

## **Concerning the plan of Russian Antarctic Expedition to drill a further 50 meters through lake ice at Vostok Station**

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### **Background information**

In 1989 – 1998, deep ice coring at the Russian Vostok Station was carried out as a joint Russia-USA-France project. Recognizing the SCAR recommendation that the lake underlying Vostok should not be contaminated by the drilling operations, the three parties initially planned to terminate drilling at 3650–3700 m below the ice-sheet surface, that is 100–50 m above the ceiling of subglacial Lake Vostok. The depth at which the drilling of hole 5G-1 actually stopped at the end of the last joint Vostok season (1997/98) was 3623 m. The drilling operations was not resumed during the next Antarctic season and the completion of the three-party project at Vostok Station was declared.

Following the guiding principles of the Lake Vostok Workshop (LVW) recommendations (Cambridge, 1995, 1999; St. Petersburg, 1998) calling to develop entry and sample retrieval protocols that would not alter the nature of subglacial lakes, the Ministry of Industry, Science and Technology of the Russian Federation set up and funded in 1999 – 2001 a project entitled “Justification and development of the ecologically clean technology for entry the subglacial Lake Vostok” The work under the project (to be finalized by the end of 2001) has been performed by the Arctic and Antarctic Research Institute (AARI) and the St. Petersburg Mining Institute (SPMI) in Russia. The procedure developed for Lake Vostok entry and sampling was approved in the course of the State Ecological Expert Examination in March, 2001. The “Expert Conclusion” attracted a great deal of attention of the international scientific community and the general public after it had been diffused among the participants of the XXIV Antarctic Treaty Consultative Meeting (St. Petersburg, 2001).

The next inevitable stage in advancing of suggested sampling technology (see the Expert Conclusion for details) should be its testing at sites other than Lake Vostok, where full environmental monitoring of the operations would be possible. The ice shelf near Novolazarevskaya Station is viewed as one of possible proving grounds for the field tests. However, it is not clear at present whether this work could be continued in the near future.

The funding assigned to the project ends in 2001 and does not assume any field experiments to be done.

Independently on the above mentioned work, AARI and Russian Antarctic Expedition (RAE) together with five other research institutions in Russia have been involved in the long-term (1999-2008) Federal Research Program "Investigation of subglacial Lake Vostok". The Program is aimed at exploring the lake using non-penetrating techniques such as remote (radio-echo and seismic) survey of ice, sub-ice water and lake sediments as well as accreted ice sampling and studying. Indeed, the first results obtained from the deepest section of the Vostok core have demonstrated the potentiality to obtain valuable information on lake water chemistry and microbiology through accreted ice study without entering the lake itself.

In the frame of this Program and in full agreement with international plans and recommendations developed for Lake Vostok exploration at the four preceding LVWs (Cambridge, 1995, 1999; St. Petersburg, 1998; Washington D.C., 1998), RAE intends to resume drilling in hole 5G-1 at Vostok during 2002/03 Antarctic field season and to continue coring of accreted ice with existing technology from 3623 m down to approximately 3670 m depth.

### **Why drill deeper at Vostok?**

Isotope studies, ECM and gas content measurements have shown that, below a depth of 3538-3539 m, the Vostok core consists of ice refrozen from Lake Vostok water (Jouzel and others, 1999). This discovery opens the way for investigations, through lake ice studies, of a microbial population of Lake Vostok isolated from the rest of the biosphere for more than million years (Priscu and others, 1999; Karl and others, 1999; Abyzov and others, 2001; Bulat and others, in preparation). Chemical and gas composition of sub-ice water needed for evaluation of biological observations can also be inferred from lake ice analyses.

