GLACIERS, ICEBERGS AND GROUND ICE

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

Keywords: glaciers, icebergs, snow cover, sea ice, ground ice, ice shelves, ice wedges, massive ices, structure forming ice, climate change

Contents

Summary

Ice is the most abundant solid substance on Earth. It can exist in a great range of temperatures and pressures. The total ice mass contained in glaciers, icebergs, ground ice, snow cover and the atmosphere is 2423 x 10^{22} tons. As a consequence of climate, more than 96.6% of ice area and 90% of ice volume is concentrated in the Greenland and Antarctic ice sheets. Outside the ice sheet area there are several isolated ice domes. Large slabs of floating ice, called ice shelves surround much of the Antarctic continent. The ice shelf is considered in relation to the ice sheet that feeds it. There are several types of icebergs: tabular, domelike, pyramidal and destroyed. There are 28 types of fresh ice, which can be divided into three groups: congelation ice (all ice of fresh water reservoirs and streams), ground ice (sedimentation ice) and metamorphic (glacier) ice. Floating ice can be distinguished by its origins into marine, river, lake and land

varieties, as well as by dynamics (immobile or fast ice and mobile, also called drift or pack ice).

Ground ice is a general term use to refer to all types of ice formed in freezing and frozen ground. Sediments that contain excess ice are often referred as "ice rich" or "icy" sediments. Various types of buried ice (glacier ice, sea, lake or river ice) fall under this classification, which results in ten mutually exclusive ground ice forms. The terms massive ice or massive ice bodies are usually reserved for relatively pure ground ice where the ice content averages at least 250% for a thickness of several meters. Segregated ice is a broad term for soil with a high ice content. Major developments in the field of glaciology have been due to the wealth of information obtained from analyses of cores from polar ice sheets.

1. Ice in Space

Ice can exist in a great range of temperatures and pressures. There are eleven varieties of ice, which are differentiated from each other in a manner similar to rocks. Under terrestrial conditions, it is possible to form only one variety of ice, which is called ice–I. The other ten varieties are only stable under specific conditions (definite ratios of pressure, density and temperature). However, almost all of them may be found in the Solar System.

Water content in the planets increases with distance from the Sun, and ice becomes the predominant water state. On Mercury there is no water, while on Venus the atmosphere contains 0.02% water, occurring as water vapor. On Earth, water exists as vapor, liquid and solid. Both poles of Mars are covered by ice sheets, which oscillate seasonally. In winter they range up to 45^{o} latitudes. In sub–polar areas, the ice sheets mainly consist of frozen CO_2 with some water ice. In the middle part of the ice sheets there are gas hydrate zones, while in circumferential areas the ice sheets consist of ordinary ice. There is no surface water on Jupiter and Saturn, but their nuclei partially consist of ice. Jupiter's moons consist of as much as 70–90% ice. Small moons (with diameters less than 730 km) are composed of common ice (ice–I), while larger ones are built up from various ice modifications (ice I, II, V, VI, VII.). Jupiter's moon Europa is completely covered by ice. Uranus' moons are possibly covered by layers of icy particles.

Ice is the most abundant rock on Earth. The total ice mass contained in glaciers, icebergs, ground ice, snow cover and the atmosphere is 2423×10^{22} tons (see Table1**)**. This is nearly thirty times more than the total mass of land surface water. The high purity of glacier water is very important when considering the worsening water deficiency on Earth.

Ice type	**Mass of (tons)**	**Distribution area**		
		%	**Million Km^2**	**%**
Glaciers	$2{,}398\times10^{16}$	98.95	16.3	10.9 Land
Icebergs	7.65×101^{2}	0.03	63.5	18.7 Ocean
Snow cover	1.05×10^{13}	0.04	72.4	14.2 Earth
Marine ice	$3{,}483\times10^{13}$	0.14	26.0	7.2 Ocean

Ground ice	$(2–5) \times 10^{14}$	0.83	21.0	14.1 Land
Atmosphere ice	1.68×10^{12}	0.01	510.0	100 Earth
Total	$2,423 \times 10^{16}$	100		

