

# AIR CIRCULATION IN KULOGORSKAYA CAVE SYSTEM

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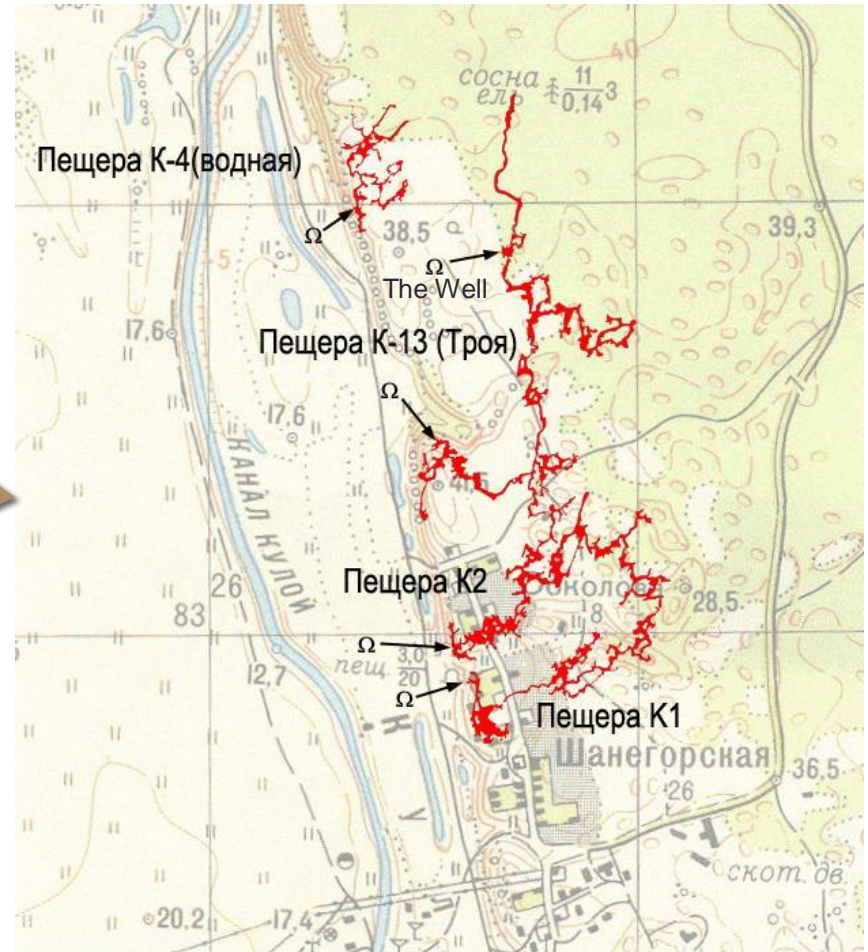
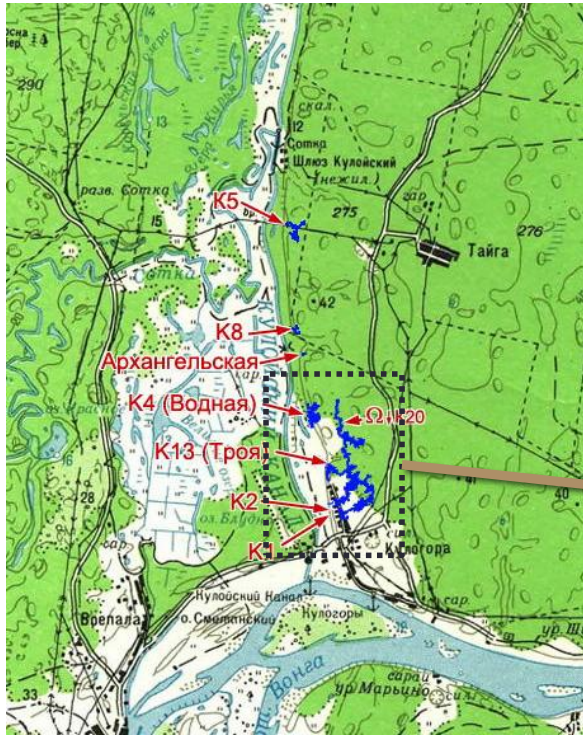
Archangelsk speleological association “Labyrinth”