There is evidence supporting the existence of two distinct layers in the accreted ice stratum. The upper 70-m layer (3538-3609 m) containing visible mineral inclusions is thought to have been accreted over turbulent lake water (Wuest & Carmack, 2000). The isotope and gas content data (Souchez and others, 2000; Lipenkov & Istomin, 2001) suggest that formation of this upper section of the lake ice was accompanied by trapping and subsequent freezing of liquid-water inclusions (so-called "water pockets"). On the other hand, extremely low and uniform gas content of ice and the absence of mineral inclusions in the lower section of the accreted ice stratum (from 3609 to 3623 m and

likely down to the ice-ice water interface) rule out significant involvement of liquid-water pocket formation in the freezing process. This deepest ~140-m section of the Vostok ice has likely been accreted at the maximum water depth where the geothermal convection of the lake water can not reach the ice ceiling, thus making the ice accretion a purely molecular process (Wuest & Carmack, 2000). Consistent with this, both the gas content and the concentrations of major ions are found to be few orders of magnitude higher in the upper layer of the accreted ice than in the lower one.

Isotopic, chemical and gas composition of Lake Vostok's waters can be inferred from the composition of the accreted ice, provided the volume fraction of liquid water inclusions trapped by growing ice and the partition coefficient between lake water and ice are properly determined. Because the liquid water trapping did not occur during formation of the lower layer of lake ice, the latter may be even easier interpreted in terms of lake water composition than already studied upper section of accreted ice.

In summary, further drilling of the "clean" lake ice below 3623-m depth could provide new insights into the composition of Lake Vostok's waters and allow continuation of the exciting microbiological studies ongoing now at a number of laboratories in Russia, United States and France. As the age of lake ice becomes younger when depth increases, decipherment of recent evolution of Lake Vostok's water could also be anticipated.

### **Why do we believe that coring of further 50 m of accreted ice will not disturb integrity of subglacial lake?**

The vertical seismic profiling experiments (Masolov and others, 2001) and the borehole temperature measurements (Salamatin, 2000; Barkov and others, 2001) repeatedly performed in the existing hole 5G-1 down to its bottom at 3623 m suggest that the thickness of remaining ice separating the hole from sub-ice water is 130–140 m (corresponds to a total thickness of the ice sheet of 3750–3760 m<sup>\*</sup>). From ground-based radar sounding (Popov and others, 2000) the ice-sheet thickness in the vicinity of the hole is 3775±15 m (corresponds to 140-170 meters of remaining ice). Thus, in the worst case, further drilling of 50 m of accreted ice will reduce the remaining ice thickness to 80 m, which still exceeds (by factor of 3) the minimum allowed thickness (25 m) established at the LVW held in Cambridge in 1995.

The lower layer of the accreted ice is characterized by exceptionally large ice crystals (from 10 to 100 cm and larger). The high crystalline quality, as revealed by recent X-ray

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\* Because the borehole is slightly curved, the total length of 5G-1 (3623 m) is 3 meters longer than its vertical depth (3620 m).

diffraction measurements of these crystals (Montagnat and others, 2001), indicates that lake ice is not plastically deforming under in-situ conditions. This result supports earlier assumption that accreted ice in the vicinity of Vostok Station is blocked by the lake edge (Lipenkov and Barkov, 1998). In addition, low lattice distortion (low dislocation density) of these crystals rules out significant diffusion of the drilling fluid through ice lattice.

Given the lake ice results from the slow freezing of the mixture frazil ice plus trapped water pockets (Souchez and others, 2000), one can expect polycrystalline ice with crystal size not exceeding some millimeters immediately after freezing. Crystal growth should therefore occur after initial freezing and during the long annealing time while lake ice remains at a temperature close to the melting point. It is considered that the *abnormal* grain growth is probably at the origin of the structure of lake ice with exceptionally large and high crystalline quality grains typically characterized by well ordered grain boundaries (Mantagnat and others, 2001).

Both well ordered (low energy) grain boundaries and very large crystal size (extremely low vein density factor) make the permeability of accreted ice to drilling fluid very unlikely. We should therefore not fear for the long-term contamination of sub-ice water due to drilling fluid intrusion from the borehole bottom, at more than 80 m above the lake surface.

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