Scientific Committee on Antarctic Research

Subglacial Antarctic Lake Exploration Group of Specialists (SALEGOS)
Meeting Report – 6

Bremen, Germany
July 20, 2004

The sixth, and final, meeting of the Subglacial Antarctic Lake Exploration Group of Specialist (SALEGOS) was convened buy J Priscu on July 20, 2004 in conjunction with the SCAR Open Science Conference and SSG Business Meeting in Bremen, Germany. The members that were present included: J Priscu (Convener, US), M Kennicutt II (Secretary, US), R Bell, (US) S Bulat (RUS), C Ellis-Evans (UK), J Petit (FR), R Powell (US), M Siegert (UK), and I Tabacco (IT). V Lukin (RUS) sent his regrets.

1.0 The Reports of National Programs

Each SALEGOS member was asked to report on activities related to subglacial environment exploration and research within their respective countries.

1.1 France

While the ERS1 data have been used to study the interaction of the lake on ice flow, the study of the subglacial environment has concentrated on laboratory analysis of the lake Vostok ice core samples. The accretion ice samples are still considered as the best template to decipher water chemistry, biological content and geological properties of the Lake Vostok environment. The Lake Vostok water body represents an extreme environment, and a probable limit for life on Earth. The search for life in the accretion ice sample is of importance, and due to the very low biomass in the accretion ice, the risk of the forward contamination of the sample by drilling operations and laboratory handling requires very careful evaluation and controls. To this end, the ice geochemistry put independent constrains to the lake environment which have been used to validate the likelihood of the biological findings. The studies have been conducted in a collaborative effort joining scientists from different laboratories from France, Russia, Germany and Belgium.

France national plan for sub glacial environment exploration and research

Ice core samples
In the coming years, further study of Vostok accretion ice is planned. New samples from the deep lake (accretion ice 2) are now available and will be analyzed. After application of an improved decontamination technique which will be controlled at each run, the samples will be studied by an international

consortium (France-Russia-USA) allowing replication of analysis and observations (among them: confocal microscopic observations, cultures, flow cytometry, molecular biology, geochemistry, ions and dissolved organic carbon analysis). Analysis of glacier ice from shallow depths from different sites in Antarctica (Vostok, Epica) will be conduced for comparison with deep Vostok ice. Studies of the biological content from Alpine and from Andean ice cores are also planned.

Access hole technology development

This plan for subglacial lake exploration is under discussion (August 2004). The following represents a preliminary draft:

The objective will be to develop the technology for an access hole to be used for ice geophysics (temperature, inclinometry measurements) as well as for bedrock sampling. The technique based on the fast mechanical access drill proposed by Clow and Koci (2002) [Clow, G.D., and B. Koci, A fast mechanical-access drill for polar glaciology, paleoclimatology, geology, tectonics and biology, Mem. Natl. Inst. Polar res., Spec. Issue (56), 5-37, 2002] now used widely in the petroleum industry will be adapted to the ice. The system will be developed and upgraded incrementally to take into account all environmental aspects allowing clean lake entry and sediment collection.

The permanent station at Dome Concordia, supported by France and Italy, represents an opportunity for the support of rather heavy operation associated to subglacial lake exploration. Several lakes have been detected in vicinity of the station, and the largest one, Lake Concordia, may serve as a possible analogue for Lake Vostok. The project will also benefit of the synergy from the IPY and the planned international project (e.g. Italy, Russia, USA) to explore the east Antarctic plateau by traverse or for RES study of the subglacial environment.

The project would address the following milestones:

- Conducting tests for shallow (400 m) to medium depth (2000 m) holes in the vicinity of Dumont Durville and Concordia Station.

- If successful drill holes in other locations for geophysics (e.g. Northern area of Lake Vostok) and geological sampling e.g., Adelie Land, Dome A).

- Upgrade the access hole technology to reduce the environmental impact associated with the non-freezable drilling fluid.

- Upgrade to a cleaner technology allowing lake entry with minor impact, permanent access for in situ instrumentation, water sampling.

- Upgrade technology to include lake sediment sampling.

- Conduct a pilot study in Concordia Dome C vicinity and plan a test in a small closed lake.

- Assuming an acceptable CEE, plan for sampling Concordia Lake.

