

Программа научных исследований на станции Восток – Антарктида

В.Ф. Ежов

ПИЯФ НИЦ КИ

По материалам конференции

«Биогеохимические, биофизические и
астробиологические исследования на российской
станции «Восток» в Антарктиде: заделы и перспективы»

24-26 сентября 2018

ПОЛЯРНЫЙ ГЕОФИЗИЧЕСКИЙ ИНСТИТУТ,
МУРМАНСК

Цель

Существует проект реконструкции станции Восток

Создать программу научных исследований на станции Восток

Финансирования научных исследований нет с 2016 г. после завершения ФЦП Мировой океан

Vostok.



- **План: $78^{\circ}30'$ ю. ш., $107^{\circ}00'$ в. д.**
- **Факт: $78^{\circ}28'$ ю. ш., $106^{\circ}48'$ в. д.**
- **Высота над уровнем моря 3488 м**
- **Открыта 16 декабря 1957 г.**

Уникальность станции Восток

- Под станцией Восток расположено самое крупное подледниковое озеро, изолированное от биосферы Земли порядка 14 млн. лет.
- Гляциологические исследования вблизи станции Восток позволяют проследить изменения климата вплоть до 1 млн. лет.
- Местоположение станции Восток делает ее практически в центре авроральной активности, что позволяет осуществлять мониторинг и текущего прогноза (nowcasting) «космической погоды» по данным наземных магнитных измерений.
- Низкая влажность и температура, высота над уровнем моря, отсутствие источников света, исключительная прозрачность атмосферы, длительная полярная ночь и полярный день создают уникальные условия для астрономических наблюдений в инфракрасном, субмиллиметровом и миллиметровом диапазонах, а также прецизионные оптические наблюдения небесных тел вплоть до 24^m-26^m.
- Сбор космической пыли – Уникальная чистота снега (2 μm mode; 10-15 ppb)

Megascience project

Lake Vostok

The discovery of **Lake Vostok** was reported at the **23rd session of SCAR** in Rome in **1994**

Data were published in ***Nature*** (Kapitsa et al., **1996**)

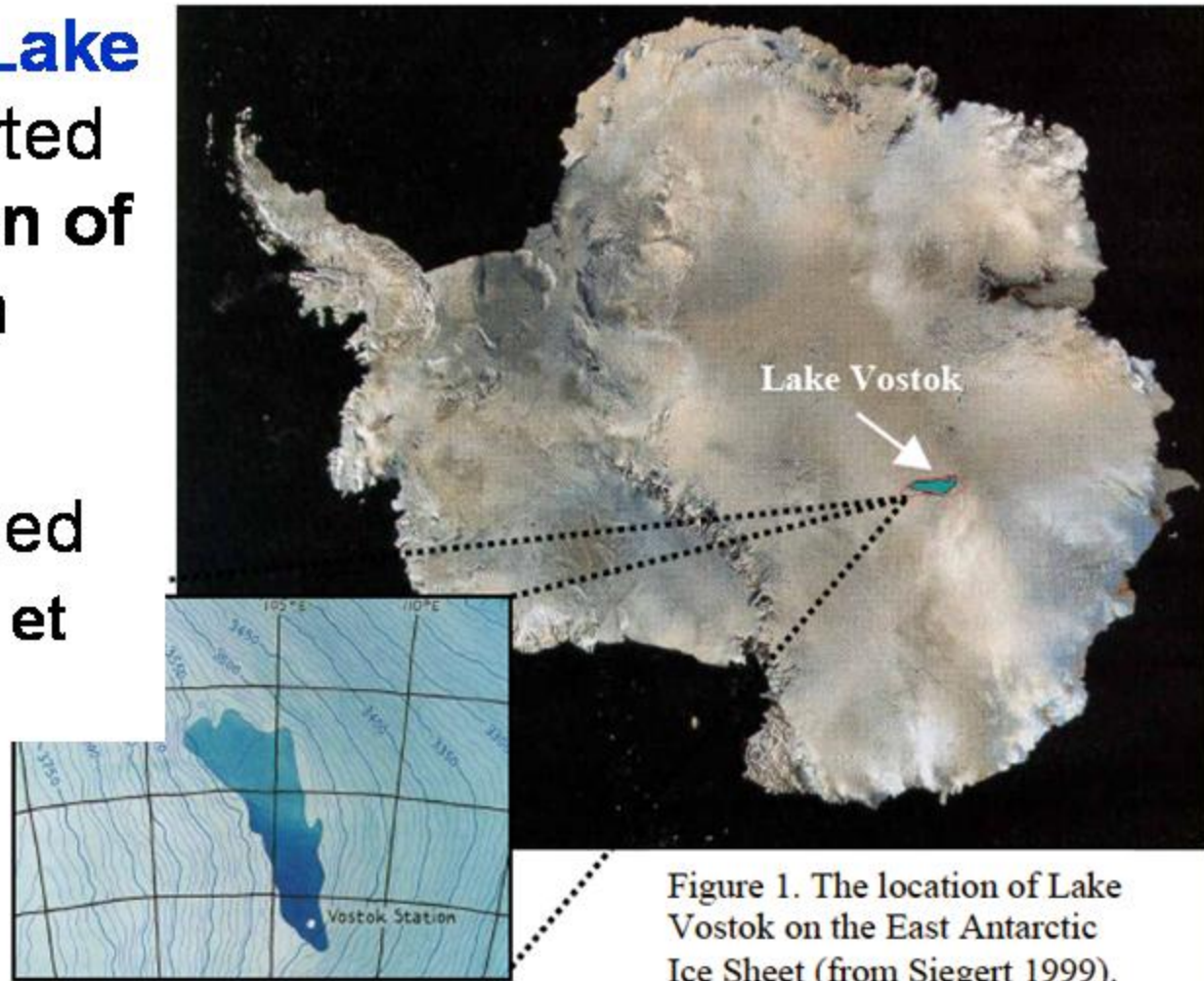


Figure 1. The location of Lake Vostok on the East Antarctic Ice Sheet (from Siegert 1999).