# Climate conditions

## Климатические условия

Среднегодовая температура Annual average air temperature	+0.2° C
Среднегодовое количество осадков Annual average precipitation	560 мм
Продолжительность зимы Winter	140 дней, ноябрь – март 140 days, November-March
Самый холодный месяц Coldest month	Январь, -13° C January
Продолжительность лета Summer	Конец июня – начало августа End of Jun – beginning of August
Самый тёплый месяц Hottest month	Июль, +15.4° C July
Температура в пещерах Air temperature inside cave	+2.5° C

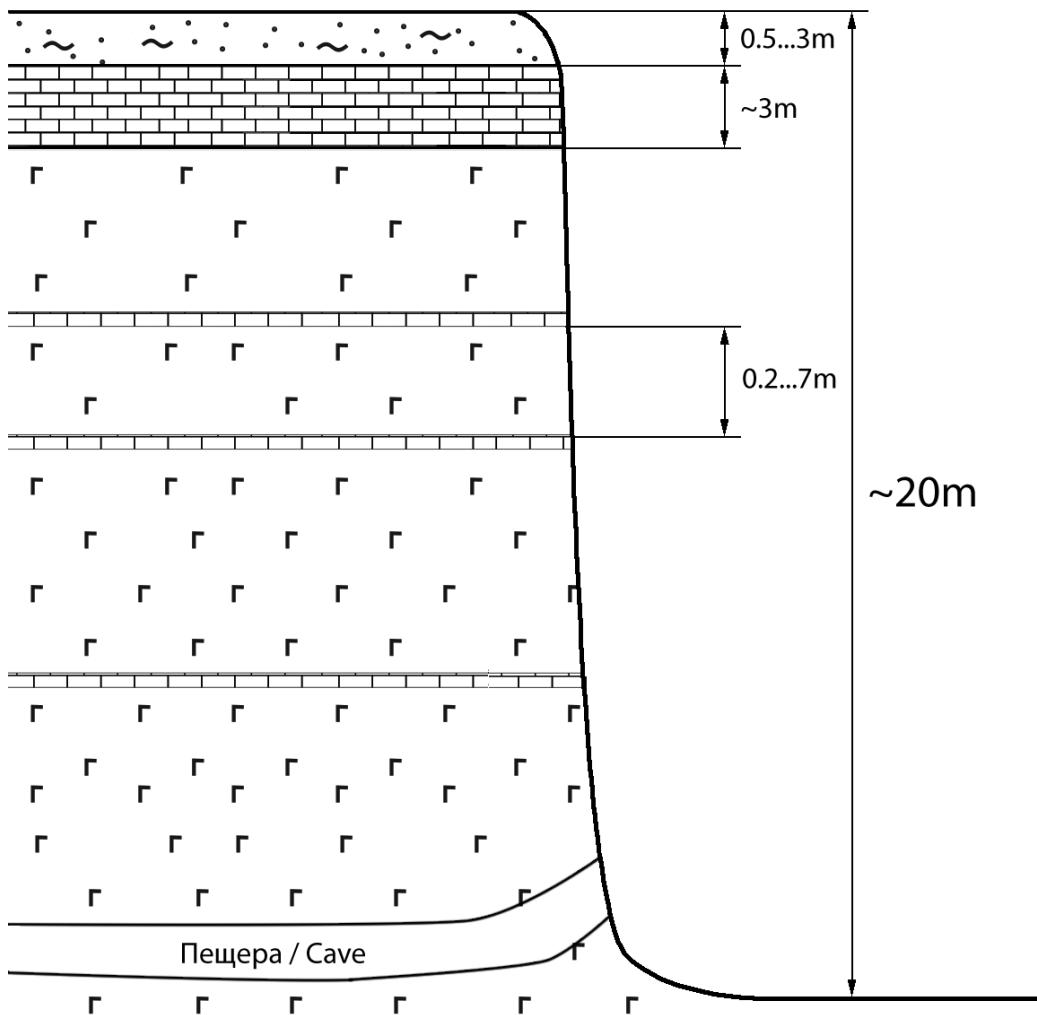
# Kulogorskaya Cave System Кулогорские пещеры



- 7 known caves, above 22 km total length.
- 1 artificial entrance – the Well.