Publications arising from French involvement in subglacial lake research:

2004

Bulat , S., Alekhina, I.A, Blot, M., Petit , J.R. de Angelis , M., Wagenbach, D, Lipenkov , V.Y. Vasilyeva, L. Wloch, D., Raynaud D. Lukin , V.V. : DNA signature of thermophilic bacteria from the aged accretion ice of Lake Vostok : implications for searching life in extreme icy environments, J. of Astrobiology, in press

De Angelis M., Petit J.-R., Savarino J., Souchez R., and Thiemens M.H, Contribution of an ancient evaporitic-type reservoir to lake Vostok chemistry, Earth Planet. Science Lett, 222, 751-765., 2004

Petit J.R., Alekhina I, and Bulat S.A.: Lake Vostok, Antarctica: exploring a subglacial environment and searching life in an extreme environment: in Lessons for Exobiology, M. Gargaud Ed. Springer, in press 2004.

Salamatin, A.N, E. A. Tsiganova, Lipenkov V.Y and Petit J.R.: Vostok (Antarctica) ice-core time scale from datings of different origins. Annals of Glaciology, 39, in press.

2003

Petit, J.R., M. Blot, and S. Bulat Lac Vostok : A la découverte d'un environnement sous glaciaire et de son contenu biologique, in Environnement de la Terre primitive, edited by M. Gargaud , J.P. Parisot, ed, pp. 273-316, Presses Universitaires de Bordeaux, Bordeaux, 2003.

Priscu, J.C., R. E. Bell, S.A. Bulat, C. Ellis-Evans, V.V. Lukin, J-R. Petit, R.D. Powell, M. J. Siegert, I. Tabacco. 2003. An International Plan for Antarctic Subglacial Lake Exploration. Polar Geography, 27 (1): 48-62.

Souchez , R., J.R. Petit , J. Jouzel , M. DeAngelis, and J. Tison, Re-assessing lake Vostok's behaviour from existing and new ice core data, Earth and Planetary Science Letters, 217, 163-170,2003

2002

Souchez, R., P. Jean Baptiste, J.R. Petit , V.Y. Lipenkov , and J. Jouzel What is the deepest part of the Vostok ice core is telling us?, Earth-Science Reviews, 60, 131-146, 2002.

2001

Montagnat, M., P. Duval, P. Bastie, B.Hamelin, O. Brissaud, M. de Angelis., J.R. Petit, and V.Y. Lipenkov., High crystalline quality of large single crystals of subglacial ice above Lake Vostok (Antarctica) revealed by hard X-ray

diffraction, C.R. Acad. Sci., Earth and Planetary Sciences, 333, 419-425, 2001.

Siegert, M.J., J.C. Ellis-Evans, M. Tranter, C. Mayer, J.R Petit, A. Salamatin, and J.C. Priscu, Physical, chemical and biological processes in Lake Vostok and other Antarctic subglacial lakes, Nature, 414, 603-609, 2001.

Jean-Baptiste, P., J.R. Petit, V. Y. Lipenkov, D. Raynaud and N. I. Barkov, Constraints on hydrothermal processes and water exchange in Lake Vostok from helium isotopes. Nature, 411, (6836) 460-462, 2001

2000

Souchez, R., J.R. Petit, J.-L. Tison, J. Jouzel and V. Verbecke, Ice formation in subglacial Lake Vostok, Central Antarctica. Earth Planet. Sci. Lett., 181, 529-538, 2000

Remy, F., L. Testut, and B. Legresy, Topographie des calottes polaires par altimétrie, Compte-rendu de l'académie des Sciences, 330, 457-467., 2000.

1999

Jouzel, J., J.R. Petit, R. Souchez, N.I. Barkov, V.Y. Lipenkov, D. Raynaud, L. Stievenard, N.I. Vassiliev, V. Verbecke, and F. Vimeux, More than 200 meters of lake ice above subglacial Lake Vostok, Antarctica. Science, 286, 2138-2141, 1999.

Rémy, F., P. Schaeffer, and B. Legresy, Ice flow physical process derived from ERS1 high-resolution map of Greenland and Antarctica. Geophys. Int .J., 139, 6645-6656, 1999.

Others communications, symposium resulting from French involvement with subglacial lake research:

2004

Alekhina I.A., J-R. Petit, S.A. Bulat: Precautions and controls in studying bacterial contents of Vostok ice core, East Antarctica: Geophysical Research Abstract, 6, 06029, EGS 2004.

Bulat S.A., I.A. Alekhina , V.Ya. Lipenkov, J-R. Petit: Is the subglacial lake Vostok, East Antarctica, lifeless? A case of forensic biology study of accretion ice: Geophysical Research Abstract, 6, 05916, EGS 2004.