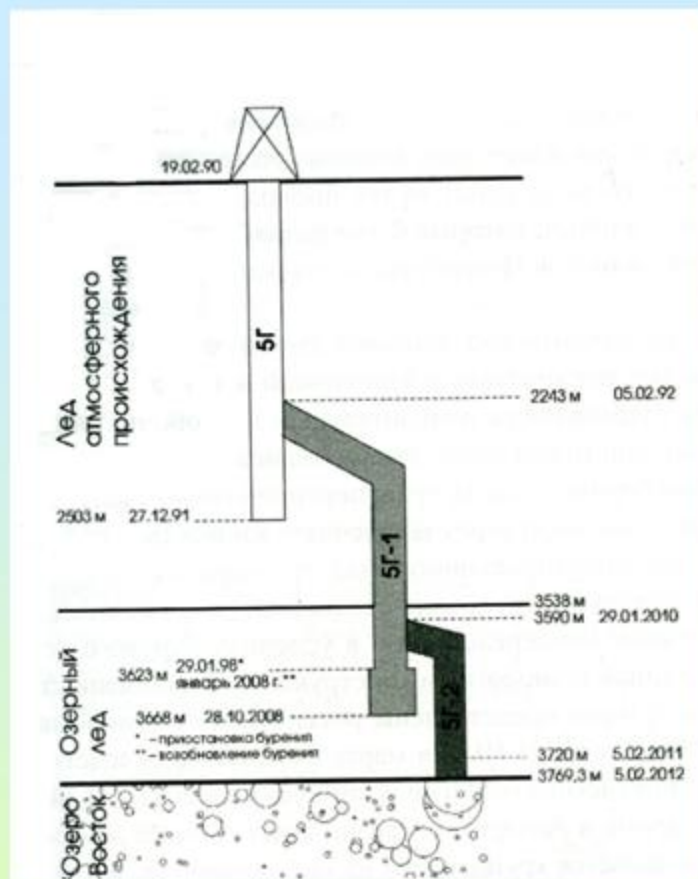
SCIENTIFIC MILESTONES



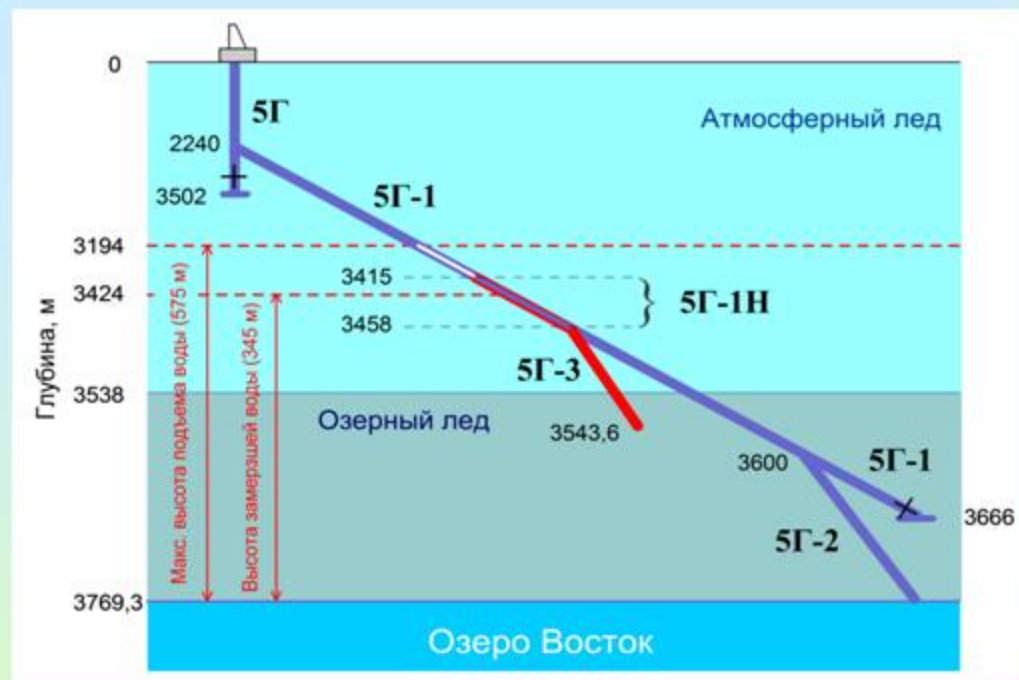
Скважина 5Г - результаты буровых работ во льду на глубинах свыше 3000 м и вскрытие подледникового озера Восток

Литвиненко В.С., Васильев Н.И.,
Дмитриев Д.Н., Подоляк А.В., Кабанов
О.В., Соловьев Г.Н.

Проникновение в озеро Восток.



05 февраля 2012 г.



25 января 2015 г.

POLAR RESEARCH

Russians celebrate Vostok victory

Team finally drills into biggest Antarctic subglacial lake.

BY NICOLA JONES

After two decades of chilly drilling and fiery debate, a Russian team has finally broken into Lake Vostok. The largest of the lakes hidden under Antarctica's ice, and the most deeply buried, Vostok has been isolated for millions of years and may contain specially adapted microorganisms. "I'm sure they're drinking vodka this week," says John Prisco, an Antarctic researcher at Montana State University in Bozeman, who has been in contact with the Russian team.

According to Valery Lukin, director of the Russian Antarctic programme, the drill hit lake water 3,769.3 metres down at 10:25 p.m. on 5 February local time (see 'Long way down'). Temperatures were plummeting as the Antarctic summer ended, and scientists left the next day before it became too cold for planes to fly safely. "Talk about suspense. It has been a nail-biter for the past couple of weeks," says Prisco.

Although the Russian scientists have taken samples, which are most likely to be from a pocket of water just above the lake (one container was presented to Russian Prime Minister Vladimir Putin with great fanfare), they will have to wait until December to extract any frozen lake samples, and until 2013–14 to retrieve unfrozen lake water. "This is a technological achievement. The scientific pay-off is still many years away," says Mahlon Kennicutt, president of the international Scientific Committee on Antarctic Research.

The Vostok drilling project began as an ice-coring effort to examine ancient climatic conditions. By the mid-1990s, scientists had confirmed that a giant lake lurked beneath the borehole and speculated that sampling its water might yield signs of ancient life. By the end of the 1990s, the research community had agreed that the Vostok drilling should stop until researchers could be sure that the lake would be protected from contamination by the underlying kerosene and Freon being used as drilling fluids. Drilling started up again in 2005 with a new plan: when the drill neared the lake, it would be replaced with a thermal probe to melt through the ice, and a plug of clean silicone fluid that would help to protect the lake water from the dirty kerosene above.

Although it is unclear whether the Russian team used the thermal probe and silicone, it

probably avoided contaminating the lake. When the drill broke through to the lake, water surged roughly 30–40 metres up the borehole, forcing 1.5 cubic metres of drilling fluid out of the top of the hole. "If everything went as they said, the only flow would be out of the lake, not into the lake," says Kennicutt.

The lake water at the bottom of the hole will freeze, and the researchers plan to drill it out next season. Previous studies found cells in samples of accretion ice³ — the bottom couple of hundred metres of the glacier made from frozen lake water — but contamination has not been ruled out. The fresh ice plug is unlikely to clear up that controversy, because the samples must be brought to the surface through drilling kerosene, says Kennicutt. The freezing process may also exclude or kill microbes, he adds.

The Russian team plans to explore the lake in 2013–14 using a variety of probes, cameras and water samplers carried down the borehole in a hermetically sealed container. One probe will measure physical conditions such as temperature and acidity, while another will carry a spectrometer to study any organic compounds in the water.

Meanwhile, the United Kingdom and the United States aim to sample water and sediments from different Antarctic subglacial lakes a year earlier, in 2012–13. Both projects will use heated glacier meltwater to bore holes that should stay open for 24 hours, a cleaner and quicker process that should allow the UK team to get through 3.1 kilometres of ice into Lake Ellsworth in just 3 days. Vostok's thicker glacier and lower temperatures would have made the process too energy-intensive to be practical there, however.

Kennicutt hopes that the Vostok, Ellsworth and US Lake Whillans projects will form the first three nodes of a network that will better sample the hundreds of subglacial Antarctic lakes. "They're not actually at the extremes of pressure and temperature, but they are limited in nutrients and energy," says Kennicutt. If life is eventually confirmed to reside in these inhospitable places, "the question is how microbes make a living down there". ■

1. Koshkin, A. P. *et al.* *Nature* **403**, 684–686 (2000).
2. Lukin, V. & Prisco, J. *Geophys. Res. Lett.* **38**, L17307 (2011).
3. Karl, D. M. *et al.* *Science* **286**, 2144–2147 (2009).

IN FOCUS NEWS

LONG WAY DOWN

About two decades after drilling at Lake Vostok began, a Russian team has finally hit water, having coped with major technical problems and contamination concerns.

1990 — Drilling begins at Vostok Station

Borehole SG

1992 — Drilling of borehole SG-1 begins

Borehole SG-1

3,538m

3,769m

3,897m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

3,900m

Accreted ice

Lake Vostok

1998 — Stopped for more than 5 years

2007/08 — Drill stuck

2011 — Ice-water boundary reached

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

Borehole SG-2

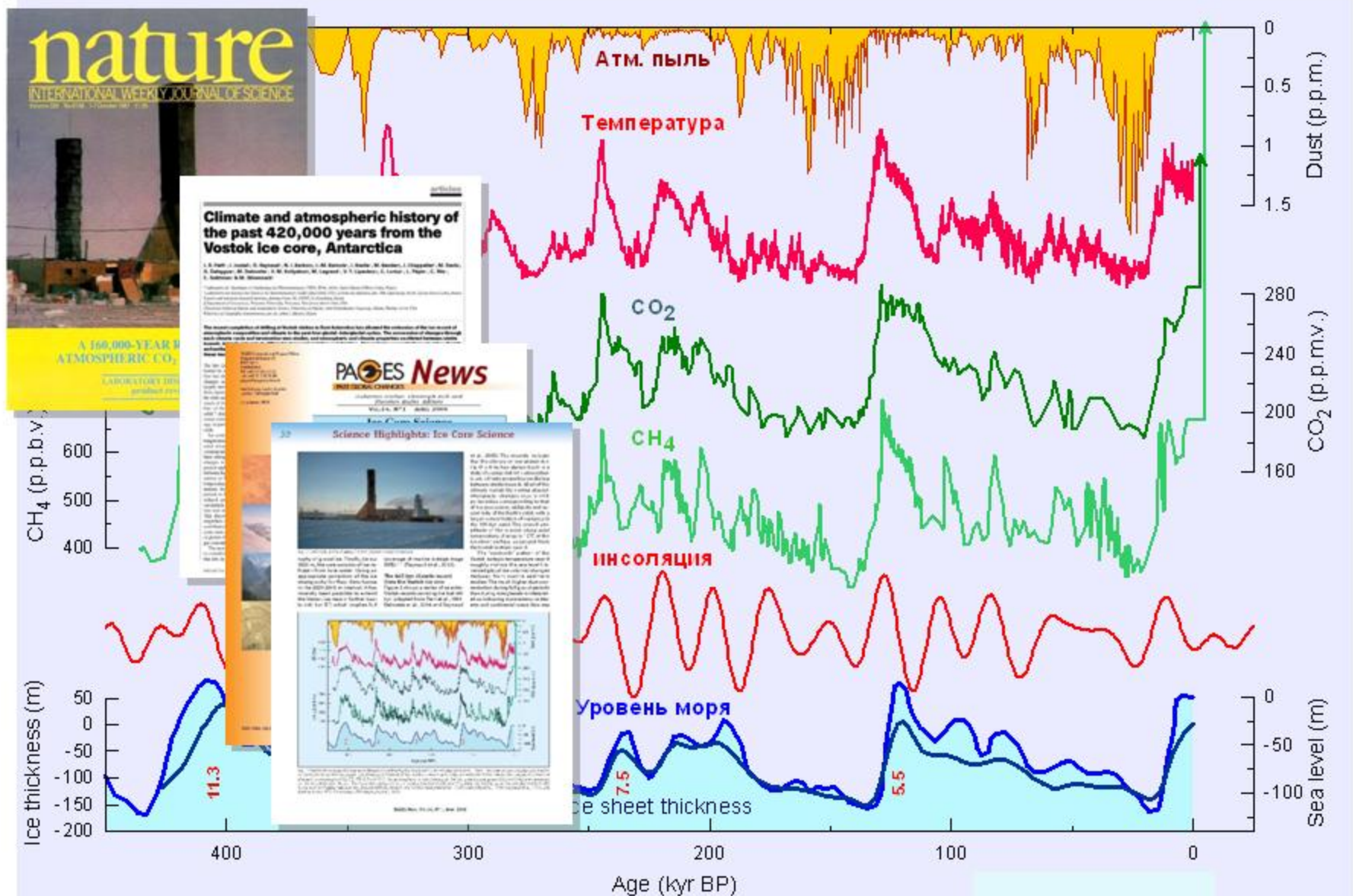
Paleoclimatic data

Vladimir Lipenkov

Arctic and Antarctic Research Institute



"Cornucopia of paleoclimatic data"



