MEETING REPORT

FRANCE-RUSSIA-UNITED STATES COLLABORATIVE PROGRAM ON THE LAKE VOSTOK ICE CORE: SAMPLES 3612 TO 3623 OF THE ACCRETION ICE

U.S. National Science Foundation
Arlington, VA
17-18 April 2002

Executive Summary

Drilling of ice core samples from Vostok Station has been a joint effort of the French, Russian and United States national Antarctic programs. By prior agreement, the ice core samples have been allocated with one third to each country (including archived core segments stored at the Vostok site). The directors of each national program are responsible for overseeing the subsequent distribution of ice to scientists and for determining the course of future scientific endeavors related to study of the ice.

Recently a meeting was held with scientists and Antarctic agency representatives from France, Russia and the United States to discuss the dispensation of recently retrograded samples of Lake Vostok accretion ice. These samples of accretion ice (belonging to all three countries) are currently stored at Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE) in Grenoble, France. During the two-day meeting, the scientific importance of these ice core samples was discussed and potential areas for research were outlined. A specific plan was developed for the allocation of samples among the three countries and for establishing a mechanism for formal international collaboration between French, Russian and US scientists. To facilitate comparison of biological results, an experiment was designed to allow for controlled evaluation of two different decontamination methods from French-Russian and US laboratories.

Significance of the Ice Core Samples

The French-Russian-US collaboration in the collection and study of the Vostok ice core has made a significant contribution to documenting Earth’s climate history. The glacial ice samples provide a long-term archive for the chemistry of past atmospheres and analyses of these core segments have allowed for the reconstruction of temperature variations over the past 420,000 years. This information has provided valuable insights for understanding the forcing functions for environmental variability on this planet and has implications for studying environments on other planets. The confirmation in 1996 of the existence of a lake under the drilling site has enhanced the importance of this collaborative project and has stimulated much scientific discussion and speculation about the origin, nature and fate of subglacial lakes and associated ecosystems.

Background on Accretion Ice

When drilling at the Vostok site was completed in 1998, the borehole had reached a depth of 3623 m, with an estimated 130 m of ice remaining to the lake surface. The top 3538 m of the core is glacial ice. The lower 84 m (3539-3623 m) is referred to as accretion ice and has distinct physical and chemical characteristics relative to the ice from shallower (glacier) portions of the core. For example, the accretion ice has disrupted layers, larger ice crystals and lower gas content. Accretion ice is believed to have formed from alternating periods of melting and thawing that involved the base of the ice sheet moving against the surface water of the lake. The pattern of ice formation and development, as well as the age of the accretion ice is unknown; although it is speculated that the bottom of the accretion ice is probably younger than the top layers.

Within the accretion ice that has been cored, there are further distinctions between the ice above and below 3609 m. The uppermost layer of accretion ice has mineral inclusions, water pockets, smaller crystals and higher gas content than the very clear ice below 3609 m. To distinguish between the two, the top layer is referred to as accretion ice I and the bottom layer as accretion ice II.

Subsamples of glacial and accretion ice from the core had been removed from the Lake Vostok site by 1998. This included samples representing all of the accretion ice I and the upper 2 m of accretion ice II. The remaining core portions of both ice types were archived on site along with the entire bottom 11.74 m of the accretion ice II that was cored in 1998. In December 2001, these last 11.74 m of accretion ice II core sections were sub-sampled in the field. A small slice (~1 cm) was removed from along the entire vertical axis, consistent with previous sampling of the core (Figure 1). This sample will be used for analyses of stable isotopes, ECM and crystal structure. The remaining core segments were cut longitudinally in half. Half of the core was left at Vostok Station in a snow cave as an archive and the other half was transported from Antarctica to the LGGE in Grenoble, France with the understanding that the distribution of this ice would be decided by a joint meeting of science and agency representatives from the three nations.

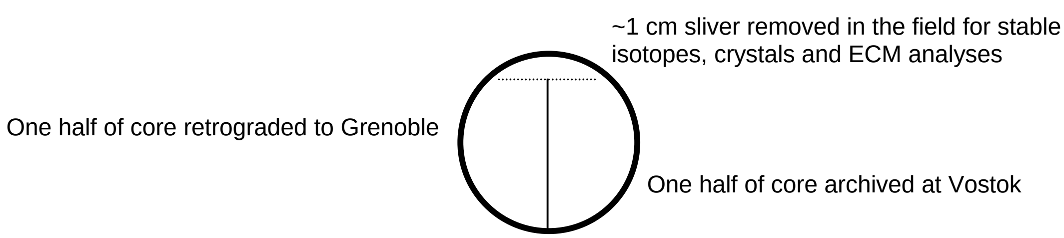

Figure 1. Cutting pattern of ice core for subsampling (original diameter was 10 cm).