Bulat S.A., I.A. Alekhina, J-R. Petit: Lake Vostok: forensic biology: Lessons for exobiology purposes: Geophysical Research Abstract, 6, 05933, EGS 2004.

Bulat S.A., I.A. Alekhina, J-R. Petit: Lake Vostok, Eastern Antarctica, is an earthy model for decontamination studies in terms of forward contamination of Mars: COSPAR04-A-00676, F3.5/B0.11-0011-04, Paris 2004.

Bulat S.A., I.A. Alekhina, V.Ya. Lipenkov, J-R. Petit: Is the subglacial lake Vostok, East Antarctica, lifeless? A case of forensic biology study of accretion ice: SCAR open conference Bremen July 2004.

Delmonte B., J.R. Petit, I. Basile-Doelsch, A. Michard, and V.Lipenkov: Geochemichal characterization and dating of basal rock sediment from Lake Vostok accreted ice: SCAR open conference, Bremen, S19/P03, July 2004.

Petit J.R.: Implications of an energy balance model to water exchanges and ice sheet dynamic for the subglacial lake Vostok: SCAR open conference, Bremen, S19/P08, July 2004.

Petit J.R, P. Jean Baptiste, S. Bulat, I. Alekhina, D. Raynaud, V. Lipenkov: Helium enrichment in Vostok lake ice suggests a contribution from seismotectonic activity: SCAR open conference, Bremen, S19/O07, July 2004.

Petit J.R, Jouzel J, Souchez R., Vaikmae R., and Lipenkov V.Ya: Stable isotope composition of the accreted ice constrains the geographical location of the melting area for Lake Vostok.: SCAR open conference, Bremen, S19/O04, July 2004.

Petit J.R. Exploring the environment of the subglacial Lake Vostok (Antarctica): constraints and open questions from ice core samples analysis: AMICS workshop, Bruxelles, 6-7 April, 2004.

Petit J.R., Alekhina I.A., Bulat S.A. A hydrothermal contribution to the Vostok subglacial lake (Antarctica) suggested from bacterial gene analysis and the stable isotope composition of deep ice core samples. COSPAR04-A-00832, F3.3-0009-04, Paris, 2004.

Salamatin A.N., J.R. Petit, V.Ya. Lipenkov: Lake Vostok isolation time estimations from an ice model for the melting area: SCAR open conference, Bremen, S19/O05, July 2004.

2003

Alekhina, I.A., J.R. Petit, V.V. Lukin, and S. Bulat Bacterial study of Vostok drilling fluid: a tool to make ice core findings confident, EoS, Geophys. Res. Abstract 5, EAE03-A-03273, 2003.

Bulat , S., I.A. Alekhina, V.Y. Lipenkov , G. Leitchenkov, D. Raynaud, and J.R. Petit Limitations for life in lake Vostok, Antarctica, EoS, Geophys. Res. Abstract 5, 2003.

DeAngelis, M., M.H. Thiemens, J.Savarino, and J.R. Petit, Contribution of an ancient evaporitic-type reservoir to Lake Vostok chemistry, EoS, Geophys. Res. Abstract 5, 2003.

Delmonte, B., I. Basile-Doelsch, A. Michard, J.R. Petit , V. Maggi, B. Gemmiti, and -.R.M. Revel, Sr-Nd Signature of potential source areas for dust in east Antarctica : preliminary results, Terra Antarctica report, 8, 83-85, 2003a.

Delmonte, B., J.R. Petit, I. Basile-Doelsch, A. Michard, and V.Y. Lipenkov Samarium-Neodymium model age and geochemical signature (Sr-Nd) of an inclusion from Vostok accretion ice., EoS, Geophys. Res. Abstract 5, 2003.

Jean Baptiste, P., J.R. Petit , D. Raynaud, J. Jouzel , and B. S., Helium signature and seismotectonic activity in Lake Vostok, EoS, Geophys. Res. Abstract 5 (08205), 2003.

