



Viruses in Permafrost

Jean-Michel CLAVERIE

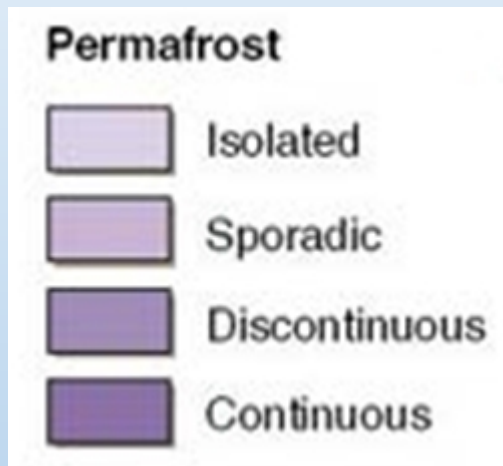
Aix-Marseille University & CNRS

Mediterranean Institute of Microbiology

JM.Claverie@me.com

Understanding and Responding to Global Health Security Risks from Microbial Threats in the Arctic Hanover, nov. 6-7, 2019

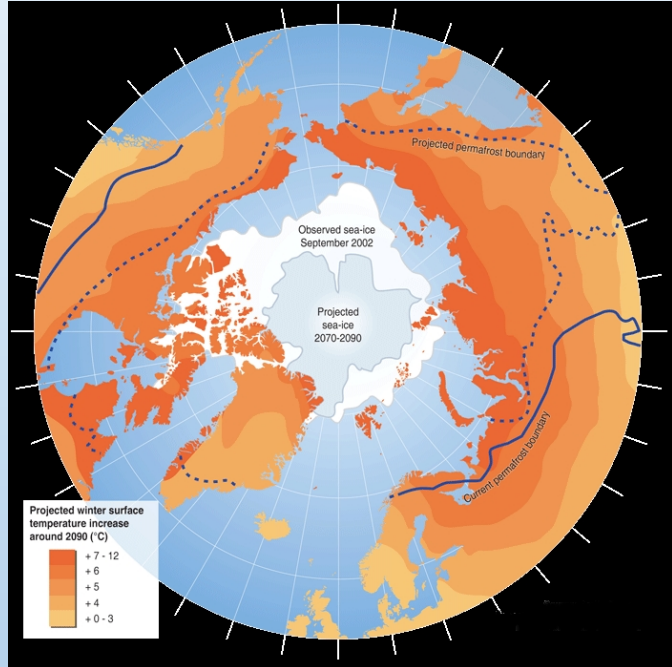
Permafrost: where?



24 % of the north hemisphere.

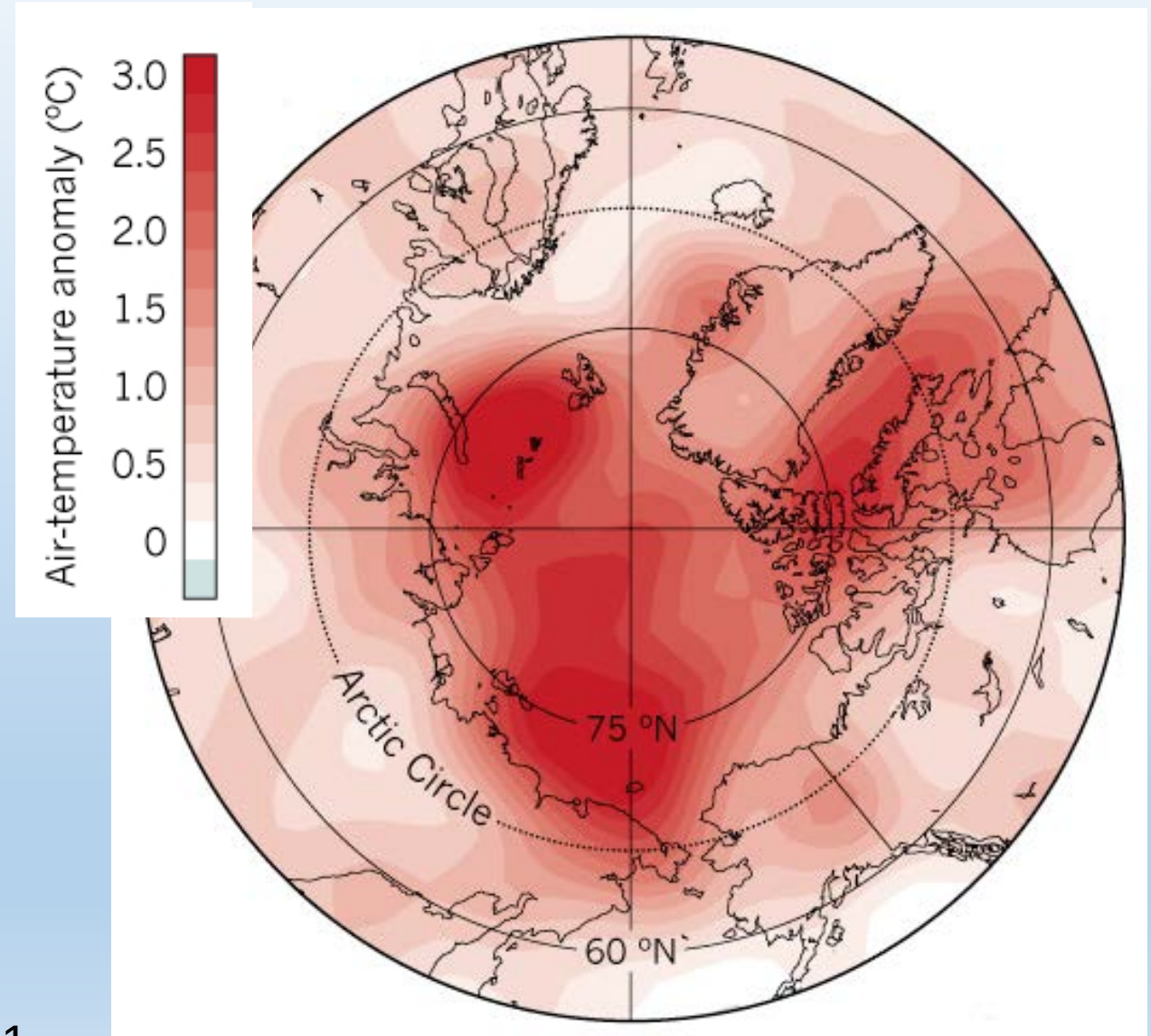


Arctic is warming up twice as fast



Average T is 3° C warmer since 1971

Nature (2017): doi:10.1038/nature.2017.21911



Natural consequences



Batagaika

- Enormous "holes " in the ground
- Spontaneous explosions
- Opening/sinking areas
- Billions of environmental microbes recirculated



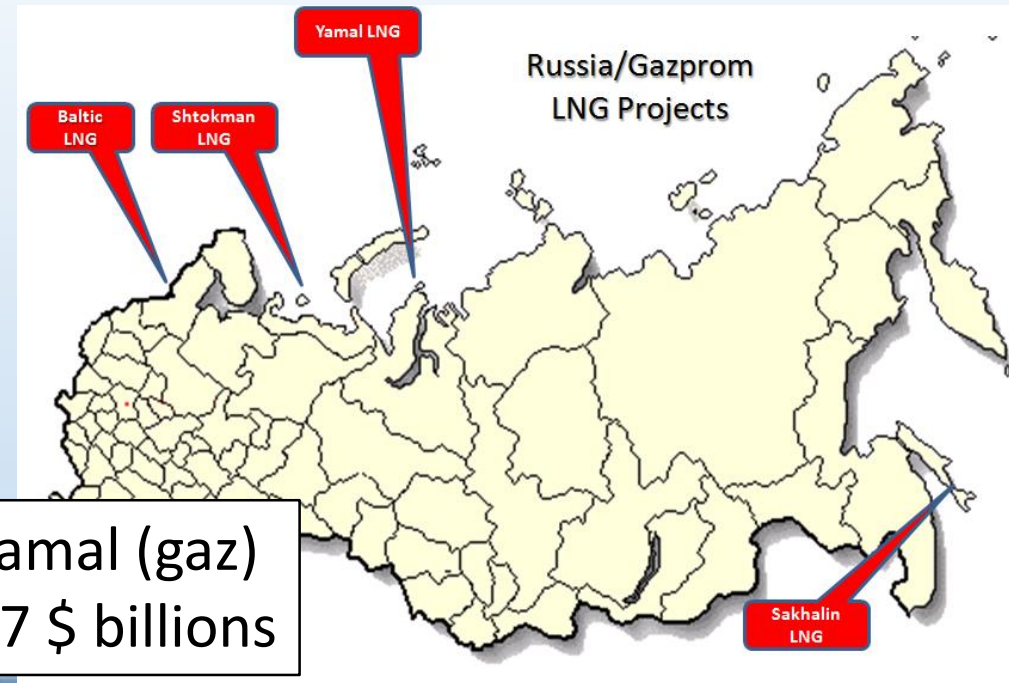
Gigantic industrial ventures

Mirny, Yakutia

H= 305 m, $\varnothing=805$

V= $52 \cdot 10^6$ m³

$52 \cdot 10^{20}$ bacteria



"Portable" nuclear power plant
70 Mwe, 300 MW heating
(100,000 h)