Helium isotopes and neon in Vostok glacier and lake ice : 25 years of French-Russian collaboration

Nartsiss BARKOV
Vladimir LIPENKOV

AARI-St Petersburg

Sergey BULAT
Yury CHETVERIKOV
Victor EZHOV
Valeri SOLOVEI

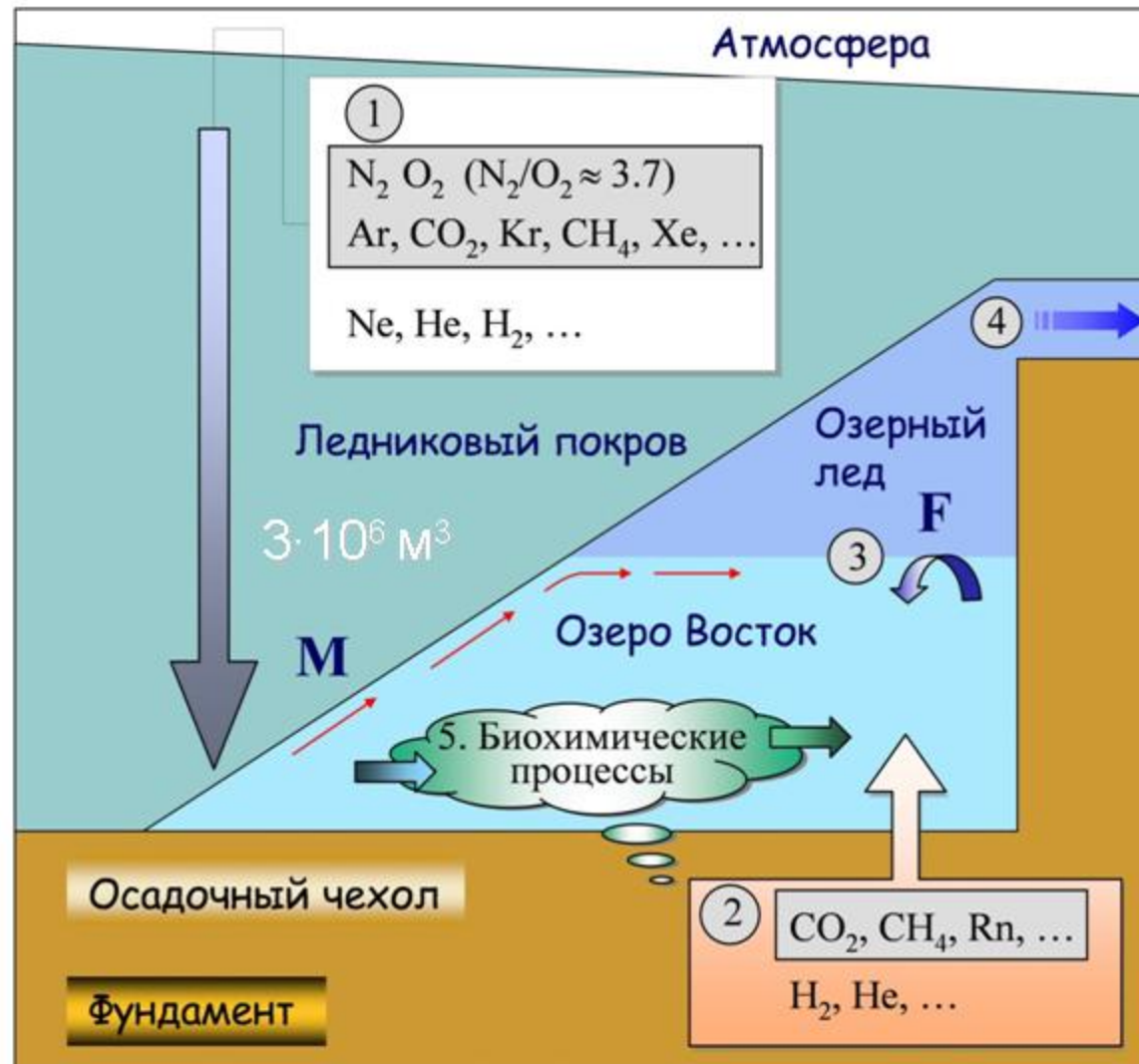
PNPI-Gatchina

Philippe JEAN-BAPTISTE (CEA-Saclay)
Elise FOURRE (CEA-Saclay)

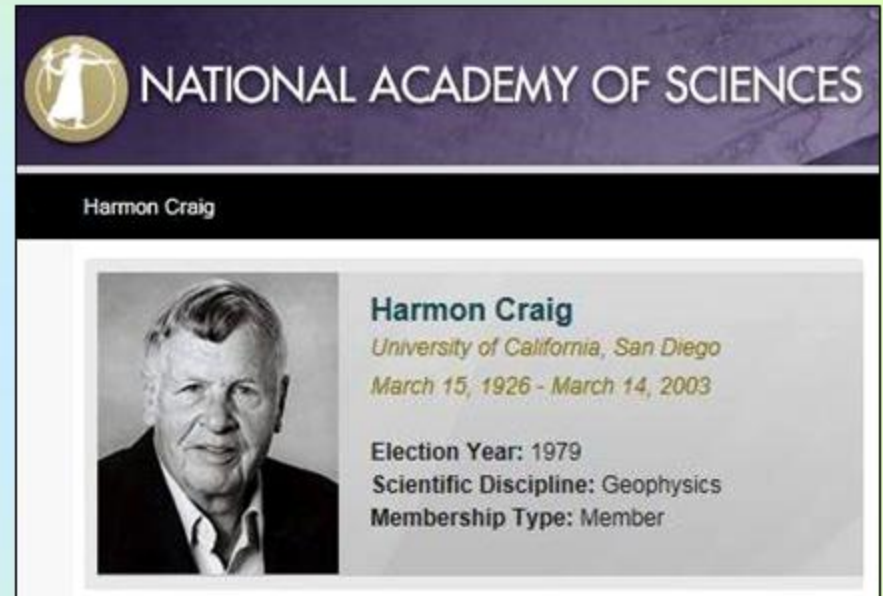
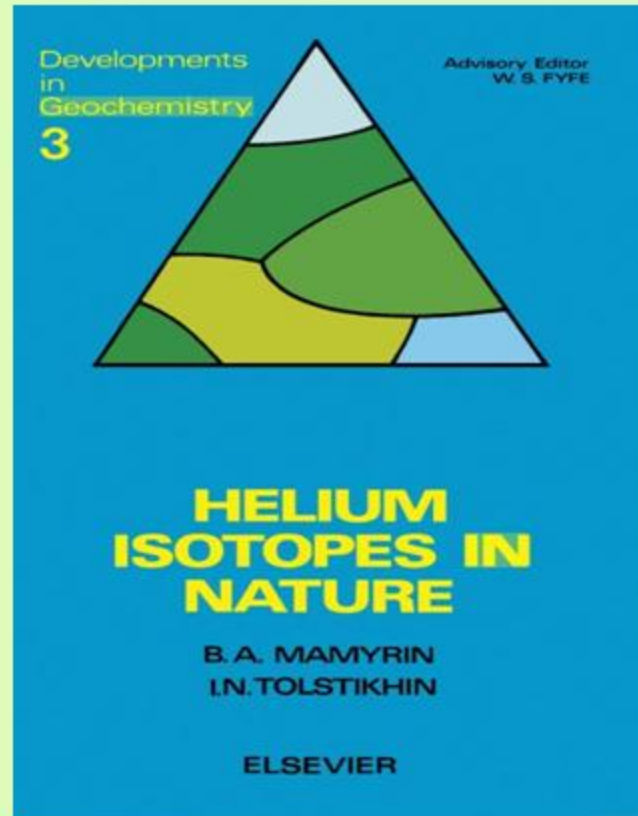
Dominique RAYNAUD
Jean-Robert PETIT