Jouzel, J., J.R. Petit, R. Souchez, R. Vaikmae, and V.Y. Lipenkov, Geographical location of Lake Vostok Melting area, EoS, Geophys. Res. Abstract 5, 5 (05580), 2003.
Lipenkov, V., V.A. Istomin, D. Raynaud, S.A. Bulat , and J.R. Petit Investigation of the gas budget in the subglacial Lake Vostok, EoS, Geophys. Res. Abstract 5, 2003.
Petit, J. R., Ice water exchange in Lake Vostok constrained by an energy balance model, EoS, Geophys. Res. Abstract 5(EAE03-A-03628), 2003.
Petit, J. R.: The water cycle in Lake Vostok: melting rate, thermohaline circulation, accretion processes and the energy balance constraints. ISAG 7, Milano, 25-29 August: Abstract-238. 2003.
Planchon, F.A.M., C. Barbante, C. Boutron, S. Bulat, C. G. Cozzi, A. Dommergue, C. Ferrari, P. Gabrielli, and J.R. Petit, Trace elements in accreted ice from the Vostok sub-glacial lake, Antarctica, EoS, Geophys. Res. Abstract 5, 2003.
Planchon, F. A. M., C. Barbante, Boutron, C, Bulat, S, Cescon, P, Cozzi, G, Domergue, A., Ferrari, C., Gabrielli, P., Petit, J.R: Initial results on trace elements in the deepest part of the Vostok ice core, Antarctica: information on the sub-glacial lake environment. ISAG 7, Milano, 25-29 August: Abstract 246, 2003.
Salamatin A.N, J.R. Petit, and V.Y. Lipenkov An estimate of LV isolation time from a sensitivity experiment for the melting area, EoS, Geophys. Res. Abstract 5, 2003.

2002

Bulat, S.A., I.A. Alekhina, M. Blot, J.R. Petit, D. Waggenbach, V.Y. Lipenkov, D. Raynaud, and V.V. Lukin. Thermophilic microbe signatures in Lake Vostok Antarctica, Eos Trans, 83 (19) B021-A09, 2002.
De Angelis, M., and J.R. Petit, Chemical composition of the lake ice above the subglacial lake Vostok, EOS, Trans, 83 (19) B22A-09, 2002.
Lipenkov, V., V.A. Istomin , S.A. Bulat, D. Raynaud, and J.R. Petit, An estimate of the dissolved oxygen concentration in subglacial lake Vostok, EOS, Trans. AGU, 83 (19) B21A-06, 2002.
Petit, J.R., C. Ritz, P. Jean Baptiste, R. Souchez, V.Y. Lipenkov and A.N. Salamatin. Hot spots in Lake Vostok?, EOS, Trans. AGU, 83 (19) B21A-05, 2002

1.2 United Kingdom

Subglacial lakes research in the UK has focused on the following activities:

- **Modelling of physical processes in subglacial lakes** - The UK NERC has funded several research projects related to Antarctic subglacial lakes. Numerical models have been built that simulate the hydrological processes of subglacial environments using computation

fluid dynamics models to predict water circulation processes. Initially small subglacial cavities have been examined but the models will be scaled up to the dimensions of known subglacial lakes. Results demonstrate the influence of rotational plumes within ascending and descending water bodies, driven primarily by the Coriolis force.

- **Examination of particulates in accreted ice -** In collaboration with J Priscu (US), Lake Vostok 'accreted' ice has been examined in order to understand the processes leading to the incorporation of particles in the ice. A size distribution model of the particles that applies stokes settling velocities suggests that the majority of particles in Lake Vostok are held in suspension. Larger particles will also be held in suspension if up-welling rotational plumes are present as suggested by the computational fluid dynamic modelling.

- **Glacial history of Antarctica -** Subglacial topography in Antarctica has been examined to reveal bed roughness characteristics. The topography at Dome C has a glacial origin from an ice sheet which predates the current configuration. This implies that at Dome C the ice sheet has been dynamic in the past and that subglacial lakes here have a subglacial origin that is much younger than the landscape.

- **Inventory of subglacial lakes.** Researchers from the UK, US, Italy and Russia have compiled a revised inventory of subglacial lakes. The current total now stands at 145 features. Subglacial lakes have now been identified over most of the continent where ice thickness is greatest.

- **Subglacial Lake Ellsworth.** Radio-echo sounding reveals a 10 km-long lake beneath 3.5 km of ice near the Ellsworth Mountains in West Antarctica, 20 km from the ice divide. Subglacial Lake Ellsworth is located within a distinct topographic hollow, which is over 1.5 km lower than the general level of the surrounding bed. The slope of the lake's ice-water interface, which is thought to control the circulation of lake water, is greater than in most other subglacial lakes. Consequently, Lake Ellsworth may be more dynamic than others. The environments of all subglacial lakes are controlled by common features (they will be at the same temperature, in complete darkness and under considerable pressure). Consequently life is as likely in Lake Ellsworth as in any other lake. Judging by the bed slopes flanking the lake, the water depth is at least 10s of meters. Calculations of basal temperature reveal the ice base to be warm both now and during full glacial periods. Given these characteristics, Lake Ellsworth is well suited to further examination.