# Geological Structure

## Геологическое строение



Гипс  
Gypsum

Доломиты  
Dolomites

Четвертичные отложения  
Quaternary cover deposits

- All natural cave entrances are located at the bottom of the ledge.
- Average number of collapse sinkholes above cave system is around 3000-4000 per 1km<sup>2</sup>, sometimes exceeding 10000. Almost all sinkholes are tuft-covered.

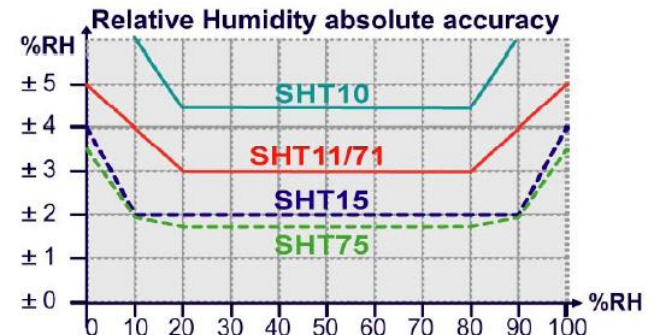
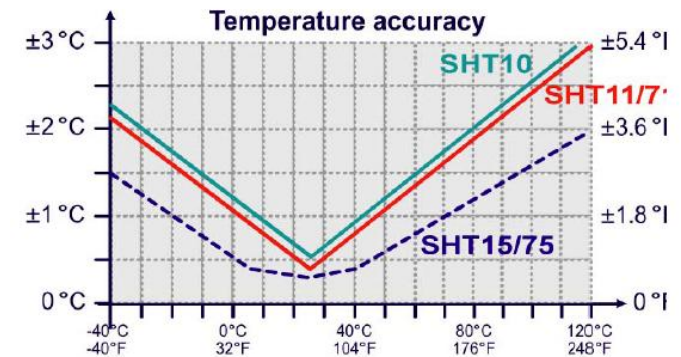
# Research equipment

## Методика исследований

- Since 1970
  - Temperature measurement with mercurial thermometer 0.1°C
  - Air movement direction measurement with permanganic acid powder and wet paper.
- Present days
  - Temperature loggers employing SHT1x sensors from Sensirion
  - Temperature measurement with KTY83-110 positive temperature coefficient resistors
  - We do not measure wind speed, because it is extremely low

# Dataloggers employing SHT1x sensors from Sensirion Даталоггеры на основе датчиков SHT1x фирмы Sensirion

- Models
  - Laskar EL-USB
  - Voltcraft DL-120TH
- Measured parameters
  - Temperature
  - Relative humidity
- If submersion possible we use sealed boxes, measure temp only.
- Price ~70 Eur
- Replaceable but expensive battery
- One of the loggers had error magnitude of some degrees, should be checked before use



