PROPERTIES OF GLACIAL, ICEBERG AND PERMAFROST WATER

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

Keywords: ice cores, ^{14}C dating of the ice, $^{10}Be/^{36}Cl$ –dating, tritium, methane, catastrophes'

Contents

Summary

The most precise method of obtaining age-depth relationships is by counting seasonal changes distributed by $\delta^{18}O$, dust particles or acidity. Beyond the Holocene or latest Pleistocene in the case of GISP2, less precise methods are used such as (1) matching reference horizons of known age; for example, in the Byrd core by volcanic acidity maxima; (2) radioactive dating of carbon–14; by $^{36}Cl/^{10}Be$ ratios, or for a short term, ^{32}Si or ^{210}Pb; (4) matching of the δ record with another dated climatic record, principally deep sea records; and (5) by the less precise method of ice flow models.

Examination of climatic records shows that solar minima correlate not only with increased cosmogenic production, as evidenced in the ^{10}Be record over a solar cycle, but also with periods of lower temperature. The ^{10}Be profiles in both Greenland and Antarctic cores match very well and are well correlated with atmospheric $\Delta^{14}C$. A detailed comparison of ^{10}Be and $\Delta^{14}C$ improves the depth–age relation for the ice cores.

Ground ice may be dated using ^{14}C from air bubbles and from organic material incorporated into ground ice. Air bubbles in ground ice may give valuable information

about genesis and age of the ice. Tabular massive ground ice has been dated in the Pleistocene Mackenzie Delta at Peninsula Point by Late Wisconsin. By means of AMS, the ice wedges themselves can now be dated directly by their organic remains found in the ice. Direct ^{14}C dating of Late Pleistocene and Holocene ice–wedges by AMS, shows a clear age stratification of the ice wedges. Tritium in permafrost mainly associated with modern ice formation. Ice body of Miocene age has been found in Beacon valley in the Dry valley region, Antarctica. It is of interest that oscillations of $\delta^{18}O$ in syngenetic ice wedges are close to $\delta^{18}O$ variations in another Quaternary cryosphere objects (i.e. ice cores) for the same time interval.

Properties of different forms of ice use to study of environment, palaeoclimatic changes, modern condition for building constructing and future.

1. Palaeoclimatic Studies

Palaeoclimatic studies in glaciers, ice sheets and ground ice first of all connected with precise **dating** of ice age. The most precise method of age–depth relationship is seasonal variations of $\delta^{18}O$, δD dust particles or acidity counting. The chronology of GRIP core in Greenland is determined by counting annual layers back to 14 500 years and beyond this date, by ice flow modeling. Annual layers have been counted back almost 80000 years in the GISP2 core (in Greenland also). Beyond the Holocene or latest Pleistocene in the case of GISP2, less precise methods are used such as matching reference horizons of known age; for example, in the Byrd core by volcanic acidity maxima; radioactive dating of carbon-14; by $^{36}Cl/^{10}Be$ ratios, or for a short term, ^{32}Si or ^{210}Pb; matching of the δD and $\delta^{18}O$ records with another dated climatic record, mainly deep sea records; and by the less precise method of ice flow models.

The incorporation of radioisotopes into ice layers involves contributions from three types of material: gas trapped from ambient atmosphere, atmospheric particulates of contemporary origin (e.g. biogenic material) or having quite different radioisotope content (e.g. wind–born loess and volcanic ash), ice irradiated *in situ* by cosmic rays during the period before it becomes buried to a depth of the order of 10 m, when self–shielding reduces radioisotope production to insignificant levels; *in situ* production also occurs at the margins of the ice sheets, where old ice is again exposed to a cosmic rays; the ratios of ^{14}CO to $^{14}CO_2$ are not the same for *in situ* and atmospheric ^{14}C transferred to ice. In the case of ^{14}C, about 60% of the radioisotope produced *in situ* during ice formation is retained as ^{14}CO and the remainder as $^{14}CO_2$ – providing a signature for *in situ* produced ^{14}C (atmospheric ^{14}C occurs as CO_2 with much less than 1% CO). Age of carbon dioxide from air bubbles has been obtained in Dye 3 (Greenland); the corrections were made according to counting annual layers. At the depth 1665 m corrected age of the ice is 6790 +310/ –330 yr, 1709 m - 7670 +170/ –190 yr and 1777 m - 9670 +420/ –580 yr (Andree et al., 1986).

