Drilling the Ice from the Past to the Future

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Vostok
Fortune favors the brave
(an ancient Latin phrase)

Fortune favors the fool
(an old Russian wisdom)
Fortune favors the brave
(an ancient Latin phrase)
Vostok Station
Altitude: 3490 m a.s.l.
Mean annual temperature: -55.5°C (coldest place on Earth)
Precipitation rate: 23 mm (60 times less than in Ljubljana)

Operating as wintering-over station since 16 December 1957

Scientific activity
Meteorological observations
Observations of magnetosphere
Ground glaciological observations
Deep ice coring
Lake Vostok studies
1970: beginning of the deep drilling (nothing to do with the Lake yet)
Deep ice drilling to study the remote past
“Cornucopia of paleoclimatic data”
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Diagram showing variations in atmospheric dust, temperature, CO₂, CH₄, sea level, and ice sheet thickness over time (kyr BP). The inset text references the climate and atmospheric history of the past 420,000 years from the Vostok Ice core, Antarctica.
Can melt-water exist under deeply frozen Antarctic glacier?

Igor Zotikov (1926-2010)
Byrd Station, 2164 m (29 January 1968)

Ueda: Byrd Station drilling 1966–69

Fig. 2. Winch set-up in main tunnel, 1966.

Fig. 3. Overall drilling set-up, Byrd Station, 1966.
FIG. 2. Section of 24-channel seismic record from Vostok relevant to the sub-ice water layer. This records movement over a vertical line of seismometers from 49 m to 2.5 m depth in a profile 380 m from the explosion. It covers a period from 1.8 s to 2.0 s after the explosion of the TNT at 39.3 s depth and 38.1 s from the vertical seismometer line. Open circles are locations of all twelve seismometers at 29 m intervals that recorded the same event as those marked by the second reflection (b) in the time window above 2.0 s after the explosion. The echo is from the base of the floating ice. A second reflection (c) is not shown at 1.92 s and 2.66 s against a much higher background noise. The echo from the base of the floating ice reaches the seismometer line at 1.34 s or first at 1.35 s. It then travels up the seismometer line to the surface where it is reflected downward to pass the first reflection and is recorded (d). The section is an example of a record that shows the sub-ice water layer clearly.

Both likely, our best estimate of the residence time of the lake water is of the order of 50,000 years. Other features of the water mass can be deduced from the relationship between surface elevation and thickness of floating ice (Fig. 4). The close scatter of points around the fresh-water line (Fig. 5) indicates a hydraulic pressure equivalent to a head of water close to 3,140 m above sea level over the whole lake. It also confirms the presence of relatively fresh water in the lake. Any difference between the mean slope of plotted points and the green line could be due to residual effects from boundary stresses, to errors in ice thickness and/or to the effect of limited sampling on water density within a range of 0.00 and 0.05.

The decrease in ice thickness of 0.5 m from north to south of the lake means that the ice-water contact temperature will be 0.4°C lower at the north than at the southern end. This may be sufficient to drive slow circulation of sub-ice water and affect basal heat distribution in the lake, but not the total heat flux. Ice cores from Vostok contain micro-organisms carried by air to Antarctica on dust particles from low latitudes. Melting of basal ice will release those microorganisms into lake water around one million years after deposition on the ice surface. Sediments on the lake bed may be several million years old, an exceptional environment that should provide useful information to the biological community and to geologists.

The lake occupies the lower part of a basin or rift (Figs. 1, 5). Unlike grounded ice, basal drag is negligible over an ice-water interface.
Gordon de Q. Robin, 1970s

Ridley et al., 1993
Lake Vostok:
The 5\textsuperscript{th} largest lake in the world!

Popov et al., 2011
Lake Vostok:
The 5th largest lake in the world!

Popov et al., 2011
Aquatic environments beneath the Antarctic ice sheet

>22,000 km³ of water in >145 sub-ice lakes:

- Affect ice sheet and ice stream dynamics
- Control drainage of the EAIS and contribute to sea level rise
- Provide a “Natural laboratory for ecological experiments”, and
- Earth-bound analogues for extraterrestrial ice worlds

Subglacial lakes and major drainage routines from Siegert et al., 2007
Why Lake Vostok?

Antarctica

Lake Vostok

Sovetskaya

90°E Lake

100 km

Ridge B

Europa

230 m of accreted lake ice

©Studinger, 2006 /Bell et al., 2006
From 5G-1 to 5G-2

5G-1 (6°)

Lost drill

Layer with mineral inclusions

3606.30 - 3606.50 m

The new 5G-2 core

3607.00 - 3606.10 m

5G-2 (5°)

3649.78 m (25 Jan. 2010)

3606.30 - 3606.50 m

February 1 2010, 5G-2, 3598.6 m

3597

3598 m

3595

3594

3592
What do we know about the Lake Vostok?

- Accumulation of impurities coming to the lake due to glacier ice melting
- Hydrothermal activity at the lake bottom
- High concentration of gases including oxygen!
- Not perfect mixing of melt water with the resident lake water
- Ultra-oligotrophic environment
- Expected micro-organisms: oxygenophilic chemooautotrophs
Show must go on, Alexey
Now the time for some pictures
График нарастания интенсивности

Вероятность проникновения в озеро при достижении данной глубины

Глубина по керну (м)

Глубина (%)
Lake Vostok

Borehole 5G-2

accreted ice

3770 m

3750

3740

3720

3750

11 cm
What next?

2011/12
Antarctic season:
Drilling of the frozen lake water
Teams set for first taste of Antarctic lakes”, Nature, 2010

WATER BELOW THE ICE
Three countries plan to drill through the Antarctic ice sheet to explore hidden lakes. Russian researchers hope to reach Lake Vostok next year.

ANTARCTICA
Ellsworth
Whillans
Vostok
Ross Ice Shelf

Antarctic ice sheet
Drill
Frozen lake water
Lake Vostok
4 km
“Second penetration” to LV: direct measurements and water sampling

Lake Ellsworth (West Antarctica)

Siegert et al., 2006
Thank you!
Problem N1: “The warm ice”
Problem N2: big ice crystals make the core breakoff difficult