Joint Meeting

The joint meeting was held 17-18 April 2002 at the US National Science Foundation with eleven people in attendance (see Appendix 1). Brief presentations were made by each country to provide an overview of the current status of research relative to the newly retrieved accretion ice core samples. It was recognized that this ice is unique and represents one of the few collections of samples from ice overlaying a subglacial lake. These samples may contain further information about paleoclimates, but more importantly, they should provide important data for evaluating and understanding the physical, chemical and biological characteristics of Lake Vostok and other subglacial lakes.

Ensuing discussions focused on two issues. First, based on results of previous meetings and workshops, the group identified the essential analyses required to address the key scientific questions about the physical and biological aspects of the accretion ice layers and the lake ecosystem. Second, a specific plan was devised for the distribution of the ice samples and the development of a research initiative that would foster international research collaboration among Russian, American and French scientists.

Recommended Areas of Focus for Scientific Research

There are three main areas of research that were targeted as the focus for future studies on the accretion ice II samples. These areas relate to the physical, geochemical and the biological properties of the ice. The outline below summarizes the types of measurements suggested.

1. *Physical properties*

   The accretion ice has formed at the dynamic interface of the bottom of the ice sheet and the lake surface. While remote sensing has provided clues about ice flow trajectories over the lake, essentially nothing is known about the rate of ice formation or the physics of accretion ice development and aging. The following measurements and documentation are recommended to determine the age of the accretion ice and to study how it was formed and how it is developing over time.

   a. Digital photography of core segments prior to further cutting to document bulk physical properties (e.g., presence/absence of large fractures, triple junctions, etc.)
   b. X-ray analyses to provide data for lattice structure and development of ice
   c. Analyses of ice fabric (e.g., crystal number, size and orientation)
   d. Determination of total gas content (volumetric measurement of gas in bubbles trapped in solid ice samples)

   Note: Activities described above do not require decontamination of the core segments.

2. *Geochemistry (Chemical content of ice)*

   Quantification of the following chemical characteristics was considered to be crucial for understanding both the chemistry and the biology of the ice. (Parameters with asterisks must be measured after sample has been decontaminated, see further discussion about decontamination below under the Biology section.)

a. Concentration of specific gases present in solid ice (e.g., CH_4, CO_2, N_2O, etc.)
b. Stable isotope composition
   i. Gases from solid ice (e.g., $\delta^{15}N$, $\delta^{18}O_2$, $\delta^{13}C$) (These analyses routinely performed on longitudinal sample sliver collected in the field, see Figure 1.)
   ii. Isotopes in meltwater (e.g., $\delta^{18}O$, δD)
c. ^3He content for information about extraterrestrial inputs and mantle sources
d. Concentration and distribution of polycyclic aromatic hydrocarbons (PAHs) to determine extent of drilling fluid (kerosene) contamination
e. *Concentration and composition of particle inclusions
f. *Concentration of trace elements (includes heavy metals)
g. *Major ion chemistry
h. *Dissolved and total organic (and possibly inorganic) carbon concentrations (DOC, DIC, TOC) for characterization of ice chemistry and to monitor decontamination efficiency

3. *Biology (Presence of nucleic acids, viruses and cells)*

There are many biological questions about the accretion ice: What organisms are present? At what densities? Are they living or dead? Are they metabolizing? Are there differences between microhabitats of triple junctions and monocrystals? Are the organisms present indigenous to the ice or to the lake, or have they been carried to this location by wind? Are they similar or identical to present day (extant) populations? Or have they been locked in the ice and isolated for so long that they are relics of taxa now extinct at the Earth's surface?

It was unanimously agreed that biological results need to be interpreted relative to the geochemical data and that biological methods should not be applied until ice samples have been decontaminated to remove drilling fluids, cells, viruses, nucleic acids and other molecules that could have been introduced during the drilling and subsequent handling of cores. There have been very few biological investigations on accretion ice and the disparity between existing results has raised questions about decontamination methods. Since decontamination procedures are not standardized and have not been satisfactorily evaluated by all parties, a comparison study was proposed at this meeting. Details for the implementation of the comparative work are presented under the Agreement section found later in this report.

The list below includes the recommended observations for biological data.

a. *Cell and viral concentrations
b. *Viability vs. non-viability (e.g., live/dead staining with microscopy)
c. *Cultivability (cultures can be later used for physiological studies)
d. *Nucleic acids: concentrations and nucleotide sequences
e. *Presence and concentrations of proteins and other metabolites
f. *Biodiversity (microscopy and molecular methods)
g. *Assessment for epidemiology (pathogenic/non-pathogenic)

Agreement

After further discussion, the three parties agreed on a strategy for the allocation and distribution of the accretion ice II core samples and recommended a plan for fostering future French-Russian-US collaborations.

