Новости с **озера Восток** в Антарктиде

С.А. Булат
(ФГБУ «ПИЯФ», Гатчина)

indescribable

Elusive microbial life at the uppermost water layer in subglacial Lake Vostok, East Antarctica

Sergey Bulat*

CryoAstrobiology group/labo

FSBI PNPI, NRC Kurchatov Institute

Leningrad region, Gatchina, RU

*Russian-French GDRI consortium

RUB from RFBR, RossHydroMeth

GDRI consortium

- **PNPI FSBI, St Petersburg, RU**
  - **Sergey Bulat** - PI
- **AARI FSBI, St Petersburg, RU**
  - **Vladimir Lipenkov** - PI
  - Valery Lukin – logistics
- **VNIIOceangeologia, St Petersburg, RU**
  - German Leitchenkov
- **LGGE CNRS-UJF, Grenoble, FR**
  - **Jean Robert Petit - PI**
  - Michel Legrand (DOC)
- **Université de Bretagne Occidentale, Brest, FR**
  - Mohamed Jebbar
- **Station Biologique de Roscoff, Roscoff, FR**
  - **Dominique Marie**
- **Ecologie Microbienne UCB-Lyon I, Lyon, FR**
  - Philippe Normand

Main BIO

INMI, Moscow

LTHE, FR
Jean Martins

Culturing
Microscopy

Cell counts

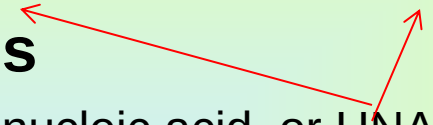
Repetition
Culturing

Life around us?

Searching for extraterrestrial life is one of the aims of astrobiology, and there are several potentially habitable worlds in the Solar System, in addition to Earth. Two of Jupiter's moons (Ganymede and Europa) and two of Saturn's moons (Titan and Enceladus) harbour **liquid-water oceans**. And Mars probably had vast liquid-water environments during much of its early history.

Lazcano 2012 Nature 488: 160-1

Pinheiro et al 2012 Science 336_341-344 **Six new xeno-nucleic acids (XNAs) capable for Darwinian evolution and folding into defined structures**



Anhydrohexitol nucleic acid, or HNA amongst others: CeNA, LNA, ANA, FANA and TNA

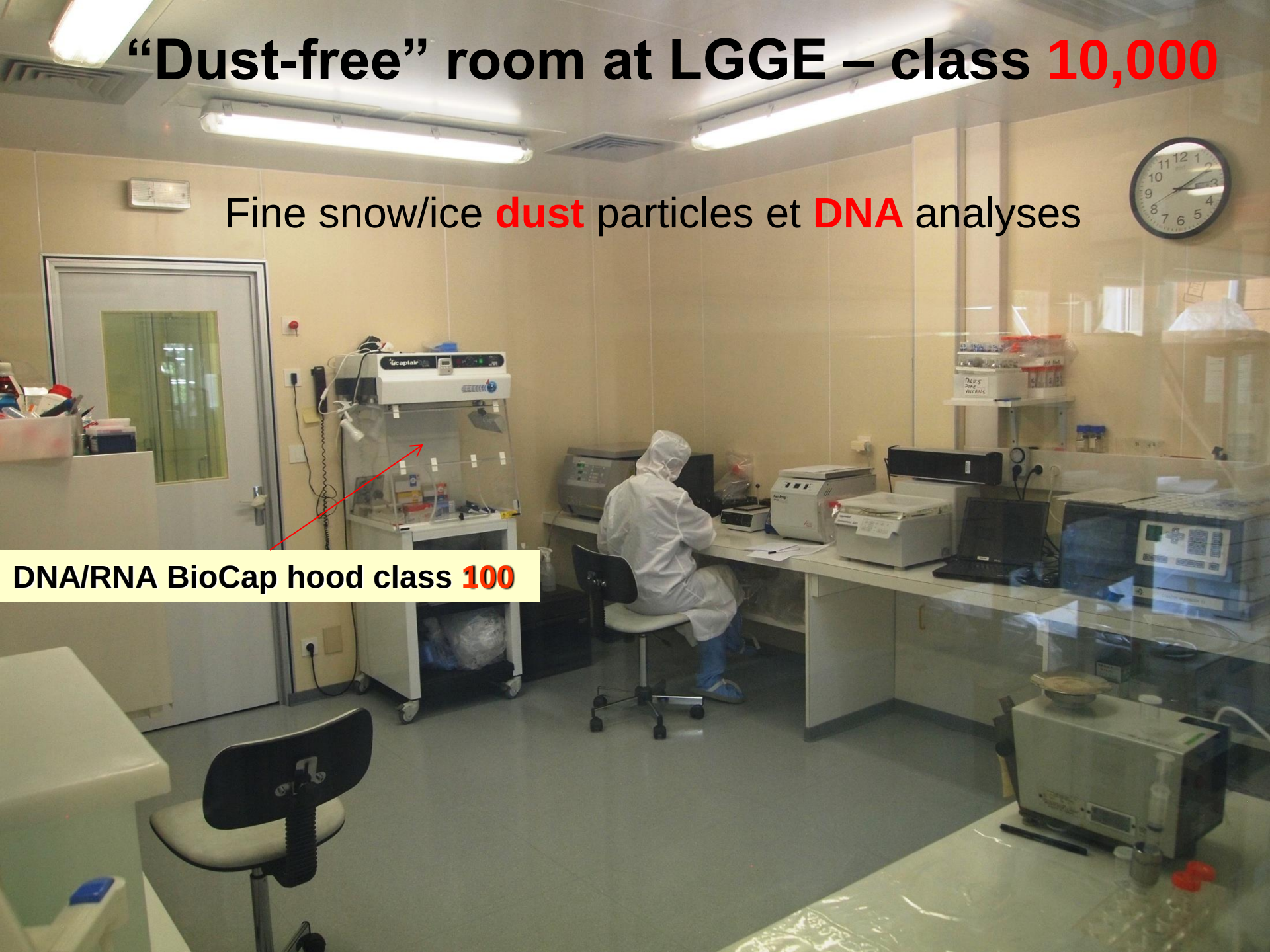
Working on Earth-known microbial DNA/RNA

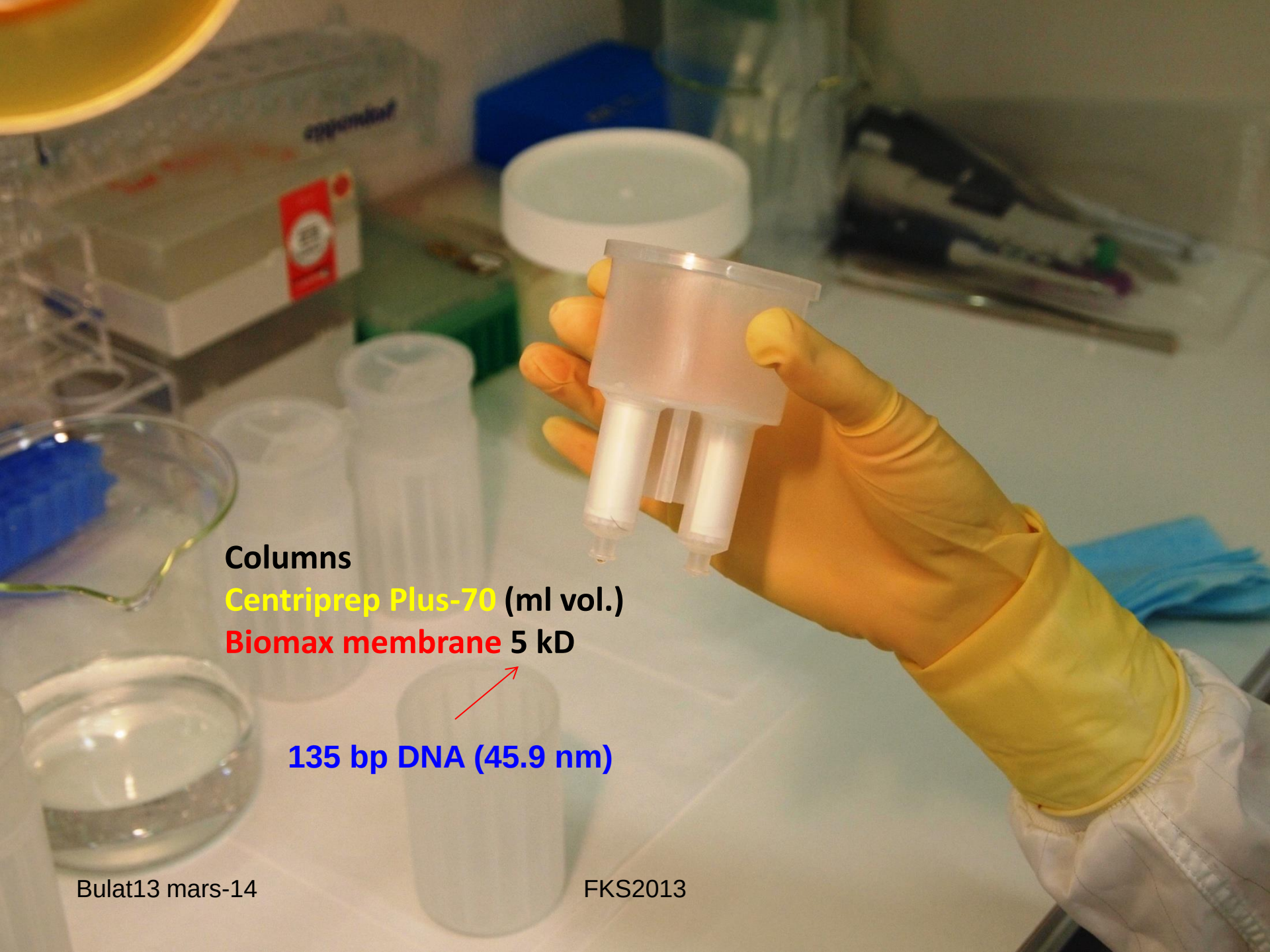
4 primary nucleotides based on: cytosine, guanine, adenine and thymine - C, G, A, T