Periodical return of anthrax outbreaks

Anthrax Outbreak In Russia Thought To Be Result Of Thawing Permafrost

August 3, 2016 · 8:32 PM ET

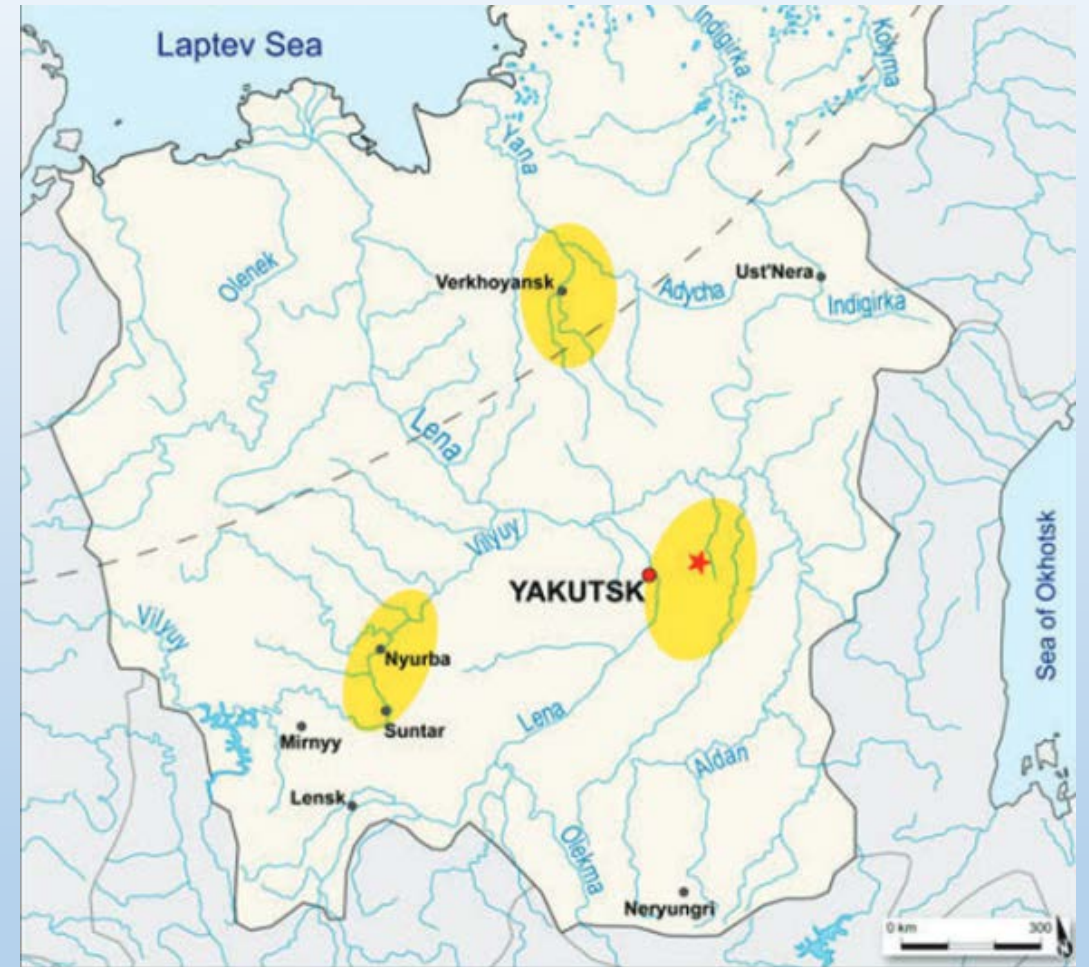


Traces of smallpox viruses



1628 - 1640

C. Theves, P. Biagini and E. Crubezy (2014)
Clin Microbiol Infect 20, 210–218.



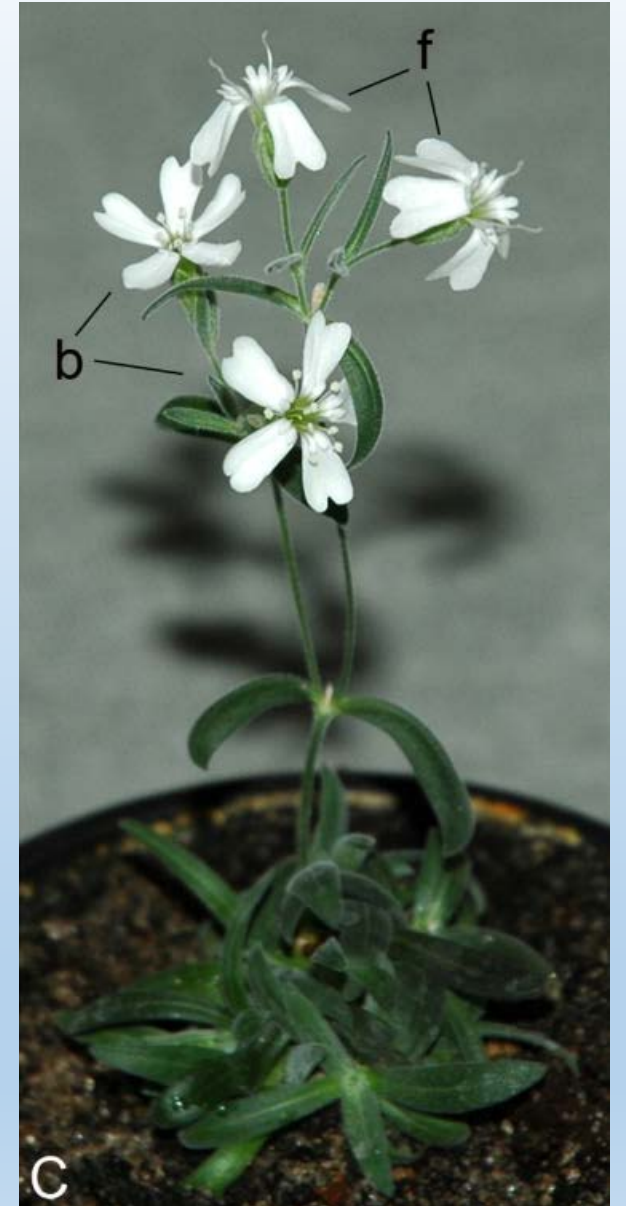
Farther back in time: Neanderthal



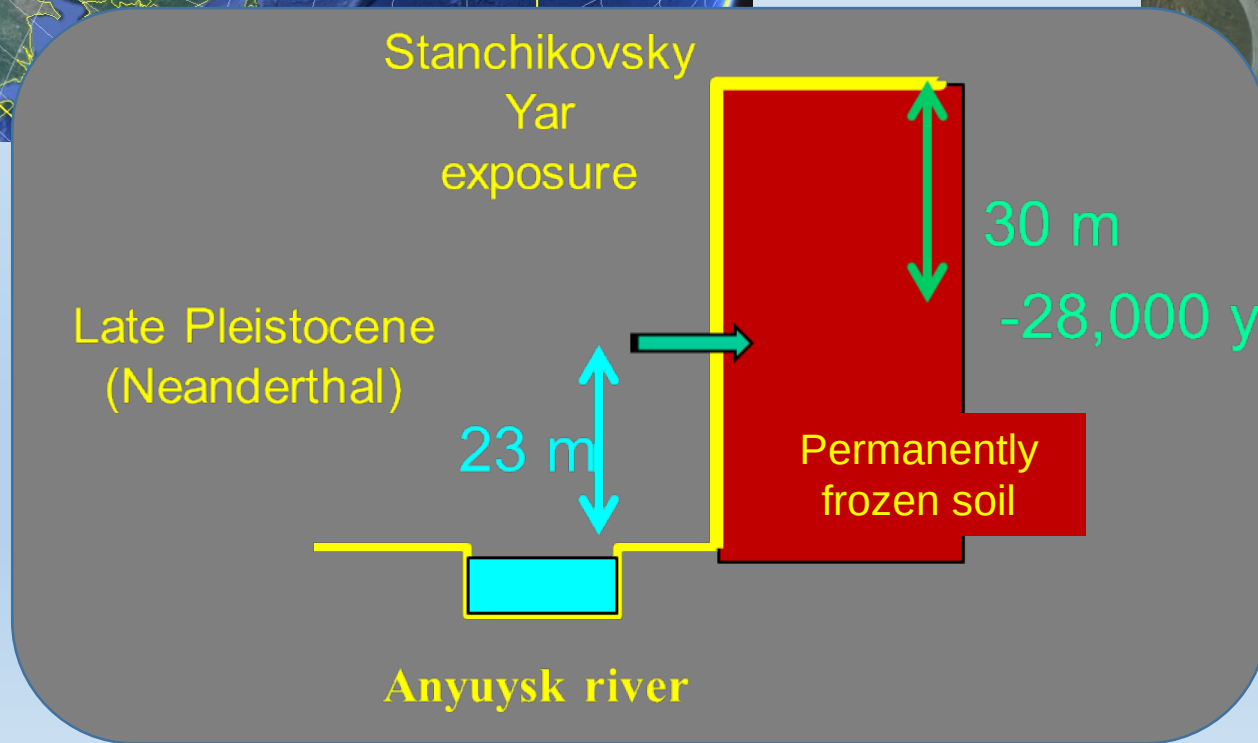
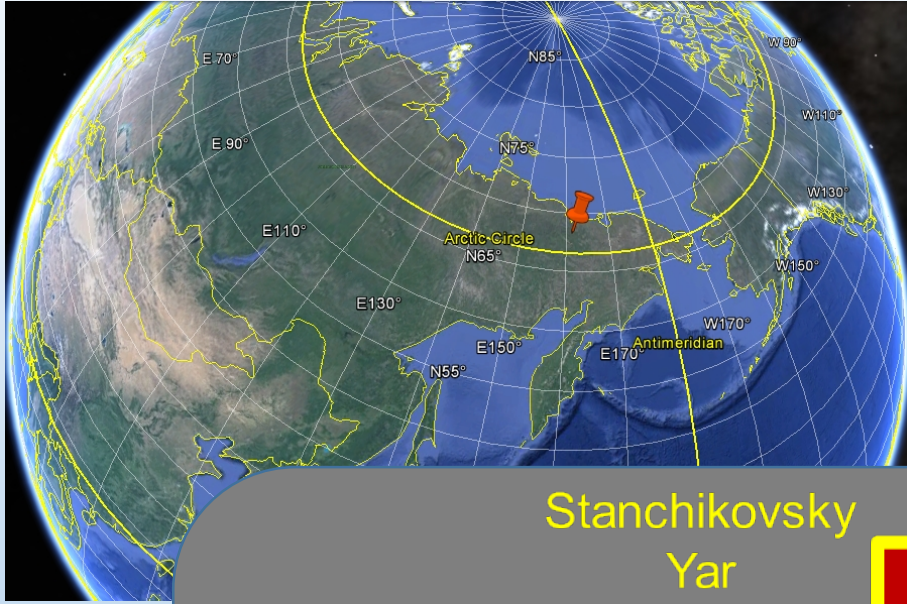
Dr. David Gilichinsky
(1948 – 2012)

Founder of the geocryology laboratory, in