# Temperature measurements with КТУ83-110 PTC Thermistors

## Измерения с помощью терморезисторов КТУ83-110

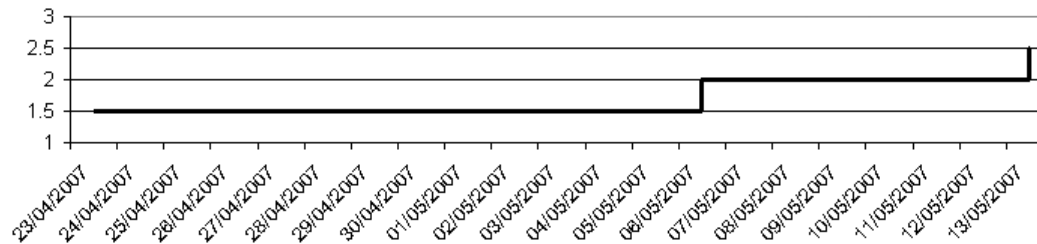
- Before use measure resistance  $R_0$  at  $t=0^\circ\text{C}$  of each thermistor.
- Resistors destined to be used in air are covered with paraffin to prevent fast heating from a person making the measurement.
- To measure temperature one measure resistance and derive temperature as  $T=\lambda \cdot (R-R_0)$ , where  $\lambda$  – coefficient provided by manufacturer.
- High quality multimeter is required. Cheap multimeters make large errors when working at temperatures around  $0^\circ\text{C}$ . It's desirable to use precision resistor to check multimeter in cave before use.
- Extremely low price allow us to permanently fix large number of sensors in caves. However a human operator is required to make measurements.



# Seasonal air circulation

## Сезонная циркуляция

- Caves exhibit classical air circulation pattern, where natural exits serve as lower entrances for air, inhaling air at winter and exhaling at summer.
  - Circulation change from winter to summer mode can be seen on temperature log from K-1 cave:

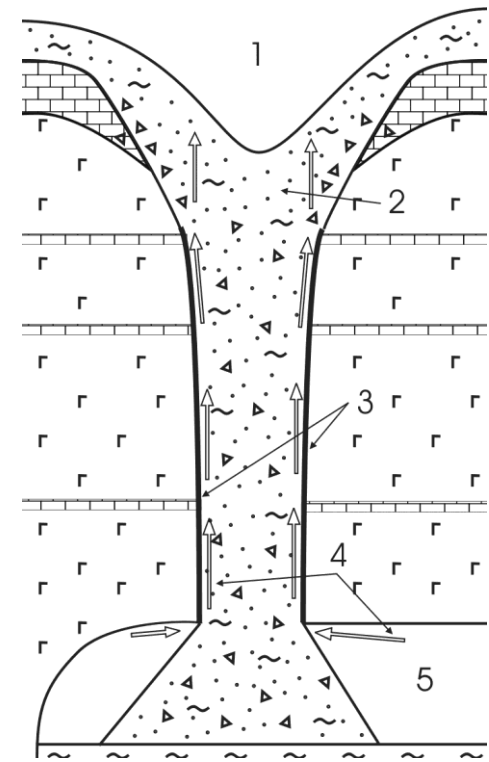


- Such circulation system is common for open karst, however at Kulogory region there are no open air vents from cave to the surface.
- What serves as an upper entrance for circulation system?

# Vertical air filtration

## Вертикальная фильтрация воздуха

- During construction of the Well in 1990 it was found that between stone walls of natural well and filling material there is «corrosive rantklyuft» 5...15 mm wide, with single cavities 50...80 mm wide.
- Such rantklyuft can provide air flow from cave to the depth of 3...4 m to the crater bottom. The air can penetrate this layer of well-washed sandy loam.
- Large number of rantklyufts below sinkholes may serve as “upper entrance” for cave ventilation system.



- 1 – sinkhole,
- 2 – air filtration zone,
- 3 – rantklyuft,
- 4 – air flow,
- 5 – cave.

## The Well and air circulation in K-13 cave

### Колодец и система воздушной циркуляции в пещере К-13

- While the Well was being build it was expected that it will serve as “upper entrance” for cave ventilation system
- However, when cavers first enter the Well in winter they found out that the cold air enter the cave via the Well, as if it is a “lower entrance”:

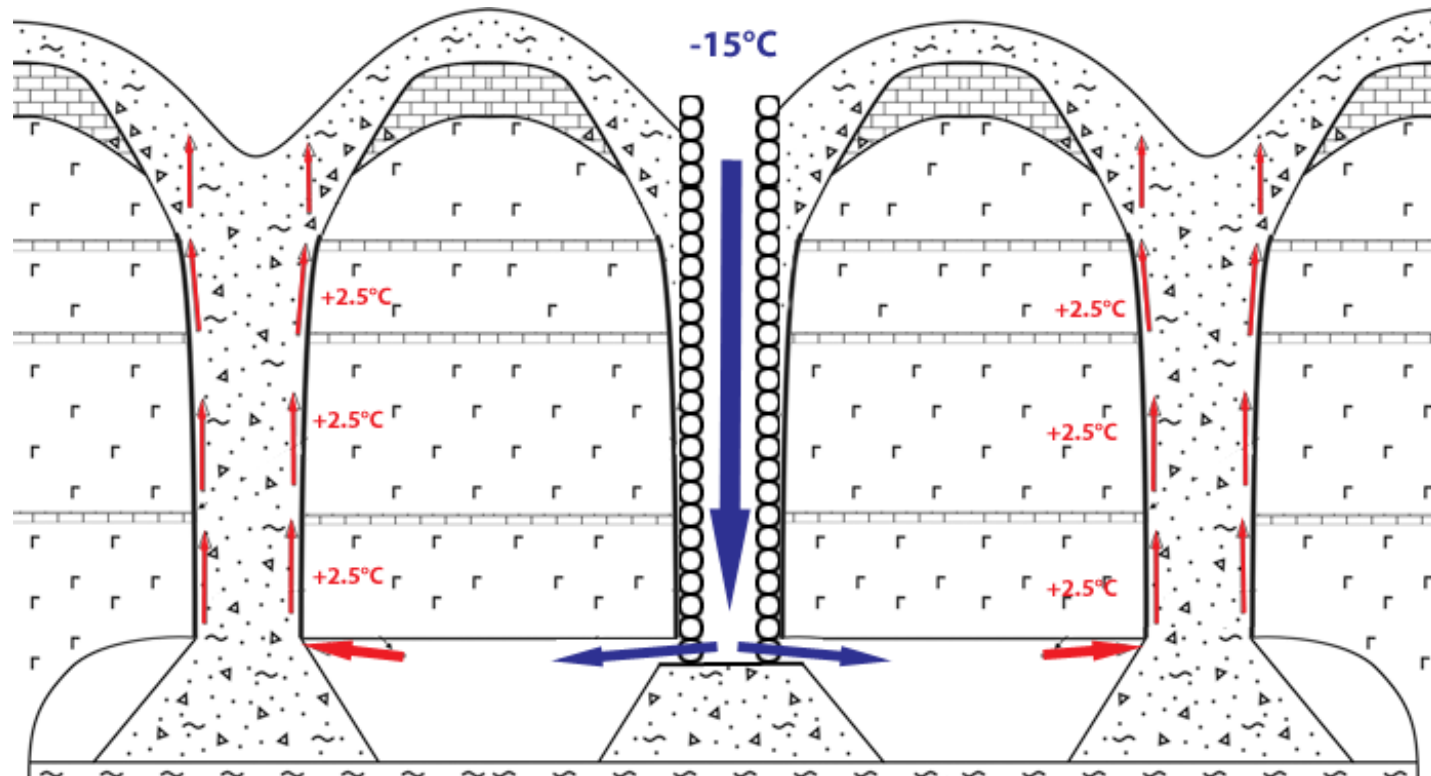
- How this is possible?



## The Well and air circulation in K-13 cave

### Колодец и система воздушной циркуляции в пещере К-13

- Diameter of the Well (0.6... 1m) is large enough for cold air to enter it from surface.
- Air in rantklyufts have the same temperature as rock.

