Подледниковые водоёмы Антарктиды

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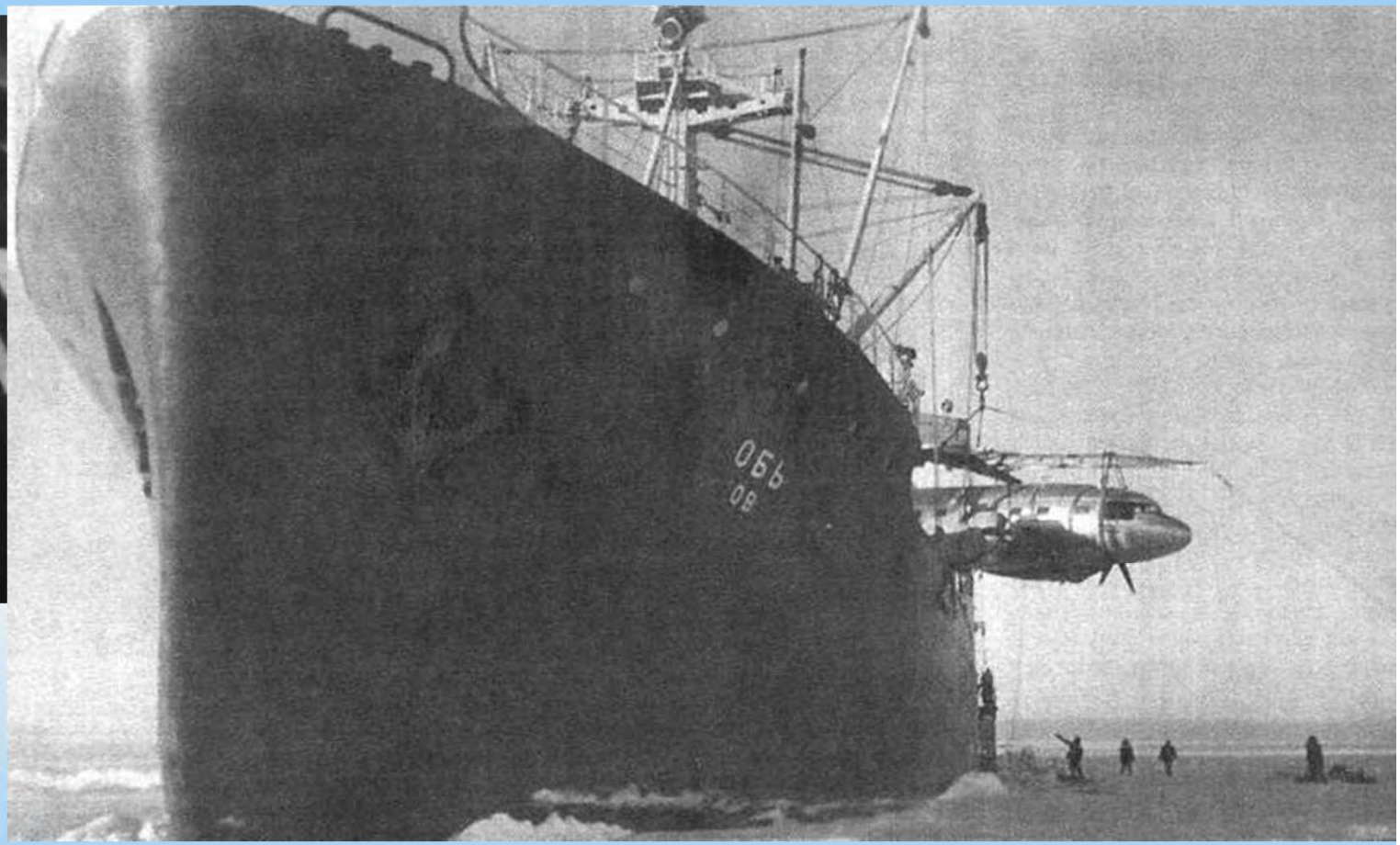
СПбГУ
3 октября 2019 г.

Открытие станции Мирный

30 ноября 1955 г. д/э «Обь» вышел из Калининграда в Антарктиду. Первую экспедицию возглавил д.г.н. Герой Советского Союза Михаил Михаилович Сомов
5 января 1956 г. судно прибыло в Антарктиду.