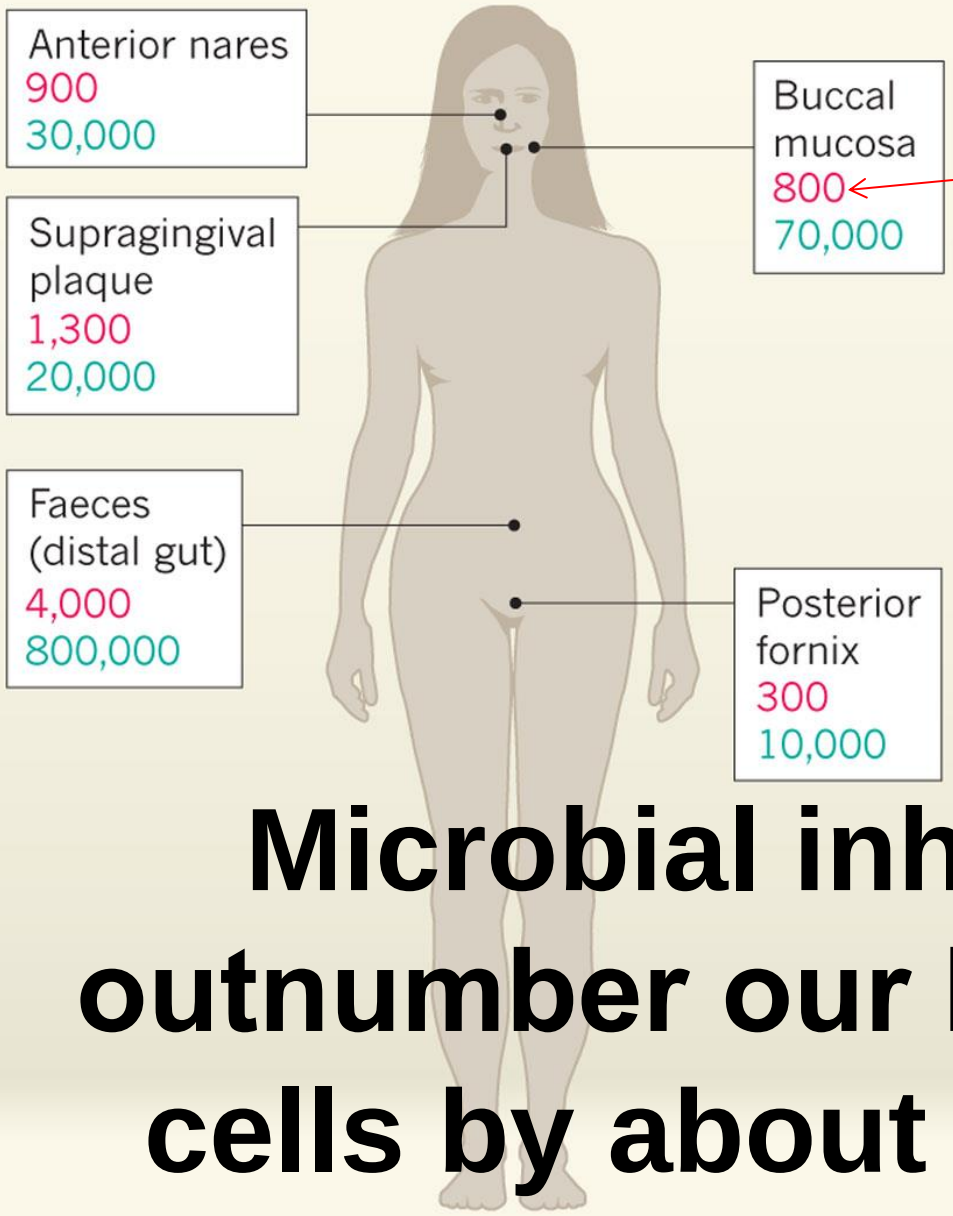
GenBank sequence database

“Dust-free” room at LGGE – class 10,000

Fine snow/ice **dust** particles et **DNA** analyses




Columns
Centriprep Plus-70 (ml vol.)
Biomax membrane 5 kD
135 bp DNA (45.9 nm)



Number of microbial **species** (red)
Number of microbial genes (blue)

Microbial inhabitants outnumber our body's own cells by about ten to one

Relman 2012 Nature 486_194-5

Vostok ice for Biology

REQUIREMENTS:

- Comprehensive **Biological controls**
  - Sham/mock DNA extraction
  - Negative PCR
  - Ice core wash water
  - Lab Environment (dust)
  - Vostok drill fluid
  - Outer-core (optionally)

235 seqs **Fev 2013**

Contaminant databases

Vostok ice for Biology

REQUIREMENTS:

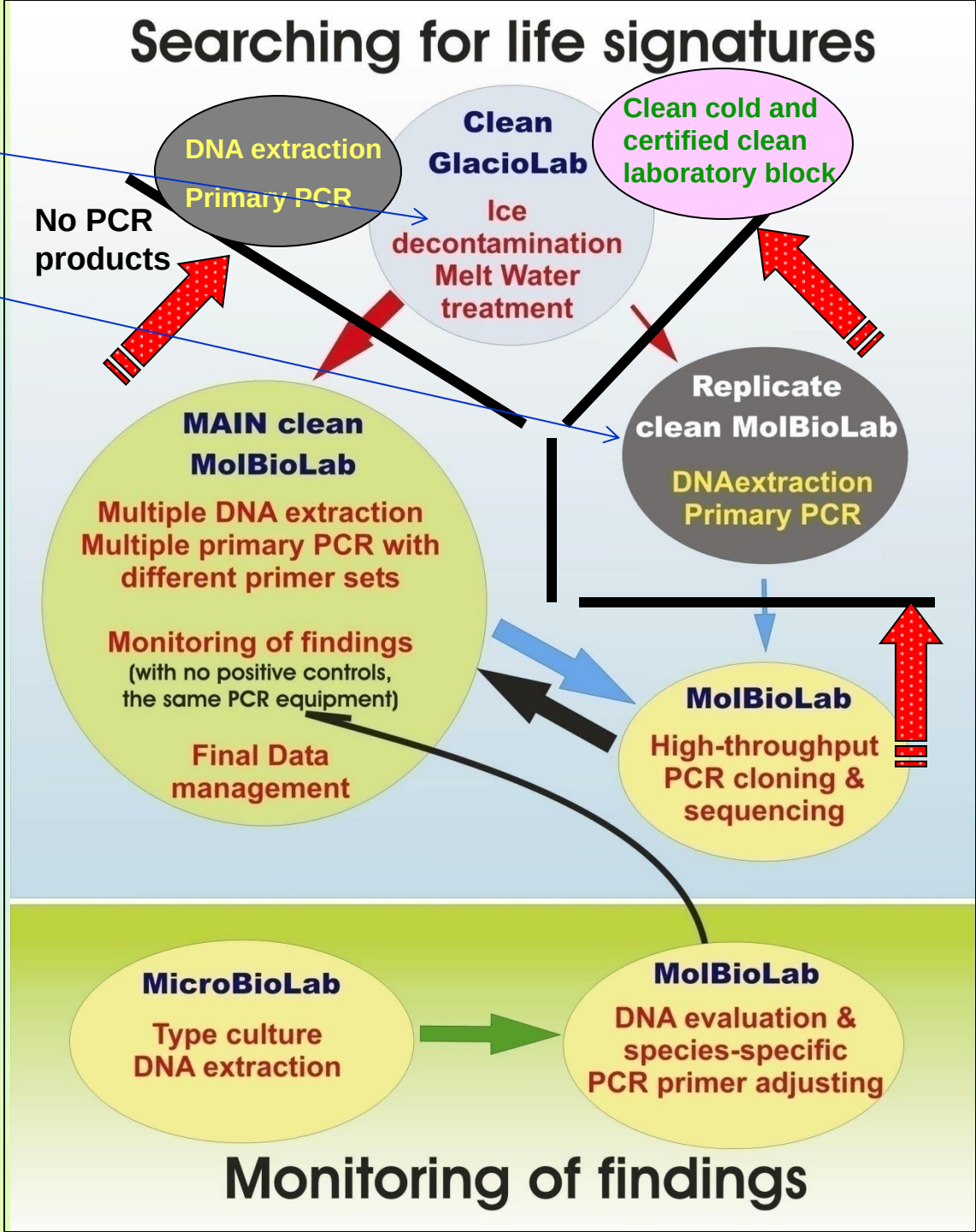
- **Authentication** of findings **by ecology** (environmental conditions)

"Everything is everywhere, but, the environment selects"
– Baas Becking, 1934

Gatchina – PNPI?

Dubna – JINR?

A **framework** for biological studies adopted for Lake Vostok



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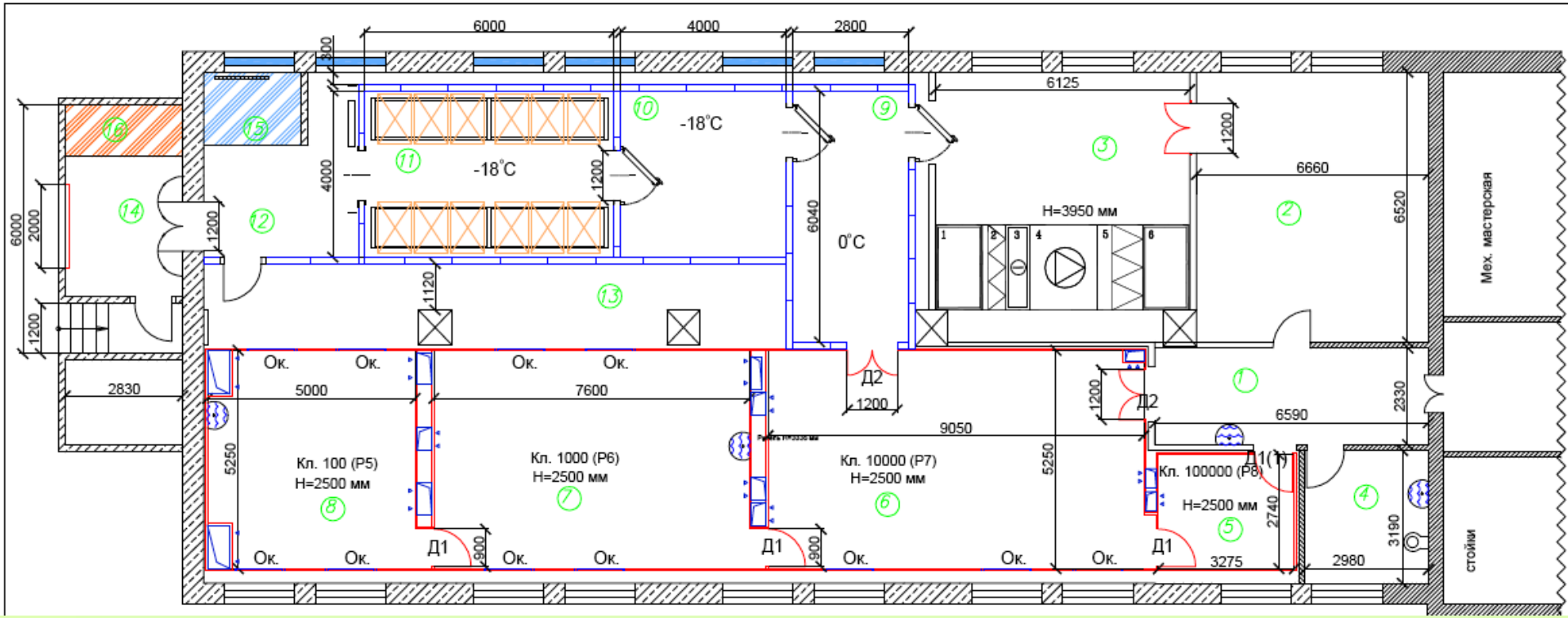
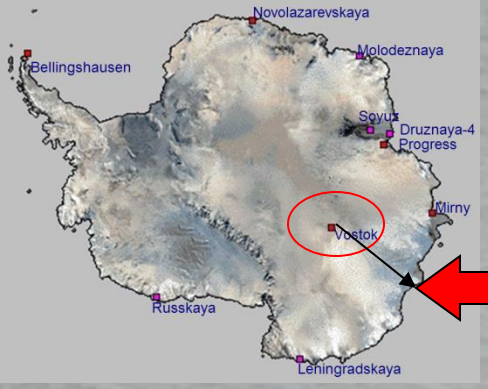
PNPI NRC Kurchatov Inst Gatchina

clean et cold rooms astrobiology laboratory





Vostok station (+3488m)

(78°S, 106°E) **(since 1957)** 67 kPa – 67% oxygen

1260 km from the coast

RADARSAT, CSA

Absolute minimum -89.2°C
Average ann. Temp. -55.1°C

Lake Vostok (-3663m)

Vostok SURFACE

SNOW

Vostok Surface snow

(0 – 130m **up to 4 Kyr**)