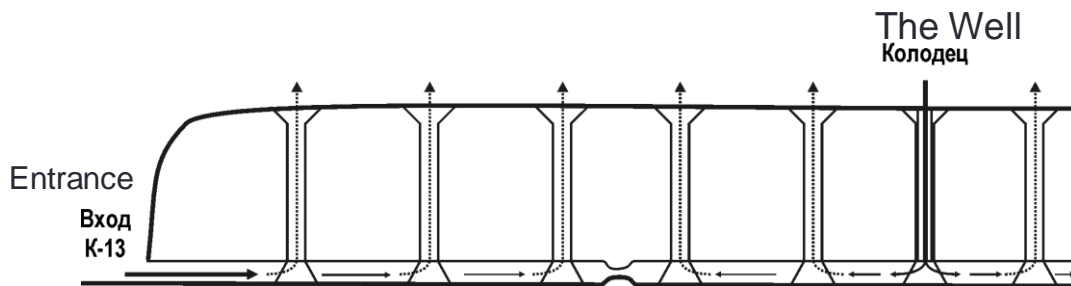
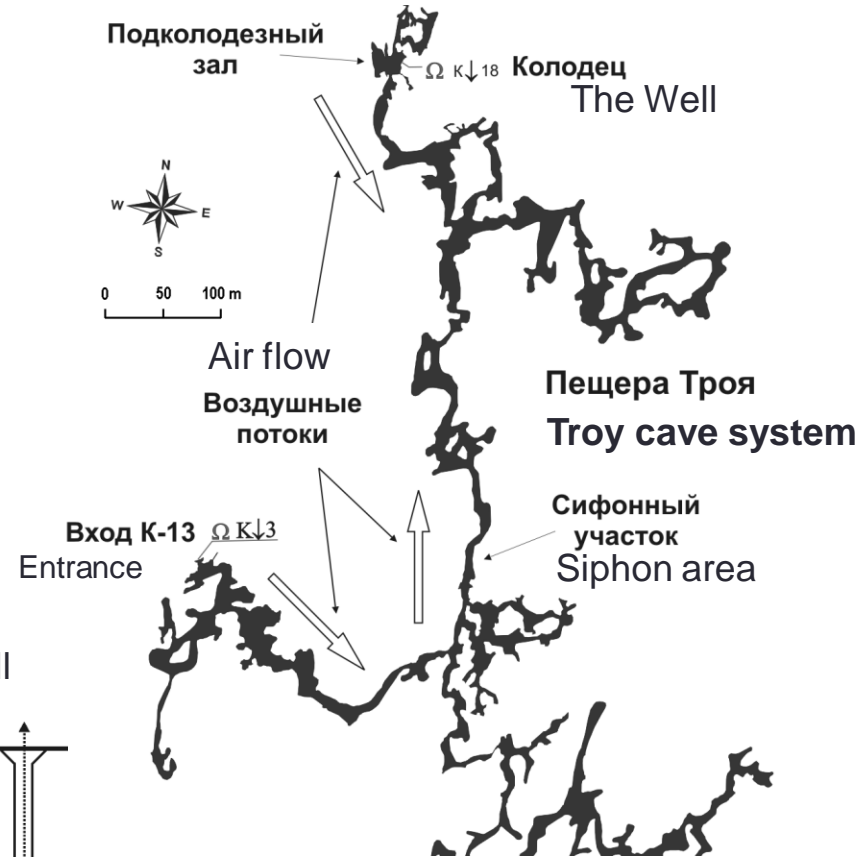


# Winter circulation in K-13 Troy cave

## Зимняя циркуляция в пещере Троя

In autumn the area around the Well is separated from lower entrance by high levels of water in the Siphon area. At this time a separate air circulation system start working around the Well.

However when water levels decrease in winter both systems continue to operate independently of each other, with both natural entrance and the Well working as “lower entrances” for air.