Фотографии из фондов ААНИИ

Открытие станции Мирный



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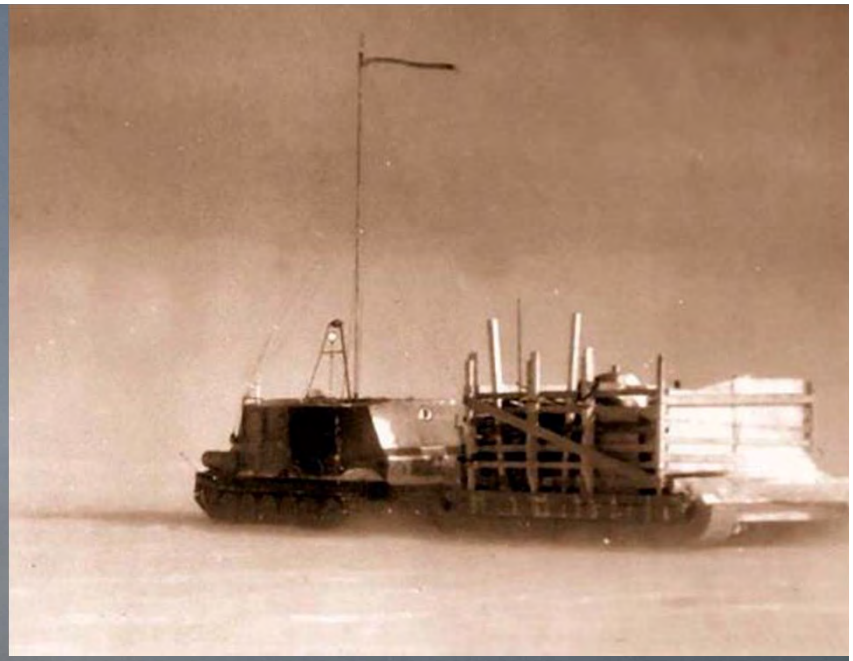
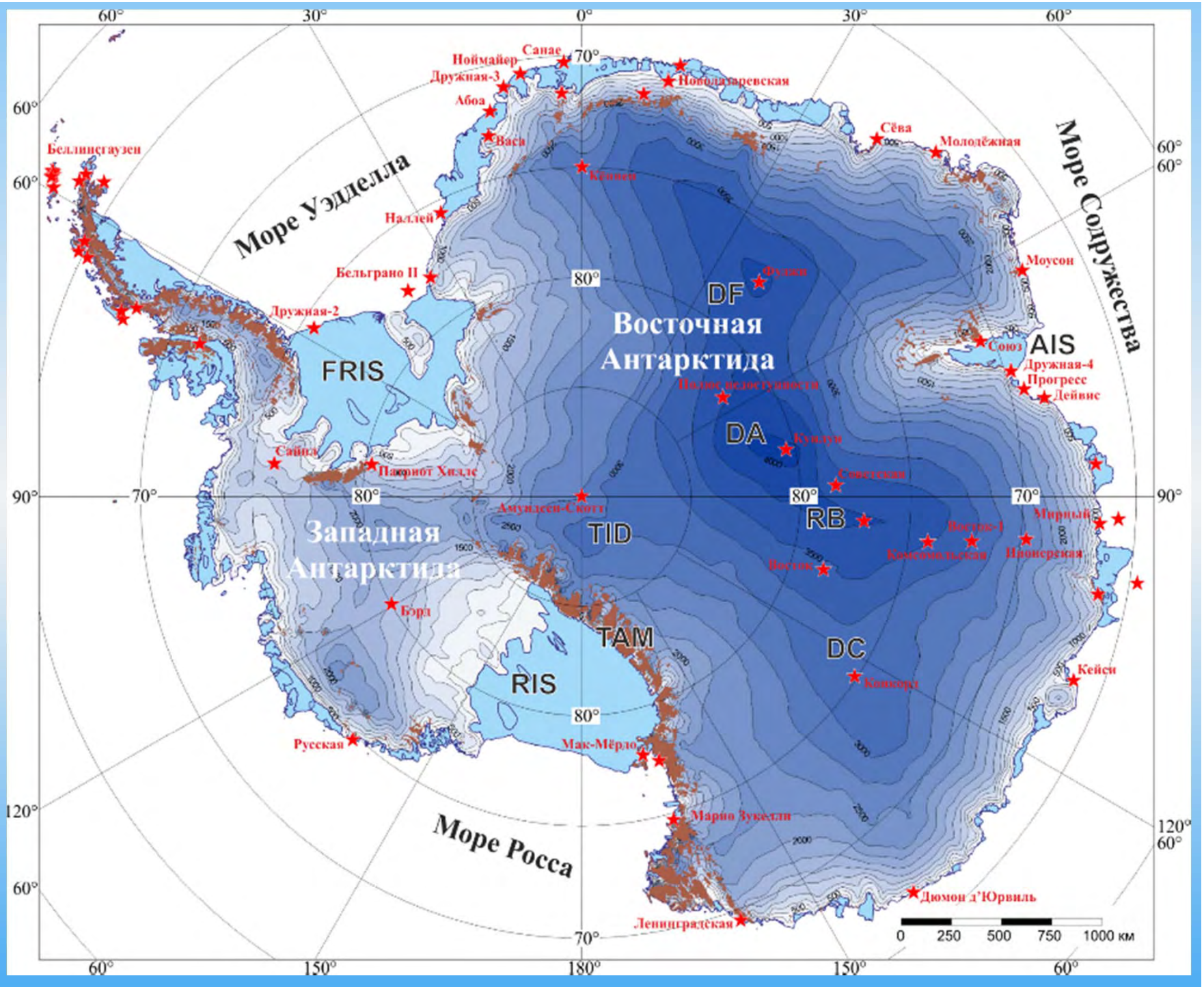
30 ноября 1955 г. д/э «
Антарктиду. Первую эк
Советского Союза
5 января 1956 г. су

Станция Мирный

1 СГП вышел 2 апреля 1956 г.




Море Уэдделла
Море Содружества
Море Росса
Западная Антарктика
Восточная Антарктика
FRIS
RIS
TAM
TID
DA
DC
DF
RB
AIS
Санае
Ноймайер
Дружная-3
Новолазаревская
Абоа
Васи
Сёва
Молодёжная
Беллинсгаузен
Кёниг
Моусон
Наллей
Бельграно II
Фуджи
Дружная-2
Союз
Дружная-4
Прогресс
Дейвис
Полюс недоступности
Кунлун
Сайпл
Пакриот Хиллс
Советская
Амундсен-Скотт
Мирный
Восток-1
Комсомольская
Пионерская
Восток
Бэрд
Кейси
Конкорд
Русская
Мак-Мёрдо
Марио Зукелли
Дюмон д'Юрвиль
Ленинградская
0 250 500 750 1000 км

27 мая 1956 г. основана первая отечественная внутриконтинентальная станция Пионерская

Фото ААНИИ

Pionerskaya at present
374 km from Mirny

photo by A. Ekaykin

Aurora Australis

Journal of Glaciology, Vol. 39, No. 133, 1993

Identification of subglacial lakes using ERS-1 radar altimeter

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ABSTRACT. Radar-altimeter data from ERS-1 allow detailed topographic mapping of Antarctica to 82° S to be carried out, revealing several notable surface features. Among these is the large subglacial lake near Vostok which is mapped here in detail. The central part of the lake is found to have an exceptionally smooth surface with r.m.s. elevation variations of less than 0.2 m. A search for other large Antarctic lakes in the data is made based on the smoothness and low gradient of the surface. A number of other flat areas are identified with lake locations previously determined from radio-echo sounding observations. However, radar-altimeter observations show that a minimum lake size of 20 km is required for a surface above a lake to become flat. Numerous bowl-like features can be seen in the surface topography, and these may be associated with intermediate-sized subglacial lakes. It is determined that high spatial-resolution radar altimetery could be used to identify subglacial lakes greater than 10 km in lateral extent. Flat regions of the ice sheet are particularly useful as they may be used as height-reference surfaces to help fix the orbits of radar-altimeter satellites.

INTRODUCTION

Previous satellite-radar altimeters such as Geosat and Seasat provided coverage for high-precision mapping of

Oswald and Robin (1973) showed that water flow in the direction of ice flow can be prevented by a basal slope against the flow, provided the basal gradient is approximately ten times that of the surface. If the flow

implications for basal temperatures, and hence the creep properties of the basal layer of ice (Shoemaker, 1991; Alley, 1992). The pressure gradient beneath a glacier normally serves to drive out subglacial water; however,

used to detect the change in gradient from the ambient grounded ice to that over the lake.

The only subglacial lake known to have been previously observed with radar altimetry is in Terre

A large deep freshwater lake beneath the ice of central East Antarctica

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In 1974–75, an airborne radio-echo survey of ice depths over central East Antarctica led to the discovery of a sub-ice lake of unknown depth and composition, with an area of about 10,000 km² and lying beneath ~4 km of ice[1]. In 1993, altimetric data from satellite measurements[2] provided independent evidence of the lake's areal extent, thus confirming it to be the largest known sub-ice lake by an order of magnitude. Here we analyse new altimetric and radio-echo data, along with existing seismic data[3], to show that the lake is deep (mean depth of 125 m or more) and fresh, and that it has an area that exceeds previous estimates by about 50%—dimensions comparable with those of Lake Ontario. We estimate that the residence time of the water in the lake is of the order of tens of thousands of years, and that the mean age of water in the lake, since deposition as surface ice, is about one million years. Regional ice-dynamics can be explained in terms of steady-state ice flow along and over the lake.