LGGE, CNRS-Grenoble



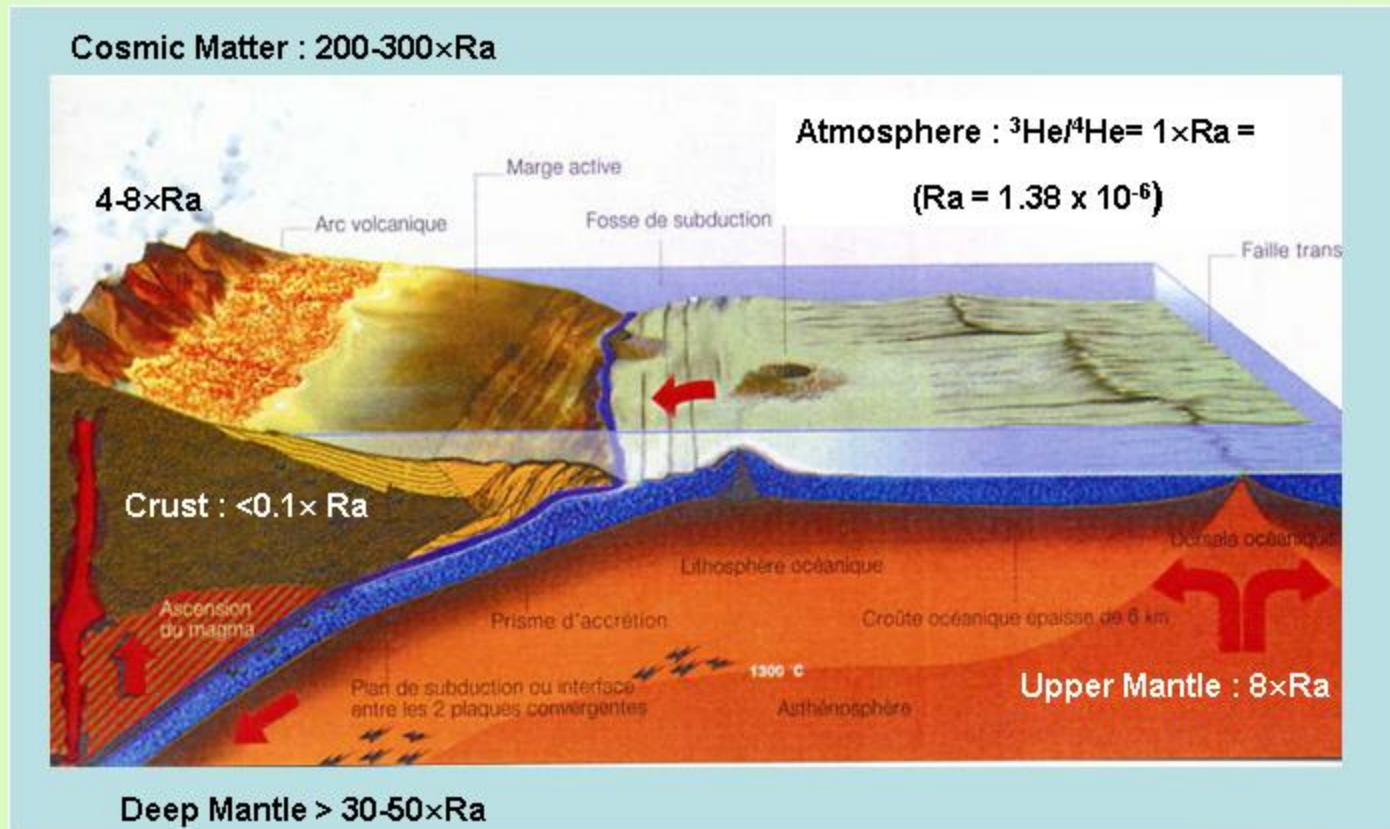


Pioneers in helium isotopes research in geosciences



in the 1970 's

Contrasted $^3\text{He}/^4\text{He}$ ratios in the main earth reservoirs



$^3\text{He}/^4\text{He}$ ratio is a tracer of the origin of helium in natural systems

GEOFYSICAL INVESTIGATIONS OF THE LAKE VOSTOK AREA



St.-Petersburg
September 25, 2015

S.V. Popov, P.I. Lunev, V.N. Masolov,
Polar Marine Geosurvey Expedition,
St. Petersburg, Lomonosov, Russia

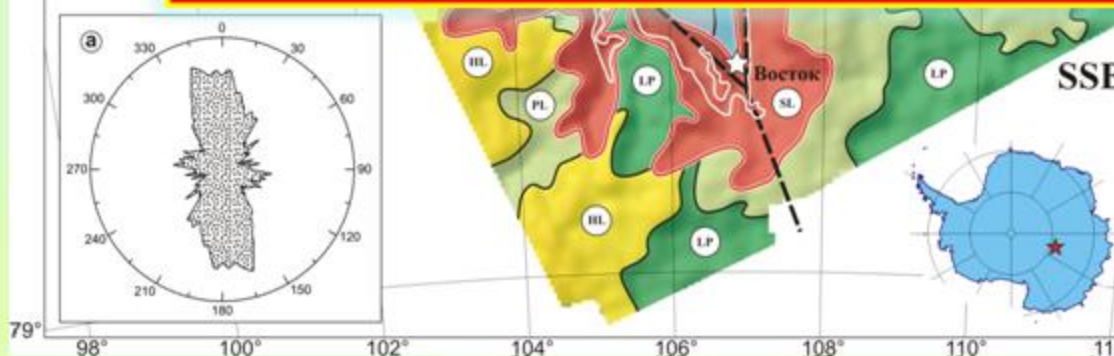
Orography



1. Atlas of the Lake Vostok Area



2. Geomorphological interpretation of the bedrock topography data (erosion, landscape evolution)





Возмущённость магнитного поля на станции Восток как показатель состояния "космической погоды"

О.А.Трошичев
ААНИИ, С.Петербург

Searching for **life** in the subglacial **Lake Vostok**

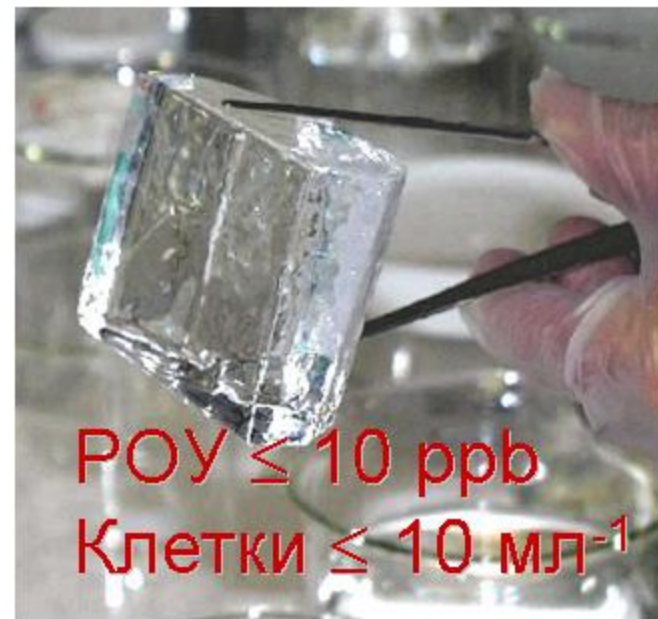
Sergey Bulat

Cryoastrobiology lab

FSBI PNPI, NRC Kurchatov Institute

Leningrad region, Gatchina, RU

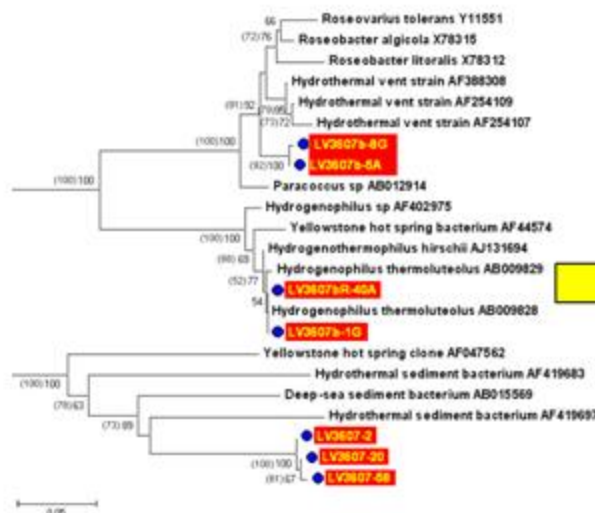
Биология льда ($\Rightarrow$ воды) озера Восток