- **Future exploration of Lake Ellsworth**. In April 2004, scientists from 9 UK universities and research institutions met in the British Antarctic Survey to plan for the exploration of Subglacial Lake Ellsworth (after its geophysical exploration). The next meeting is to be held in Bristol (1 September 2004), where a full proposal for the exploration of the lake will be developed.

- **A web page of subglacial lakes research** – A summary of UK subglacial lake research is available at:

http://www.ggy.bris.ac.uk/research/glaciology/personalpp/siegert/subglacial_lakes/Subglacial%20lakes.htm

1.3 Russia

Relevant Russian activities for the next 5 years (and beyond) will focus on the following items:

- **Over-snow geophysical studies (radar profiling and reflection/refraction seismic experiments) in the area of Lake Vostok.** The aim of these studies is to define: stratification of ice above Lake Vostok and the nature of internal surfaces (layers) in the ice, lake boundaries (grounding line), lake water thickness, bedrock morphology of the lake shores and lake bottom, sedimentary patterns under the lake, physical characteristics of bedrock topography in the area of lake Vostok, and the geological/tectonic nature of Lake Vostok.

- **Airborne geophysical surveys over the East Antarctic Highland between 75^{o} E and 110^{o} E.** The proposed survey will result in acquisition of airborne ice-penetrating radar, magnetic and gravity data over the large portion of East Antarctic Highland that will enable new insight in its bedrock topography, sub-ice environments, crustal structure and tectonic evolution. Line spacing is expected not to exceed 20 km using a long-range aircraft based at Russian Station “Progress”.

- **Clean Lake Vostok drilling technology development, lake entry and water sampling, and eventual sediment sampling.** Direct studies of physical, chemical and biological characteristics of the water column and bottom sediment layers of Lake Vostok present the most important stage of investigating the process of water formation and genesis, peculiarities of its stratification and circulation, paleoclimatic changes and geological history of the pre-glacial period of Antarctica and microbial diversity and evolution of the life forms of

this natural body. This stage of the studies is impossible without water and bottom sediment sampling and without determining the spatial-temporal non-uniformities of the water masses using sounding complexes and recorders of parameters located at fixed points in different depth horizons.

Development of such instruments is a rather sophisticated engineering problem, which became more complicated by the needs to apply the ecologically clean technologies. Such devices by their originality, reliability and simplicity of operations do not practically differ from similar measurement instruments used in space studies.

On the one hand, the presence of the deep ice borehole and the drilling equipment at Vostok station simplifies and makes possible technologies for lake water and sediment sampling and studies cheaper, but at the same time this enhances the requirements for the needs for efficient decontamination of observatories in contact to water.

In particular, the Russian program plans to develop:

- short-term observatories with a wide set of hydrophysical, hydrochemical and biological sensors and instruments with data recording to solid memory and operational transmission to the surface using cable systems;

- long-term observatories of water parameters with the same set of sensors and instruments for permanent recording and transmission of data;

- rosette water samplers for water and possibly suspended matter sampling in lake bottom horizons;

- soil samplers featured by coring capacity for lake surface sediments sampling;

- special cases for observatories and water-sediment samplers ensuring their decontamination status during transportation through the drilling fluid column in the borehole.

The development, production and application of these tools will be made in full compliance with the requirements of the Protocol on Environment Protection to the Antarctic Treaty.

- **More detailed Lake Vostok studies by drilling near the lakes north edge where the ice thickness is greater than 4,000 m and**

no ice accretion processes persist. New geophysical and glaciological data from this part of the lake will allow us to obtain a longer paleo-climatic data series on changes in ice cover of Antarctica and understand better the thermo-hydrodynamic balance of the lake water body. This gives us an opportunity to create more accurate mathematical models of water circulation and processes of ice melting and accretion in its shallow and deep areas, respectively.