Table 1. Mass and distribution area of ice on Earth.
Source: Shumsky, Krenke, 1969

2. Glaciers

Ice covers more than 16.3 x 10^6 km^2, i.e. 11% of the Earth surface. The total ice volume of modern glaciers ranges from 26.8 x 10^6 km^3 to 30.3 x 10^6 km^3. If this ice layer were to cover the Earth uniformly, its thickness would be approximately 55–60 m). However, ice is distributed unevenly throughout the Earth. Due to climatic features, more than 96.6% of ice area and 90% of ice volume is concentrated in the Greenland and Antarctic ice sheets (see Table 2).

Area	**Glaciation area, km^2**	**Water reserves of glaciers, Km^3**
Greenland	1,802,600	2,704,400
Canadian Archipelago	149,990	42,770
Eurasian Arctic Islands and Byrranga mountains	91,130	22,710
Iceland	11,785	3,968
Europe(continent)	7,395	482
Asia (continent)	119,730	11,140
North America (continent)	123,700	24,960
Northern Hemisphere	**2,306,330**	**2,810,430**
South America (continent)	32,300	5,430
Africa (continent)	13	1
Australia (continent)	0	
New Zealand	817	64
New Guinea Island	7	1
Antarctic Islands	25,500	5,700
Antarctica (continent)	13,589,000	27,480,000
Southern Hemisphere	**13,647,637**	**27,491,196**
Earth Land	**15,953,967**	**30,301,196**

Table 2. Modern surface glaciation of the Earth
Source: Dolgushin, 2000

Glaciers are divided into several types according to their morphology and location:

- Summit glaciers (cone summit, flat summit and caldera glaciers).
- Slope glaciers (slope glaciers, hanging glaciers, corrie glaciers and corrie-valley glaciers).
- Valley glaciers (valley glaciers, dendrite glaciers, expanded–foot or bulb glaciers, piedmont glaciers and basin glaciers).

- Plateau glaciers, diffluent glaciers, recemented glaciers and others.

3. Ice Sheets

The area of the Antarctic Continent is 14 x 10^6 km^2; the mean diameter of the Antarctic ice sheet is 4000 km, the least is 2900 km, and the maximum is 5500 km. Mean surface level is 2040 m, the maximum is more than 4000 m above sea level. The Antarctic Continent is covered by thick ice sheets broken in several places by nunataks and mountains.

The coastline is about 30 000 km, of which 28 000 km is ice cliff. Exposed rock occupies only 0.3% of the total area, resulting in the area of the Antarctic ice sheet being roughly equal to the continental area. Most of the central Antarctic continental bedrock is lower than sea level. According to geologic structure, the continent is divided into the Western and Eastern Antarctic Continent. The surface of the Eastern Antarctic Continent is high and flat, with several slightly pronounced domes. The ice sheet surface rises sharply from the coast to the inland areas where the sub-horizontal ice surface is more than 3000 m above sea level.

In the Western Antarctic Continent, the ice surface is lower, and there are three distinctive ice domes, as follows: the Middle Dome (2000 m above sea level), another in Marie Byrd Land (2000 m above sea level), and in the south of the Antarctic Peninsula (2150 m above sea level).

The Antarctic ice sheet consists of (1) stagnate ice slightly sloping toward the sea with several domes, (2) active glaciers and (3) shelf glaciers. The thickness of the shelf glaciers ranges from ten meters to 1300 m, with a mean thickness of about 400 m. The thickness of active glaciers is ten meters to 1000 meters. Mean thickness of the Antarctic ice cover is 1800 m, and the total volume is 24.9 x 10^6 km, i.e. this is 22.4 x 10^6 km^3 or 90% of the ice on Earth.

Greenland is the largest island on Earth. Its area is 2 186 000 km^2; the length is about 2900 km, and the maximum diameter is 1200 km. Ice sheet covers 80% (1726.4 km^2) of the island's area, mainly inland areas. Wide ice streams come down to the ocean and fiords.