The satellite ERS-1, launched in 1991, was the first to be specifically programmed for altimetric surveys of large polar ice sheets. An analysis of the initial fast delivery data gave mean surface elevations every 6.7 km along the satellite track[2]. These defined areas of level ice, which roughly matched the lake

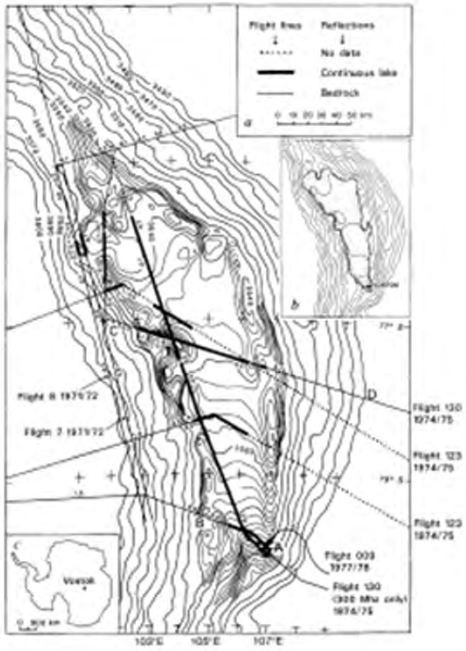
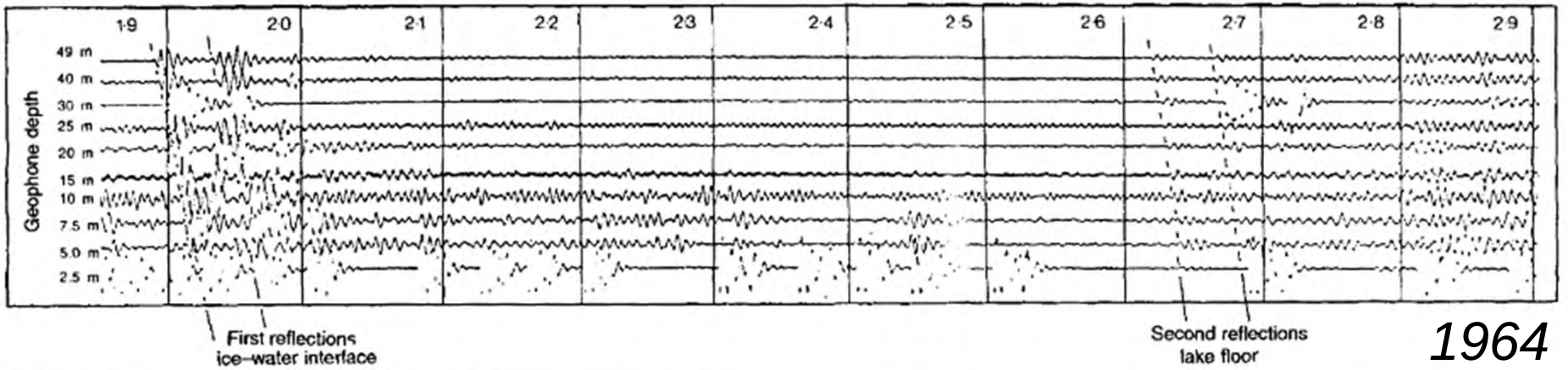


FIG. 1 Surface topography, ERS-1 waveform product (WAP) altimeter maps of the Vostok region. The improved altimetry comes from two 168-day repeat cycles of satellite orbits. The WAP analysis[2] gave 600,000 mean



thickness as 510 m and the lake bed at 710 m below sea level.

Along RES flight lines, the depth of floating ice changes slowly. The lake bed is around 700 m below sea level near both ends of the lake. Assuming this applies over the whole lake bed, the mean

floating ice and a water layer 125 m thick gives a residence time of 1.25×10^5 years. Increasing the water input from basal melting of surrounding grounded ice and increasing the volume of the water in the same proportion leaves the residence time unchanged. With

Oswald G.K.A., Robin G.Q. Lakes beneath the Antarctic ice sheet

Fig. 1 Flight lines completed in the 1971–72 season of SPRI-NSF radio-echo sounding programme. Some lines from 1969–70 are also included. ♦, Positions of the sub-ice lakes observed on these flights; ■, scientific stations.

shown that these characteristics can be explained in terms of the statistical properties of the ice-rock and ice-air surfaces. To produce fading as seen in Fig. 2 requires a bedrock roughness with a horizontal scale of 20 m or less and a vertical scale comparable to the wavelength of the radio waves (3 m in ice). We note also that the irregular echo returns persist for two or three microseconds after the first arrival, as a result of the broad beamed antenna used for sounding which collects scattered energy returns through angles up to 35° from the vertical. The echo pattern could result either from an irregular distribution of morainal rocks of sufficient size in the basal ice, or from the bedrock roughness mentioned above.

We have noted a number of sites, shown in Table 1, where the normal fading characteristics of the bottom echo change to that which we would expect from an extended smooth surface. Examples are shown in Fig. 2b, *c* and *d*. At these sites, the fading length increases to 200 m and more, fading of the echo is much reduced and is absent in some cases, as seen at an enlarged horizontal scale in Fig. 2*d*. At the same time the duration of the bottom echo decreases to a length similar to that of the transmitted pulse (1.0 μs for Fig. 2*b*, *c* and *d*). These characteristics all indicate that specular reflexion is taking place from an extended smooth surface. These surfaces seem to be almost horizontal, with slopes generally less than 1 in 150, except for one case with a slope around 1 in 50.

There is a marked increase in echo strength of 10 to 20 dB as we move from an area of normal fading to one of specular reflexion. The reflexion coefficient of an ice-rock interface is estimated to range from −14 to −20 dB (ref. 2), whereas the reflexion coefficient at an ice-pure water interface would be around −3 dB, provided we are dealing with a thickness of water of the order of a metre or more in depth rather than the usual sub-glacial film of a fraction of a millimetre. Thus the reflexion coefficient suggests that we are dealing with a substantial layer of water, rather than an exceptionally smooth

Table 1 Location and Width of Sub-Ice Lakes

Site No.	Latitude S	Longitude E	Depth of ice cover (m)	Width along flight line (km)
1	76° 42′	122° 45′	3,302	4
2	73° 15′	157° 12′	2,830	5
3	77° 28′	123° 42′	3,600	2
4	74° 08′	124° 35′	4,094	7
5	72° 41′	127° 21′	3,889	4
6	72° 18′	123° 54′	3,254	3
7	77° 59′	122° 43′	3,666	3
8	72° 55′	156° 23′	2,840	2
9	76° 04′	128° 14′	2,969	2
10	75° 56′	127° 21′	3,231	15
11	75° 43′	126° 05′	3,189	4
12	75° 00′	121° 52′	3,057	1
13	75° 54′	122° 06′	3,517	4
14	75° 10′	126° 30′	3,436	3
15	73° 55′	120° 21′	4,047	5
16	76° 42′	136° 23′	3,101	2
17	76° 20′	87° 45′	4,200	7