- **Lake Vostok accretion ice retrieval (3623 – 3700m) and its complex studies of microbiology/molecular biology, glaciology, ice chemistry, and gas contents (new accretion ice and/or inclined core for repetitive analyses as compared to deep glacial ice).** We have already obtained 16S rDNA sequencing data for several cores from accretion ice I and II showed that the accretion ice in general is very clean in DOC and extremely pure and heterogeneous in microbial contents. Preliminary microscopy and flow cytometry data are in a full agreement with such a view. This presents a hard-to-overcome problem with extraneous/forward contamination. Even the use of stringent physical-chemical-based ice decontamination procedures in a clean room facility along with sterile (DNA-free) molecular biology reagents and consumables gave 10 times more contaminants than ice indigenous microbes. Among them, we have confidence in chemolithoautotrophic thermophile and 2-3 more unclassified bacterial phylotypes, all which successfully passed all contaminant criteria including a comprehensive contaminant database. Chemical and gas data of accretion ice testify for unusual highly oxygenized lake environment which can provide a severe constraint for life in the water body assuming that the accreted ice properly reflects the actual lake water. Finally, the finding of the thermophilic microbial DNA in accretion ice originating from a shallow depth bay provided data that allowed us to hypothesize that tectonic-driven hydrothermal influences in the lake sediments occurs, probably within deep faults; these microbial data are supported by geophysical/geological evidence.

- **Analogous lake (e.g. Radok) and ice (e.g. EPICA, NorthGRIP 'red ice') studies for microbiology and genomics** (along with French and Danish laboratories). Such studies will verify the decontamination approach and molecular methods used in Vostok ice core studies and test and improve novel water and bottom sediment sampling technologies. In addition, more data on microbial communities in Antarctic lakes environments will be gathered.

2.0 SALE as a SCAR Scientific Research Program (SRP)

Subglacial Antarctic Lake Environments (SALE) was endorsed as a SCAR Scientific Research Program by the Life Sciences and Geosciences Standing Scientific Groups in Bremen in 2004. The proposal for SALE had previously been approved for submission to the 2004 Delegates meeting in Bremerhaven by the SCAR Executive Committee in Brest in 2003. Based on the advice of the Executive Committee the SALE proposal was revised to specifically address the newly developed SCAR SRP proposal evaluation criteria with special reference to data management strategies and outreach efforts. The revised proposal was provided to the SCAR Executive Director.

3.0 Recent Publications and Presentations

Subglacial Antarctic lake environments continue to be of great interest to the scientific community and the public. This is reflected in the ever increasing number of publications in the peer reviewed literature, lay science articles in the popular press (journals, magazines, newspapers, and television and radio shows), and oral and poster sessions held at scientific meetings world-wide. Subglacial environments were included as an oral and poster session at the 2004 SCAR Open Science Conference. There were 10 oral presentations and 10 posters. SALEGOS keeps a current bibliography on its web site.

Recent or pending publications in the last year include:

- Bulat , S., Alekhina, I.A, Blot, M., Petit , J.R. de Angelis , M., Wagenbach, D, Lipenkov , V.Y. Vasilyeva, L. Wloch, D., Raynaud D. and Lukin , V.V. : DNA signature of thermophilic bacteria from the aged accretion ice of Lake Vostok : implications for searching life in extreme icy environments, J. of Astrobiology, 3, 1-12. 2004.

- De Angelis M., Petit J.-R., Savarino J., Souchez R., and Thiemens M.H, Contribution of an ancient evaporitic-type reservoir to lake Vostok chemistry, Earth Planet. Science Lett, 222, 751-765. 2004.

- Leitchenkov G.L., Belyatsky B.V., Popkov A.M. and S.V. Popov (2004) Geological nature of subglacial Lake Vostok, East Antarctica. Mater. Glyatsiol. Issled. 97 (in press).

- Parrenin, F., Rémy, F., Ritz, C., Siegert, M.J. and Jouzel, J. New modeling of the Vostok ice flow line and implication for the glaciological chronology of the Vostok ice core. Journal of Geophysical Research. (accepted, pending revision).

- Petit J.R., Alekhina I, and Bulat S.A.: Lake Vostok, Antarctica: exploring a subglacial environment and searching life in an extreme environment: in Lessons for Exobiology, M. Gargaud Ed. Springer (in press 2004).

- Royston-Bishop, G., Priscu, J.C., Tranter, M., Christner, B., Siegert, M.J., Lee, V. Incorporation of particulates into accreted ice above subglacial Lake Vostok, Antarctica. Annals of Glaciology, Portland (in press 2005).

- Royston-Bishop, G., Tranter, M., Siegert, M.J., V. Lee, P. Bates. Is Lake Vostok in chemical and physical steady-state? Annals of Glaciology, 39. (in press 2004).

- Salamatin, A.N, E. A. Tsiganova, Lipenkov V.Y and Petit J.R.: Vostok (Antarctica) ice-core time scale from datings of different origins. Annals of Glaciology, 39, in press.