Development of AMS techniques made possible measurements in ice of longer lived radionuclide such as ^{10}Be, and ^{36}Cl. Be^{10} in ice cores is useful for monitoring short–term solar cycles because it has a short residence time in the atmosphere (about 1.5 yr). The Be^{10}record from Dye 3 extends back to 1423 AD with continuing evidence for the 10.8–yr cycle despite the absence of sun spots during the Maunder Minimum (1645 to 1715

AD). Maunder Minimum also is known as Little Ice Age because of the sustained low temperatures recorded in Europe with winter fairs being held on the frozen Thames. Other broad maxima in both radiocarbon and Be^{10} concentrations coincide with Sporer (1420 to 1540 AD) and Wolf (1280 to 1350 AD) minima. Maxima with periods of 93 and 202 years are also seen in ^{10}Be data from the Milcent ice core (Greenland) and core from the South Pole. Combined results from Camp Century (Greenland) and Dome C (Antarctica) ice core for the period 2500 BC to 1000 AD also show a considerable similarity in the major features and good concordance with tree ring ^{14}C record (Beer et al., 1988). Examination of climatic records shows that solar minima correlate not only with increased cosmogenic production, as evidenced in the ^{10}Be record over a solar cycle, but also with periods of lower temperature. A total depth of 2500 m has been sampled at Vostok, Antarctica, to provide ^{10}Be information to an age of approximately 220 ka (Petit et al., 1999). The ^{10}Be profiles in both GISP2 and Siple Dome cores match very well and are well correlated with atmospheric $\Delta^{14}C$. A detailed comparison of ^{10}Be and $\Delta^{14}C$ improves the depth–age relation for the ice cores. Measurements of ^{10}Be in an ice core from Camp Century show a dramatic increase in radionuclide concentrations at depths corresponding to the end of the last period of glaciation (approximately 11 ka BP) as defined by $\delta^{18}O$ results for the same core and hence the ambient temperature during formation of each ice layer (Beer et al., 1988).

Ground ice may be dated using ^{14}C from air bubbles and from organic material incorporated into ground ice. Air bubbles in ground ice may give valuable information about genesis and age of the ice. Tabular massive ground ice has been studied in the Pleistocene Mackenzie Delta at Peninsula Point. ^{14}C age estimates for the gases trapped in the ice range from 13860 ± 100 BP to the greater than 32000 BP. (Moorman et al., 1996). Age of the ice-wedge ice has been determined by ^{14}C measurements from CH_4 in the air bubbles Obtained ages of ice wedges in Oiyagoskii Yar is 3539±87 yr. BP, and in Big Lyahovsky Island is 4782±113 yr BP (Morizumi et al., 1995).

The Sajama cores contain intact insects; insect fragments and polylepis bark fragments that allowed AMS ^{14}C dating to constrain the time-scale. The sample was divided into two portions that gave dates of 24 950 ± 430 $^{14}C_{cal}$ yr (Lawrence Livermore National Laboratory) and 24 020 ± 140 $^{14}C_{cal}$ yr (Woods Hole Oceanographic Institution) ago. These dates confirm that the near-basal ice on Sajama is of Late Pleistocene age (Thompson et al., 2000).

Direct ^{14}C dating of Late Pleistocene and Holocene ice–wedges by AMS, shows a clear age stratification of the ice wedges. Six sites in the Siberian permafrost was investigated (Vasil'chuk et al., 2000a, 2001, 2002). The first site is located near the Seyaha settlement in the central part of Yamal Peninsula, at the coast of the Ob Bay (70°N, 72°E). The second site is located in the Shchuch'ya River valley, in the southern part of Yamal Peninsula (67°10'N, 69°5'E). Direct dating of Late Pleistocene and Holocene syngenetic ice wedges was done on organic material included in the ice. The time of formation (in ^{14}C years) is 21 000–14 000 BP for Seyaha, and 7100 BP for Shchuch'ya River (Vasil'chuk et al., 2000).