Below 3m the snow is pristine

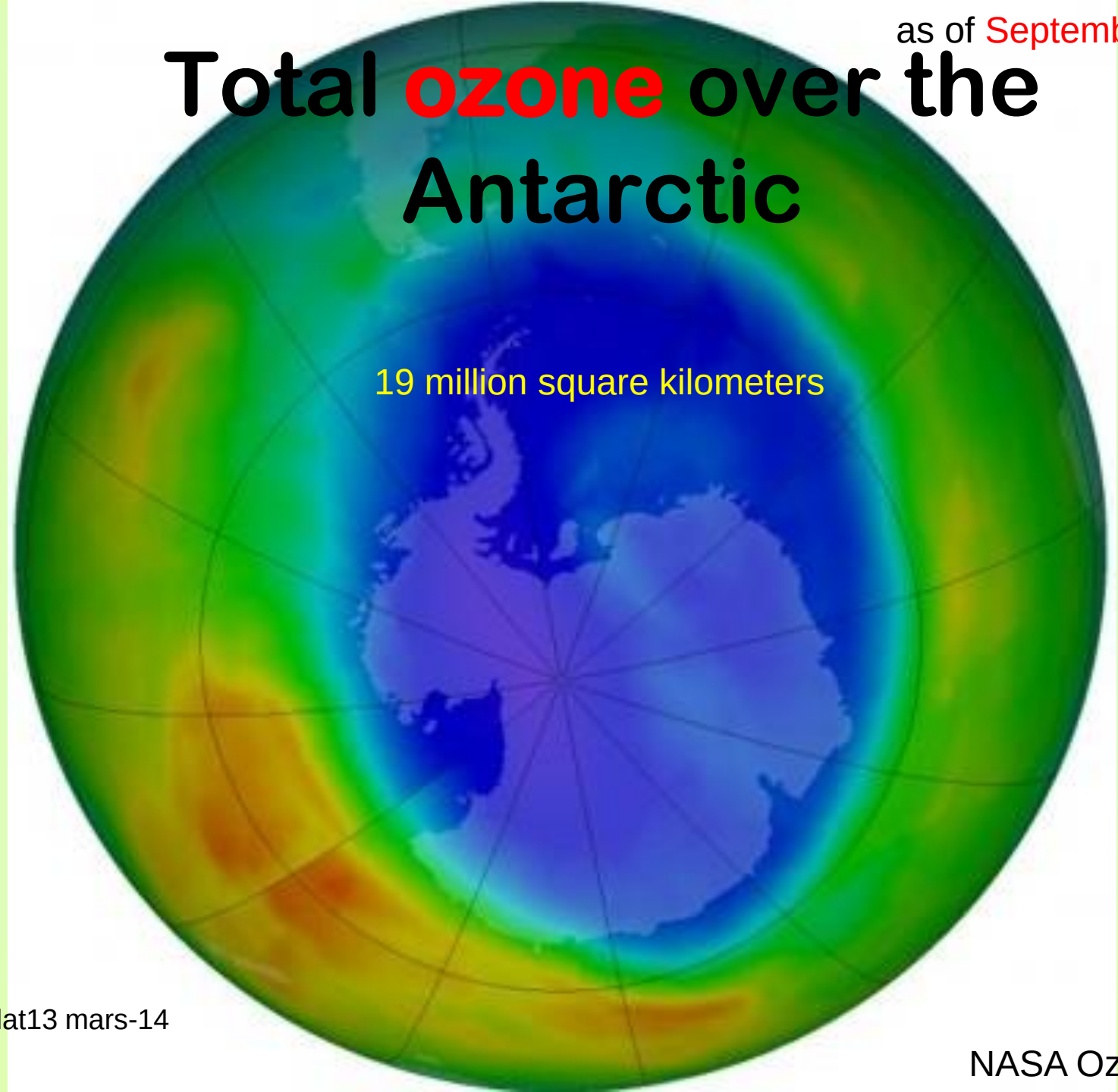
Very clean 'life-hostile' environ

NO FREE (only BOUND) WATER!

- Low accumulation – **2.1-2.4g /cm^2/a**
- Low Aeolian dust input (**6-6.5 cm/a – snow / needles!**)
  - **2 µm** mode; **10-15** ppb (summer time)
- Harsh **irradiation (UV-B, C etc.)** **('ozone hole' – Aug-Nov)**
  - + Water-Oxygen → **free radicals**
  - **Oxidized organics** (photochemical reactions at ice-air interface)
- Low **freezing temperatures** – below **-36°C** (**-55.1°C** ann.)

as of September 11, 2012

Total ozone over the Antarctic



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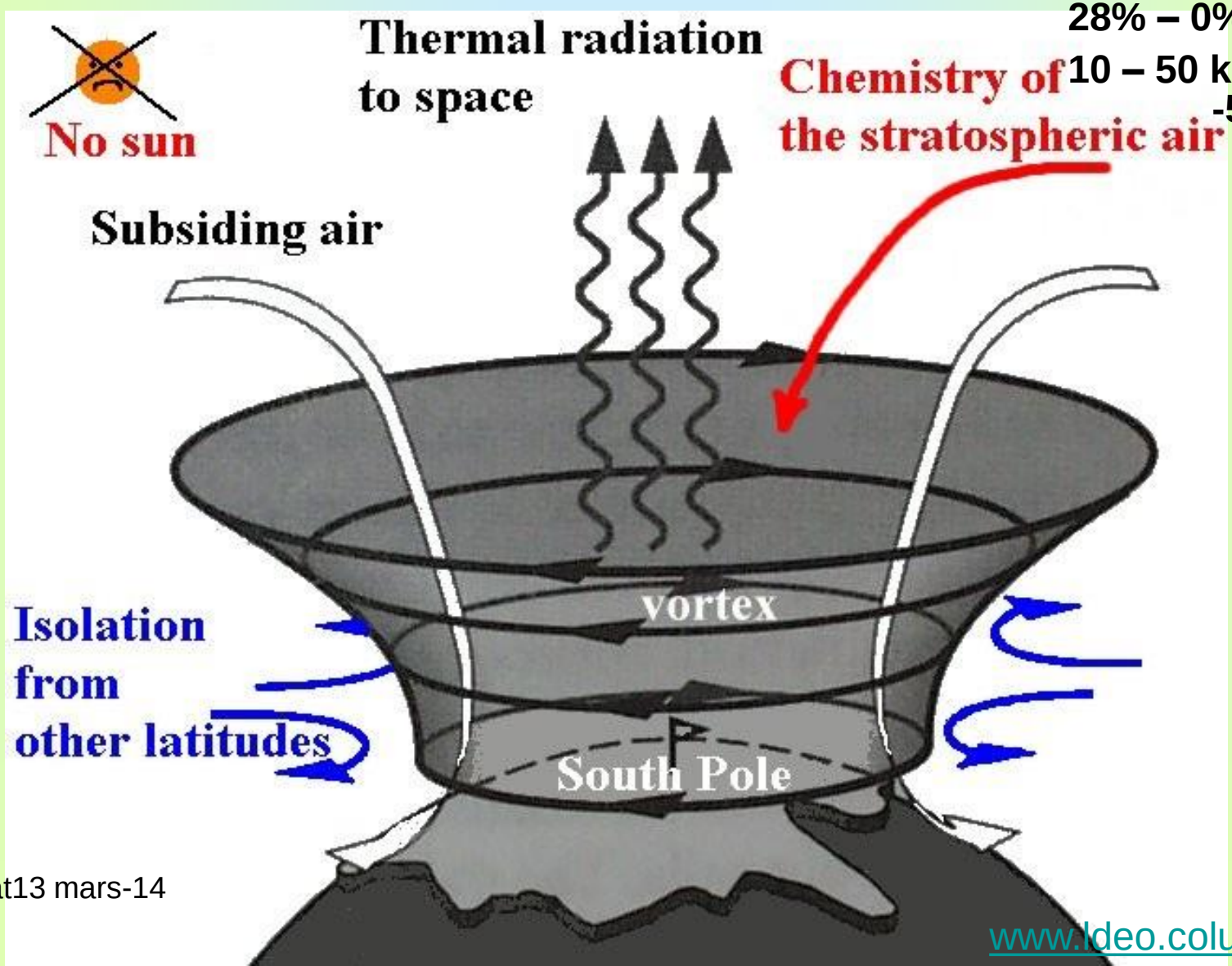
NASA Ozone Watch

May – August
at Vostok

Antarctic polar vortex effect

28% – 0% oxygen
10 – 50 km
-57 – 0°C



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www.ldeo.columbia.edu

Vostok MEGA- et Colossal-snow 2011

Snow **drifts** by wind for max. **10 km** distance

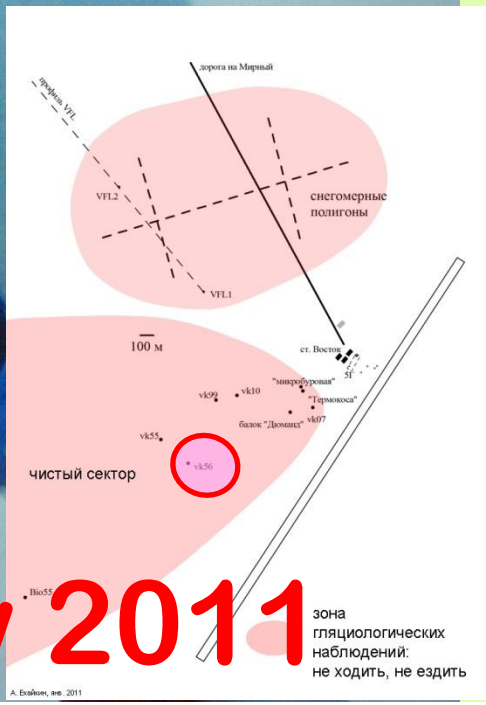
Отбор проб снега для геохимических и биологических исследований

CS11 (78,4722S, 106,7796E)
(VostokCollossalSnow2011 *(RAE 56)*

Программа исследований 3-м шурфа:

1. Стратиграфия
2. Космическая пыль (20-см)
3. Биология (20-см)
4. ^{10}Be (3-см)
5. Основные ионы (3-см)
6. Дейтерий и кислород-18 (3-см)
7. Бета-радиоактивность (5-см)

ОК!



Trouble!

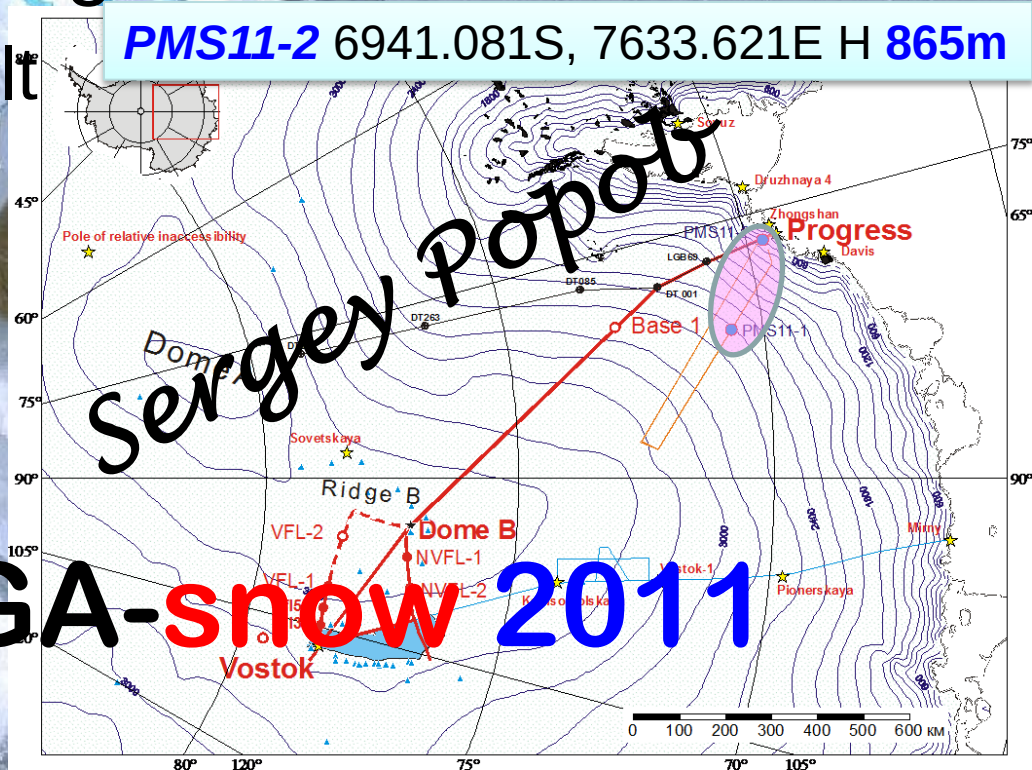
Vostok Colossal-snow 2011

Courtesy of A. Ekaykin et al (RAE56)

- **216km** from coastal Progress – **PMS11-1**
  - Crate 23L → **8.6**L melt
- **29km** from coastal Progress – **PMS11-2**
  - Crate 23L → **7.6**L melt