Puschino (Russia).
Studied permafrost bacteria since 1985.

Lyubov Shmakova, Elizaveta Rivkina
Institute of Physicochemical & Biological Problems in Soil
Science, Pushchino, Russia.

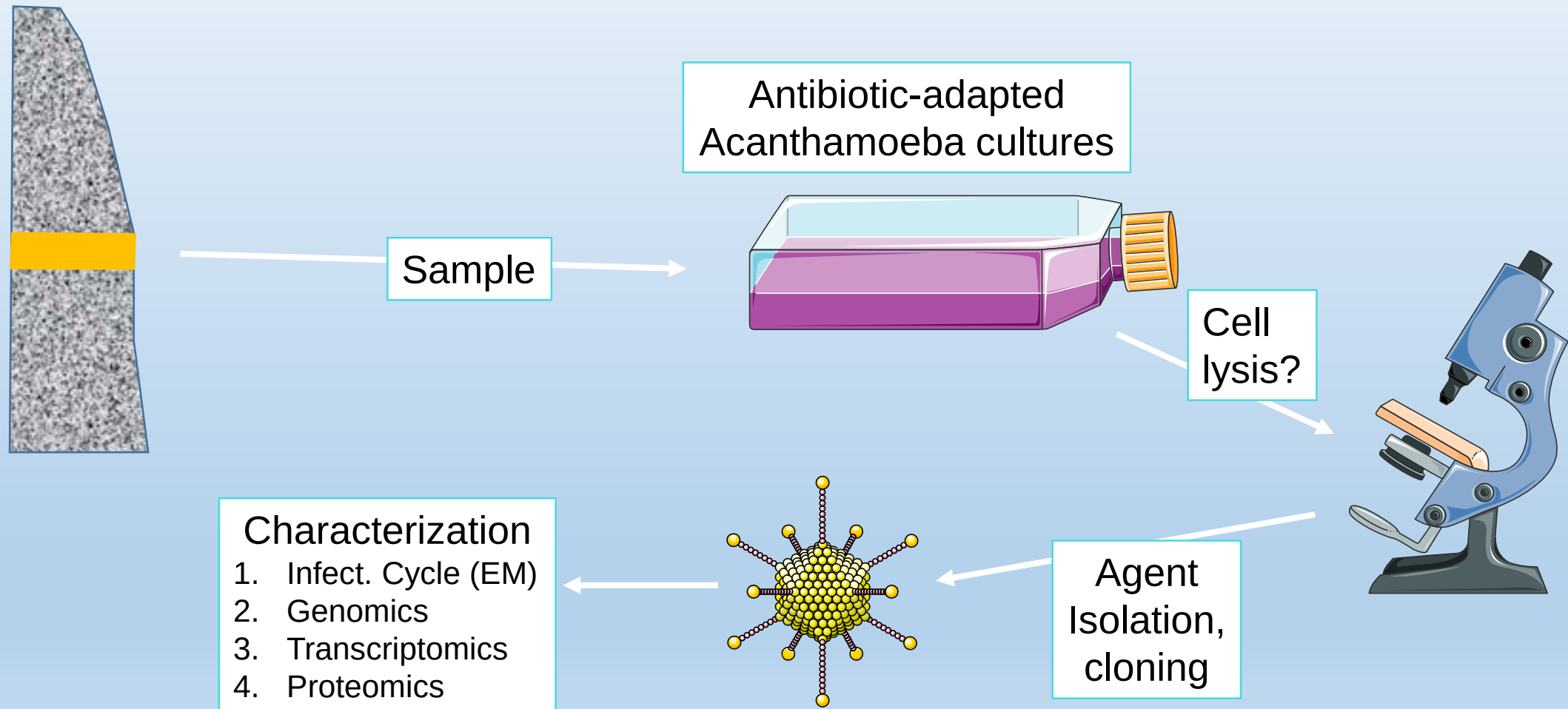


Location: Chersky area/ Kolyma lowland



Yakoutia/Chukotka border

Systematic search for acanthamoeba-killing viruses

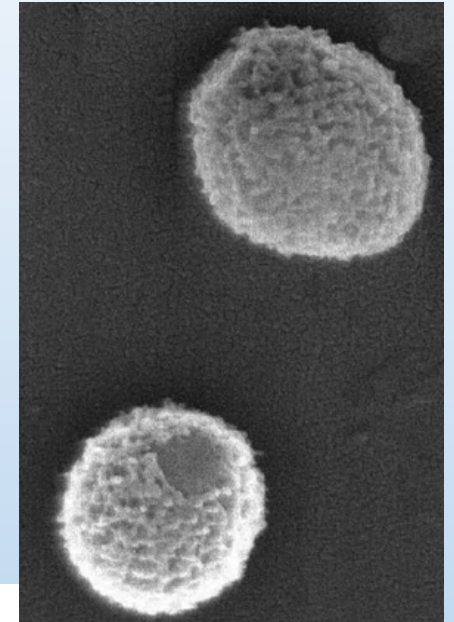


Giant viruses from late pleistocene (end of neanderthal)

In-depth study of *Mollivirus sibericum*, a new 30,000-y-old giant virus infecting *Acanthamoeba*