The most important results are the AMS–dating of organic material of micro inclusions directly from Late Pleistocene ice–wedge ice of ice–wedge complex Bison, located on the right bank of Lower Kolyma River (Northern Yakutia) , in a mouth of Lakeevskaya creek (69^{o}N, 158^{o}E). The in details tested fragment of ice wedge, height 5 m in the main exposure wall is dated on microorganic from 26.4 up to 32.6 thousand years (8 radiocarbon dates): Zelyony Mys (28-13 ka BP), Duvanny Yar (31-23 ka BP), Plakhinski Yar (17 ka BP) in Lower Kolyma River valley and Mamontova Gora in Aldan River valley (19-17 ka BP). A result of ^{14}C AMS-dating of Late Pleistocene syngenetic ice-wedge ice provided precise setting of detail stable isotope plots to a geochronological scale (Yu.Vasil'chuk et al., 2002, 2004).

Both the structure and composition of syngenetic ice wedges have been preserved from their time of formation until today. The δ^{18}O and δD values in modern ice–wedges correlate well with mean winter temperatures: the ice formed from the melt water, which penetrates into the frost cracks in early spring, and which had its origin from winter precipitation. Based on δ^{18}O and δD measurements collected for many ice wedges from the permafrost zones in Northern Eurasia and Northern America and meteorological data, an empirical relation between δ^{18}O values of the ice and winter temperatures could be deduced. Assuming that the relationship derived from modern ice wedges can also be applied to Late Pleistocene and Holocene conditions, therefore, δ^{18}O and δD values in ancient ice–wedges enable the reconstruction of paleotemperatures. Radiocarbon dating of organic material yields a timescale (in BP) for such palaeotemperature records.

Caves containing ice bodies occur in many parts of the world. Ice-cave is essentially frozen ground water that had been in contact with the soil atmosphere and contains more than 1000 of CO_2 carbon kg^{-1} ice. The ice is easy to date as it contains by polar ice core standards, very large quantities of CO_2. Wilson and Donahue (1992) obtain ancient dates (1.8-1.7 ka BP) from the ice caves in New Mexico for both a normal sample and the ice that entrapped it.

Tritium (^{3}H) is a radioactive isotope of modern age with a short half–life (12.43 years). Its detection in the upper layers of permafrost, in the active layer, and in seasonal ice bodies is useful in determining recent water migration into permafrost, the age of seasonal frost mounds, or recent ice wedge growth. Tritium in permafrost mainly associated with modern ice formation. In modern injected sheet ice and small pingo the maximum tritium concentration was 323 TU and the mean concentration was 191 TU.

2. Physical Properties

Very few glaciers show the entire sequence: dry snow zone, percolation zone, wet-snow zone, superimposed-ice zone. The transformation of snow to ice in the percolation and wet snow zones differs from that in the dry snow zone. A superimposed–ice zone represents the extreme case. Crystal size increases at a constant rate if the temperature remains constant. A single ice crystal deforms under an applied stress. A single ice crystal normally deforms by gliding on its basal planes. In glaciers and ice sheets, the ice is deformed for hundreds or thousand of years. Ablation includes all processes by which snow and ice are lost from the glacier. Ice in glaciers is re-crystallizing continuously. Crystal size of the ice depends on salinity. The ice grain diameter, density and shear modulus increases with the increase of the depth. Porosity of solid transparent ice is as high as 1 kg (cm^3/kg) of solid sea ice is 1–50 cm^3/kg. Effective thaw heat of sea ice decreases abruptly with increase of salinity. The regelation is a moving of heavy thing throughout the ice without any ice disturbances. Due to molecular thermal oscillations and defects of ice crystals the water molecules can diffuse. The electrical properties of ice are distinguished by the fact that the charge carriers in ice are protons (Bogorodsky, Gavrilo, 1980; Hondoh, 2000).

Mass balance studies of glaciers are concerned with changes in the mass of a glacier and the distribution of these changes in space and time. More particularly, to measure the change in mass in given year. Such studies form important link in the chain of events connecting advances and retreats of glaciers with changes of climate. Climate fluctuations caused variations in the amount of snow that collects on the glacier and in the amount of snow and ice lost by melting. Accumulation and ablation represent the income and expenditure terms in the glacier's budget. Accumulation normally takes place at or near the glacier surface. Ablation includes all processes by which snow and ice are lost from the glacier. Melting followed by run-off, evaporation, removal of snow by wind, the calving of icebergs are examples.