PMS11-1 7034.925S, 8124.103E H **2376m**

PMS11-2 6941.081S, 7633.621E H **865m**



Vostok MEGA-snow 2011

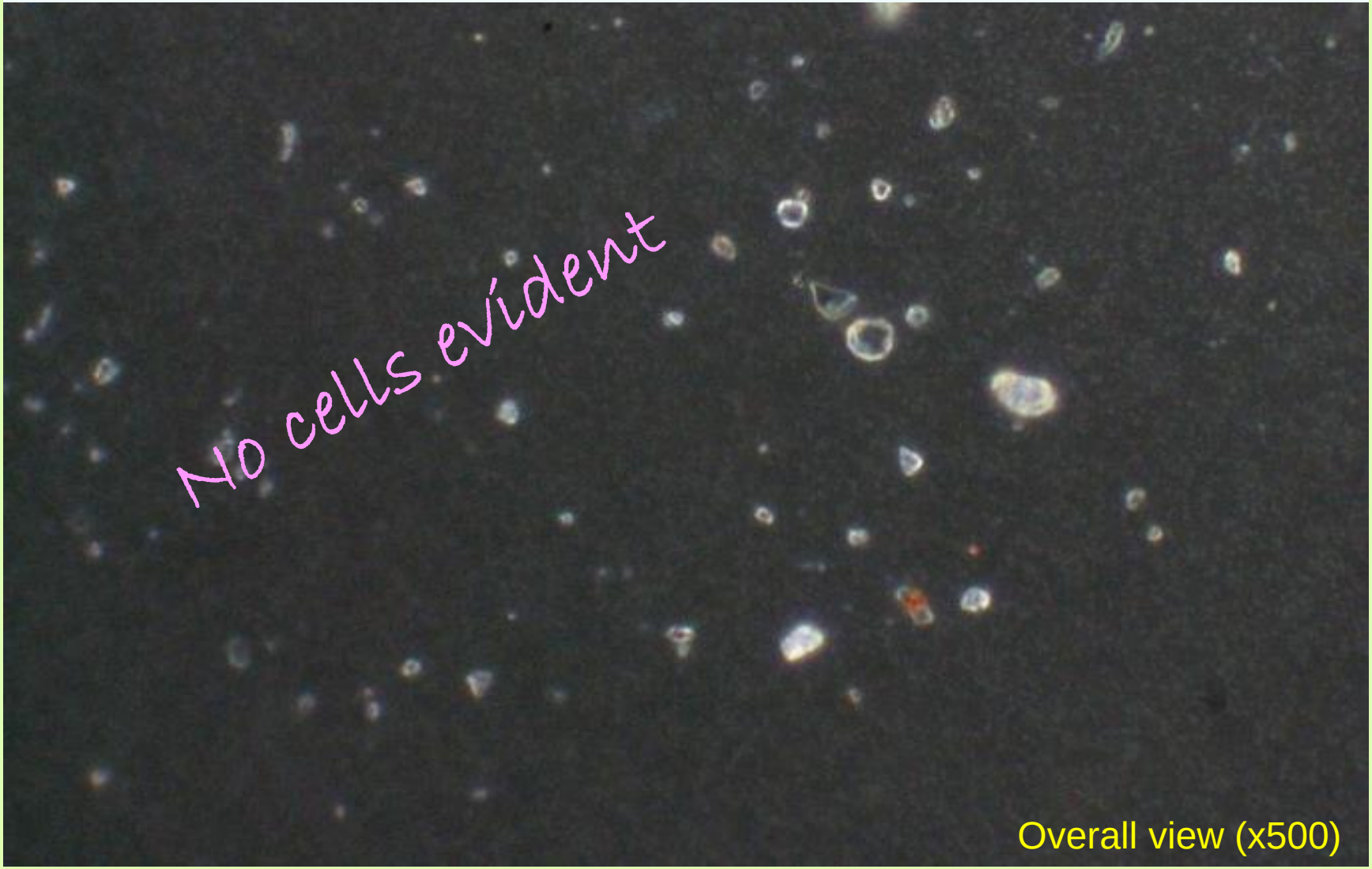
Метод Electrical Sensing Zone (Coulter counter, Beckman, США)

Vostok MEGA- et Colossal-snow 2011 - *RESULTS*

Dust particle counts

Sample	N/g	M/g (ppb)	Masse(0.8-2)	Masse (2.2-5)	Mass >5
Vivendi ELGA-26	1347	7.63	2.79	4.30	0.00
Ultra-pure water	577	1.45	1.45	0.00	0.00
	3549	**9.2**	7.28	1.17	0.00
PMS11-1	4821	12.14	9.09	2.27	0.00
216 km Progress	5375	**16.19**	10.45	4.11	0.00
PMS11-2	4933	**14.6**	10.22	3.29	0.00
29 km Progress	4241	11.8	8.80	2.00	0.00
	3811	10.7	7.90	1.86	0.00
CS11-15 **Vostok**	3643	11.94	7.52	3.41	0.00
2.8-3.0 m deep	3754	**13.13**	7.93	4.07	0.00

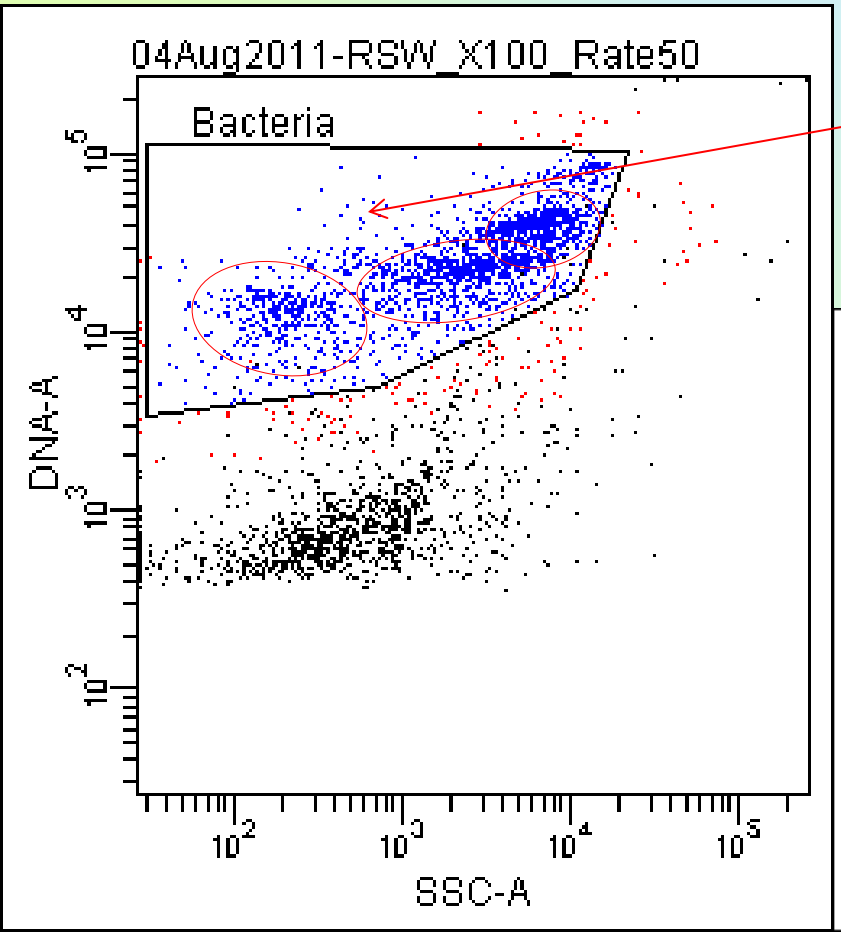
CS11-15 – light microscopy
OLYMPUS BH-2

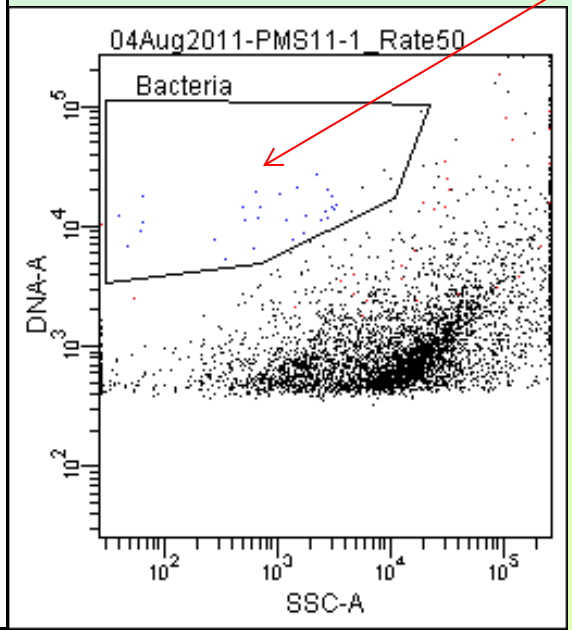


Vostok MEGA- et Colossal-snow 2011 - *RESULTS*

Cell counts

Sample	Bacteria / ml
Roscoff sea water	30961
PMS11-1 - 216 km Progress	45
PMS11-2 - 29 km Progress	0
CS11-15 Vostok - 2.8-3.0 m deep	0





Vostok MEGA- et Colossal-snow 2011 - *RESULTS*

PCR - phylotypes

Sample	Bacteria / ml
PMS11-1 - **216 km Progress**	**45**

V4-v8 16S rDNA amplicon sequencing →

HA-Pseudomonas sp (*alpha-proteo*) **- 80%**

99% *Ewingella americana* (*gamma-proteo*, *Enterobact.*)

Bradyrhizobium sp(elkani) (*alpha-proteo*)

Clinical specimens including wound, sputum, urine, stool, blood etc.
Sources of infection – domestic air conditioning units, ice baths etc.

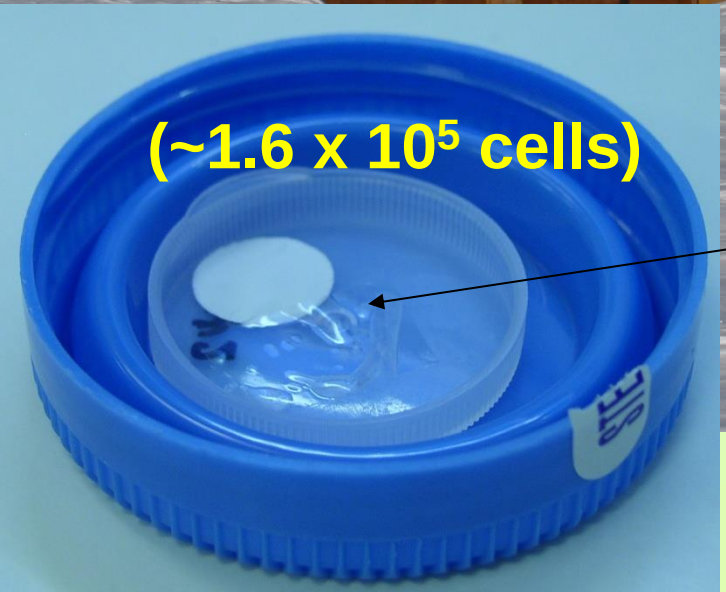
Vostok Contaminant Library
Human Normal Microbiome

Pre CONCLUSION

- **Vostok** [even 29km from coast!] **SURFACE snow contains a few(?) cells / ml - NO CELL populations [lifeless]**

Background contamination?