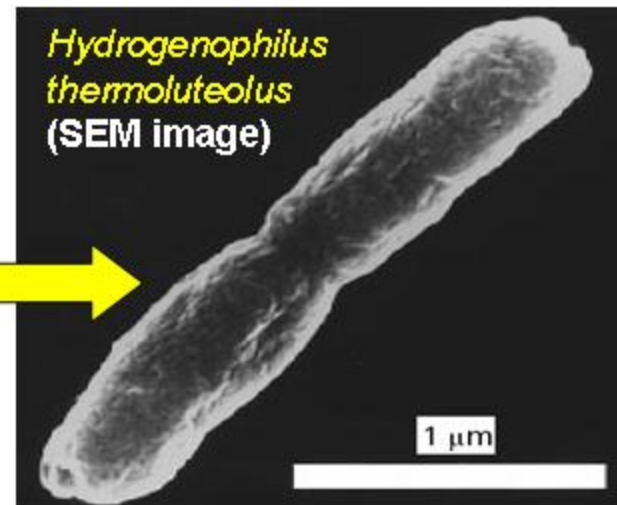
РОУ ≤ 10 ppb
Клетки ≤ 10 мл $^{-1}$

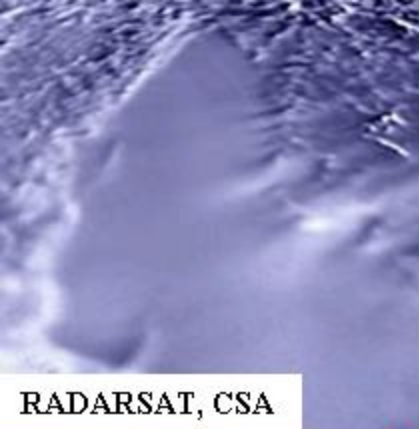
Потенциальные
обитатели озера:

Оксигенофильные
хемоавтотрофные
пъезофильные
психрофилы



*Hydrogenophilus
thermoluteolus*
(SEM image)





Lake Vostok

known since 1994
Published in *Nature* (Kapitsa et al., 1996)

Friendly environment?

FREE (LIQUID) WATER!

- Deeply ice buried (in dark) – 4 km
- High pressure – 337-377 bar
- Permanently BUT not very cold – -2.65°C
- Likely oxygen supersaturated - 800 mg/L ?
(upper bound 700-1300 mg/L)

5G-1N-3429 16S rRNA gene



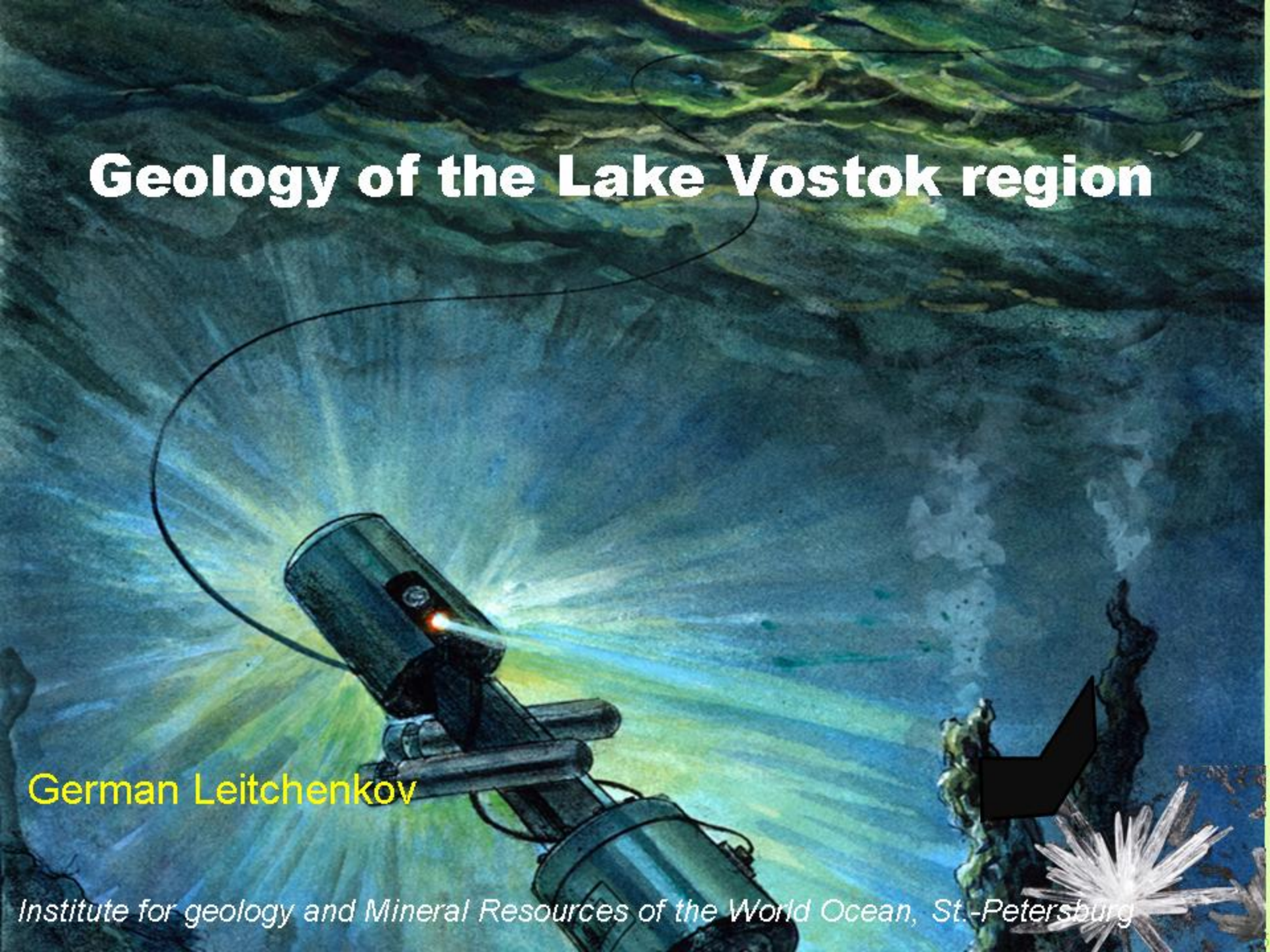
Clone v3-v5
Clone fgene
Clone v4-v8?

3429v3-4 - 93-*Janthinobacterium* sp Beta-Proteobacteria

Неизвестный род и вид
бактерий (**Burkholderiales**,
Oxalobacteraceae, **Beta-**
Proteobacteria)