1. *Allocation and Distribution of Accretion Ice II Samples*

   It was agreed that the accretion ice core II sample will be allocated with one third to each country as indicated in Appendix 2. In preparation for transport from Vostok Station, the core was cut into 1 m-long subsamples and then halved longitudinally. Five of these 1 m-segments are fragmented into two pieces (samples 3614, 3615, 3619, 3620 and 3622; see Appendix 2). Two of the 1 m-segments were broken into three pieces, with the mid-piece being a very small fragment (3-4 cm long). These mid-pieces were taken for X-ray analyses. The whole 1 m core pieces will be cut into thirds and distributed with the fragments described above to make the allocation to each country as close to one third as possible.

   Each country's allocation will remain in storage in Grenoble until the ice is needed for research. Scientists can either request that ice be sent to them or they can travel to Grenoble to personally transport ice back to their respective laboratories. Each country will determine which of their scientists receive their allocated ice samples.

2. *Preliminary Analyses (prior to distribution of allocations)*

   The French curators will perform visual characterization and digital photography of each ice sample before the ice is further cut and distributed to various labs. These processes will document the gross structure of the core samples and provide data on ice crystals.

3. *International Collaborative Studies*

   It was decided to set aside two meters of the ice core (segments from 3613 and 3621) for international collaborative studies. These two meters are intact approximately 1 m-segments from the upper and lower portions of the accretion ice II core. Drs. Jugie, Lukin and Erb, the directors of the three national Antarctic programs, will formulate a plan for research proposal submission and selection of proposals for awards. It is expected that this plan will be finalized by October 2002, awards announced late in 2003, and collaborative work could begin by the end of 2003 or early 2004.

4. *Caveat for Biological Studies*

   For proper evaluation of biological data and to verify the decontamination process, ancillary data on the geochemistry of the ice from the same horizon is required. Biologists should plan for such chemical measurements in their research design. Moreover, since there has been such a high level of variation between the molecular results of different laboratories, it is recommended that core segments slated for biological analyses be further cut longitudinally, resulting in two one-quarter sections of the original core segment. One of these subsamples will be used for the planned biological investigations and the replicate one-quarter segment should be archived for future sharing and exchange for independent verification of results, if necessary.

5. *Intercomparison Experiment for Decontamination Procedures*

While analytical methods for characterizing the geochemistry of the ice are fairly well standardized and data from different sources are readily accepted, decontamination is a controversial issue for comparing biological results from the ice. Presently, a variety of decontamination methods are used prior to biological testing of the ice. Because of the wide variation in results on how much and what kind of life is present in the ice from the Lake Vostok site, it was agreed that an international intercomparison of decontamination methods is warranted. A plan for such a study was devised. Biologist Dr. Sergey Bulat will visually inspect and select a small piece (e.g., 15 cm length) of the Russian allocation of the accretion ice II. The ice core segment selected will be cut vertically to produce two one-quarter sections of the original core. One replicate piece will be sent to a biological laboratory in the US (selection of the US lab will be made by NSF/OPP) and Dr. Bulat will analyze the second replicate. Each laboratory (designated A and B in Figure 2) will decontaminate the quarter section of the core using their preferred method. After decontamination, a small aliquot from each lab will be forward to an independent laboratory (US or France) for measurement of DOC and ion concentrations. If there are no significant differences in the chemical composition of the decontaminated samples, then the remainder of the sample in each biology laboratory will be split so that one half can be analyzed by each group for comparison of the presence of nucleic acids and organisms (Figure 2).

It was also suggested that preliminary complementary studies could be done with artificially seeded laboratory-made ice cores. In this case, ice cylinders are formed in the freezer with a dilute suspension of one species of microbe and then a second species is spread over the ice surface to mimic a contaminant. Both taxa can be easily tracked during the decontamination procedure to determine efficiency of contaminant removal.