Vostok SURFACE solar RADIATION



(~1.6 x 10^5 cells)

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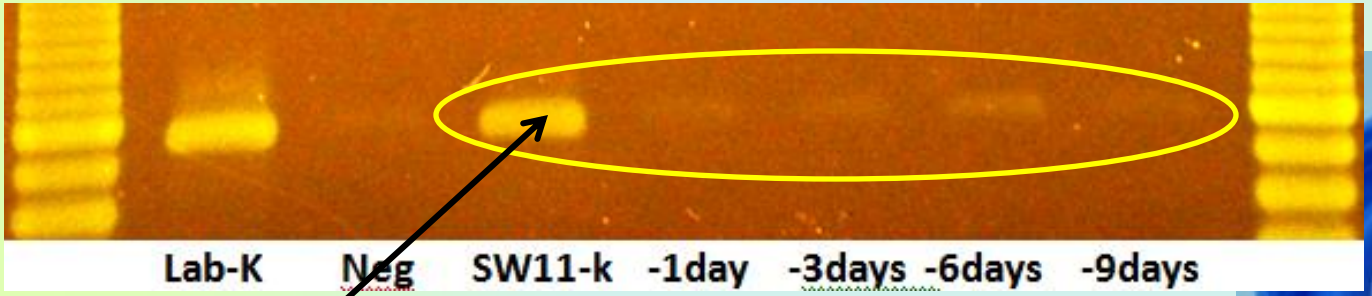
Summer (January) 2008:
exposure during one month

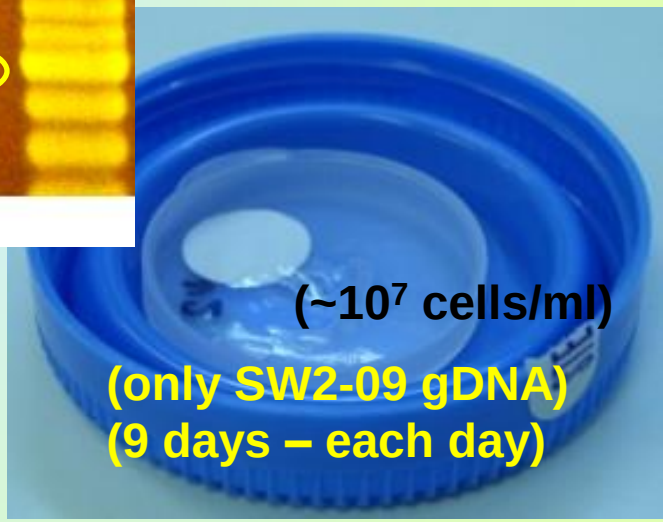
BIO-EXPOSURE 2011

BIO-EXPOSURE 2011



No exposure at Vostok

RESULTS



No signals

(v4-v8^{890bp}, v3-v5^{590bp}, v6^{170bp} reg. 16S rDNA) even in one[1st] day!

CONCLUSION

Intensive solar (UV-B?) radiation

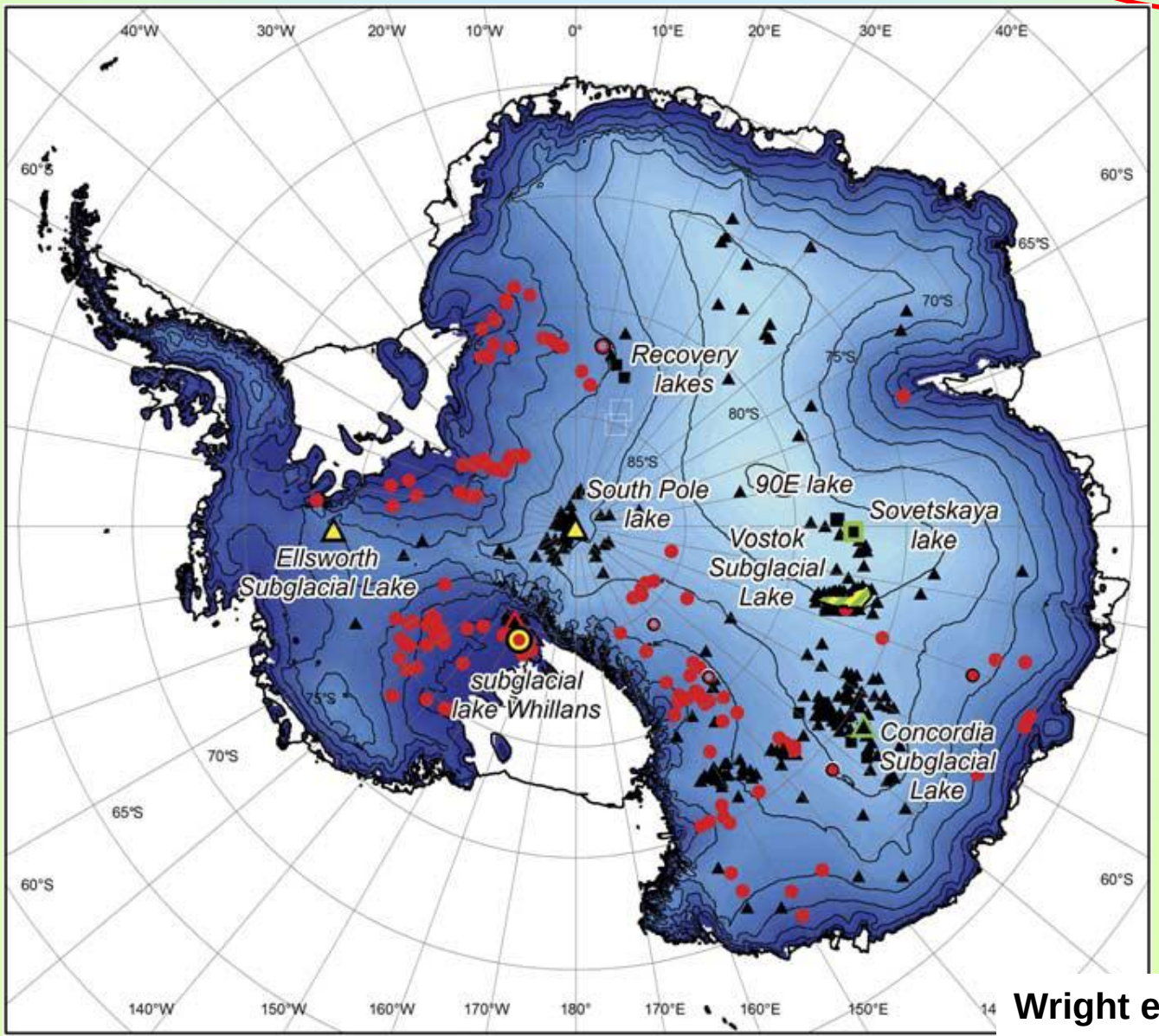
as effective cell/DNA ‘killing’ factor?

Arctic et Antarctic **PERMAFROST**
bioExposure trial in a progress

Vostok ICE CORE

Towards the subglacial Lake Vostok

SALE Subglacial Antarctic Lake Environments - 379



Wright et Siegert , 2012

RADARSAT, CSA

Lake Vostok known since 1994

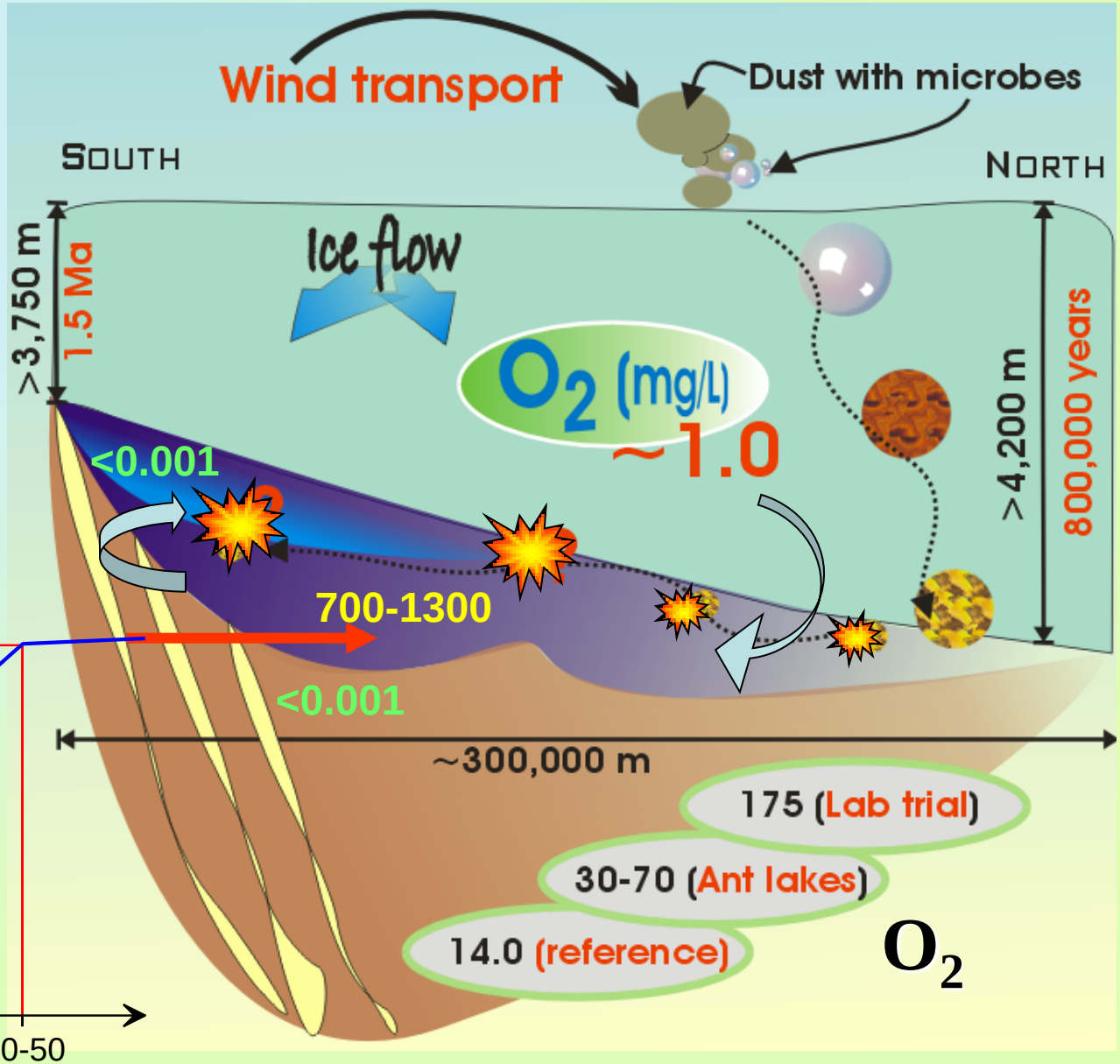
Published in ***Nature*** (**Kapitsa et al., 1996**)

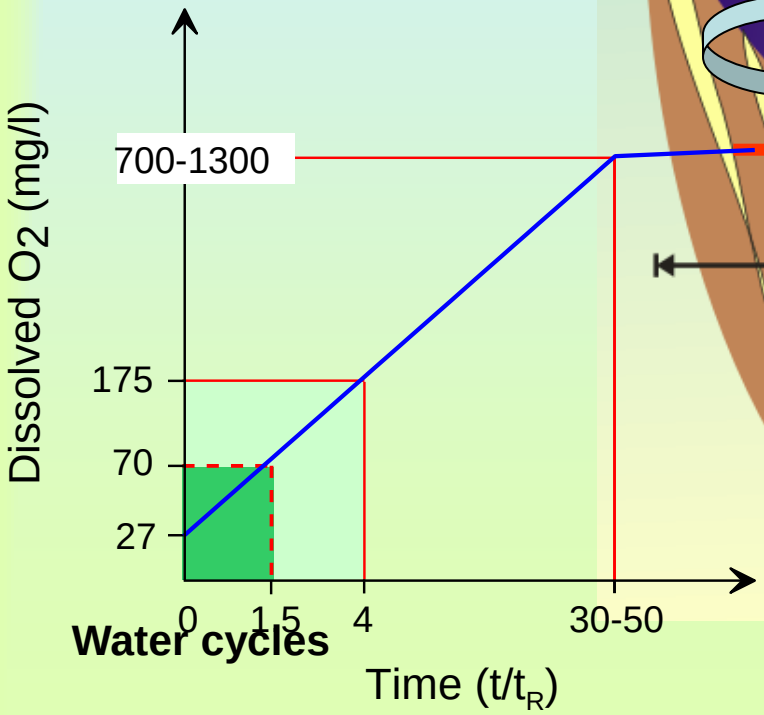
Friendly environment?

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)

OXYGEN in lake water





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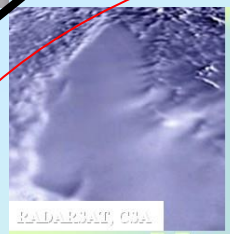
No life

ISOLATED



Lake Vostok known since 1974

Much less hostile environ?