In glaciers and ice sheets there is an upper layer some 15–m thick, in which the temperature varies in response to seasonal changes in surface temperature. In winter the ice is warmer than the air and so the heat is conducted upwards through ice. Changes of surface temperature with periods much greater than one year, such as those due to climatic changes, penetrate to depth much greater than 20 m. In the most areas, the mechanism of heat transfer in the surface layers in summer differs from winter mechanism. Except in the interiors of Greenland and Antarctica, or near the tops of some very high mountains, there is enough heat in summer to cause melting at the surface. The mean annual air temperatures at 10–m temperatures at the stations in dry snow areas of Greenland and Antarctic are very close – Greenland: Camp Century –23.5 – air, –24.5 – firn; Station Centrale –28.3 – air, –27.6 – firn; Northice –30.0 – air, –28.0 – firn; Antarctic: Byrd –28.2 – air, –28.3 – firn; Vostok –56.6 – air, –60.2 – firn; South Pole station –49.3 – air, –50.8 – firn (Paterson, 1981).

Geophysical classification of glaciers bases on ice temperature and mount of surface melting. This categories are temperate, sub–polar, and high polar.

A temperate glacier, as usually defined, is one in which the ice at the melting point throughout except for surface layer, some 15 m thick, is subject to seasonal temperature changes.

Temperature data from glaciers in the Alps are evidenced that accumulation areas at high elevations are not temperate. On Mon Blanc the 15–m temperature is –16.7^{o}C at 4785 m elevation, –10.5^{o}C at 4250 m, and –7.3^{o}C at 3960 m. In Austria, where precipitation is less than in western Alps, the 15–m temperature in the upper part of the ablation area of Hintereisfener Glacier is –1 to –2^{o}C. Only accumulation areas below 3800 m in Alps are temperate, although the critical elevation varies with the aspect of slope.

Deformation in glaciers is simpler than in rocks because there is only one driving force, gravity. Unlike rocks, the ice is a single substance, although the superimposition of several phases of deformation can make its structure extremely complex. Ice deforms sufficiently rapidly that deformation rates can be measured and estimated of total strain made.

Porosity normally is characterized by ratio between total pore volume and sample volume or sometimes total pore volume of 1 kg ice (cm^3/kg). Porosity of solid transparent ice is as high as 1 kg (cm^3/kg) of solid sea ice is 1–50 cm^3/kg. Under high thermodynamic or mechanic action the porosity increases to10–100 cm3/g and ice become cloudier. The ice with high porosity (50–400 cm^3/kg) looks like snow.

-
-
-

Bibliography

Andree M., Beer J., Loetscher H.P., Moor E., Oeschger H., Bonani G., Hofmann H.J., Morenzoni E., Nessi M., Suter M., Wolfli W. (1986). Dating polar ice by ^{14}C accelerator mass spectrometry *Radiocarbon*. **28** (2A) [Proceedings of the 12th International ^{14}C Conference. Eds. M.Stuiver, R.S.Kra). 417–423. [The dates of air bubbles of Dye 3 ice core are presented].

Beer J., Siegenthaler U., Bonani G., Finkel R.C., Oeschger H., Suter M., Wolfli W. (1988). Information on past solar activity and geomagnetism from ^{10}Be in the Camp Century ice core. *Nature*. **331** (6158). 675–679.[The record of Be^{10}concentration in annual layers of ice, from measurements on a Greenland ice core (Dye 3) is discussed].

Bogorodsky, V.V., Gavrilo, V.P. (1980). *Ice. Physical Properties. Modern Methods of Glaciology.* Leningrad. Gidrometeoizdat. 384 p. [In Russian]. [Physical properties of the ice are considered very detail].

Budantseva N. (2003). Ice wedge and palsa formation in the Holocene (Bol'shezemel'skaya tundra and north-west Siberia). PhD summary. Moscow State University. 26 p. [In Russian]. [It was presented of the heavy metals content and isotopic composition of Holocene ice-wedge and palsa ice].