There are many flat hills, ridges, terraces and cavities in the elliptical surface of the Greenland Ice Sheet. They are formed due to local differences in snow accumulation, deflation, ablation, and ice movement. The surface is made rugged by summer melt water streams at heights lower than 1800 m in marginal areas. The mean height of the ice surface is 2135 m. The summit area of the ice sheet is a convex crown stretching from the North to the South. There are two top points of the crown, the South Dome (64^o N) at 2850 m and the North Dome (72^o N) at 3300 m.

An ice divide is located along 37^o W, close to the eastern margin of Greenland. In the North, it is close to the center of the island. Outside the ice sheet area there are several isolated ice domes. The largest is Succertoppen with an area of 2330 km^2 and a height of 1200 – 1700 m, located on the southwest coast. Fleid-Iceblink on the northeast coast of Greenland is another. The mean thickness of the ice sheet is 1790 m. The maximum thickness is 3416 m in the center part of the island, which is considerably less than that in the Antarctic continent (4350 m).

4. Ice caps of Arctic and Antarctic Islands

The majority of glaciers in the Eurasian and Canadian Arctic are classified as ice caps by their morphology and as diffluent glaciers by their movement features. The ice caps of many islands come down to the sea, forming ice cliffs as a result. The largest Eurasian ice caps are located in Iceland, Franz Josef Land, Spitsbergen, Novaya Zemlya Island, Severnaya Zemlya Island, Bennett Island, Henriette Island, Jeannette Island, Victoria Island, Ushakov Island and Schmidt Island. The largest ice caps of the Canadian Arctic Archipelago are on Baffin Land, Ellesmere Island, Devon Island, Axel-Heiberg, Melville Island, and Meighen Island. In the vicinity of Ellesmere Island is located a small shelf glacier named Word Hunt, that produces table icebergs.

The largest glacier in Iceland is Vatnajцkull, with a maximum thickness of about 1000 m. The thickness of most arctic glaciers (both Eurasian and Canadian) ranges from 300 to 500 m. Therefore, the total volume of water contained in arctic glaciers is near 70 000 km^3 (see Table 3).

Eurasian Arctic		**Canadian Arctic archipelago**	
Glaciers	**Area, km^2**	**Glaciers**	**Area, km^2**
Iceland	11,785	Baffin Land	36,830
Vatnajцkull	8,400	Terra Nivea Ice Cap	165
Langjцkull	1,025	Grinell Ice Cap	130
Western Svalbard	21,240	Hall Ice Cap	490
North–East Land	11,135	Penny Ice Cap	5,960
West Ice	2,623	Barnes Ice Cap	5,935
East and Southern Ice	7,985	Ellesmere Island	77,180
Franz Josef Land	13,735	Glaciers of United States Ridge	28,210
King George Land	2,241	GlaciersVictoria and Abert mountainsl	20,400
Vilchek Land	1,892	Glaciers of Prince of Wales mountains	17,300
Gram Bell Island	1,215	Axel Heiberg Island	12,560
Edgeшya Island	1,880	McGill (Akaioa) Ice Cap	7,250
Novaya Zemlya	24,322	Steacie Ice Cap	3,040
North Island	23,802	Bylot Island	4,895
South Island	520	Devon Island	16,575
Severnaya Zemlya	17,472	Koburg Island	230
Komsomoletz Island	5,903	North Kent Island	140
October Revolution Island	7,580	Meighen Island	76
Bolshevik Island	3,318	Melville Island	335
Total	**102,950**	**Total**	**149,990**

Table 3. The largest ice caps of Arctic islands. (Source: Dolgushin, 2000)

Due to the very cold and humid climate around the Antarctic Continent, glaciers form on the many islands. The closer to the Antarctic Continent, the thicker the glaciers become, and mountain glaciers become mountain ice sheets.