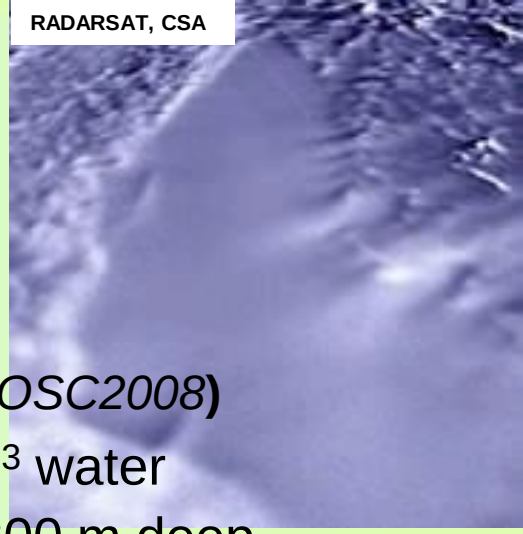
FREE (LIQUID) WATER!

- Deeply ice buried
- High pressure
- Permanently BUT not very cold – -2 /-3°C
- Likely oxygen supersaturated

FRIENDLY ENVIRON?

May host life

Bulat13 mars-14

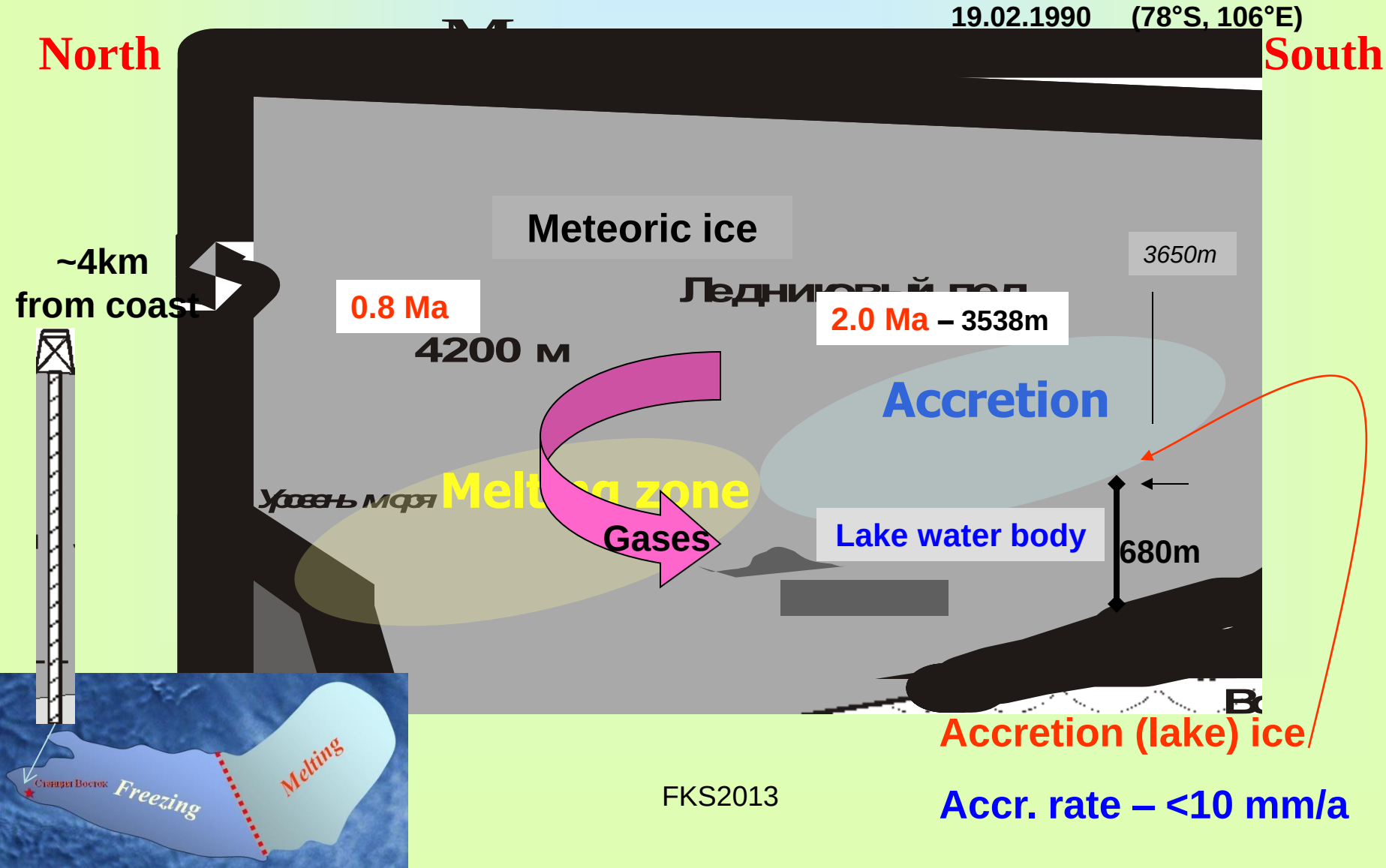


Lake Vostok settings

- **Huge** subglacial lake (*Masolov et al., SCAR OSC2008*)
  - **275 x 65** km in size; **15 500** km^2 area; **6 100** km^3 water
  - **Two main basins** with the ridge between 150-200 m deep
  - Average depth - **300** m; max depth – ~**1650** m (south basin)
  - Water renewal – **80-100** Kyr
- **Buried** beneath 2.0-0.8 Myr old **3750-4200** m thick ice sheet
- **Isolated** from surface biota for >**14** Ma
  - Age of water (melted ice) - ~**1 Ma**
- **No hydrological links to other lakes**

2.0-0.8 Ma years old

Vostok ice core



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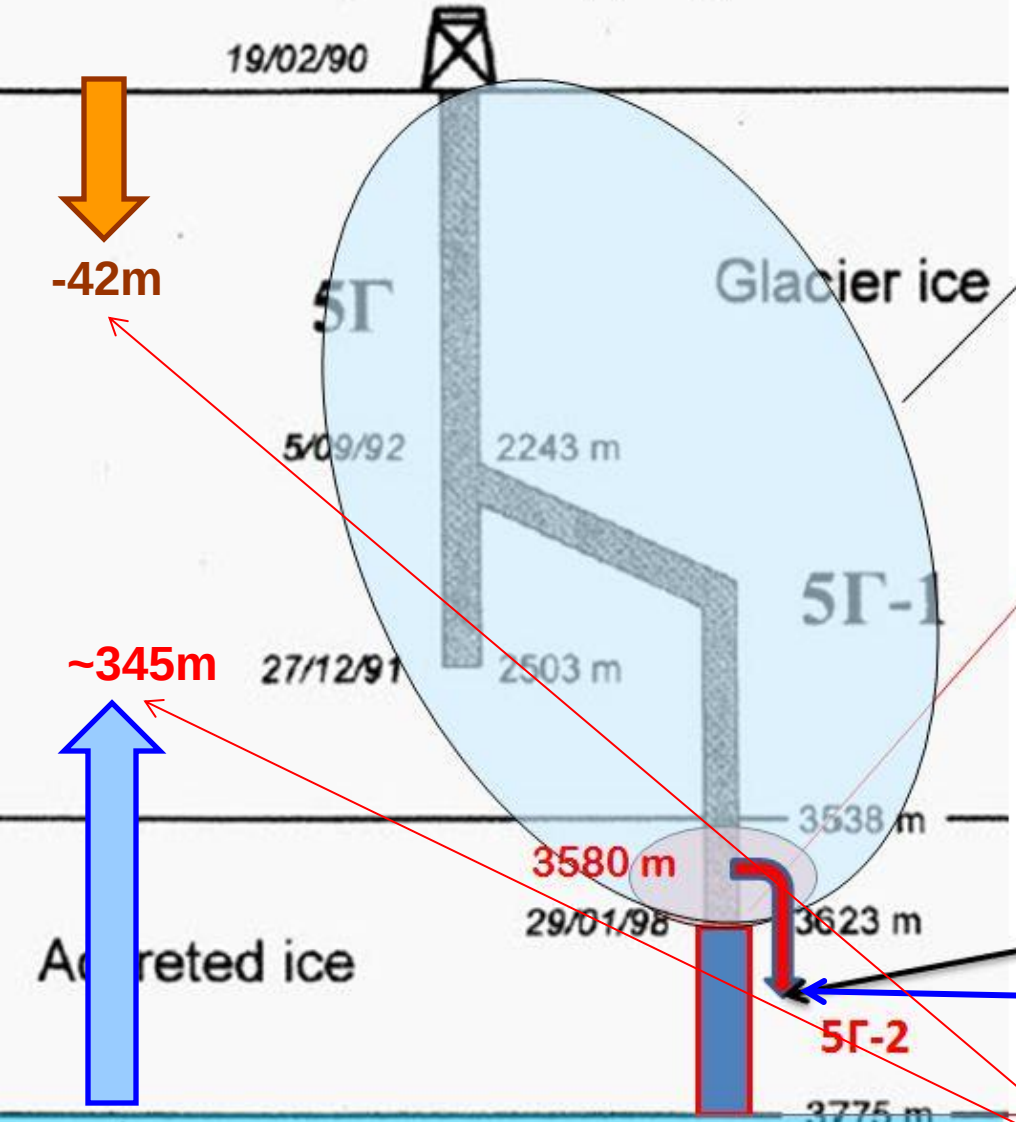
5G-1[2] Vostok borehole



Russian-French-US collaborative program of Deep Drilling and Ice Core Study at Vostok station

Each party obtained 1/3 part of core

... **stopped for almost 8 years**

3650 m – 2005/06

3659 m – 2006/07

3667 m – 2007/08

3599 m – 2008/09

3650 m – 2009/10

~80m

30m left!

3720 m - Jan 21, 2011

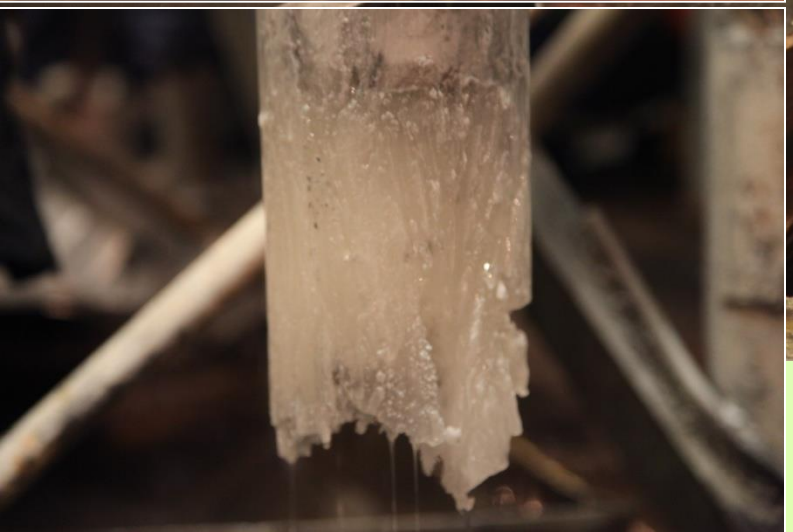
3750 m – ice-water boundary

Enter!