Chizhova Ju. (2006). Isotope-geochemical features of snow cower and glacier ice in the different glaciological conditions of the Elbrus area, Polar Ural and Khibines. PhD summary. Moscow State University. 24 p. [In Russian]. [It was presented of the heavy metals content and isotopic composition of glacier ice and snow cower]

Cuffey K.M., Conway H., Gades A.M., Hallet B., Lorrain R., Severinhgaus J.P., Steig E.J., Vaughn B., White J.W.C. (2000). Entrainment at cold glacier beds. *Geology*. **28** (4). 351–354. [It was present of the gas content and isotopic composition of debris-rich basal layers of a polar glacier].

Dansgaard W,. Johnsen S.J., Mшller J., Langway C.C., Jr. (1969). One thousand centuries of climatic record from Camp Century on the Greenland Ice Sheet. *Science*. **166** (3903). 377–381. [The first detail oxygen isotope record, which became the base of many palaeotemperature reconstructions].

Dansgaard W., Johnsen S.J., Clausen H.B., Dahl-Jensen D., Gundestrup N.S., Hammer C.U., Hvidberg, C.S., Steffensen J.P., Sveinbjornsdottir A.E., Jouzel J., Bond G. (1993). Evidence for general instability of past climate from a 250-kyr ice-core record. *Nature*. **364** (6434). 218–220. [Very detail isotope record of Summit ice core from Central part of Greenland, where ice is not deformed].

Hong, S., Candelone, J.-P., Turetta, C. and Boutron, C. (1996) Changes in natural lead, cooper, zinc, and cadmium concentrations in central Greenland ice from 8250 to 149 100 years ago: their association with climatic changes and resultant variations of dominant source contributions. *Earth and Planetary Science Letters*. **143** (1-4) 233-244. [Comparison of the heavy metal concentrations in Holocene and Eemian Greenland ice is presented].

Legrand, M. and Delmas, R. (1994). Ice core chemistry: implications for the past atmosphere. In Claude F. Boutron (ed.). *European Research Course on Atmospheres. Topics in Atmospheric and interstellar physics and chemistry.* Les editions de fisique Les Ulis. Grenoble. 387 –410. [Ice core data related to aerosols: sea salts, soil dust, sulphur derived species are interpreted in tems of atmospheric chemistry changes].

Moorman B.J., Michel F.A., Wilson A. (1996). ^{14}C dating of trapped gases in massive ground ice, Western Canadian Arctic. *Permafrost and Periglacial Processes*. **7 (**3). 257–266. [The ^{14}C dates of CO_2 from Late Pleistocene massive ice body in Peninsula Point are presented].

Morizumi J., Iida T., Fukuda M. (1995). Radiocarbon dating of methane obtained from air in the ice complex (edoma), in Arctic coast area of east Siberia. In K.Takahashi, A.Osawa, Y.Kanazawa (Eds.). *Joint Siberian Permafrost Studies between Japan and Russia in 1994. Proceedings Third International Symposium Tsukuba.* Hokkaido University Press, P.14–21. [[The ^{14}C dates of methane from Holocene ice wedges in northern Yakutia are presented]

Paterson, W.S.B. (1981) *The physics of glaciers.* Second edition. Pergamon Press. Oxford. – New York. 380 p. [Detail study of glaciers’ physical properties].

Petit J.R., Jousel J., Raynaud D., Barkov N.I., Barnola J.-M, Basile I., Bender M., Chappelaz J., Davis M., Delague G., Delmott M., Kotlyakov V.M., Legrand M., Lipenkov V.Y., Lorius C., Pepin L., Ritz C. (1999). Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature*. **399**. 429–436. [Review paper of Vostok ice core study].

Schäfer J.M., Baur H., Denton G.H., Ivy-Ochs S., Marchant D.R., Schlűchter C. and Wieler R. (2000). The oldest ice on Earth in Beacon Valley, Antarctica: new evidence from surface exposure dating. *Earth and Planetary Science Letters.* **179** (1). 91–99. [Two dolerite erratics from the till surface and one from within the ice analyzed for cosmogenic helium and neon].

Thompson, L.G. and Mosley-Thompson, E. (1981). Microparticle concentration variations linked with climatic change: evidence from polar ice cores. *Science*. **212**. 812–815. [Comparison dust concentration in Arctic and Antarctic polar ice sheets in Holocene and Pleistocene].