5. Mountain glaciers

Mountain glaciers in many dry areas of the Earth provide a considerable part of the water used for irrigation in those places. Snow line location is responsible for glacier formation in otherwise arid geography. Above the snow line the accumulation of solid precipitation is greater than the loss of mass to thawing, evaporation, or run off. The snow line level widely oscillates, depending on moisture and heat balance and local climatic conditions from sea level in the Antarctic Continent to 6000 – 6500 m above sea level on the Tibetan Plateau.

In Europe, modern glaciation is concentrated in Scandinavia, the Alps, Caucasus and Ural Mountains. There are small glaciers in the Khibiny and Perinea Mountains. According to Dolgushin (2000), there are 9529 glaciers in Europe, with a total area of 7395 km^2. On the Scandinavian Peninsula, mountain ice sheets are predominant while in the Caucasus and Alps there are complete and simple Alpine glaciers. In the Ural, Khibiny and Perinea Mountains, corrie and hanging glaciers are found. Westerly Moisture Transport causes changes in snow line elevation from west to east. Its height in the French Alps is 2500 m, while in the Central Caucasus it is 3700 – 3800 m.

In Asia, ice covers the high mountain areas of Tien Shan, the Pamirs, Karakorum and the Himalayas where many very large dendrite-type and complex mountain valley glaciers come down considerably lower than the snow line. The majority of the mountain areas in Asia are located far from sea coasts in continental climatic conditions with poor precipitation. For this reason, the snow line is located very high (for example in Tibet at 5000 – 6000 m). In the north of Asia, in spite of low temperatures and topography, glaciation is only moderate because of dryness and weak precipitation. The glaciers of Kamchatka, the Far East and South-East Asia aliment mainly from the Pacific. The glaciers in Karakorum and the Himalayas receive alimentation from the Indian Ocean, while in the case of the glaciers of western and central Asia the moisture comes from the Atlantic.

The largest centers of modern glaciation in North America are positioned in the North American Cordillera. As the relatively warm Pacific Ocean is very close to the western slopes of the Cordillera, they accumulate a great quantity of precipitation (more than 3000 mm per year). On the opposite slopes the precipitation is only 2000 mm per year. The snow line on the western and southwestern slopes is at 500 to 1000 m while on the eastern and northeastern slopes it is between 2500 and 3000 m. The sublatitudinal Alaska Ridge is also a large center of glaciation that aliments from the Pacific. Glaciation of the Rocky Mountains is not very great because no moisture source is near them.

In South America, modern glaciation occurs in the Andes, which extend for 7000 km along the Pacific coast. Throughout most of the Andes the snow line in located above 5000 m, and large centers of mountain valley glaciation occur in the Northern and Southern Patagonia Plateau. In the northern part of the range from 32^{o}S the glaciers receive moisture from the Atlantic and Amazon Lowland and less from the Pacific, while to the south it comes from the Pacific only. The snow line height ranges from 5000 m in the Atlantic province to 1000 – 2000 m in the Pacific one. Charles Darwin described a glacier in southern Chile that is located very close to subtropical forest.There are only three mounts which are higher than the snow line height (i.e. as high as 5000 m) in Africa. These are Mt. Kilimanjaro, Mt. Kenya and the Ruwenzoris. Their glaciers receive alimentation from the Indian Ocean.

In New Zealand, glaciation takes place only in the Southern Alps on South Island (between 43 and 44^{o}30'S). Moisture comes here from the warm Tasman Sea. The snow line is as low as 300–400 m above sea level and glaciers meet subtropical forest with *Podocarpus, Dacridium, Phyllocladus* and other species.

On the New Guinea Island glaciers and firn occur in the Carstence Mountains at a height of more than 5000 m. The most interesting feature of the glaciers here is the absence of seasonal temperature and moisture oscillations, while daily ones are noticeable. In the morning and bright sunshine the glaciers and firn thaw, but in the afternoon the convective clouds cover the mountains and snow falls. In the evening the temperature is below zero and snow is preserved until the morning.