3769.3 m – Fev 05, 2012


3769,30 m
3768,m

Lake water frozen



FKS2013

We believe

Whatever we find

It’s going to be special stuff, unique stuff, life forms we’ve never encountered before

Accretion ice BIO features

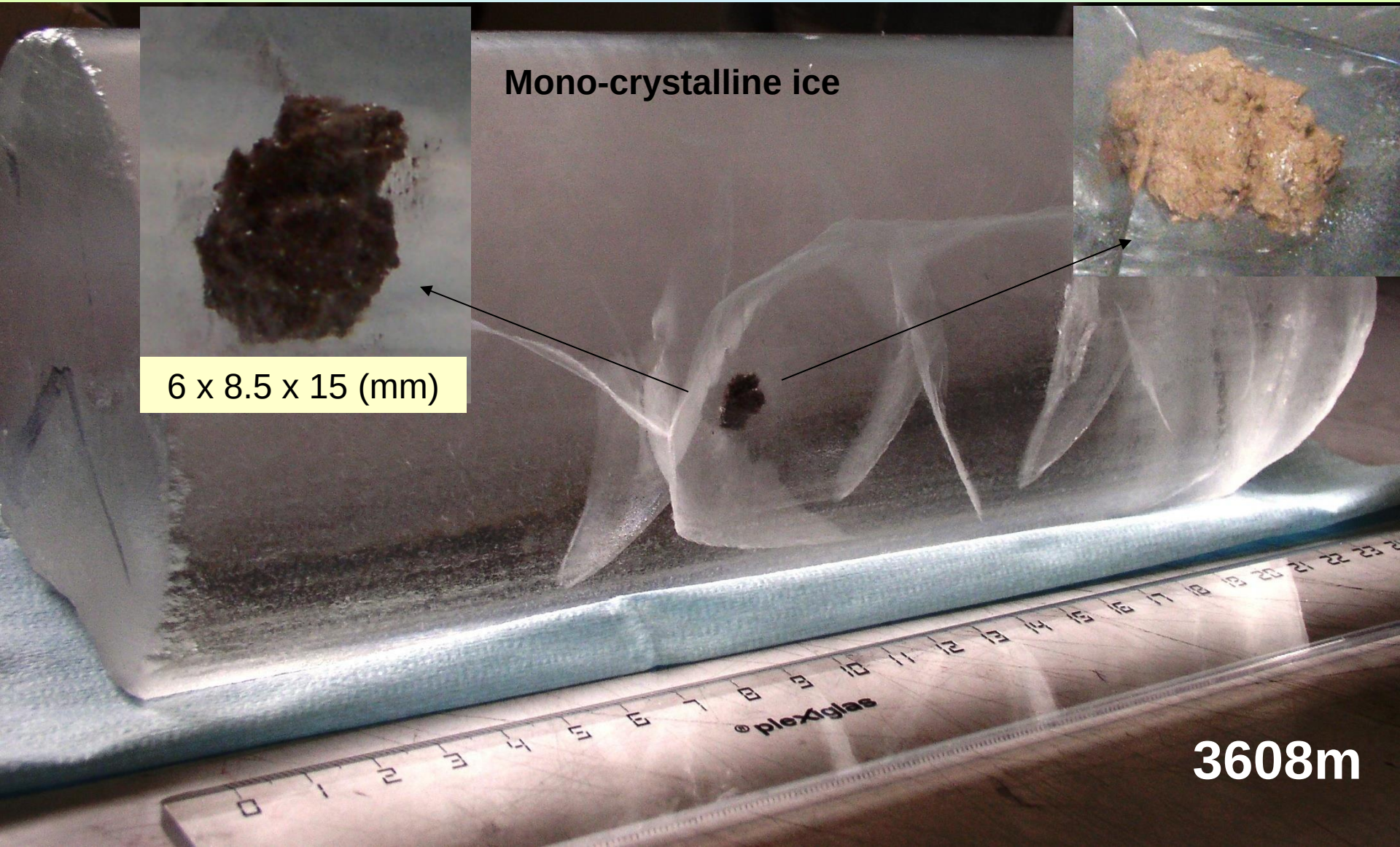
Accretion ICE	GAS contents	DOC (ppbC)	Major ions*
TYPE 1 Sediments	Low (10^{-2}) CO_2, CH_4, O_2	10 ± 9	Mg^{2+} Ca^{2+} SO_4^{2-} (S^{2-}) (no NH_4^+, nitrate)
TYPE 2 Very clean	Very low (10^{-3}) (no O_2, CH_4)	5.6 ± 4.6	- (no NH_4^+, nitrate)
Conditions	Low aerobic Anaerobic	Ultra-Oligotrophic No heterotrophs	No e-donors? (Hydrogen?)

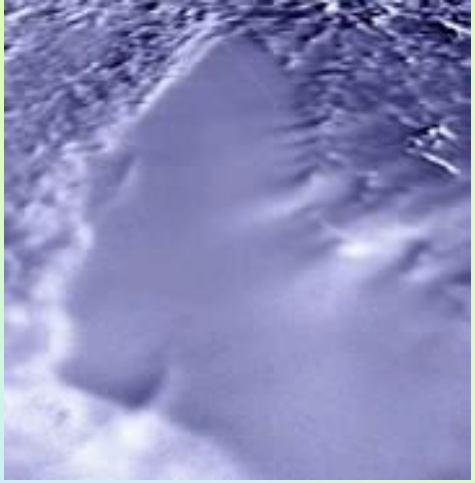
NO GAS

NO DOC

Many oligotrophic lakes have DOC's in the range of 100 to 500 ppb

3608BK - Big ‘Kamina’





Microbes in lake water

‘Oxygenophilic’(?)

Earth-unknown !

chemolithoautotrophic

piezophilic psychrophiles

Superoxide, hydrogen peroxide, singlet O, hydroxyl radicals etc. vs. carotinoids, catalase, superoxide dismutase etc.

Bacterial metabolic pathways Accretion ice type 1 et water

E-donor	E-acceptor	Carbon	Process	Microbes
H_2	SO_4^{2-}	CO_2	Sulfate reduction (H_2S)	*Sulfate-reducers*
H_2	O_2 (in mineral inclusions)	CO_2	Hydrogen-oxidation	*Hydrogen-oxidizers*
H_2	CO_2	CO_2	Methanogenesis (CH_4)	*Methanogenic archaea*
S^{2-} S^0 In mineral inclusions	O_2 (NO^{3-})	CO_2	Sulfur oxidation (SO_4^{2-} - acidic)	*Sulfur-oxidizers*

RECALL: Gas content is very low - 0.001 vs. 0.1 g/cm^3

RESULTS

Bacteria in Vostok ice core et drill-frozen water

as of March 2013

Vostok cells/phylotypes (16S rRNA - v2-v5 reg.) - SUMMARY

Ice type	Sample (m)	Cells/ml	(% Similarity with closest sequence in GenBank)
Snow (50 yr)	4.0-4.3	0–0.02	Contaminants
Glacier	122	1.9	
4.5 - 760 kyr	2005	2.4	
	2054	3–24	
	3471	1-4	
	3489	0	
	3504	1-5	
	3519	0-1	Contaminants
Accretion I	3547	0	Contaminants
30 – 40 kyr	3548	1	Contaminants
	3561	4–9	Contaminants + thermophile
	3607	ND	Thermophile (92%) Uncultured bacterium (410 bp, AF532061) ???
	3607-re	1	
	3608BK-re	ND	(95%) *Ilumatobacter fluminis* (526 bp, NR_041633) Actino
	5G2-3608	0	Contaminants
Accretion II	3613	3	
0 – 30 kyr	3621	2	
	3622	0.6	
	3635	4.7	
	5G2-3646	0	Contaminants
No more water pockets	3650	3.1	
	3650	4777	→ untreated surface
	3659	12	
	5G2-3714	0	
	5G2-3764	0	
Lake water	5G2-water* w2ori	167	Refer to below

99-100% - *thermophile Hydrogenophilus thermoluteolus* β-Proteo

?

99% - glacier sediment

Sulfate-reducing **bacteria**
Hydrogen-oxidizing bacteria
Methanogenic archaea
Sulfur-oxidizing **bacteria**

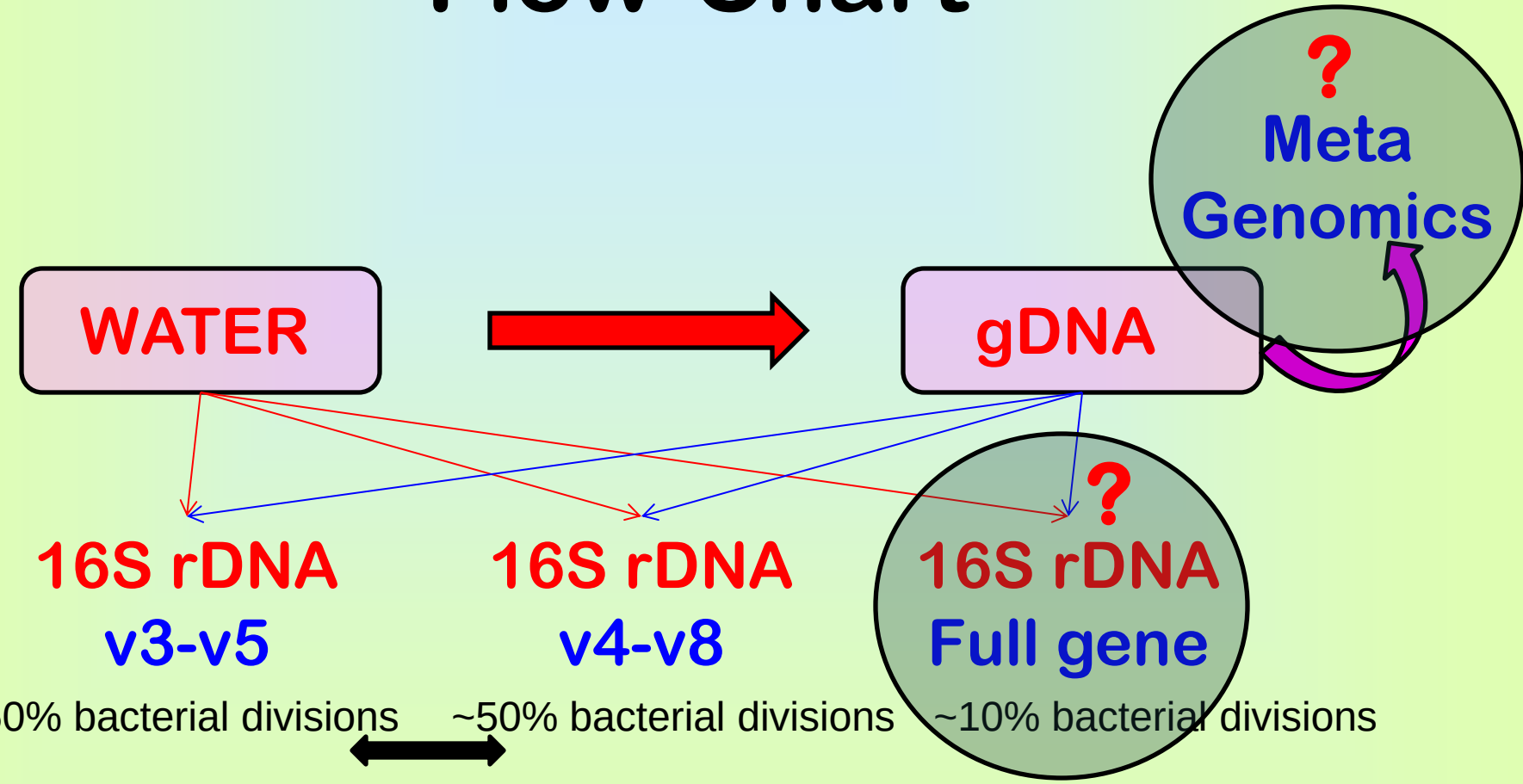
•Lake water frozen on a drill bit

Bulat et al., 2004; 2012)

Bulat13 mars-14

Water-DNA/PCR

Flow-Chart



Discovered in 'technological' lake water – mars 2013

2 identical clones – **100% *Microbacterium sp* (*ginsengisoli*) (soil, plant roots) or *Microbacterium sp* (aliphatic hydrocarbon-contaminated soil) – *Actinobacteria***

1 clone – **99% *Sporosarcina sp*. SS16.7 (coastal see sediments of King George Island, Antarctic) while can be met elsewhere –** surface **lake water** (*Sporosarcina saromensis* - An et al., 2007), **clinical** samples and even as contaminants in **clean room** facilities (*Sporosarcina contaminans* - Kampfer et al., 2010) **– *Firmicutes* (Bacillales; Planococcaceae)**