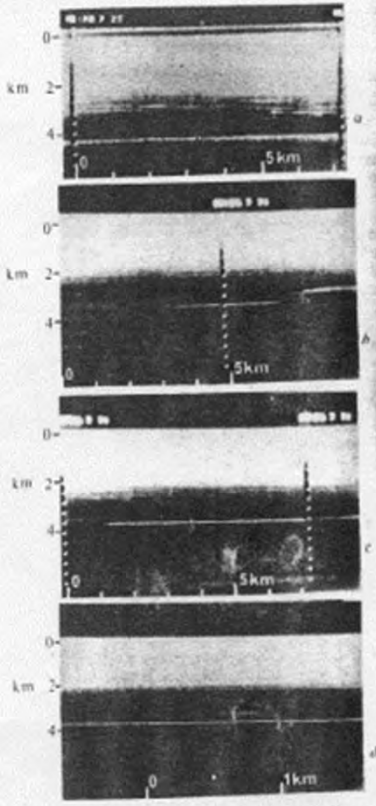


Fig. 2 *a*, Typical strong echo from bedrock, showing normal fading, and some downward extension of the trace due to non-vertical echoes. The column of white dots gives a time reference at 5 μs intervals; *b*, clearly defined example of a smooth reflecting surface under the ice, showing a steep scarp at one edge and a more gradual slope at the other; *c*, further example, with more symmetrical sloping rock margins than shown in Fig. 2b; *d*, section from Fig. 2*c* with the horizontal scale expanded four times, illustrating the slow rate and small amplitude of fading.

(Попов и др., 2012)

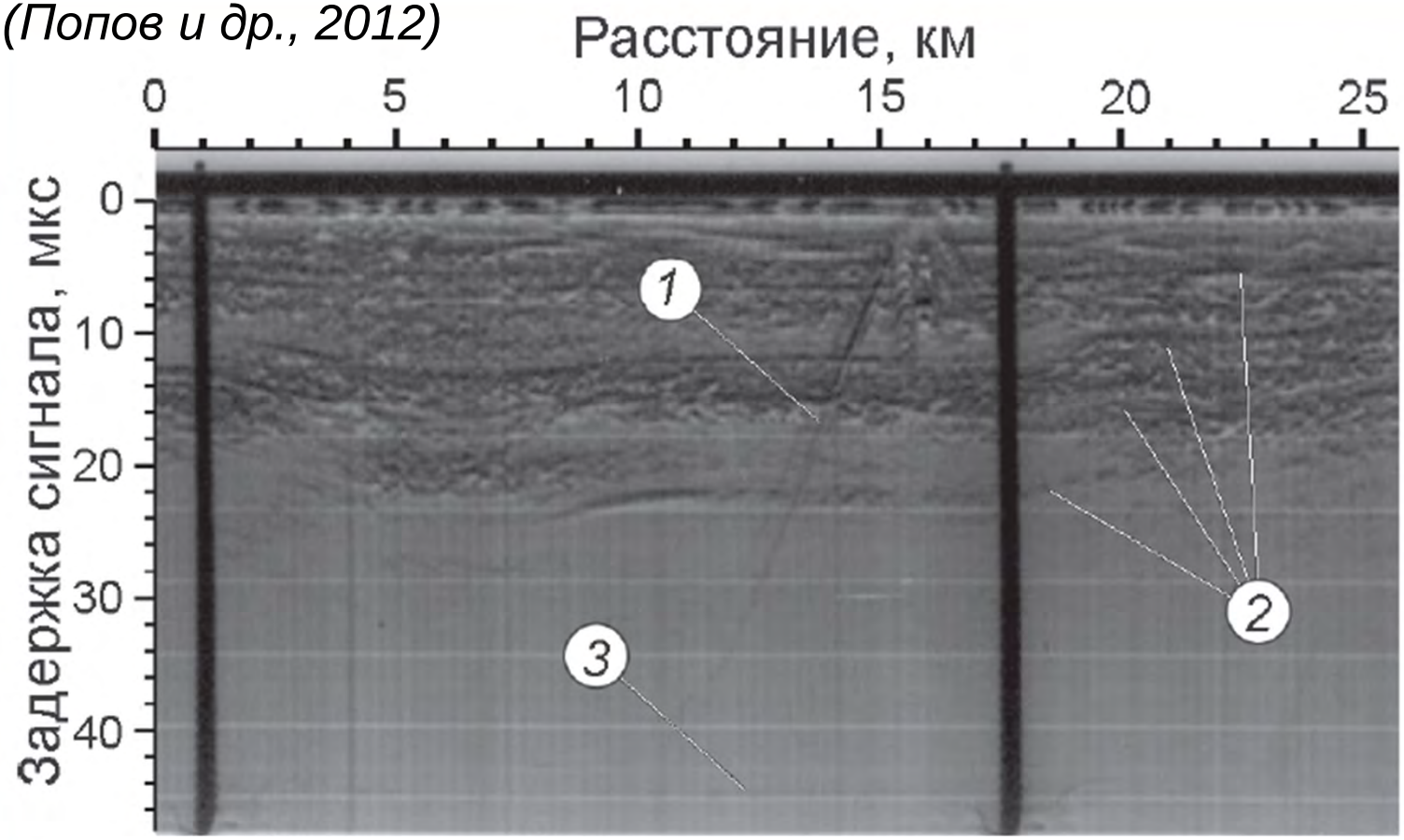
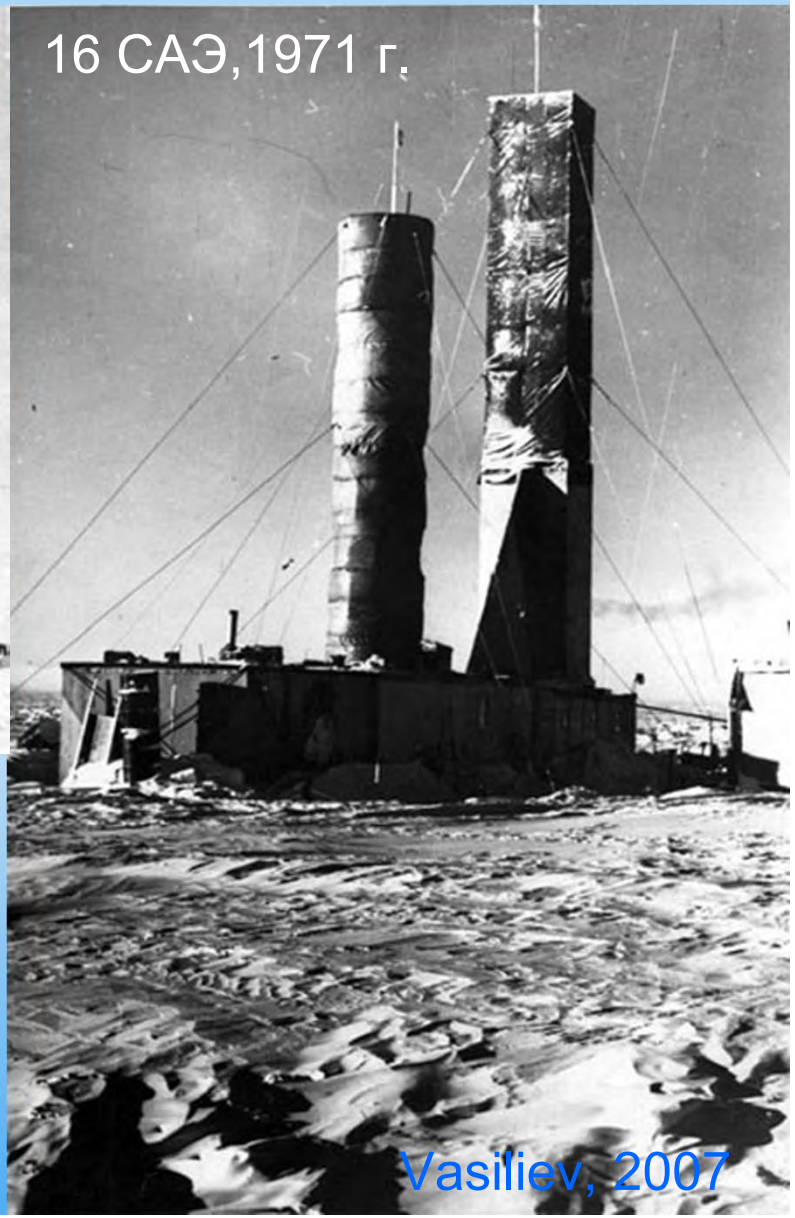