6. Hydrology of glaciers

Flow records of glacier-fed rivers provide some information about the movement of water through ice. The discharge (volume of flow per unit of time) has a marked diurnal variation superimposed on a base flow volume that changes more slowly. The maximum discharge may be roughly twice the minimum. The peak daily discharge comes a few hours after the peak in melt but, as summer advances, the daily rise and fall in discharge becomes more rapid and the time lag decreases. Total daily discharge usually reaches its maximum in late July or early August. When melting is stopped by summer snowfalls, the diurnal variation in discharge ceases and the base flow declines. When melting begins again, the base flow takes several days to reach its former level. Water flows throughout the winter; there is no diurnal variation and the base flow appears to be comparable with the volume of water melted from the underside of the glacier by geothermal and frictional heat.

During the melt season, a temperate glacier acts like a reservoir that is drained continuously by the streams emerging at its terminus, that are supplied daily by melt water. The glacier contains a considerable amount of free water. While much of this water is in the snow and firn, the ice also contains appreciable quantities in crevasses, moulins, and cavities. Some of these are isolated, at least temporally, while others are connected by a system of channels. As long as channels and cavities contain enough water, ice flow cannot close them. They close during the winter and are gradually reopened by melt water at the beginning of the following summer. During this period, some water is stored because the channels are too small to carry off all the melt water. The channel system develops during the summer as increasing amounts of melt water enlarge old channels and open up new ones. Thus the time that water spends in the glacier, and the lag between maximum melt and maximum run-off are reduced. During this period also, cavities that were initially isolated become connected to this main drainage system, so that, for a time, run-off exceeds melting. Floods recorded in stream flow records probably resulted from the draining of a series of a previously filled cavities, e.g. when barriers between a series of water filled crevasses are breached successively. Water pressure is determined by the water supply and the resistance of the channels to flow. Diurnal variations in pressure, and the high pressures observed after rain or heavy melt, must be caused by changes in the amount of water because the channels do not have time to enlarge. High pressure results from the restricted size of the channels; ice flow starts to close them in winter, when surface melting stops.

Increases in velocity during summer, especially after periods of heavy melting, have been observed in ablation areas of glaciers in polar regions. Variations in sliding velocity appear to offer the only explanation. This in turn implies that the basal ice is at the melting point and that surface melt water can penetrate to the bed, even though the bulk of the ice is well below the melting point. In polar ice sheets, the basal ice may be at the melting point in some places and not in others. Melt water formed by geothermal and frictional heat is contained by surrounding cold ice to form sub-glacial lakes. Such lakes have been detected in Antarctica. When ice flows from a region where the basal ice is melting to a place where it is not, melt water will refreeze on the ice and in this way may be incorporated into the ice. The largest known Antarctic sub-glacial lake is located at, and extends 230 km north of, Vostok station, East Antarctica. This sub-glacial lake is approximately 50 km wide and several hundred meters deep. Large sub-glacial lakes manifest themselves as flat regions on the ice surface. The mean length of sub-glacial lakes that have expression on the ice-sheet surface is about 8.3 km, while those that do not exhibit a surface morphological manifestation have a mean length about 3.3 km.