- Siegert, M.J., Taylor, J. and Payne, A.J. Spectral roughness of subglacial topography and implications for former ice-sheet dynamics in East Antarctica. Global and Planetary Change. (in press 2004).

- Siegert, M.J. Comment on "A numerical model for an alternative origin of Lake Vostok and its exobiological implications for Mars" by N.S. Duxbury, I.A. Zotikov, K.H. Nealson, V.E. Romanovsky, and F.D. Carsey. Journal of Geophysical Research, 109, E02007, doi:10.1029/2003JE002176, 2004. (2004).

- Siegert, M.J. Lakes beneath the ice sheet: The occurrence, analysis and future exploration of Lake Vostok and other Antarctic subglacial lakes. Annual Reviews of Earth and Planetary Sciences. (in press 2005).

- Siegert, M.J. Reviewing the origin of Lake Vostok and its sensitivity to ice sheet changes. Progress in Physical Geography. (in press 2004).

4.0 SALE-UNITED in the IPY 2007-2009

The ICSU and various national IPY planning committees include references to subglacial lake environments as a potential IPY 2007-2009 activity under the exploring new frontiers theme. To coordinate the multiple ideas submitted to the ICSU and national committees as part of the IPY planning process, SALEGOS has proposed that all nations with interests in subglacial lake environments join together under the auspices of the SCAR SALE SRP to promote international collaboration and partnerships. This alliance is referred to as **SALE – UNified International Team for Exploration and Discovery (UNITED)** and its mission and terms of reference are provided below.

Subglacial Antarctic lake environments are emerging as the premier, new frontier for exploration during the IPY 2007-2209. Several coordinated campaigns by various nations are in the early stages of planning and implementation. It is suggested that these efforts be developed under the auspices of the proposed SCAR Scientific Research Program (SRP) - Subglacial Antarctic Lake Environments (SALE). As the SCAR SRP SALE, these programs would join together to promote and advance common scientific, technological, and logistical issues in close consultation with COMNAP. The coalition approach recognizes that the ambitious interdisciplinary objectives of SALE, as internationally agreed during a series of workshops, and extensive discussions of the SCAR Group of Specialists (SALEGOS), can only be realized by multiple exploration programs that will investigate exemplars of the diverse subglacial environments over the next decade or more. The IPY provides an opportunity for an extensive period of initial exploration that will advance scientific discoveries in glaciology, biogeochemistry, paleoclimate, biology, geology and tectonics, and ecology to a new level that could not otherwise be achieved by a single nation or program.

Each program will be an independently managed campaign with specific scientific objectives, logistical requirements, and management structures that will contribute to, and accrue added value from, a common international research agenda. Synergy is provided by the pooling of resources were appropriate, the sharing of experiences and expertise, the coordination of logistics and technological developments, and a shared vision. The SCAR SRP SALE will serve as an international science and technology steering committee with a subcommittee structure representing the major scientific disciplines and technological needs. The steering committee (SALE) will be comprised of the leaders of each program supplemented by international experts as needed.

The following are brief summaries of the projects being pursued by groups that have tentatively agreed to join SALE-UNITED:

- **United Kingdom/US – UK** researchers and partners are conducting a diverse set of projects that are expected to continue during and after IPY 2007-2009 including: numerical models of hydrological processes of subglacial environments; in collaboration with the US, studies of ‘accreted’ ice particles dynamics and origins in subglacial environments using models; studies of subglacial topography to establish basin origins; surveys and inventory of subglacial lakes continent-wide; and surveys of and entry into Subglacial Lake Ellsworth in West Antarctica to be conducted by a coalition of 9 UK universities and research institutions,

- **US - ROV** development for ice grounding studies including water and sediment sampling, and

- **US – AUV** development for intra-lake surveys within the McMurdo Dry Valleys that include physical, chemical, and biological efforts.

- **US –** Development of an automated system to characterize (biotic and abiotic) particles in deep ice cores.

- **US –** Geophysical surveys, lake evolution studies and modeling, ice sheet interactions concentrating on the Lake Vostok region, accretion ice studies,

- **US/France/Italy/Germany** – Subglacial Lake Concordia as a site for exploration, technology development including lake entry and sampling, and microbiological, geochemical, and genomic studies (in collaboration with the German IDEA traverse project),

- **Russia** – Over-snow geophysical studies (radar profiling and reflection/refraction seismic experiments) in the area of Lake Vostok: subglacial lake bedrock and shoreline topography, ice sheet and water circulation modeling, and ice sheet/water interactions,

- **Russia** - Airborne geophysical surveys over the East Antarctic Highland between 75°E and 110°E.