Рис. 1. Фрагмент временного радиолокационного разреза с зарегистрированным отражением от поверхности подледникового оз. Восток.

1 – отражение от буровой, расположенной на станции Восток; *2* – отражения от внутренних слоёв в теле ледника; *3* – отражение от поверхности подледникового оз. Восток

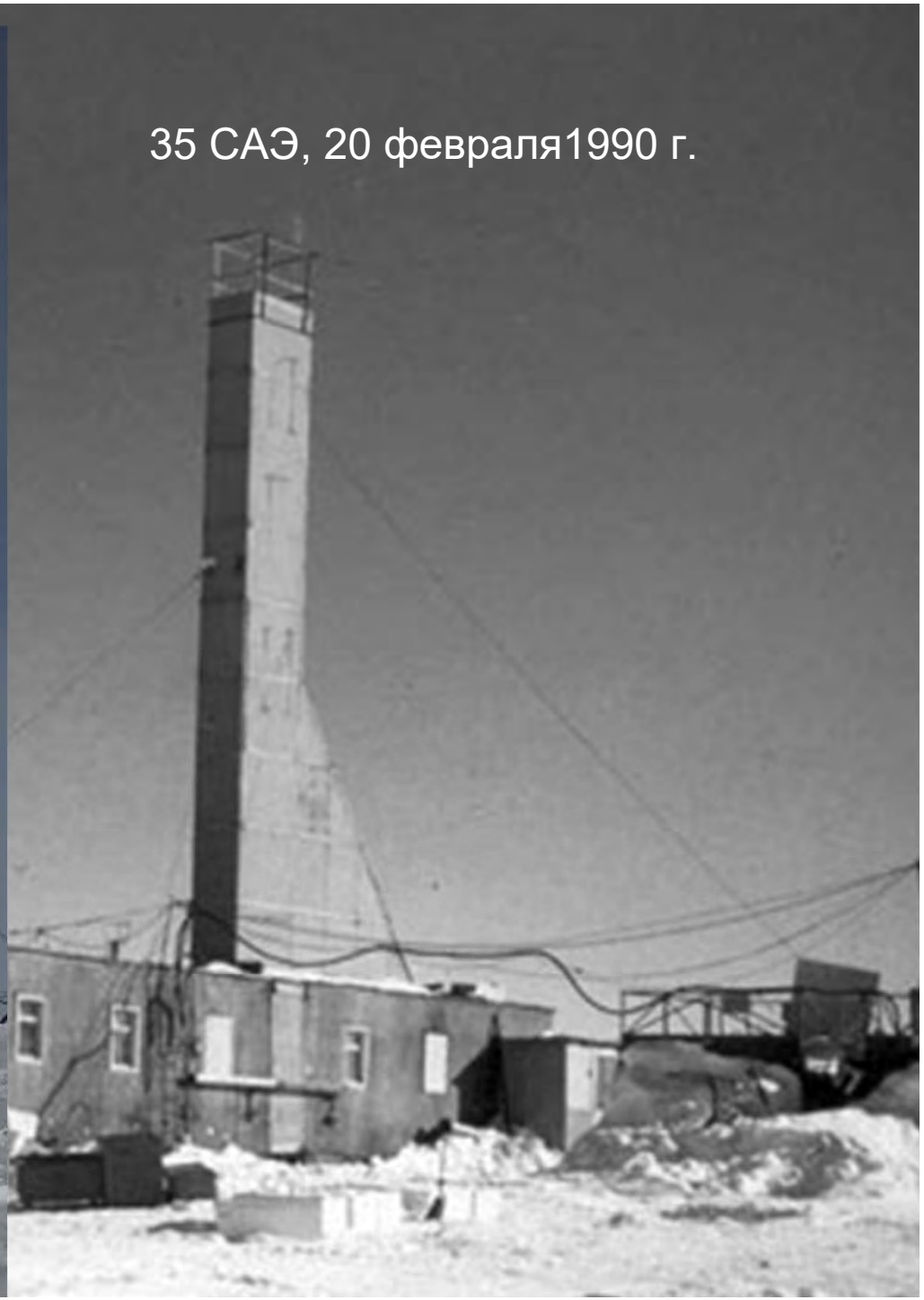
7 ноября 1987 г.

Бурение на станции Восток



58 РАЭ
январь 2013 г.

35 САЭ, 20 февраля1990 г.



Бурение на станции Восток

УКАЗ

ПРЕЗИДЕНТА РОССИЙСКОЙ ФЕДЕРАЦИИ

О награждении государственными наградами Российской Федерации

За большой личный вклад в организацию и осуществление проекта проникновения в подледниковое озеро Восток (Антарктида) в рамках Федеральной целевой программы "Мировой океан" наградить:

ОРДЕНОМ "ЗА ЗАСЛУГИ ПЕРЕД ОТЕЧЕСТВОМ" IV СТЕПЕНИ

ВАСИЛЬЕВА Николая Ивановича - заведующего кафедрой бурения скважин федерального государственного бюджетного образовательного учреждения высшего профессионального образования "Национальный минерально-сырьевой университет "Горный", город Санкт-Петербург

ЛИПЕНКОВА Владимира Яковлевича - заведующего лабораторией федерального государственного бюджетного учреждения "Арктический и антарктический научно-исследовательский институт", город Санкт-Петербург

ЛУКИНА Валерия Владимировича - заместителя директора федерального государственного бюджетного учреждения "Арктический и антарктический научно-исследовательский институт" - начальника Российской Антарктической экспедиции, город Санкт-Петербург.