7. Surges

A surge is a period of exceptionally rapid sliding during which a large volume of ice is transferred from a reservoir area to the terminal part of the glacier. Surges are confined to the lower parts of many glaciers. In others the whole glacier is affected. During quiescent periods, flow with exceptionally high values of velocity thickens the upper part of the area affected by the surge while the lower part stagnates and is thinned by ablation, and stagnant ice advances down the glacier. The surge starts when the glacier attains a critical profile. Rapid sliding is probably preceded by an accumulation of water at the bed. There is no evidence of a surge in any glacier known to be permanently frozen to its bed. Surges occur at more or less regular intervals in the same glacier. The interval is determined by the time needed to build up the critical profile. This depends on the area of the glacier and accumulation and ablation rates. Parts of at least some surging glaciers slide during quiescent periods. The velocities increase from year to year, at least in the area of rapid thickening. The velocity and the accumulation are much greater in summer than in winter. This suggests that the sliding velocity is predominantly controlled by the profile while surface melt water has an important secondary effect. An improved understanding of glacier sliding is a prerequisite to a full understanding of surges. The triggering mechanism and the reasons for the very high sliding velocities will remain obscure until we know how much water is present at the glacier bed, where it is stored, and how it drains. The best–studied surging glacier, and the only one to have been observed over a whole period between surges, is Medvezhiy Glacier in the Pamirs Mountains of Central Asia (Dolgushin, 2000). This glacier surged in 1963 and 1973, and each surge lasted about three months. Medvezhiy Glacier has an area of 25 km^2 and spans an elevation range from 2850 to 3500 m. Icefall separates the accumulation area from the tongue, which is confined in a narrow valley. Surging glaciers are found only in certain regions, but these cover a wide range of climates and geological features. A total of 204 surging glaciers have been identified in western North America, most of them near the Alaska – Yukon border. Most of the surging glaciers in the Alaska Range lie along parts of the Denali Fault and in the St. Elias Mountains. Most the glaciers in the valley of Steel Creek surge. About 40 surging glaciers have been identified in the Pamirs, 21 in Tian–Shan, 7 in the Caucasus, and one in the Kamchatka Peninsula. They have also been reported from the Karakoram, the Chilean Andes, Iceland, East Greenland, and Arctic Canada. Several glaciers and ice caps in Spitsbergen have surged, including one that advanced 21 km, the greatest movement so far recorded in a surge. Glaciers in the same area do not necessarily surge at the same time.

-
-
-

Bibliography

Black R.F. (1975) Periglacial Features Indicative of Permafrost Ice and Soil Wedges. *Quaternary Research*.**6** (1). 3-26. [Ice and soil wedges formation features are considered].

Cofaigh C., Dowdeswell J.A., & Pudsey, C.J. (2001) Late Quaternary Iceberg Rafting along the Antarctic Peninsula Continental Rise and in the Weddell and Scotia Seas. *Quaternary Research*. 56. 308 – 321. [Sediment cores from the continental rise west of the Antarctic Peninsula and the northern Weddell and Scotia Seas were investigated for their ice-rafted debris content by lithofacies logging and counting of particles less than 0.2 cm from core x-radiographs. The objective of the study was to determine if there are iceberg-rafted units similar to the Heinrich layers of the North Atlantic that might record periodic, widespread catastrophic collapse of basins within the Antarctic Ice Sheet during the Quaternary]

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. [Instability of stable isotope record of Greenland ice cores is discussed].

Dolgushin L.D. (2000). Present land glaciation. Data of glaciological studies. Publ.**88**. 157-208. [In Russian]. [This reference book contains short characteristic of present glaciation of the world and main information about large glaciers].

Dolgushin L.D., Osipova G.B. (1989). *The Glaciers.* Moscow. Mysl'. 448 p. [In Russian]. [Extensive data concerning glaciers are presented].

Dowdeswell J.A. (1989). On the nature of Svalbard icebergs. *Journal of Glaciology*. **35** (120). 224–234. [Variability of icebergs and their formation mechanism are discussed].

French H.M. (1996). *The periglacial environment. Second edition.* Longman Publishers. Essex: 341 p. [This book give a realistic appraisal of nature of geomorphic processes and landforms in high latitude periglacial environments].

French H.M., Harry D.G. (1990). Observations on Buried Glacier Ice and Massive Segregated Ice, Western Arctic Coast, Canada. *Permafrost and Periglacial Processes.* **1** (1). 31–43. [Results of isotope composition study are discussed in detail].

Haeberli W., Guodong C., Gorbunov A.P., Harris S.A. (1993). Mountain permafrost and climatic changes. Permafrost and Periglacial Processes. **4** (2). 165-174. [Review paper devoted to climatic responsibility of mountain permafrost changes].

Lisitzin A.P. (1994). *Glacial sedimentation in the World ocean*. Moscow. Nauka. 448 p. (In Russian). [Atarctic iceberg sediments are observed in detail].