- **Russia** - Lake Vostok accretion ice retrieval (3623 – 3700m) (further drilling towards lake and inclined core for repetitive analyses),

- **Russia** – Clean Lake Vostok drilling technology development, lake entry, water sampling, and eventual sediment sampling (implementation of this project will require a permit from the national Inter-Ministry Commission on Consideration of Applications of the Russian Physical Persons and Legal Entities on Activity in the Antarctic Treaty Area); development of the observatories and sampling devices and ecologically clean technical means for transportation of this equipment through the drilling fluid of the borehole towards Lake Vostok; full-scale trials,

- **Russia** – Deep ice core drilling for paleoclimate and Lake Vostok research in the northern part of the Lake Vostok,

- **Russia/France** – Complex studies of the Vostok ice core for microbiology/molecular biology, glaciology, ice chemistry and dynamics, and gas contents,

- **Russia/France/Denmark** – analogous lake (e.g. Radok) and ice (e.g. EPICA, North GRIP ‘red ice’) studies for microbiology and genomics,

- **Italy** – Detailed surveys and glaciological investigations of Dome C and the Dome C “Lake District”,

- **France/Italy** – Dome C glaciology, chemistry and ice dynamics studies,

- **France/Russia/Italy** - Technology development for access hole for ice geophysics (temperature, inclinometry measurements) and bedrock sampling. Clean technology development for lake entry, permanent access and sediment collection in small sub-glacial lakes or lake-like features,

A central common effort will be the development, implementation and promotion of environmentally benign procedures for all subglacial lake environment exploration and research programs properly vetted through national and ATCM procedures. With proper planning and careful and methodical technology development and testing SALE can be an exemplar of environmental stewardship.

The concerted multi-target approach will assure the widest possible characterization of subglacial lake environments beneath the East and West Antarctic Ice Sheets. This will advance our understanding of the range of possible lake evolutionary histories.; the character of the physical, chemical, and biological niches: the interconnectivity of subglacial lake environments; the coupling of the ice sheet, climate and the evolution of life under the ice; the tectonic setting; and the interplay of biogeochemical cycles. Research and exploration programs spanning the continent will allow for complementary investigations of subglacial lake environments of differing ages, evolutionary histories, and biogeochemical settings providing a holistic view of the development of these environments over millions of years and under changing climatic conditions. While early discoveries and exciting findings are expected during the IPY 2007-2009, a long term sustained program of research and exploration will continue far beyond 2009.

To from a mutually beneficial network of programs, SALE – UNITED will operate under these guiding principles:

- Members retain autonomy to make decisions in the best interests of their program while taking into consideration the interests of other programs and the potential for synergies.
- Programs will pursue funding through their normal national procedures while looking for opportunities to develop joint funding across programs.
- Open and timely access to data and samples for other SALE-UNITED programs and the broader scientific community while protecting the intellectual property of individual investigators and programs.

- Participation in inter-comparisons and inter-calibrations of techniques and methodologies to ensure quality and comparability of information across SALE-UNITED programs by establishing agreed data management protocols and standards.
- Share technological developments and “lessons learned” while protecting ownership and ‘or proprietary information.
- When appropriate encourage joint publications and presentations when al involved stand to accrue benefits.
- Provide due consideration of “add-on” or “spin-off” projects by others that do not compromise individual programmatic efforts but advance the common SALE-United mission.
- Assist in the promotion and communication of SALE-United goals, accomplishments, and findings.
- Respect and value the contributions of all SALE-UNITED members.

5.0 Concluding Remarks

This report marks the end of the SALEGOS. The group met six times and has addressed its terms of references. Each meeting is recorded in a detailed report posted to the SALEGOS web site. It is the intent of the GOS to migrate the SALEGOS web site to the SCAR web site where it will continue to be a resource for the Antarctic community and other interested parties. A proposal to continue the work of SALEGOS as a SCAR Scientific Research Program has been submitted. If approved by the Delegates, the program will begin in 2005 building on the extensive work of SALEGOS.

The Convener and Secretary wish to express their appreciation to all of those who served on the GOS for the open, stimulating and cooperative manner in which the group has operated over the past four years. The many experts that appeared before the group over the years brought critical information and insight to the group’s deliberations and their efforts are greatly appreciated. The impressive output of SALEGOS is directly attributable to the concerted efforts of its members and invited guests. This report concludes the activities of the SCAR Subglacial Antarctic Lake Exploration Group of Specialists (SALEGOS).