Matthieu Legendre^{a,1}, Audrey Lartigue^{a,1}, Lionel Bertaux^a, Sandra Jeudy^a, Julia Bartoli^{a,2}, Magali Lescot^a, Jean-Marie Alempic^a, Claire Ramus^{b,c,d}, Christophe Bruley^{b,c,d}, Karine Labadie^e, Lyubov Shmakova^f, Elizaveta Rivkina^f, Yohann Couté^{b,c,d}, Chantal Abergel^{a,3}, and Jean-Michel Claverie^{a,g,3}

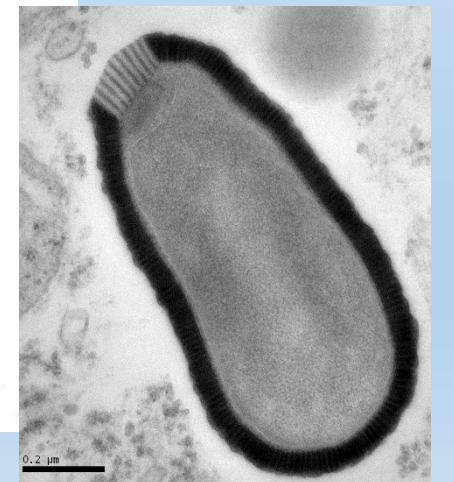
22 Sept.2015

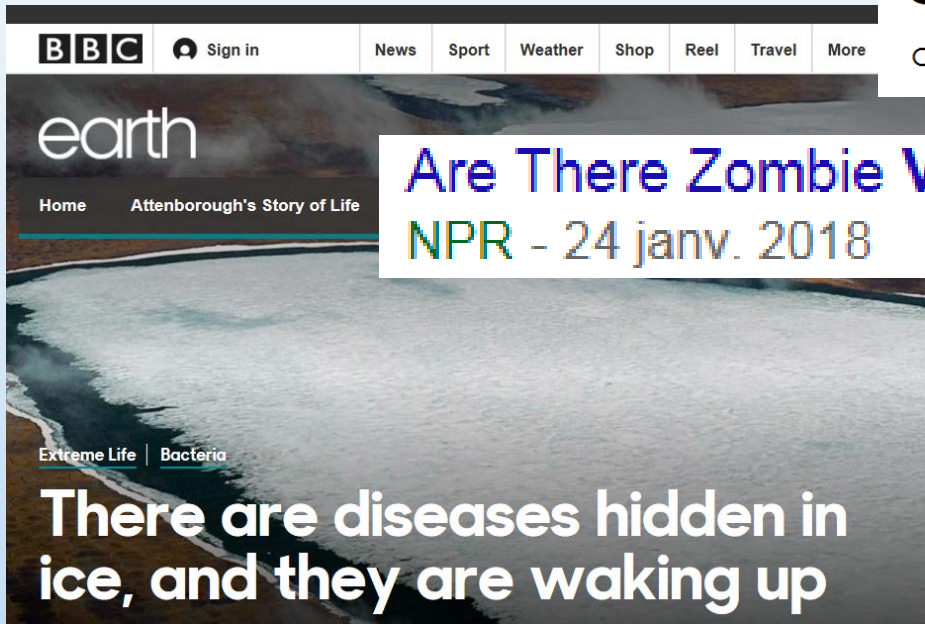


Thirty-thousand-year-old distant relative of giant icosahedral DNA viruses with a pandoravirus morphology

Matthieu Legendre^{a,1}, Julia Bartoli^{a,1}, Lyubov Shmakova^b, Sandra Jeudy^a, Karine Labadie^c, Annie Adrait^d, Magali Lescot^a, Olivier Poirot^a, Lionel Bertaux^a, Christophe Bruley^d, Yohann Couté^d, Elizaveta Rivkina^b, Chantal Abergel^{a,2}, and Jean-Michel Claverie^{a,e,2}

3 Mars, 2014



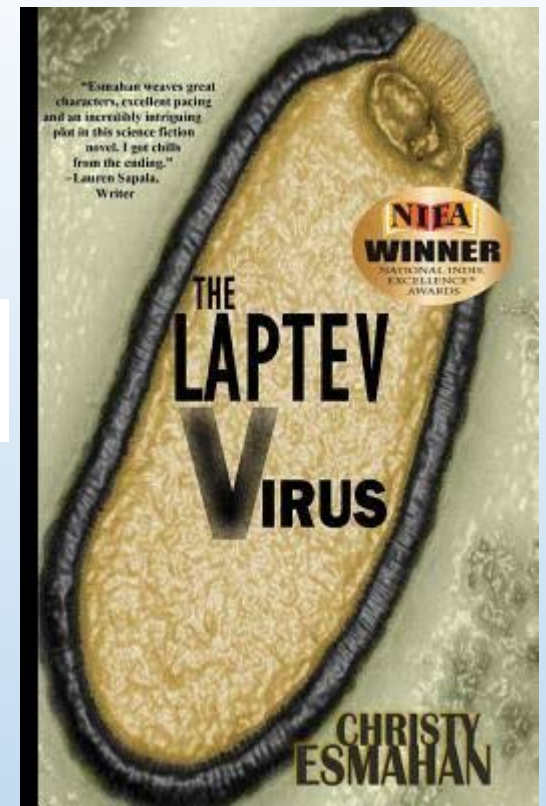


Are There Zombie Viruses In The Thawing Permafrost?

NPR - 24 janv. 2018

Ancient "Giant Virus" Revived From Siberian Permafrost

Climate change could release more ancient viruses. Is there a risk to humans?



Permafrost: a climate time bomb?

Phys.Org - 5 déc. 2018

Permafrost—soil that is frozen, although not necessarily permanently ... scientists revived a **giant** but harmless **virus**, dubbed Pithovirus ...



Global warming could unleash viruses that have lain dormant for ...

The Independent - 5 mai 2017

"**Permafrost** is a very good preserver of microbes and viruses, because it is ... when exposed to light, certain "**giant**" **viruses** could signal danger.

