis* and *Tabellaria flocculosa,* constitued almost half of the diatom population. Other common species were *Flagellaria constricta, Nitzchia amphibia, Cymbella argustata v. Hybrida and also* sporadically *Nitzschia frustulum, Pinnularia microstauron, Pinnularia borealis, Pinnularia divergenissima, Tabellaria fenestrata, Cymbella turgida, Stauroneis phoenicephala, Anomoeoneis zellensis, Stauroneis phoenicephala, Eunotia lunaris, Eunotia praerupta.* In total these five species formed 65% of the 200 counted frustules.

Most of the identified species are classified as halophobe or oligophobe, pH of their living habitat is circumneutra, indifferent or they are acidiphilus species. The life habitat of these species seems to be benthic.

In Siberia in segregated ices of upper part of Duvanny Yar cross-section there L.Pirumova described poor fresh water diatom complex consisted of 15 taxons: *Cyclotella comta (Ehr) Ktz.* –planctonic species, the others are benthic: *Navicula radiosa Kutz., Navicula Viridula, Pinnularia alpina W. Sm., Pinnularia lata W. Sm., Pinnularia borealis Ehr.* Diatom flora evidences that the ice has been formed with participation of small pools' water. Fresh water diatoms also found in ice wedges of Yana-Indigirka lowland and in Bolshoi Lyakhovskii Island: *Eunotia papilio (Grun) Hust., Eunotia sueccica A. Cl., Navicula semen Ehr., Pinnularia fasciata (Lagerst) Hust., Pinnularia lata W. Sm.*.

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Biographical Sketches

Vasil'Chuk Yurij Kirillovich, Doctor of Sciences, Professor, Academician of the Russian Academy of Natural Sciences (2004, Corresponding Member - 2000), Professor of Cryolithology and Glaciology Department, Head of Regional Engineering Laboratory, Lomonosov's Moscow State University 119992, Moscow, Lenin Hills, Lomonosov's Moscow State University, Geology Faculty, Engineering and Ecological Geology Department, Main Building, Zone A, room No 111. Prof. Vasil'chuk Yurij Kirillovich was born in 1954 in Lazo, (Moldova). He graduated Lomonosov's Moscow State University with excellent degree in geocryology and glaciology in 1975. He received a PhD in 1982 and Doctor of Sciences degree in 1991. He is Academician of the Russian Academy of Natural Sciences from.2004. Since 1992 he is a head of Glaciology and Geocryology Data Centre of Theoretical Problems Department of Russian Academy of Sciences. Since 1996 he serves as a professor of Cryolithology and Glaciology Department of Geography faculty of Lomonosov's Moscow State University and from 1997 as a Head of Regional Engineering Laboratory of Engineering and Ecological Geology Department of Geology faculty of Lomonosov's Moscow State University. His principal science interests are in area of isotope geochemistry, geochronology, Quaternary Geology, stratigraphy, geocryology, glaciology and geomorphology. He undertook field investigations in nearly all permafrost regions of Eurasia, such as Gydan and Yamal Peninsulas in the North of Western Siberia, Central and Northern Yakutia, Chukotka, Magadan region, Trans-Baikal region and Arctic Islands. Yu.K.Vasil'chuk is the author of over 200 publications, from them there are 7 monographs, such as: "Oxygen-Isotope Composition of Ground Ice" (Application to paleogeocryological reconstructions) 2-volum issued in 1992 and the textbook "Principles of Isotope Geocryology and Glaciology" (coauthored with Academician RAS V.M.Kotlyakov) issued in 2000 et al., about 20 papers he has published in "Transactions of Russian Academy of Sciences" and more than 25 ones in the International Journals, such as *Radiocarbon, Permafrost and Periglacial Processes, Nuclear Instruments and Methods in Physics Research B, Earth* and *Planetary Science Letters* etc. His recent textbook, "Soil Engineering» (2005, Lomonosov' Moscow University Press), was co-authored with V.T.Trofimov et al. This textbook characterized the ground ice as a base for constructions. Currently he prepared the new book "Ice wedge: Heterocyclity, Heterogeneity, Heterochroneity" issued in 2006..

Vasil'chuk Alla Constantinovna, PhD, Senior Researcher of the Geography Department, Laboratory of Geoecology of the North, Senior researcher, Moscow State University named M.V.Lomonosov, Vorob'yovy Hills Moscow, Russia, 119899. Dr.Alla Vasil'chuk was born in 1955 in Groznyi (formerly USSR). In 1973 she has attended a Russian secondary school in Groznyi with gold medal. She graduated a Geography Faculty Moscow State University with excellent degree in Palaeogeography (palynology) in 1979. From 1998 Dr. Alla Vasil'chuk is Official Applicant of Doctor Habilitate Degree in Laboratory of Palaeogeography of Pleistocene, Moscow State University. Her principal interests are focused in Facies and Genetic Palaeogeographic and Palaeotemperature reconstructions based on the pollen data of Late Quaternary permafrost sediments. Dr.Alla Vasil'chuk participate in field investigations in many permafrost regions in Gydan and Yamal Peninsulas in the North of Western Siberia, Central and Northern Yakutia, Chukotka, Magadan Region and Arctic Islands: Ayon, Belyi et al. Alla C.Vasilchuk is the author of 120 publications. Her monograph, "Formation features of pollen spectra in Russia permafrost area" (2005, Lomonosov'Moscow University Press) firstly contain ^{14}C dating of pollen concentrate from ice-wedge ice. It has been shown, that due to good safety of ancient pollen and spores the ^{14}C age of pollen concentrate often is older than the organic micro inclusions. A.C.Vasil'chuk is the author of over 120 publications, from them there are 2 monographs, such as: "Palynology and chronology of polygonal ice wedge complexes in Russia permafrost area" issued in 2005, and at the moment she is completing her monograph Palynology and chronology of polygonal ice wedge complexes in Russia permafrost area / Ed. Prof/ Yurij K.Vasil'chuk – Moscow. Moscow University Press. issued in 2006.