# Karst crater temperature measurements

## Термометрия карстовых воронок

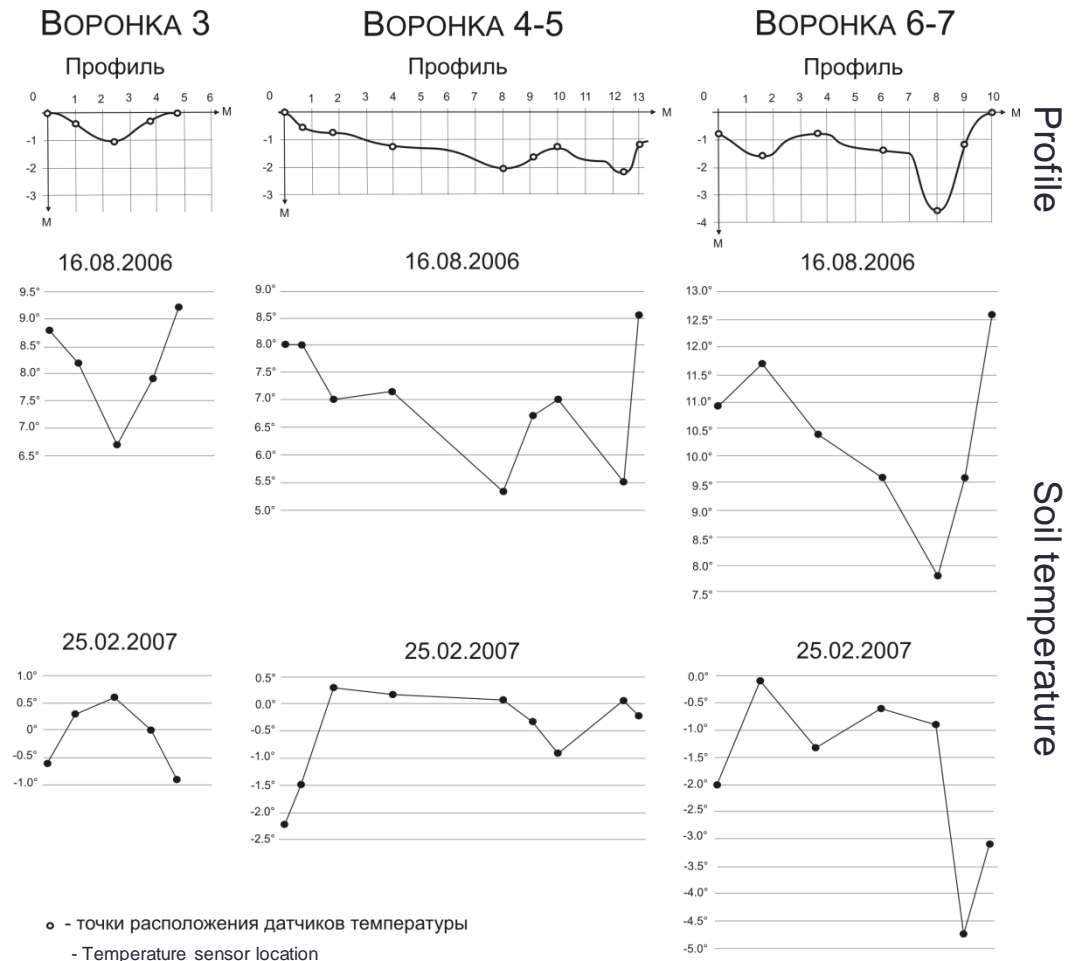
Since speed of air flow inside cave is below measurable level and rantklyufts are not available for direct observations other means are required to test our hypothesis.

One of the consequences of air filtration at sinkhole bottom should be an increase of soil temperature both in winter, when warmer air from the cave is exhaled, and in summer, when hot air from atmosphere is inhaled this way.

In order to check this we equip several craters with temperature sensors and made a series of measurements in different seasons.

Surface air temperature during measurements:

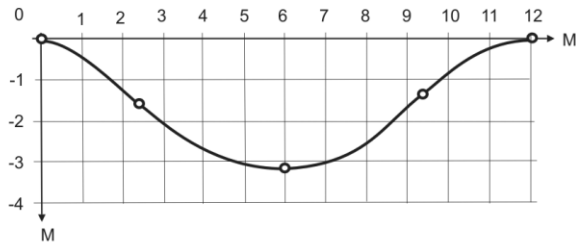
- 16.08.2006: +14° C
- 25.02.2007: -15° C