Thompson, L.G., Mosley-Thompson, E., Henderson, K.A. Ice-core palaeoclimate records in tropical South America since the Last Glacial Maximum // Journal of Quaternary Science. 2000. Vol.15. N4. P.377–393. [Isotope data for Late Pleistocene mountain tropical glacier is presented].

Tuniz C., Bird J.R., Fink D., Herzog G.F. (1998). *Accelerator mass spectrometry. Ultrasensitive Analysis for Global Science*. Boca Raton: Florida CRC Press LLC. 358 p. [Applying of AMS techniques to various environment subjects. Methods of sampling and dating is considered.].

Vasil'chuk, A.C. and Vasil'chuk, Yu.K. (2002). The first radiocarbon dating of pollen from syngenetic ice-wedge ice. *Transactions of the Russian Academy of Sciences.* Vol.383. N1.

Vasil'chuk A.C., Kim J.-C., Vasil'chuk Yu. K. (2003). First radiocarbon dating of pollen and spores from syngenetic ice-wedge ice. In *Permafrost, Eighth International Conference, Proceedings.* Zurich, 21-25

July 2003. Eds.: by M.Philips, S.M.Springman, L.U.Arenson. Vol. 2. Zürich, Zwitzerland. A.A.Balkema Publishers. Swets & Zeitlinger B.V. Lisse. The Netherlands. P. 1167 – 1172.

Vasil'chuk A.C., Kim J.-C., Vasil'chuk Yu. K. (2004). The AMS dating of pollen from syngenetic ice-wedge ice. *Nuclear Instruments and Methods in Physics Research. Section B: Beam Interactions with Materials and Atoms*. Vol. 223-224. P. 645 – 649.

Vasil'chuk A., Kim J.-Ch.,Vasil'chuk Yu. (2005). AMS ^{14}C Dating of Pollen Concentrate from Late Pleistocene Ice Wedges from the Bison and Seyaha Sites in Siberia. *Radiocarbon.* Vol. 47. N 2. P. 243 - 256.

Vasil'chuk A.C. (2005) *Pollen spectra formation features in permafrost areas of Russia.* – Moscow. Moscow University Press. 2005. – 245 pp. [The methodological problems of pollen spectra interpretation and their formation features in permafrost areas under various temperatures of vegetation and permafrost as medium of pollen and other biologic components accumulation and preservation are considered. The analysis of sub fossil pollen spectra in Arctic has been made. Taphonomy features and pollen productivity of Arctic and Sub arctic biocoenoses, evidences of successions in pollen spectra peculiarities are considered. The attention is given to structure of sub fossil pollen spectra. Pollen spectra of polar desert, tundra and forest tundra in various temperature ranges are separately considered. Pollen and spores are studied in tabular massive ice in ice-wedge ice and also in palsa and pingo].

Vasil'chuk A.C. (2006). *Palynology and chronology of polygonal ice wedge complexes in Russia permafrost area /* Editor: Academician of the Russian Academy of Natural Sciences, Professor Yurij K.Vasil'chuk – Moscow. Moscow University Press. 2006. – 400 p. [The problems of landscape and palaeotemperature signal in pollen spectra from ice-wedge ice in Russia permafrost are considered. Pollen and spores spectra from basic Late Pleistocene and Holocene sections of ice-wedge complexes are characterized in details, such as: in Seyaha, in the mouth of Mongatalyangyaha River, in the mouth of Gyda River, in north-western Siberia and Zelyony Mys, Duvanny Yar and Plachinskii Yar in Kolyma River valley. Late Quaternary pollen stratigraphy of Eurasia permafrost area in connection with Global Changes is presented. Main palynological and geochronological boundaries of Late Pleistocene and Holocene are considered. The evidences of Heinrich events on pollen and spores diagrams of ice wedge complexes are shown. The correlation of the obtained data on permafrost sections is carried out].

Vasil'chuk, Yu.K. (1992). *Oxygen isotope composition of ground ice (application to paleogeocryological reconstructions).* Moscow. 2 volumes. Vol.1. – 464 p. Vol. 2. – 264 p. [In Russian]. [Detail description of large Pleistocene and Holocene ice-wedge and massive ice in all areas of Russian permafrost is presented].