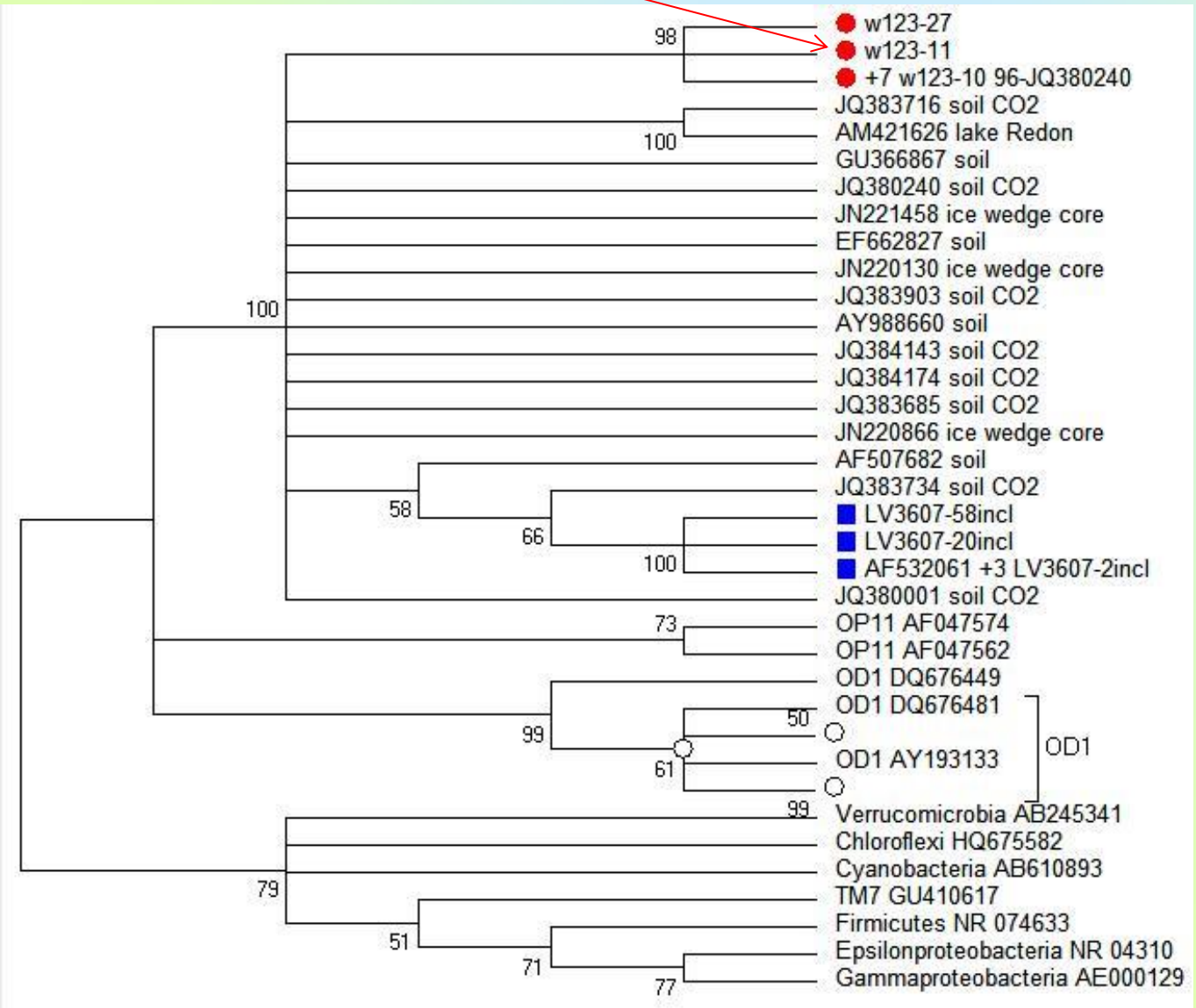
22% (7 clones) – w123-10 et al <86% OD1 – *???*

3 allelic vars

Lake ice II 3607m	**(92%) Uncultured bacterium (410 bp, AF532061)**

Bulat et al., 2004; 2012)

22% – w123-10 et al <86% OD1 – ???



Maximum Likelihood
- 369 sites

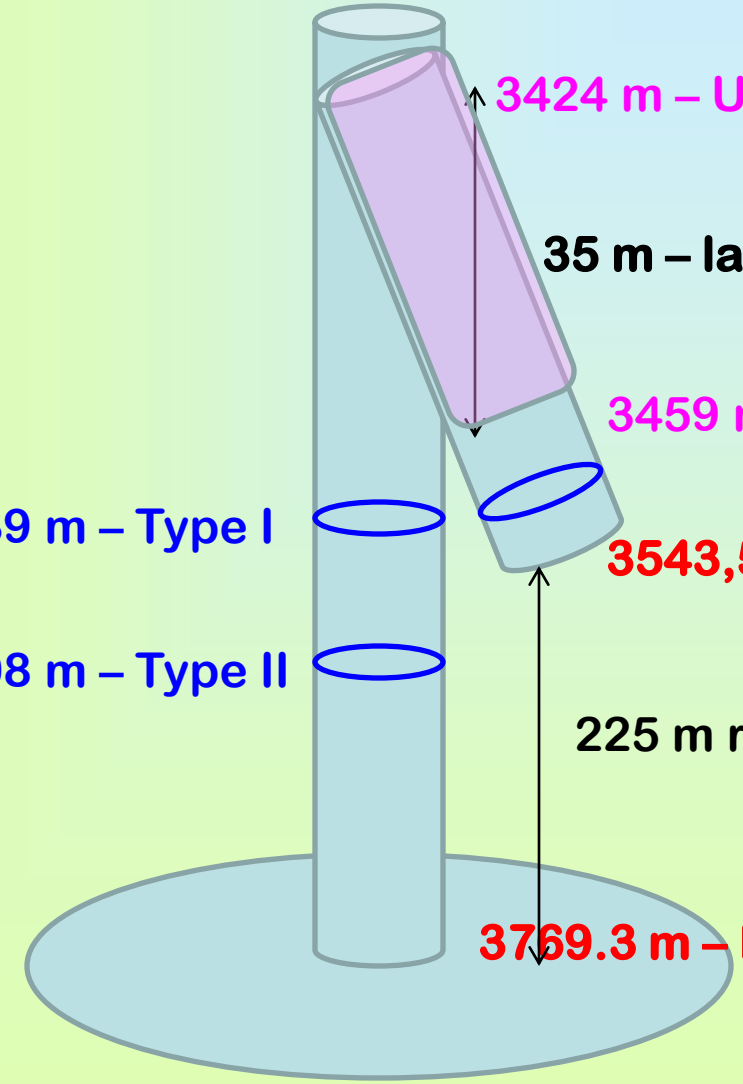
Preliminary CONCLUSION

Seems there is **UNKNOWN LIFE** (population) **in upper layer of Lake Vostok water (frozen on a drill)**

Support may come with full-gene sequencing

Proof may come late May 2013

5G-2[3] Vostok borehole fev 28, 13



3424 m – Uppermost frozen water ice

35 m – layer of frozen lake water

3459 m – Bottommost frozen water ice

3539 m – Type I

3543,56 m – Fev 2013

3608 m – Type II

225 m remained to drill – 2013/2014 season?

3769.3 m – Fev 05, 2012

Clean Vostok frozen water ice

Yu Chetverikov courtesy

SEVEN DAYS *The news in brief*

RESEARCH

Life in Lake Vostok

Russian scientists say that they have found a hitherto-unknown type of bacterium in Antarctica's largest subglacial lake. Samples retrieved last year from Lake Vostok contain an "unclassified" bacterium whose DNA is less than 86% similar to known bacteria, Sergey Bulat of the Petersburg Nuclear Physics Institute in Gatchina announced at a meeting last week in Moscow. More tests and cleaner samples are needed to establish the physiology and biochemistry of the microbe, says Bulat. See go.nature.com/ydcmw4 for more.

CIRO DE LUCA/INFOPHOTO/PHOTOSHOT

Rebuilding Naples' City of Science

The Italian government has pledged €20 million (US$26 million) to help rebuild the City of Science (*Città della Scienza*), an iconic 12,000-square-metre exhibition centre and science museum in Naples that was destroyed by fire on 4 March (pictured). Italy's research minister, Francesco Profumo, said that the government would work with local authorities on a plan to rebuild the museum in just 18 months. The museum's management is also seeking voluntary donations. Investigators had not announced an official cause for the fire as *Nature* went to press, but they were reported by the Italian media to suspect arson.

Carbon spike

Atmospheric carbon dioxide concentrations rose by 2.59 parts per million (p.p.m.) in 2012, marking the sharpest increase since 1998, according to data from the US National Oceanic and Atmospheric Administration. Atmospheric CO_2 concentrations reflect rising global emissions, driven by developing countries, as well as variations in carbon uptake by plants and the oceans. The global average, calculated from measurements at the Mauna Loa Observatory in Hawaii and other locations, exceeded 395 p.p.m. in January, representing an increase of more than 70% from pre-industrial levels.

Anti-HIV trial

A clinical trial of the preventive powers of the anti-HIV drug tenofovir may have failed because women were not actually taking the drug. In 2011, the VOICE study, in 5,029 HIV-negative women in South Africa, Zimbabwe and Uganda, suggested that neither a vaginal gel nor tablets containing the drug could prevent HIV infection (see *Nature* 480, 10–11; 2011). Even though little unused product was returned, tenofovir was present in fewer than one-third of biological samples from participants assigned to receive it, study leaders revealed last week. Too few women took the drug to assess whether it did prevent HIV infection, although earlier studies have suggested it can work.

Elephant poaching

A surge in ivory poaching has driven the population of African forest elephants down to less than 10% of what could be supported by the available range. Researchers calculate that this species (*Loxodonta africana cyclotis*) lost 30% of its range and 62% of its population between 2002 and 2011 (F. Maisels *et al. PLoS ONE* 8, e59469; 2013). The study was released as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) met in Bangkok; many scientists have urged CITES to clamp down on poaching and habitat destruction and to tackle demand for ivory (see *Nature* 494, 411–412; 2013).

Standard Higgs

The new particle discovered last year at CERN's Large Hadron Collider outside Geneva continues to behave just like the Higgs boson predicted by the standard model of particle physics, according to results presented last week at a conference in La Thuile, Italy. The latest data indicate that the boson decays into τ leptons as predicted, and also dampen earlier hints that the boson decays into pairs of photons more often than the standard model allows. No evidence yet points to theories beyond the standard model, such as supersymmetry (see *Nature* 491, 505–506; 2012).

POLICY

Trading species

Polar bears (*Ursus maritimus*) will not be given increased protection under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), but it looks increasingly likely that several species of shark will. Delegates meeting in Bangkok for the sixteenth CITES conference, which governs the trade in many animals and plants, voted against banning the trading of polar-bear parts.

RESEARCH

Life in Lake Vostok

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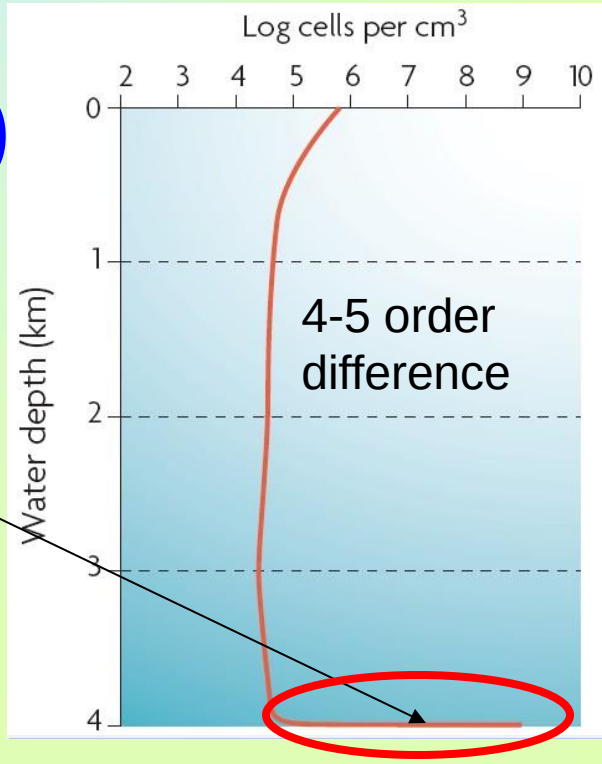
10 years FUTURE DIRECTIONS

- **Rapidly frozen lake water** (within borehole) – 2012/14

- Lake **water column (680m)**
- Lake **sediments (>300m)**



Microbial biomass at BIONTRANS (*Jorgensen and Boetius 2007*)

Subglacial Lake Entry on the Horizon in Antarctica

- Subglacial Lake Vostok, the largest known subglacial lake on earth (**3769.3m-1.5km**)
- Subglacial environments beneath two West Antarctic Whillans ice stream (**800m- 2m**)
- Subglacial Lake Ellsworth, West Antarctica (**3200m-160m**)

- **Fev 05, 2012 – Russia**
- **Jan 27, 2013 – US**
- **2013/2014? - UK**