1.5 L processed

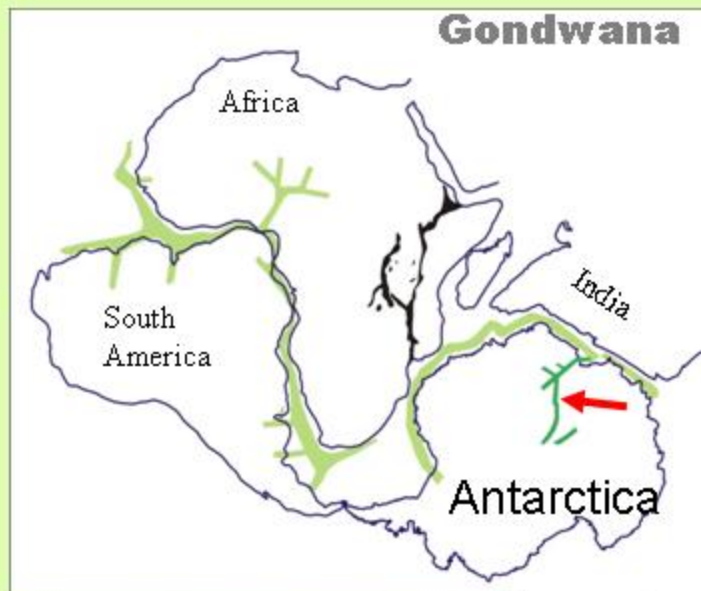
Geology of the Lake Vostok region



German Leitchenkov

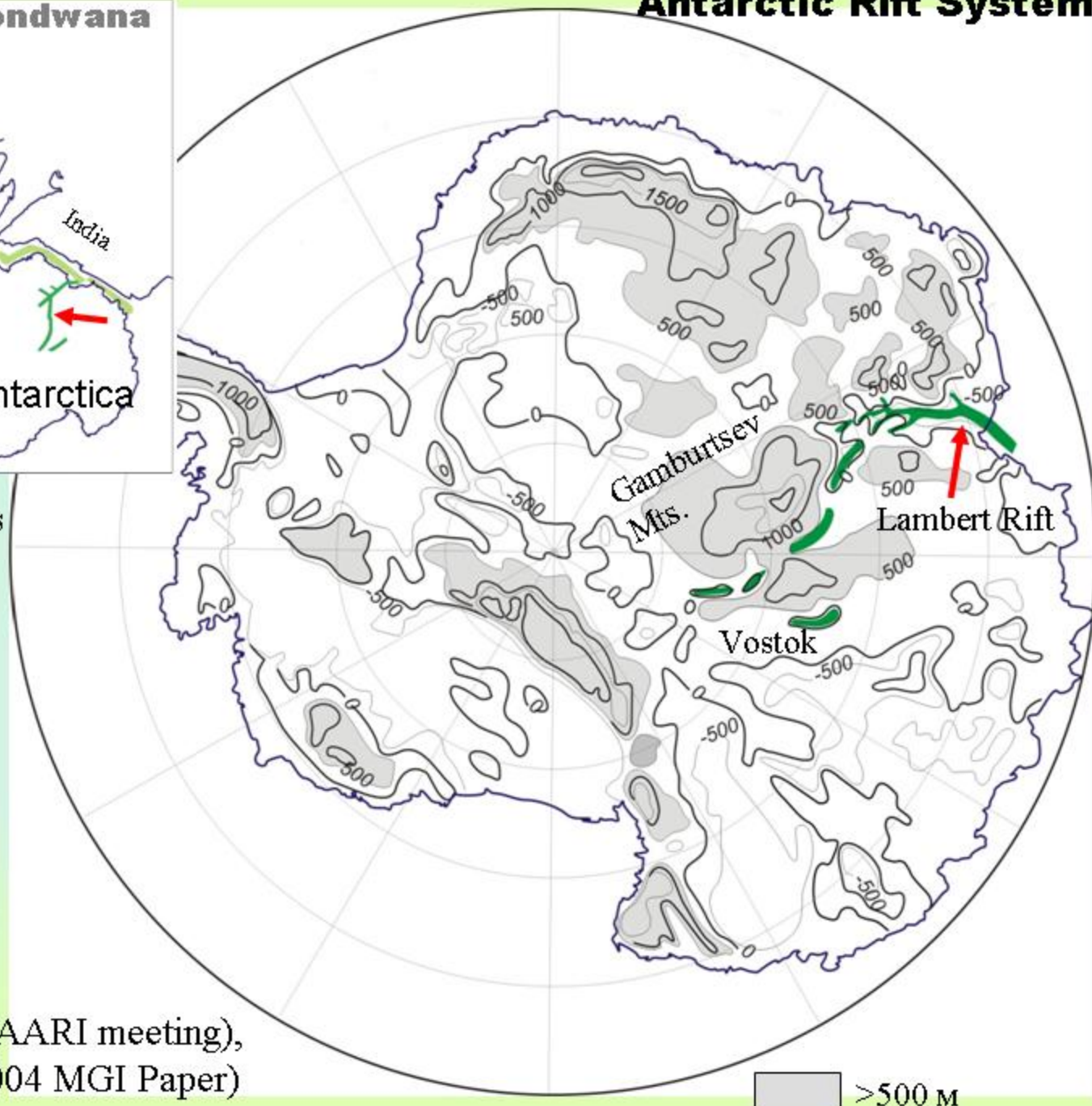
Institute for geology and Mineral Resources of the World Ocean, St.-Petersburg

Gondwana



Antarctic Rift System

-  Mesozoic Failed Rifts
-  Late Cenozoic East African Rift



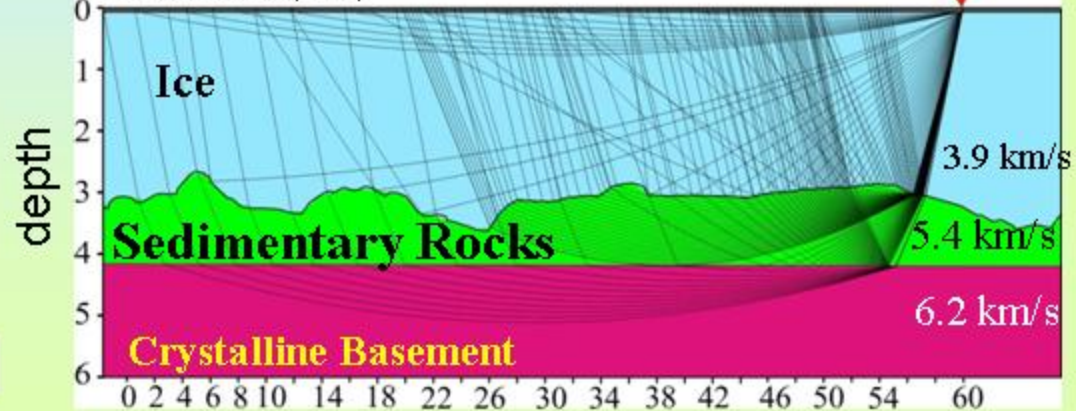
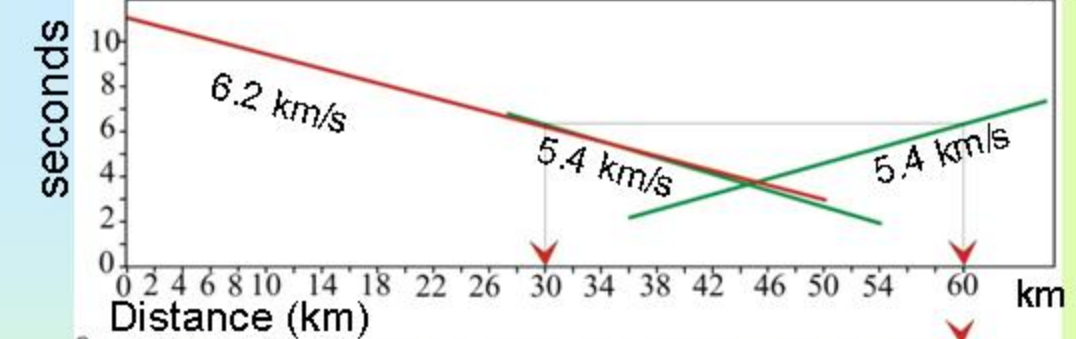
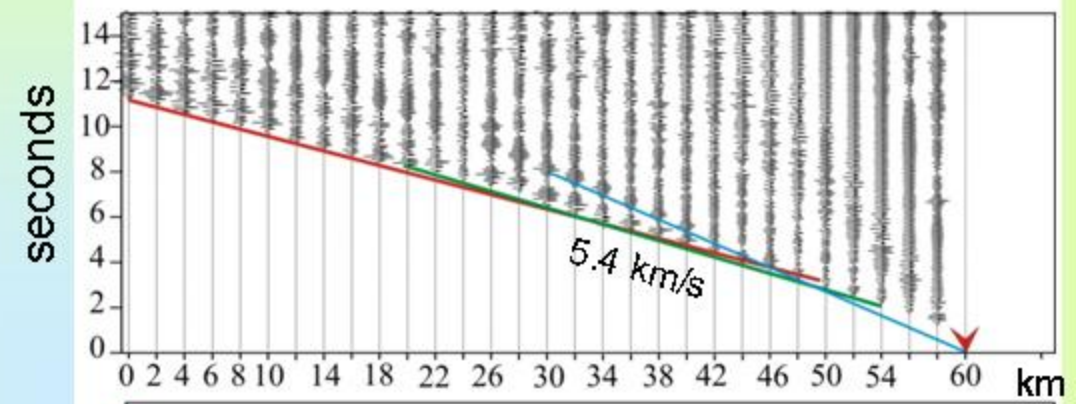
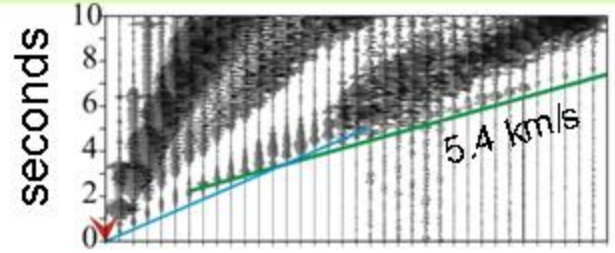
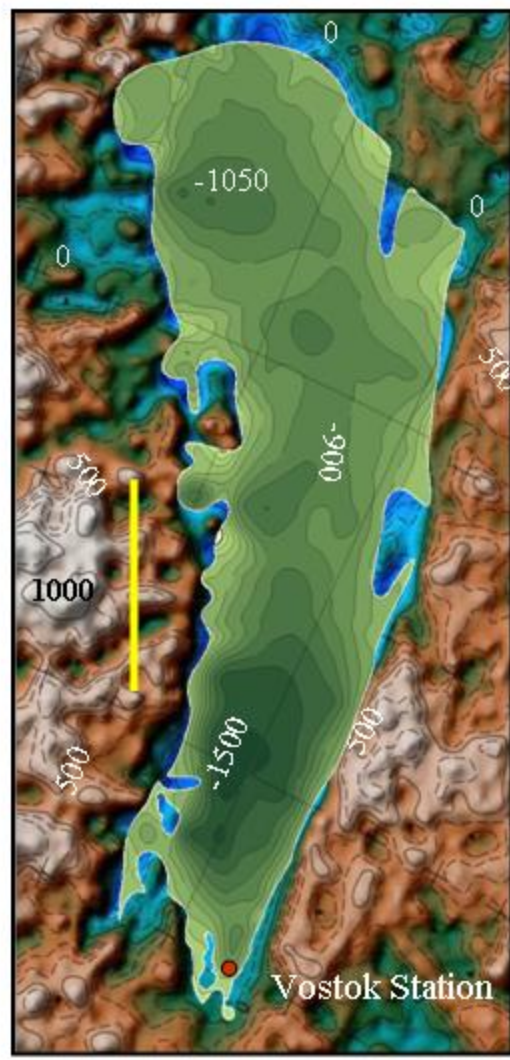
Leychenkov et al., 1998 (AARI meeting),
2003 (EGU meeting), (2004 MGI Paper)

Seismic refraction Experiment

Technology:

Two reversed lines; 1 and 2 km between receivers;
Shot points: 25-500 kg of TNT

sediments ↓



MAJOR CONCLUSIONS

1. Vostok Subglacial Highlands are underlain by 500-600 m.y. old sediments
2. The Antarctic Earth's Crust surrounding Vostok Subglacial Highlands Vostok Subglacial Highlands is mostly composed of Ancient (1.6-1.8 & 0.8-1.2 billion years) Terranes
3. Lake Vostok is a deep depression filled with thin depositional unit.