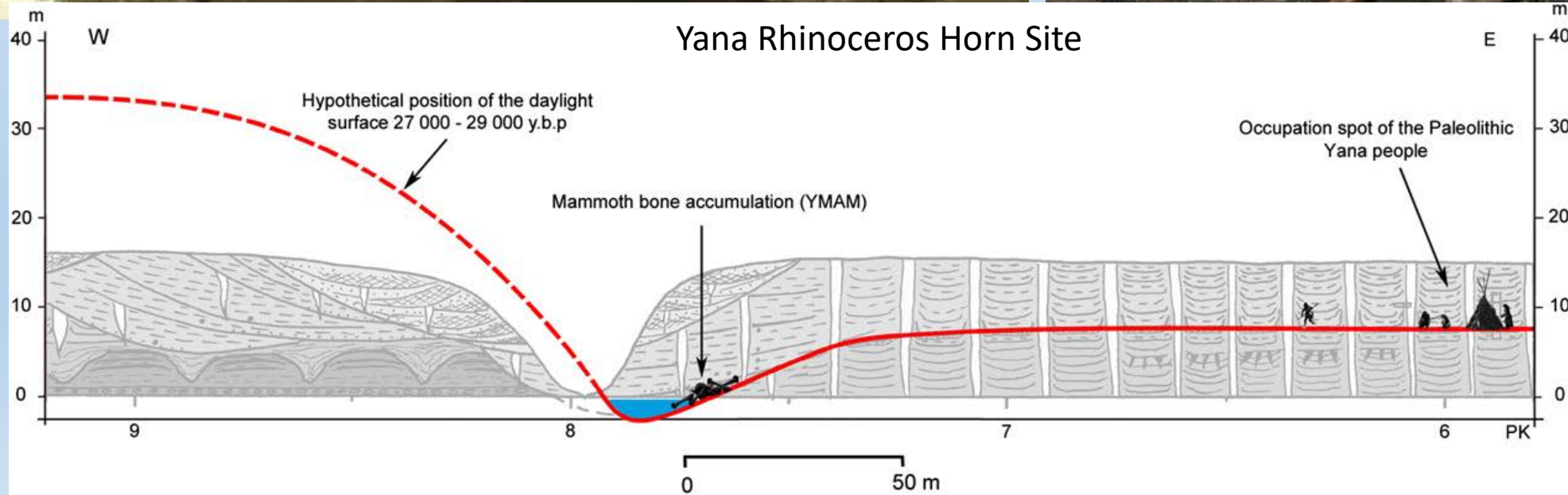


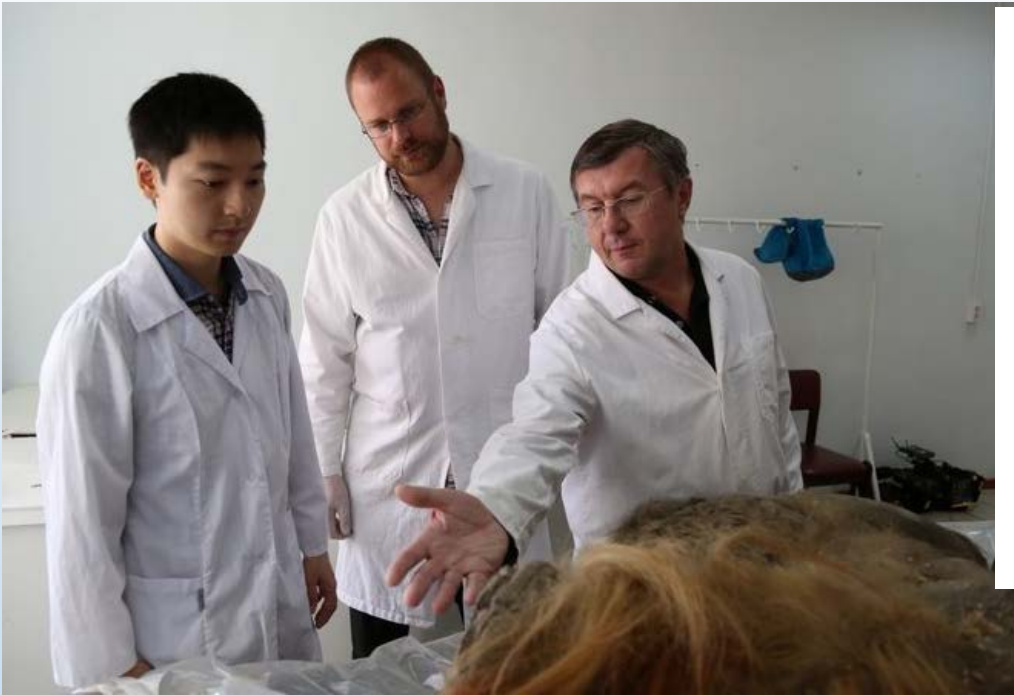
Can we confirm these results ?

- Use different sample sites
- Use different sample types
- Use different investigation methods

Paleolithic (28.000 y) Yana RHS: humans & mammoths

The Yana RHS Site: Humans in the Arctic Before the Last Glacial Maximum Pitulko & al. *Science* (2004)



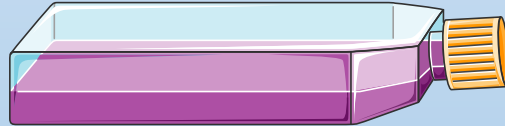


Alexei
Tikhonov
Head,
Zoology Institute,
(RAS-St Petersburg)

Research head,
Mammoth Museum
Yakustsk



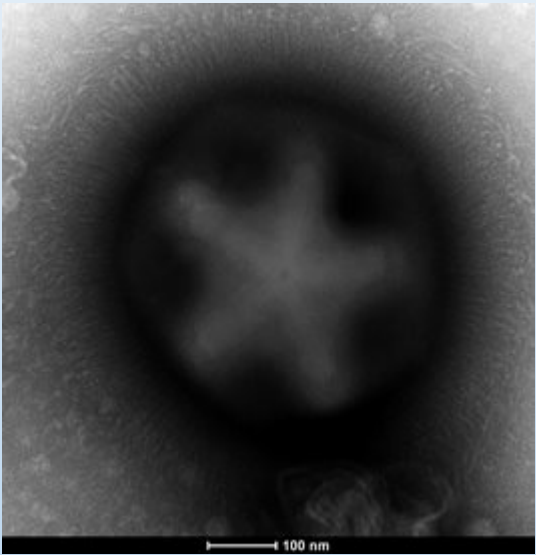
Acanthamoeba



4 new viruses



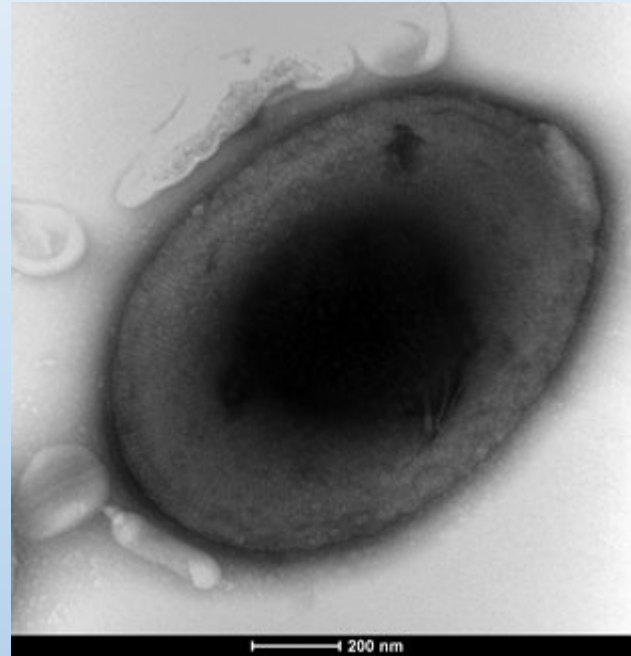
New virus isolates "associated" to frozen animal remains (28. 000 y)