Vasil'chuk Yu.K. (2006) Ice wedge: heterocyclity, heterogeneity, heterochroneity. Moscow: Moscow University Press. – 400 p. [The new concept of the author considering ice-wedge ice and its surrounding permafrost sediments as heterocyclity, heterogeneity and heterochroneity phenomena is formulated. The materials proving realization of new southern limit of modern ice wedge distribution in Eurasia are presented. The results of direct AMS-radiocarbon dating of ice-wedge ice of organic micro inclusions from the ice are generalized. This approach has allowed to carry out chronology and paleogeographical correlation of ice wedge in basic sections of north of the European part of Russia, Western and Middle Siberia, north and central part of Yakutia, Chuckotka and Magadan area, Tuva and Transbaikalia,. The new theoretical approach and new experimental data has allowed receiving more authentic paleogeographical and paleoclimatic scenario of ice wedge formation and paleocryosphere development in permafrost area of Russia as a whole for the period last 50 ka BP].

Vasil'chuk, Yu.K. and Kotlyakov, V.M. (2000). Principles of isotope geocryology and glaciology. A Comprehensive Textbook. Moscow University Press. 616 p. [This textbook presents the main principles and applications of stable and radioactive isotopes to the study of glaciers and ground ice].

Vasil'chuk, Yu.K., Punning, J.-M. and Vasil'chuk, A.C. (1997) Radiocarbon ages of mammoths in Northern Eurasia: implications for population development and Late Quaternary environment. *Radiocarbon*. **39** (1). 1–18. [Findings of mammoth carcasses, their taphonomy conditions are discussed].

Vasil'chuk, Yu.K., Kim, J.C. and Vasil'chuk, A.C. (2002). Radiocarbon AMS-dating of Late Pleistocene ice-wedge ice isotope diagrams. *Transactions of the Russian Academy of Sciences.* Vol.383. N3.

Vasil'chuk Yu. K., van der Plicht J., Jungner H., Vasil'chuk A.C. (2000a). AMS–dating of Late Pleistocene and Holocene syngenetic ice–wedges. *Nuclear Instruments and Methods in Physics Research B*. **172**. 637–641. [Principles of Late Pleistocene and Holocene ice–wedge ice AMS dating are discussed].

Vasil'chuk Yu. K., van der Plicht J., Jungner H., Sonninen E. and Vasil'chuk A.C. (2000b). First direct dating of Late Pleistocene ice–wedges by AMS. *Earth and Planetary Science Letters.* **179** (2). 237–242. [First AMS dating of Late Pleistocene ice–wedge ice by enclosed organic material is presented].

Vasil'chuk Yu.K., Kim J.-C., Vasil'chuk A.C. AMS ^{14}C dating and stable isotope plots of Late Pleistocene ice-wedge ice // Nuclear Instruments and Methods in Physics Research. Section B: Beam Interactions with Materials and Atoms. 2004. Vol. 223-224. P. 650 - 654.

Wilson A.T. and Donahue D.J. (1992). AMS radiocarbon dating of ice: validity of the technique and the problem of cosmogenic *in–situ* production in polar ice cores. *Radiocarbon.* **34** (3). (*Proceedings of the 14th International ^{14}C Conference.* Eds. Long A. and Kra R.S.). 431–435. [The dates from the ice caves in New Mexico for both a normal sample and the ice that entrapped it are presented].

Zimov S.A., Voropaev Y.V., Semiletov I.P., Davidov S.P., Prosianniov S.F., Chapin III F.S., Chapin M.C., Trumbore S., Tyler S. (1997). North Siberian Lakes: a methane source fueled by Pleistocene carbon. *Science*. **277**. 800–802. [Dating of methane from North Siberian lakes is presented].

Zielinsky G.A., Mayewski P.A., Whitlow S., Twicckler M.S., Morrison M., Mees D.A., Gow A.J., Alley R.B. (1994). Record of volcanism since 7000 BC from the GISP2 Greenland ice core and implications for the volcano-climate system. *Science*, **246**. (4937). 1589–1591. [Volcano eruptions record in terms of acidity of the GISP2 ice core is presented].

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.