The Lake Vostok Depression was formed during the time of Antarctic Glaciation (it is not older than 34 million years).

Antarctic micrometeorites and cosmic dust at the Vostok station

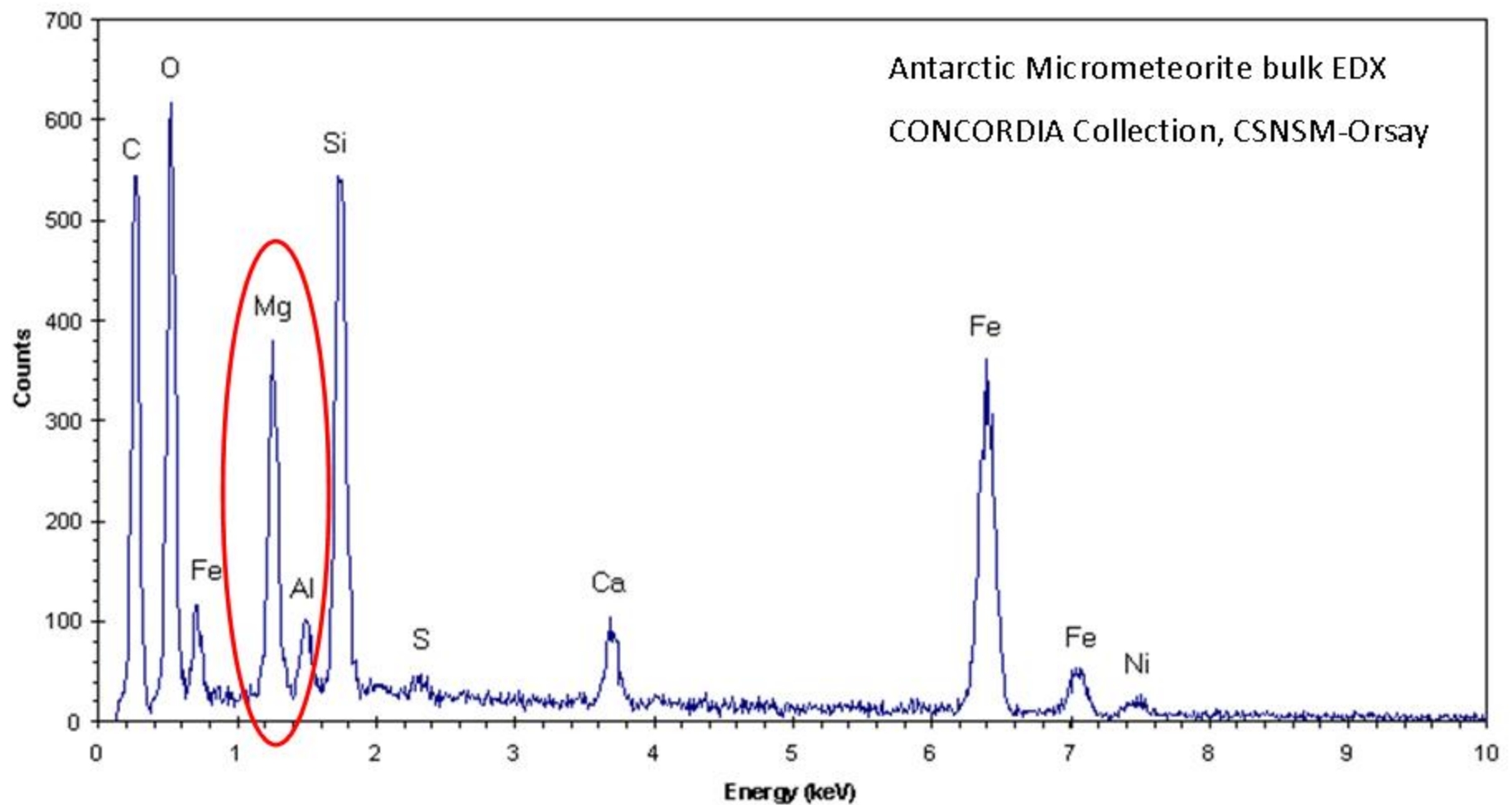
S. Bulat, V.Ezhov, V.Solovei

Cryoastrobiology lab

FSBI 'PNPI', NRC 'Kurchatov institute'

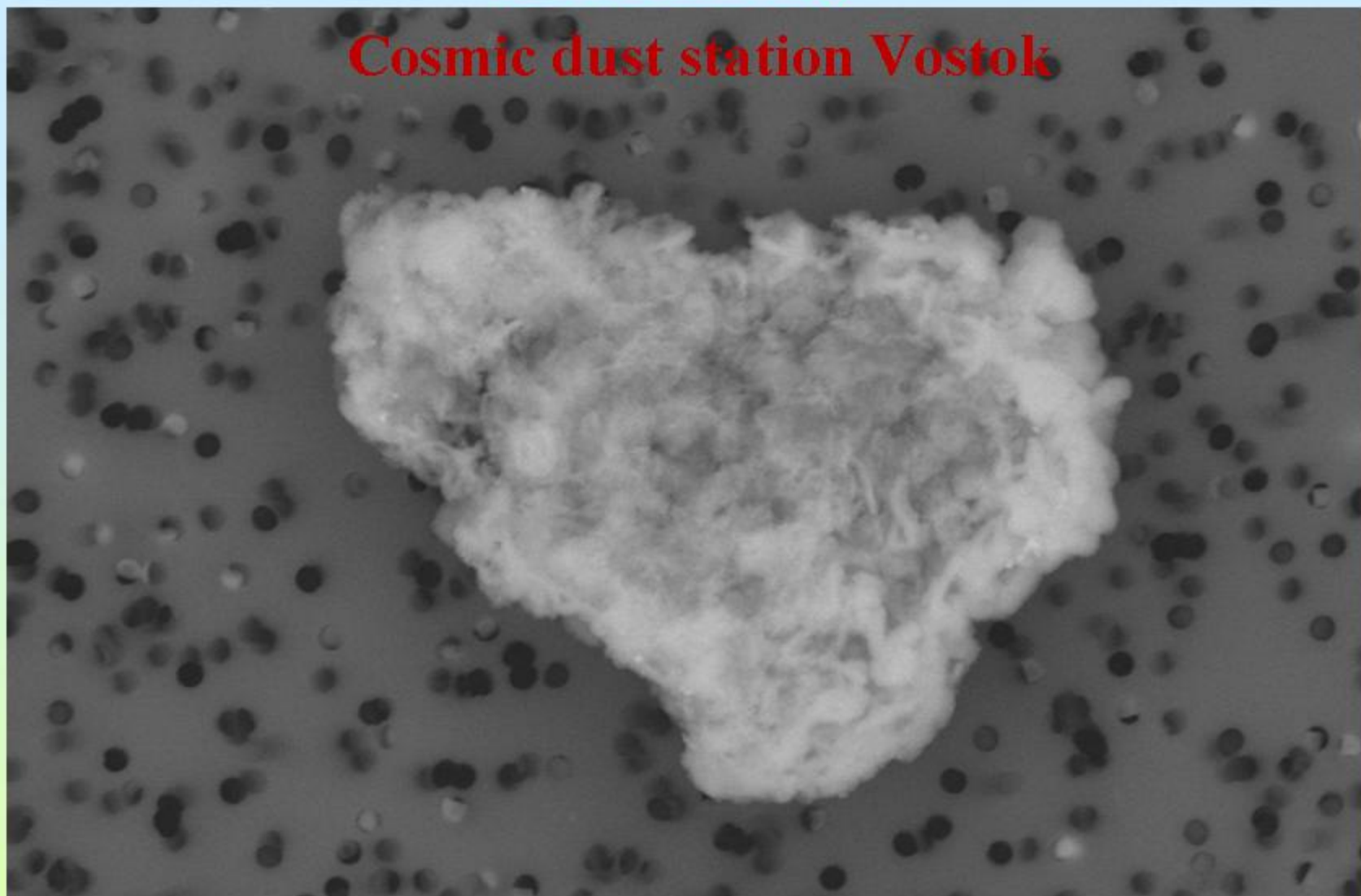
Gatchina-SPb

Concordia **AMM-1** - EDX spectra



Mobile astronomic sun-fed station for collecting cosmic dust by aerosol filtering