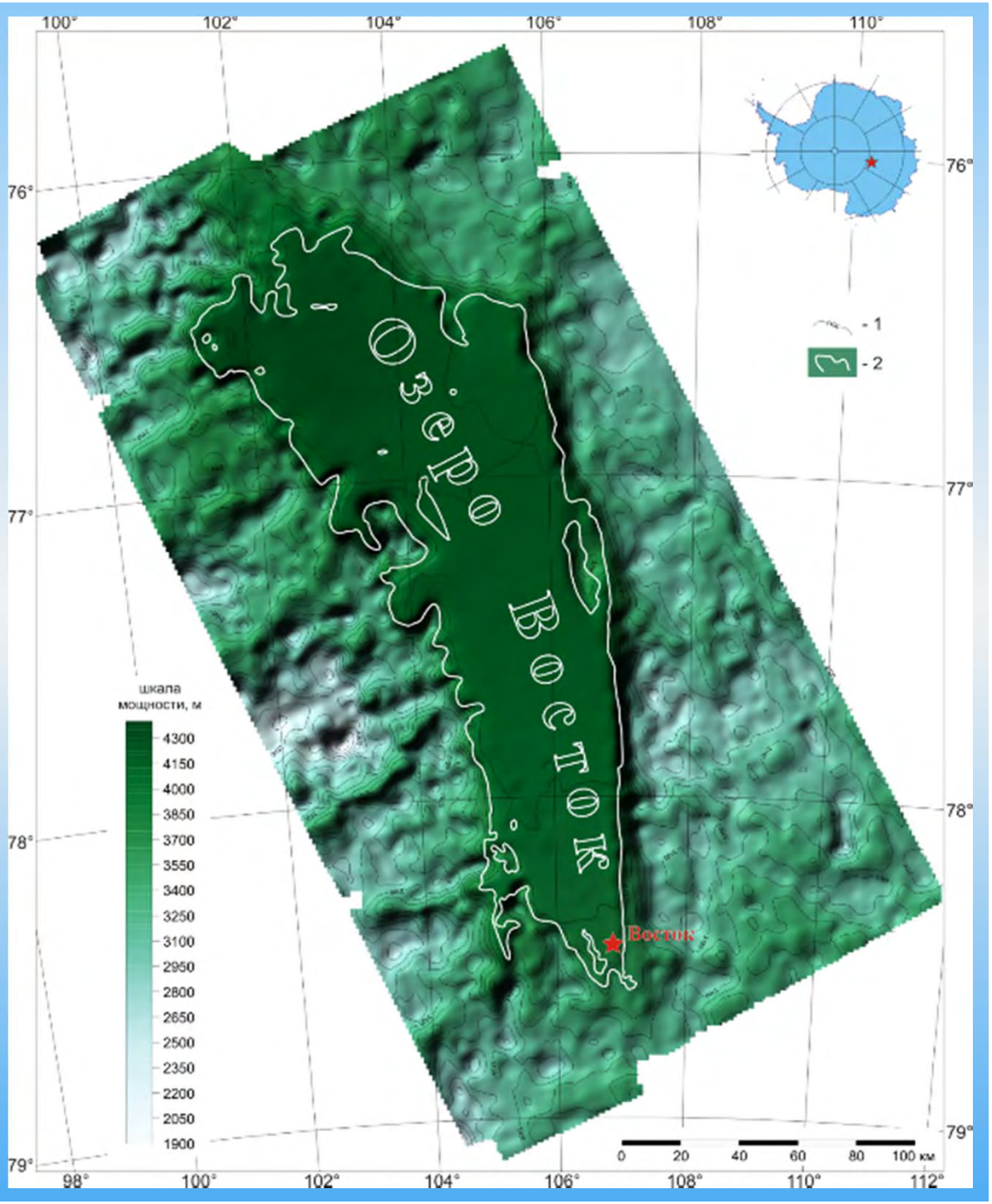
2 10002 15140 8

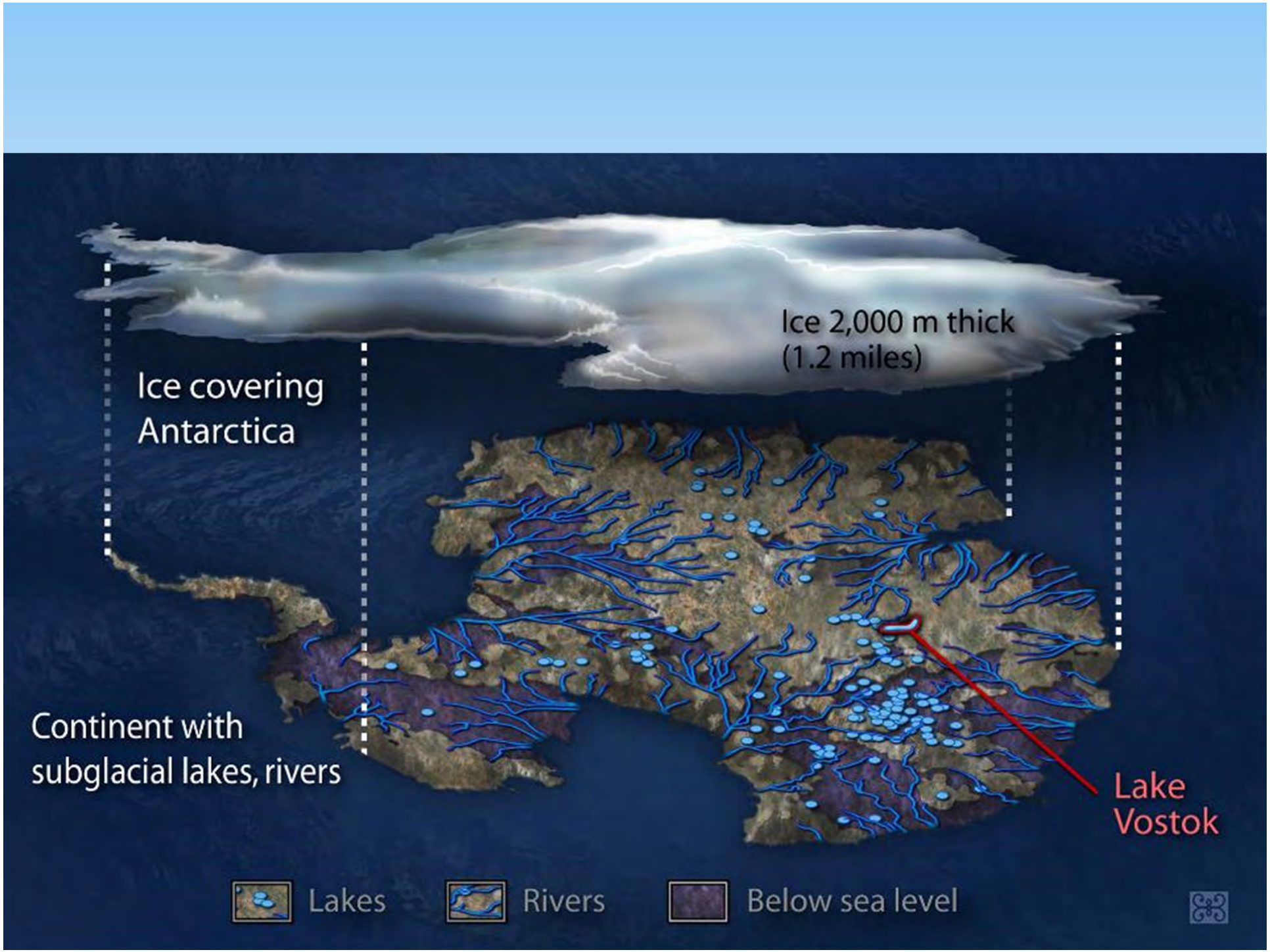
Кернохранилище
комплекс скважины 5Г-1, ст. Восток