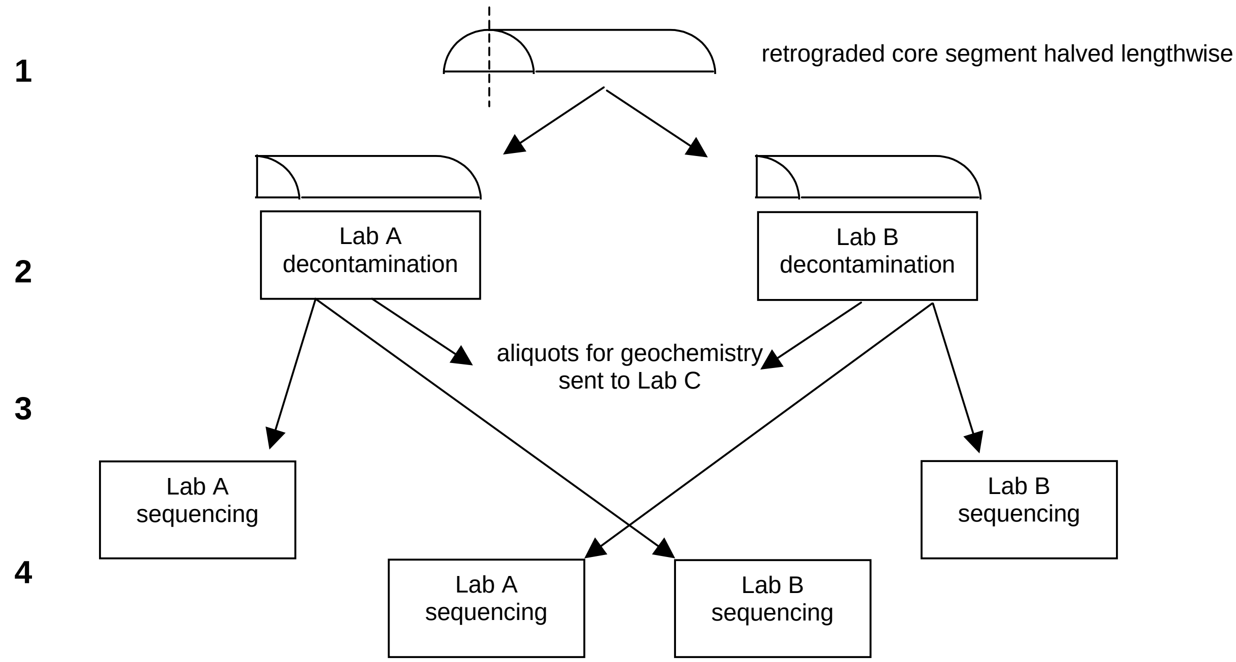

Figure 2. Scheme for design of experiment to compare decontamination methods.

Step 1: Retrograded sample cut in half to produce longitudinal one-quarter core segment.
Step 2: Labs A and B undertake independent decontamination procedures.
Step 3: Lab C performs chemical analyses on both decontaminated samples.
Step 4: Labs A and B sequence aliquots from both decontaminated samples.

Note: Step 4 sequencing activities contingent on results of Step 3 geochemistry.

6. *Exchange of Information*

In order to facilitate research on the accretion ice II samples, it is planned to share information on what analyses are being done on the core segments. As core samples are released from storage in Grenoble, the French curator, Dr. Jean-Robert Petit, will inform the US and Russian Antarctic programs of where the ice is going and what type of investigations are planned. It is hoped that this exchange of information will serve to promote further international collaborations and will avoid duplication of effort in studying these precious samples. A workshop will be organized for late in 2003 to discuss progress on the study of the accretion ice II samples and to coordinate investigations on the two meters of core that are being set aside specifically for international collaboration (see #1 above).

It is expected that the availability of the accretion ice II samples and the new information that will be derived from them will stimulate wider involvement of the science community and provide the public with a better understanding and appreciation of the importance of this scientific research.

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Appendix 2. Core description and agreed core allocation. Shaded segments for cores 3613 and 3621 represent allocations that will not be cut until international collaborative projects have been identified (see text for further explanation).

Date cut	Core #	Total length (cm)	Top depth (m)	Bottom depth (m)	Top piece (cm)		Bottom piece (cm)	# of crystals	Allocation (cm)		
									USA	Russia	France
12/12/01	3612	102	3611.00	3612.02	34	(3**)	66	6	34	33	33
12/12/01	3613	97	3612.02	3612.99	97			7	(32)	(32)	(32)
12/12/01	3614	100	3612.99	3613.99	16*		84*	11	16	42	42
12/12/01	3615	101	3613.99	3615.00	59*		42	10	59	21	21
12/12/01	3616	103	3615.00	3616.03	103.5			10 - 13	34	34	34
12/12/01	3617	97	3616.03	3617.00	97			10 - 12	32	32	32
12/12/01	3618	100	3617.00	3618.00	18	(4**)	80	15	18	40	40
12/13/01	3619	100	3618.00	3619.00	76		23	12 - 16	38	38	23
12/13/01	3620	104	3619.00	3620.04	77		27*	16	38	39	27
12/13/01	3621	96	3620.04	3621.00	96			6 - 7	(32)	(32)	(32)
12/13/01	3622	100	3621.00	3622.00	58		42	6	58	21	21
12/13/01	3623	81	3622.00	3622.81	81			6 - 7	24	27	27
								Totals	415	391	364

* marked by the three core dogs (1 cm deep, 1 cm wide) along the core
** conic broken ice taken for X-rays