Cosmic dust station Vostok



1 μm

Mag = 5.00 K X
EHT = 15.00 kV

Signal A = BSD
WD = 10.2 mm

Grenoble INP - CMTC

Date :26 Jun 2015

Astronomical Study in Antarctica

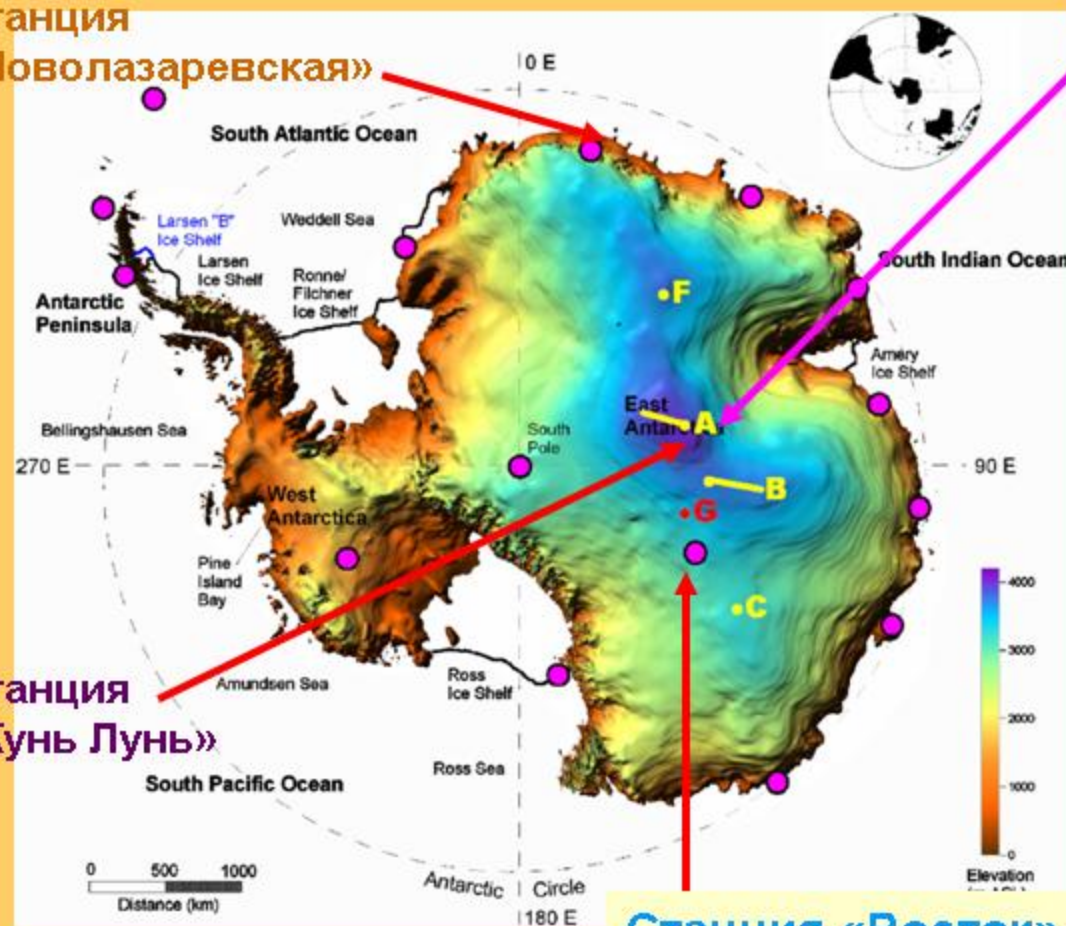
Yury A. Nagovitsyn
Central astronomical observatory
at Pulkovo of RAS



The best place

Самое сухое, холодное и безветренное место на Земле

Станция
«Новолазаревская»



Станция «Восток»

«Фотографии звездного неба с Хребта «А» должны быть по меньшей мере в три раза более четкими чем те, что можно получить на самых лучших современных наземных обсерваториях в Чили и на Гавайях» -

Уилл Саундерс

Where Is the Best Site on Earth? Domes A, B, C, and F, and Ridges A and B

Will Saunders, Jon S. Lawrence, John W. V. Storey, and Michael C. B. Ashley

Seiji Kato, Patrick Minnis, and David M. Winker // 2009 Publ. of the Astron. Society of the Pacific

The project of the renewed National Service of the Sun

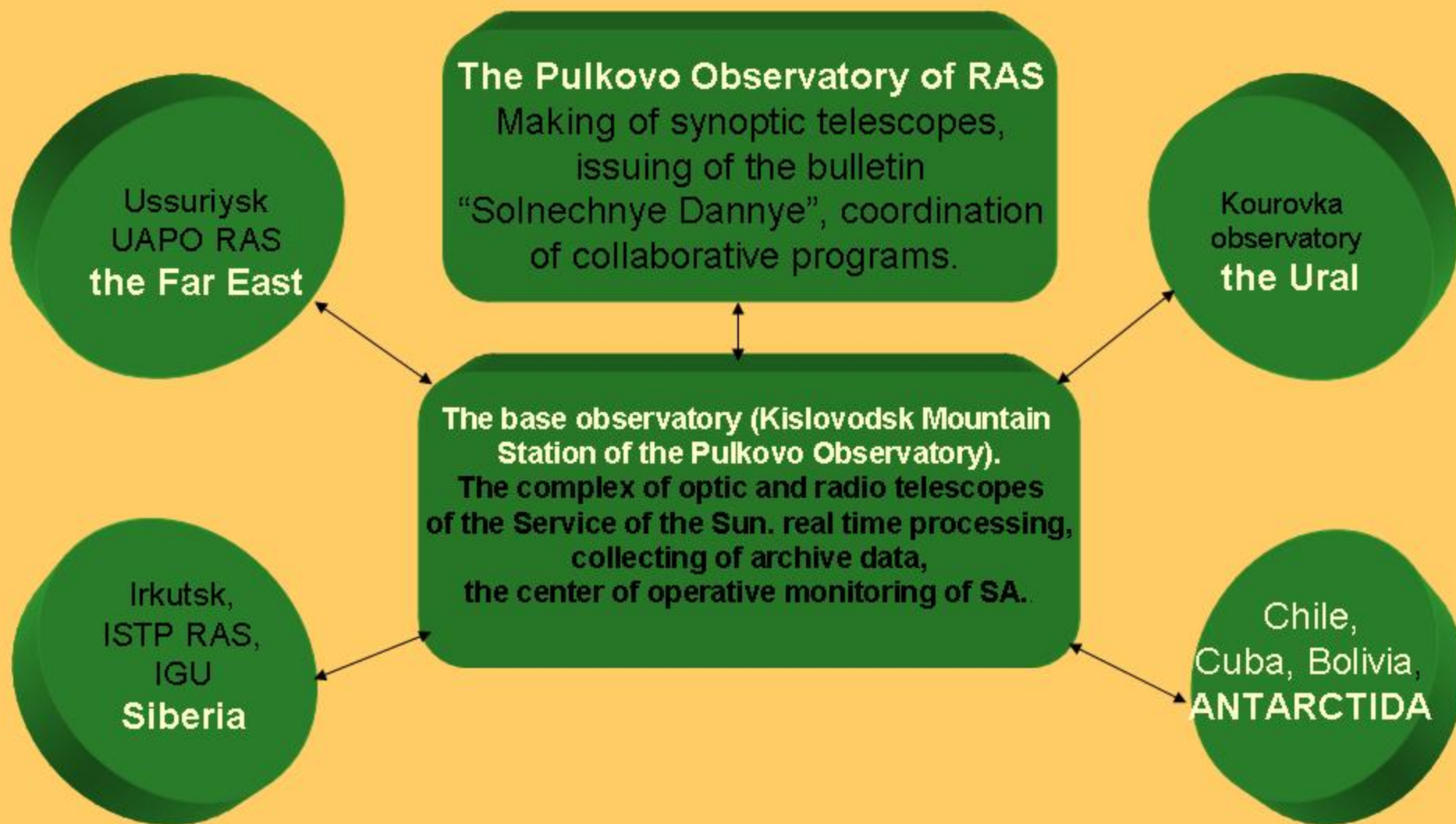
Geographic positions of stations of the Service of the Sun in the RF



Outside of the RF: El Roble (Chile), El Cacaual
(Cuba), Tarija (Bolivia), Antarctica

The project of the renewed Service of the Sun

Structure of the new Service of the Sun





*Thank you for
attention