Мощность ледникового покрова района озера Восток

Мощность ледникового покрова изменяется от 1950 до 4350 м.

Мощность ледникового покрова над акваторией озера изменяется от 3600 м в южной части до 4350 м в северной.




Ice 2,000 m thick
(1.2 miles)
Ice covering
Antarctica
Continent with
subglacial lakes, rivers
Lake
Vostok
Lakes
Rivers
Below sea level

Подледниковые водоёмы Антарктиды

Восточная Антарктида

Западная Антарктида

Море Уэдделла

Море Росса

FRIS

RIS

TAM

DF

DA

RB

TID

DC

Санае

Ноймайер

Дружная-3

Абоа

Васа

Кёниг

Шалле

Белыграно II

Дружная-2

Дружная-4

Прогресс

Лейвис

Полюс недоступности

Кунлун

Амундсен-Скотт

Восток

Восток-1

Комсомольская

Пионерская

Мирный

VSL

Бэрд

Конкорд

Кейси

Русская

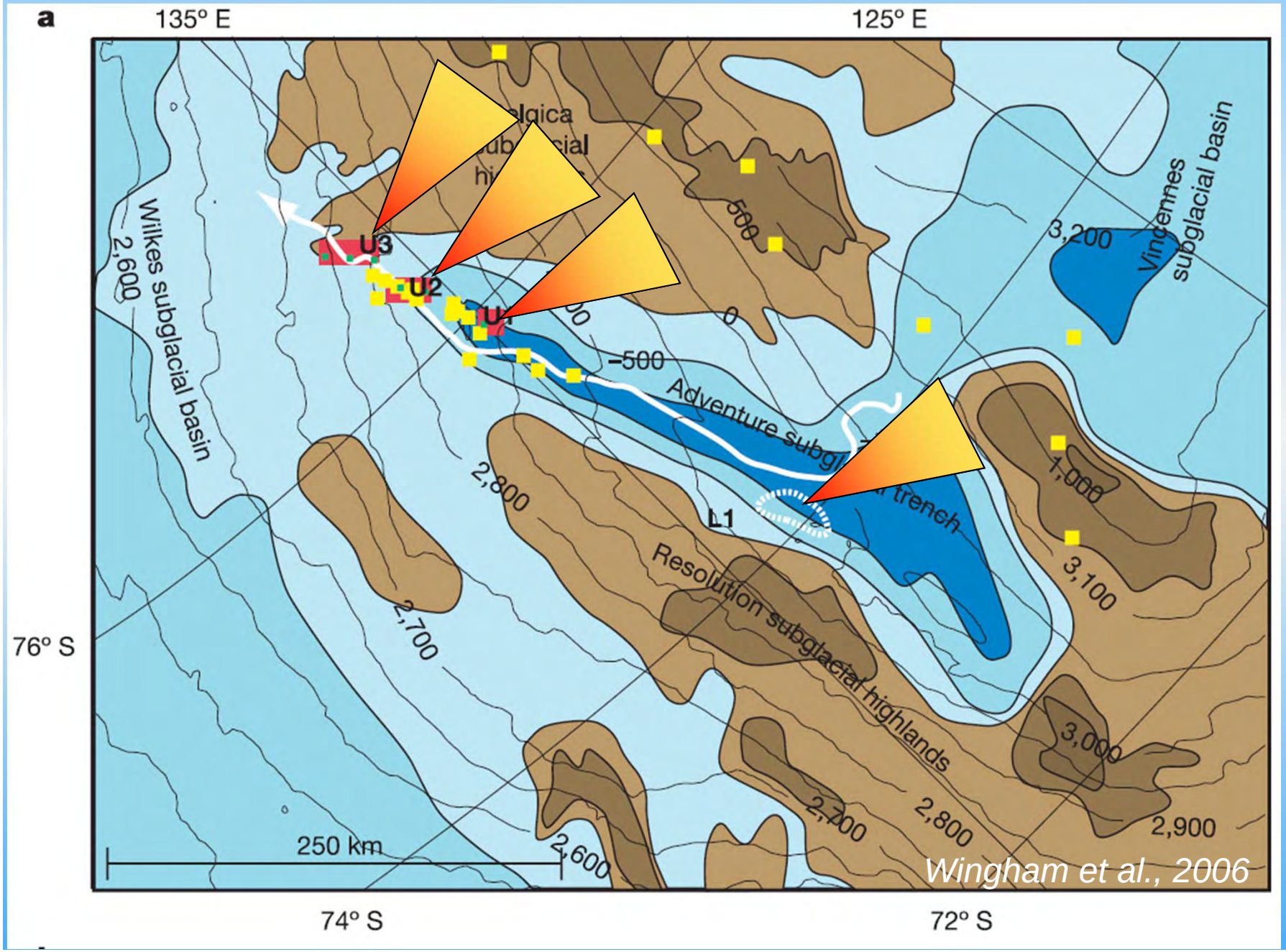
Мак-Мёрдо

Дюмон д'Юрвиль

Ленинградская

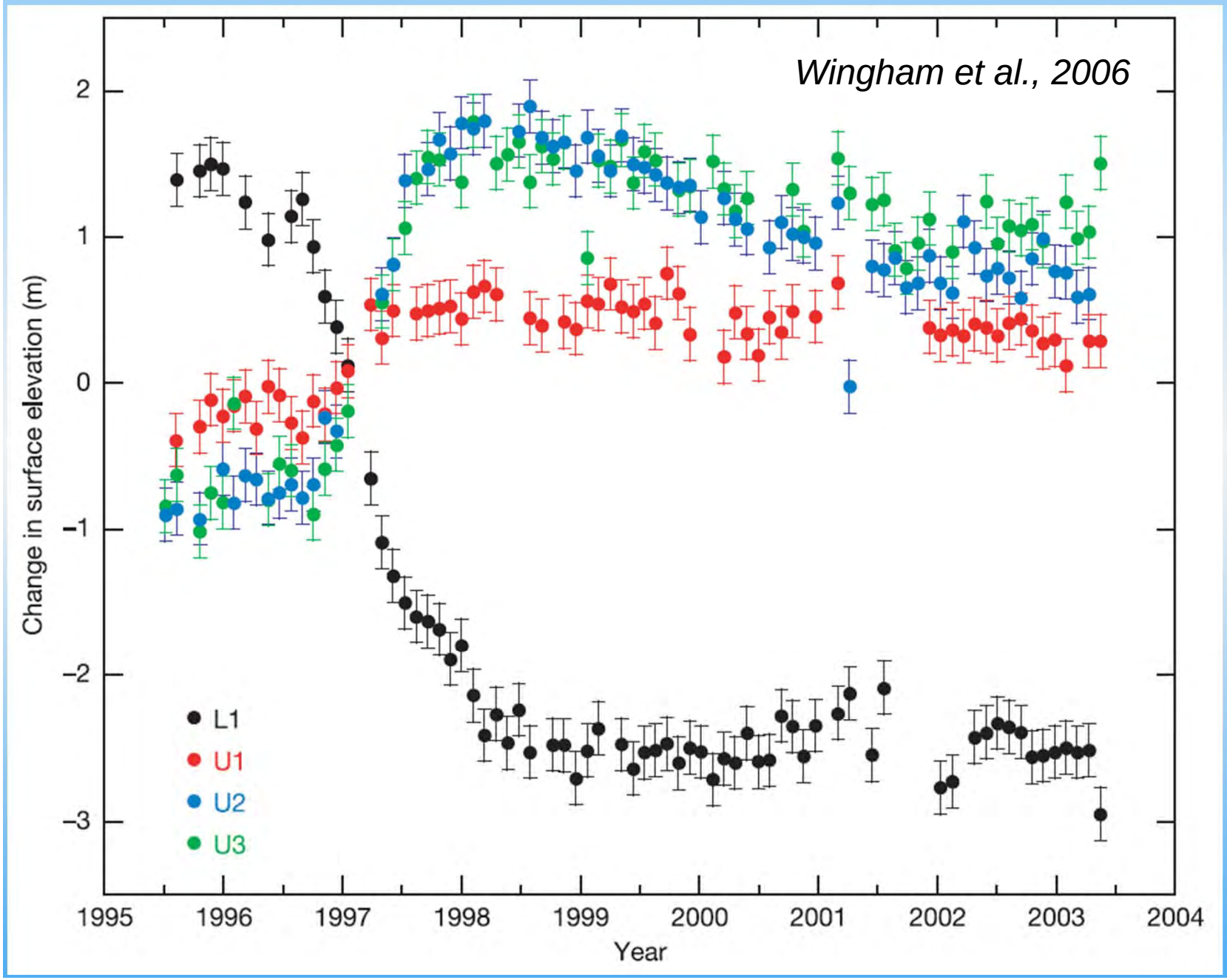
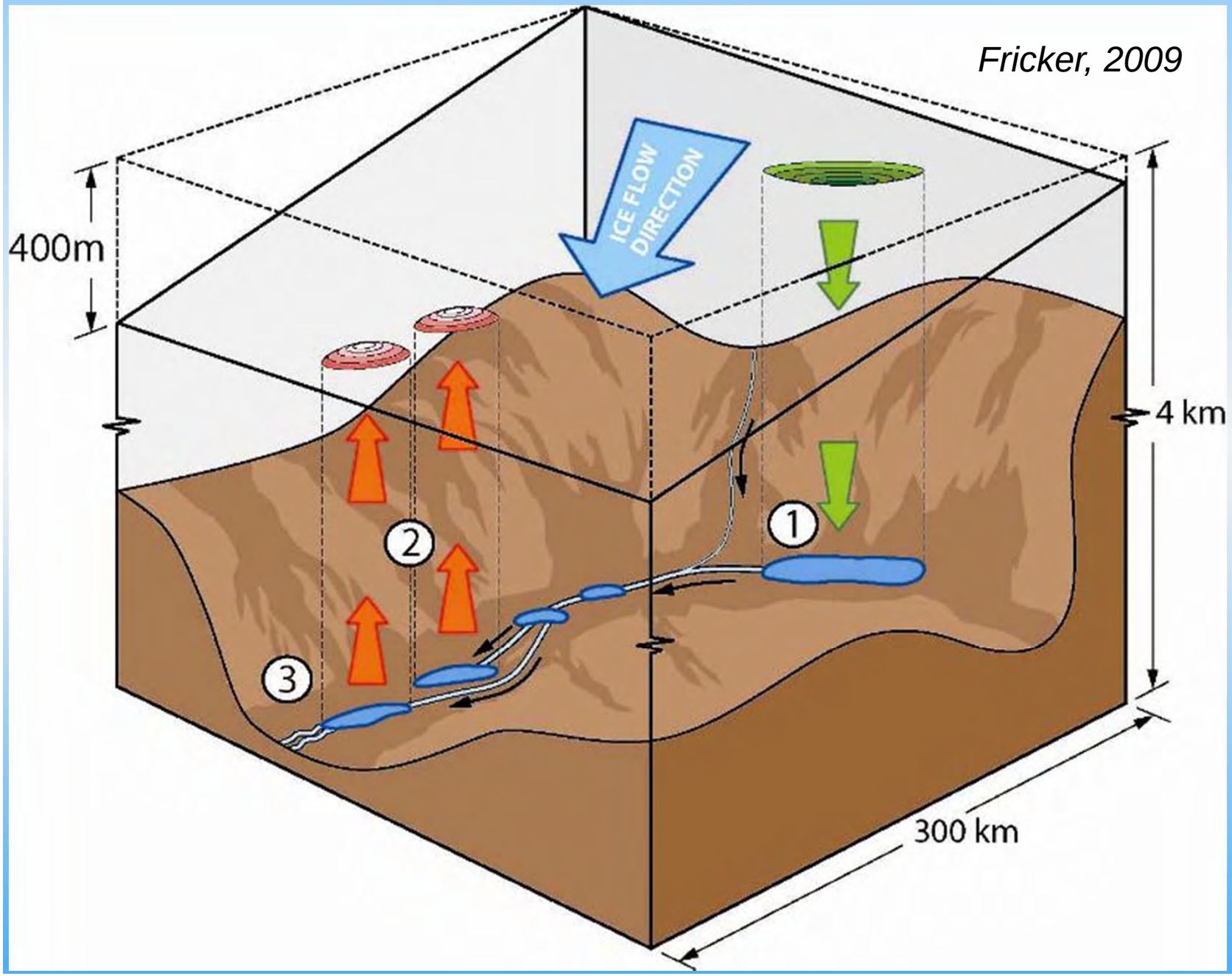
0 250 500 750 1000 км

Подледниковые паводки (*jökulhlaups*)



Wingham et al., 2006

Подледниковые паводки (*jökulhlaups*)



Подледниковые паводки (*jökulhlaups*)