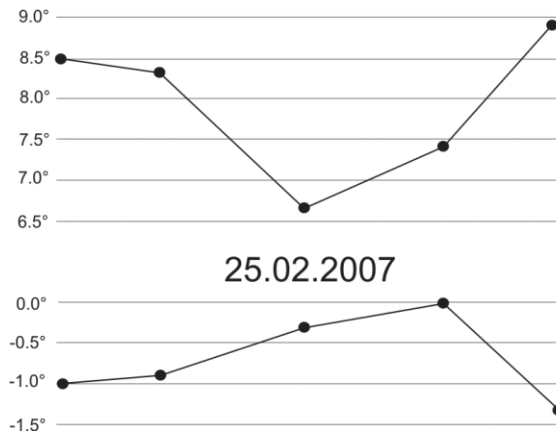
# Karst crater temperature measurements

## Термометрия карстовых воронок

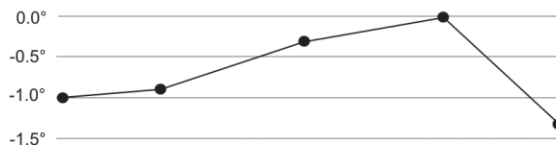
ВОРОНКА 9  
Профиль



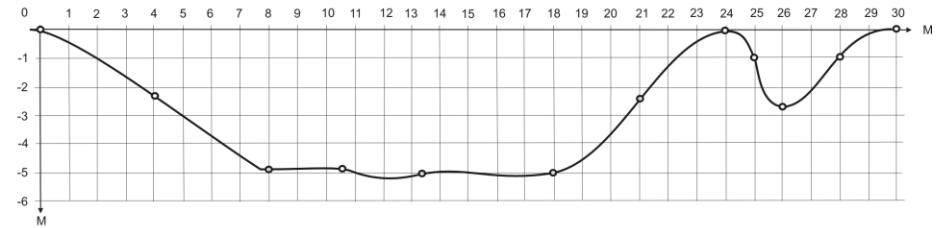
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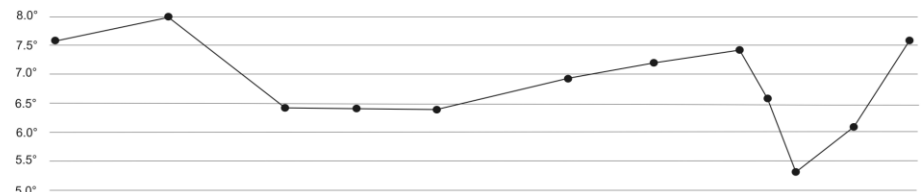
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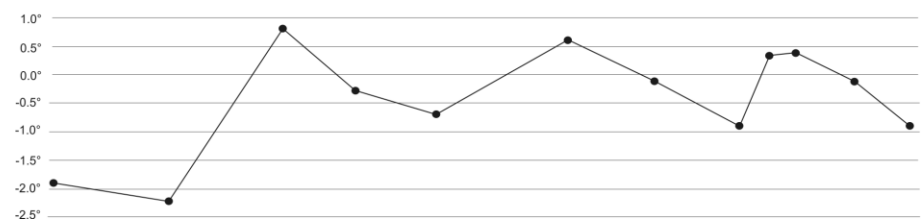
ВОРОНКА 12-13  
Профиль



Температуры 16.08.2006



Температуры 25.02.2007



Profile

Soil temperature

# Conclusions

## Выводы

- We show that turf-covered sinkholes serve an active role in the ventilation of cave system in Kulogori area.
- Air permeability of sinkholes is provided by corrosive rantklyufts. Existence of rantklyufts seems to be dependent on high speed of gypsum denudation.
- Larger, comparing with rantklyufts, cross-section of the Well and obstructed air exchange with natural entrance condition existence of two independent air circulation systems in Troy cave.
- One can expect the same air filtration mechanism to work in any region with similar conditions.

# Speculations

## Предположения

- One can propose existence of ventilation systems in caves, which do not have direct vents into atmosphere, when both lower and upper entrances are turf-covered sinkholes situated on different heights.
- In summer the Well have pulsative air flow. More observations are required to understand this.