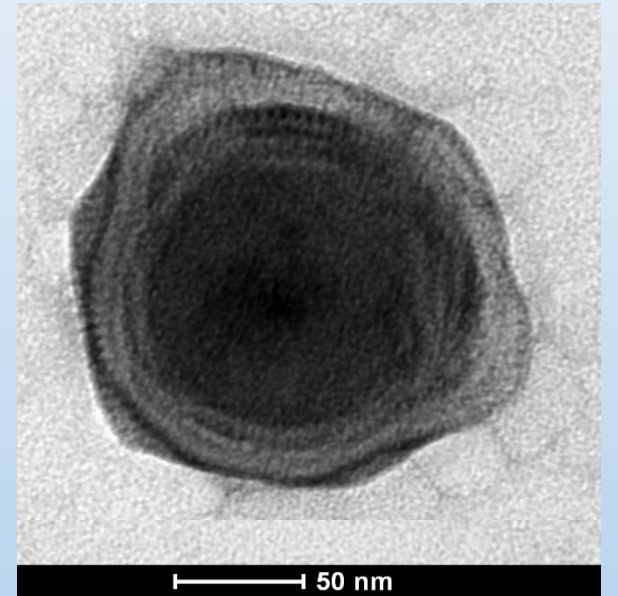
ancient
Megavirus



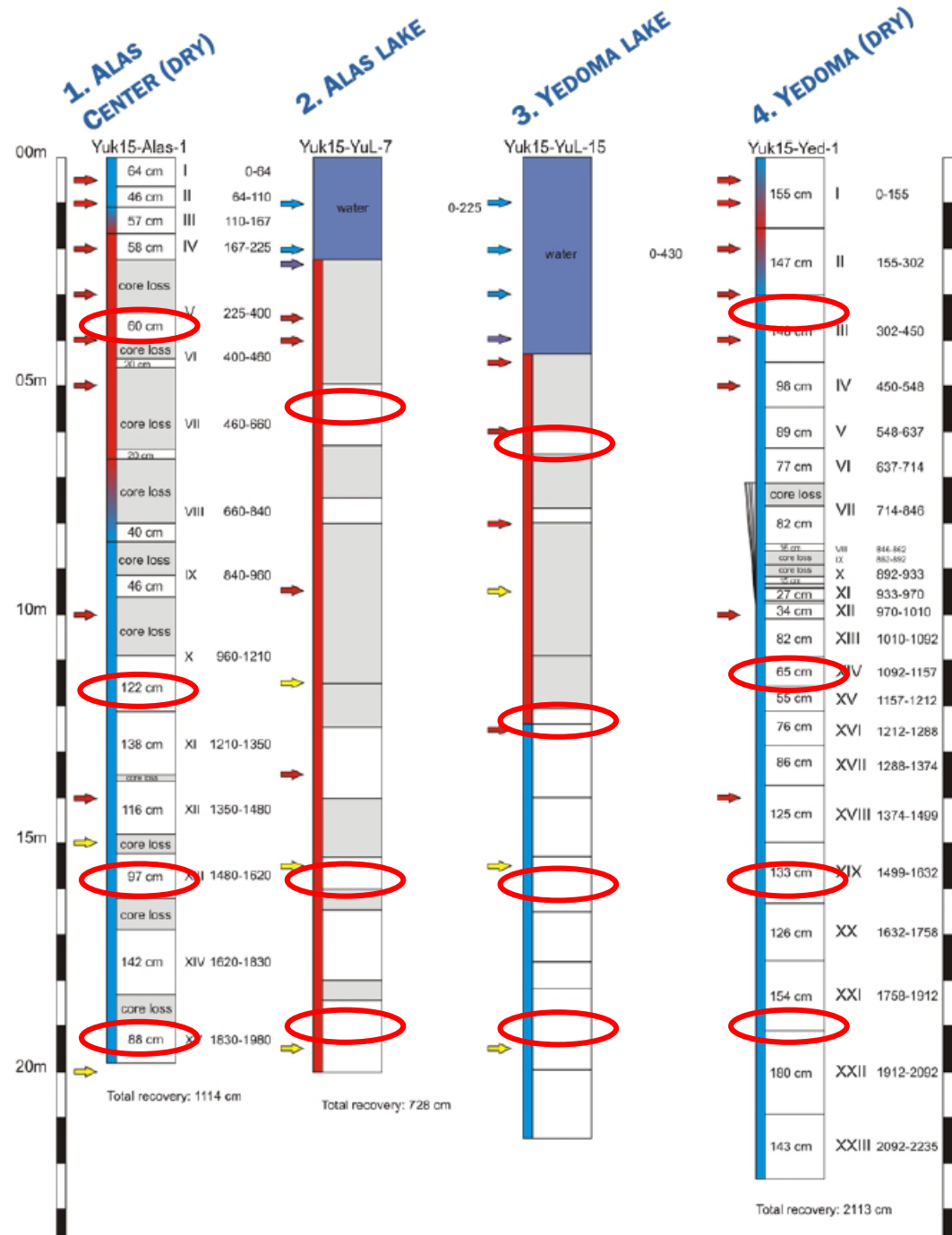
ancient
Pandoravirus



ancient
Pithovirus



"Pacman"
Asfar-like
408 kb, G+C: 41 %, 50% ORFans

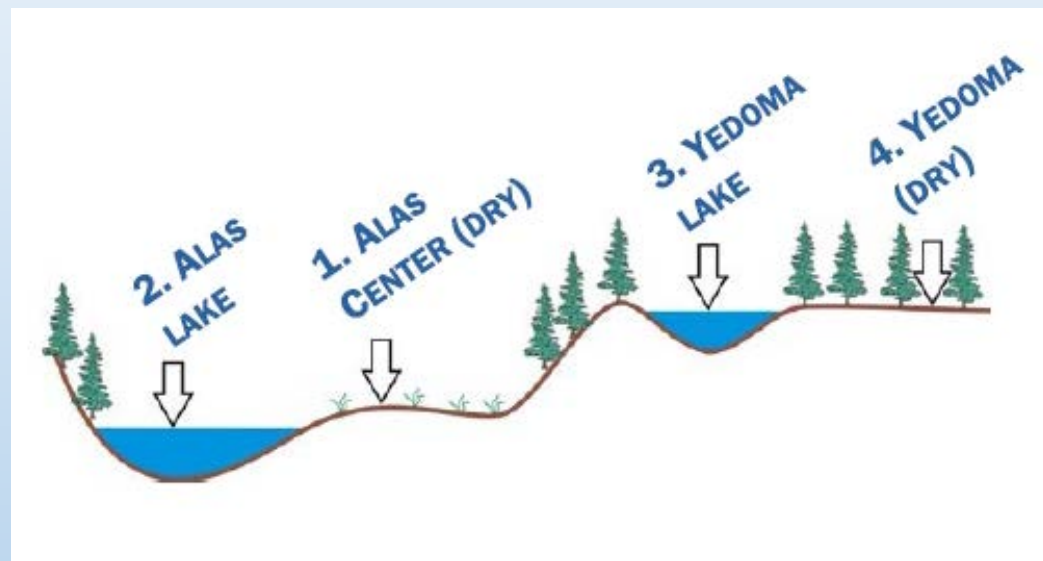


Core material from the

SPRING EXPEDITION YAKUTIA 2015

Jens Strauss

Alfred Wegener Institute, Periglacial Research Unit



Metagenomic sequencing

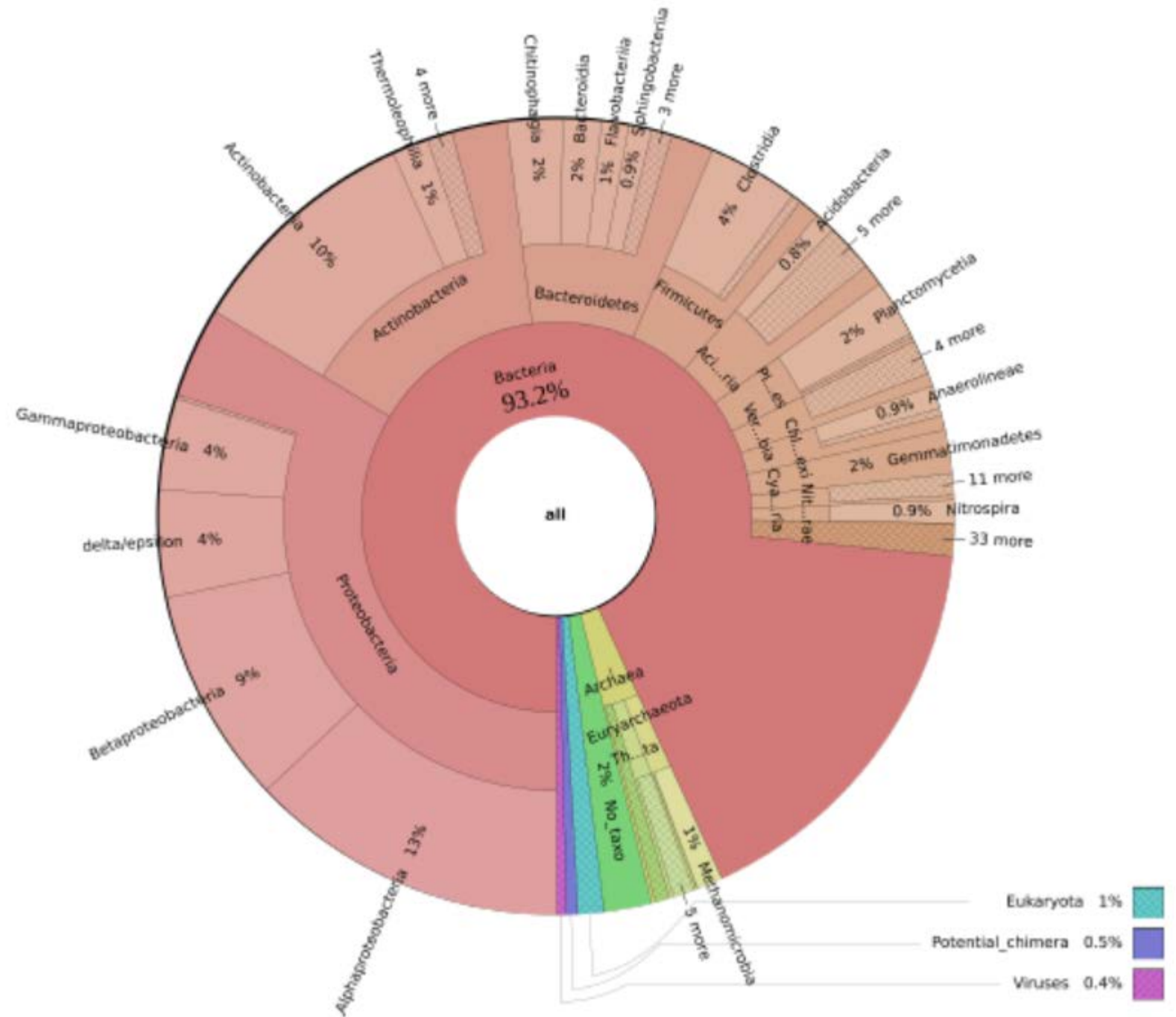
Total bp: 10.3×10^9

Contigs >5 kb: 868,850

Mostly bacteria

A huge diversity

Claverie et al., unpublished



Eukaryota 1%

Potential_chimera 0.5%

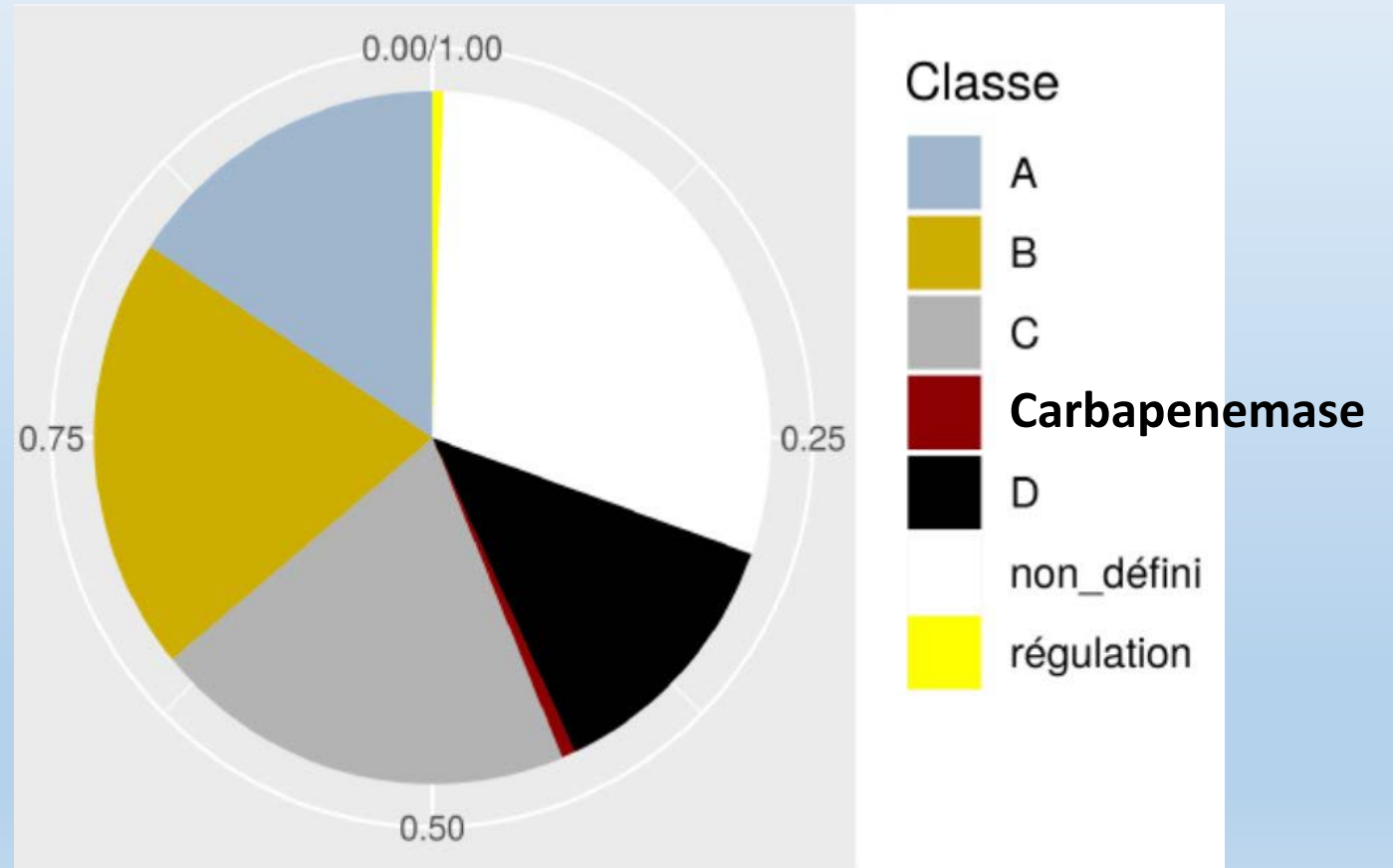
Viruses 0.4%

An unknown threat: β -lactamases

2,678 β -lactamases
1/325 contig

85,6% associated to
Gram-negative bacteria

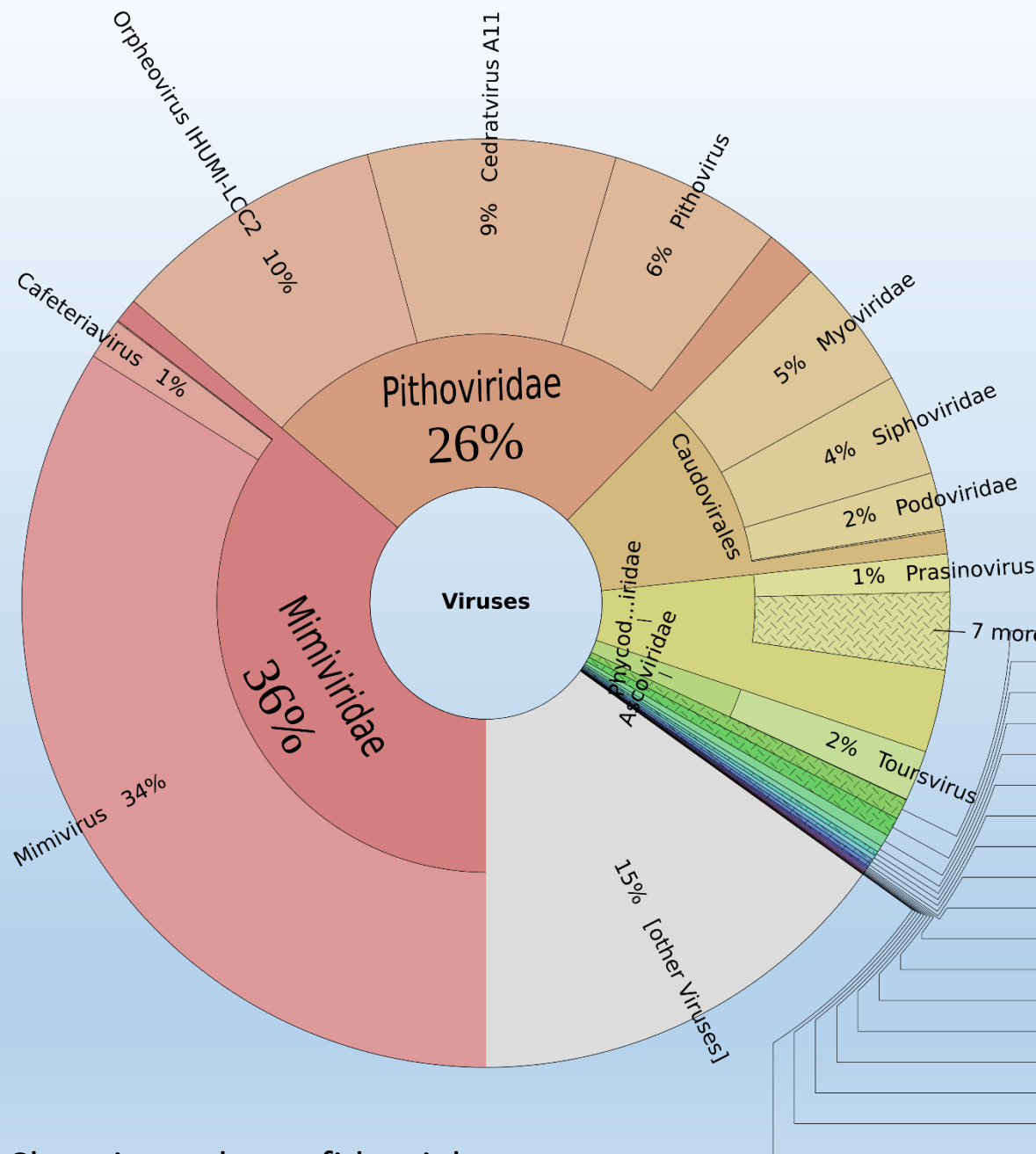
Claverie et al., confidential



Metagenomics: viruses