Mackay J.R. (1990) Some observations of epigenetic, syngenetic and anti-syngenetic ice wedges. *Permafrost and Periglacial Processes.* **1** (1). 15–29. [Formation of ice wedges in various environments is considered]

Marshall S.J. and Cuffey K.M. (2000). Peregrinations of the Greenland Ice Sheet divide in the last glacial cycle: implications for central Greenland ice cores. *Earth and Planetary Science Letters.* **179** (1). 73–90. [The reduction of strain rates due to summit position, which shifted abruptly during deglaciation is discussed for Greenland ice cores].

Shumskij P.A., Krenke A.N. (1969). Modern Glaciation of the Earth and its changes. *Geophys. Bull.*, **14**. 128-158 [in Russian] [This work provides a review of various glaciation forms]

Tison J.L., Morris E.M. Souchez R. and Jouzel J. (1991). Stratigraphy, stable isotopes and salinity in multi-year sea ice from the rift area, south GeorgeVI ice shelf, Antarctica p.357-367, Vol.37, No 127, Journal of Glaciology.

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). [Evolution of Eurasia permafrost in terms of stable isotope composition of ground ice is considered for Late Pleistocene and Holocene].

Vasil'chuk Yu.K. and Vasil'chuk A.C. (1996). Late Pleistocene oxygen-isotope curves and radiocarbon dating for syngenetic ice–wedges. In *11 International Workshop on isotope-geochemical research in the Baltic Region. Proceedings*. J.van der Plicht, J.–M. Punning, Eds., Groningen Isotope Centre Publ. 1996. P.77–96. [New cyclical model of large syngenetic ice wedge formation is presented. The fluvial origin of the sediments determines the presence of allochthonous organic material and of inversions or disturbances in radiocarbon age series].

Vasil'chuk Yu.K. and Vasil'chuk A.C. (1998). Oxygen–isotope and ^{14}C data associated with Late Pleistocene syngenetic ice-wedges, mountains of Magadan Region, Siberia. *Permafrost and Periglacial Processes.* **9** (2). 177–183. [Large Late Pleistocene syngenetic ice wedges widespread in the intermountain depressions in the valley of the Upper Kolyma River at Phoenix and Utinoe quarries. Their main feature is rock debris occurrence in peaty loam sediments of ice-wedge complex, and also the obtaining of the first radiocarbon dating. By oxygen isotope data it has been evaluated that the mean January temperatures of ice-wedge formation during period 30–15 thousand years ago were lower than modern ones by 7-9 ^{o}C].

Biographical Sketches

Yurij K. Vasilchuk, Academician of the Russian Academy of Natural Sciences, is a Professor of geology and geocryology at Lomonosov' Moscow State University. His monograph, "Oxygen Isotope Composition of Ground Ice" (1992, Moscow Press) is an encyclopedic synthesis explaining the evolution of permafrost areas in the Late Pleistocene and Holocene in Northern Eurasia with respect to permafrost response to Global Changes. This book also explains the features of isotope composition of ground ice caused by its origin. His more recent book, "Principles of Isotope Geocryology and Glaciology" (2000, Lomonosov'Moscow University Press), was co-authored with V.M. Kotlyakov. This textbook describes the main principles and applications of stable and radioactive isotopes in the study of glaciers and ground ice. It describes the relationship of isotope fractination and isotope composition with temperature of precipitation for glaciers and ground ice. It considers the records of ice cores from Greenland and Antarctic ice sheets, ice caps of Arctic Islands, mountain glaciers and ice wedges from Northern Eurasia permafrost area. Modern research methods using radioactive isotope applications for ground ice and glacier ice are discussed.

Alla C.Vasilchuk is a research associate at Lomonosov' Moscow State University. She is currently working on a project examining ^{14}C dating of pollen concentrate from ice-wedge ice. She completed her PhD in physiogeography and paleogeography at the Lomonosov' Moscow State University. Pollen extracts from Late Pleistocene ice-wedge ice was dated (together with Yu.K. Vasil'chuk) in 2002 from Seyaha (Yamal Peninsula) and a Bison River (Kolyma) cross-section. It has been shown, that due to the longevity of ancient pollen and spores, the ^{14}C age of pollen concentrate often is older than the organic micro-inclusions.