bp: 1,460 Mb

contigs >5 kb: 2,796

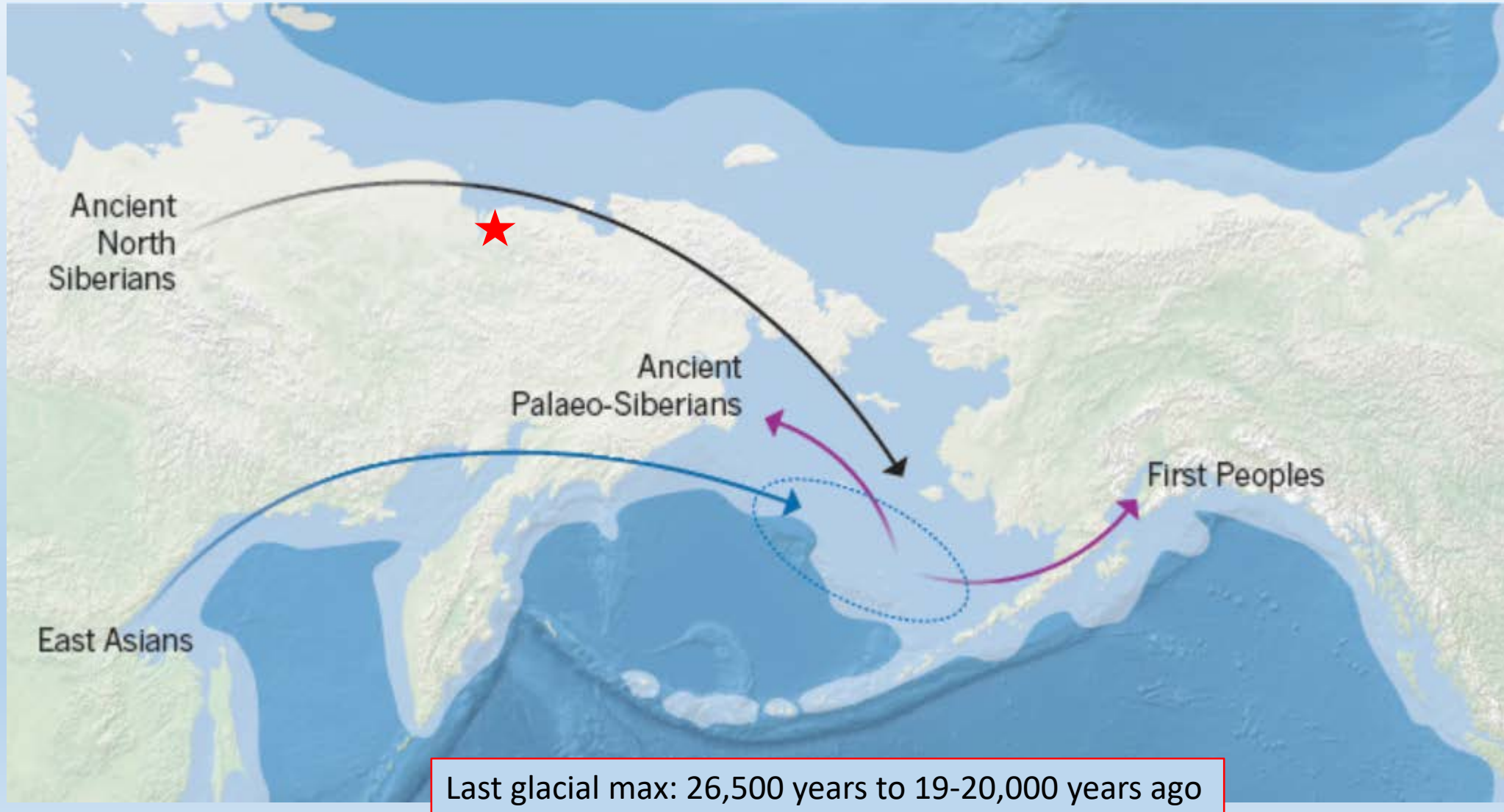


Claverie et al., confidential

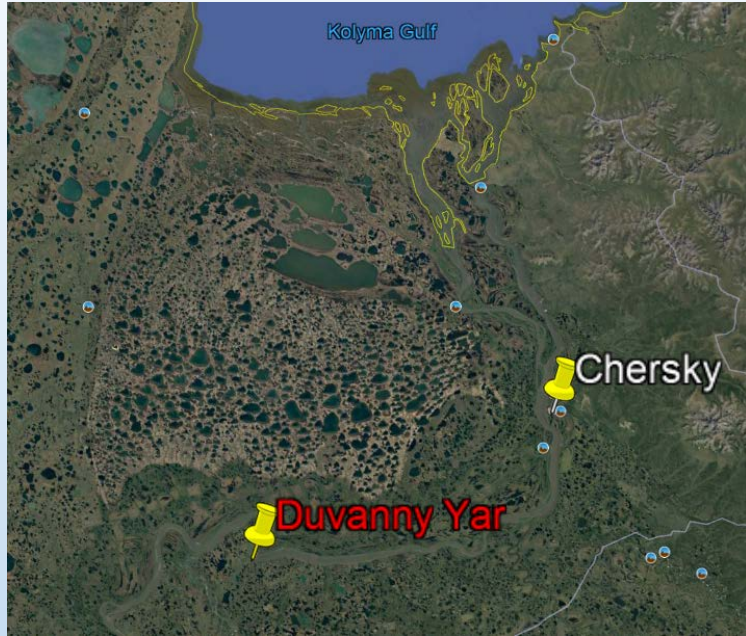
Iridoviridae	0.7%
Marseilleviridae	0.7%
Pacmanvirus A23	0.4%
Kaumoebavirus	0.2%
Lavidaviridae	0.2%
Asfivirus	0.2%
Poxviridae	0.1%
Pandoravirus	0.1%
Circoviridae	0.06%
Alphabaculovirus	0.05%
Cellulophaga phage phi14:2	0.05%
Flavobacterium phage Fpv20	0.04%
Flavobacterium phage Fpv3	0.03%
uncultured crAssphage	0.03%
Mollivirus sibericum	0.03%
Vibrio phage qdvp001	0.01%
Vibrio phage VBM1	0.01%
Tetraselmis viridis virus S20	0.009%

Our last sampling mission

(Duvanny Yar, August 15-29, 2019)



Kolyma river exposures



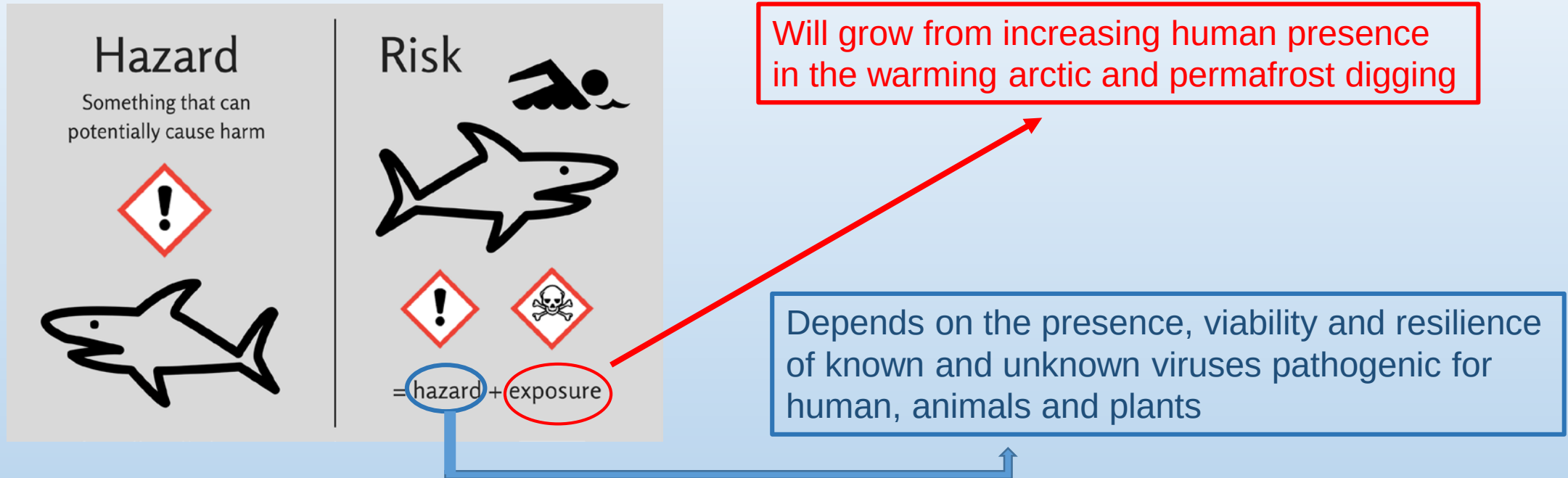


Preliminary results

- 3 new viruses from the Lena river (megavirus, pandoravirus, pithovirus)
- One new virus from the run of thawed material (pitho/cedratvirus)
- 4 viruses from pleistocene (>11,700 y) (3 Mimiviruses, one Pandoravirus)

The above results are the first independent confirmation that some DNA viruses can remain infectious since paleolithic and the end of the last glacial period.

The viral risk from thawing permafrost



1. Every large-scale arctic industrial project should include on-site competent medical surveillance
2. They should have an on-site quarantine/isolation facility and protocol.
3. More research should be performed on pathogenic permafrost microbes (including protozoa)*

* It is virtually impossible to legally export potentially infectious samples out of Russia/Yakoutia

The Structural & Genomic Information Laboratory – CNRS – Aix Marseille University



Jean-Marie Alempic

Matthieu Legendre

Eugène Christo-Foroux

Chantal Abergel

