SCIENTIFIC PROGRESS REPORT – PROJECT PN-III-P1-1.1-PD-2016-0172,

Exploring permafrost occurrence and evolution in the Rila and Pirin Mountains (Bulgaria) using a combined geomorphological, geophysical and dendrochronological approach

Report 1 (02.05.2018 – 31.12.2018)

Report 1: Exploring permafrost occurrence in the test sites (first part) and assessing the dynamics of the rock glaciers (first part)

Overview

This study aims to investigate permafrost occurrence in the highest mountains of Bulgaria. Rila and Pirin Mountains are the highest mountains in Bulgaria, reaching 2900 m in elevation. Rock glaciers are widespread in both mountain units above the tree line, indicating permafrost creeping during their activity. The presence/absence of permafrost associated with rock glaciers was not investigated so far. This research will use miniature thermistors to assess the near-surface thermal regime of the rock glaciers and geophysical investigations to examine the internal structure of glacial and periglacial landforms. We will also examine the movement of the rock glaciers using ground-based geodetic surveys, tree-ring analysis and photogrammetry. In the end we plan to get more insights into the paleoenvironmental significance of rock glaciers, considering the deglaciation timing of these mountains.

In this phase we have planned five different activities, as follows:

1. Selecting the test sites for observations and measurements;
2. Installing data-loggers to monitor the temperature of the rock glaciers near-surface;
3. Geophysical investigations and processing the geophysical data;
4. Measurements of the spring temperatures in the selected sites;
5. Ground based geodetic measurements for assessing rock glaciers dynamics;

1. Selecting the test sites for observations and measurements

We selected five test sites, considering the following criteria:

- The morphology of the landforms and the possibility to host permafrost;
- The continuity of observations in sites where we already started to measure ground surface temperatures;
- Accesibility.

Before selecting the test sites we analyzed existing satellite images, topographical and geological maps and we made several field campaigns for geomorphological observations, starting with 2016. For the geomorphological observations, geophysical measurements, ground surface temperature monitoring and measurements of the dynamics of rock glaciers we selected five sites (fig. 1).

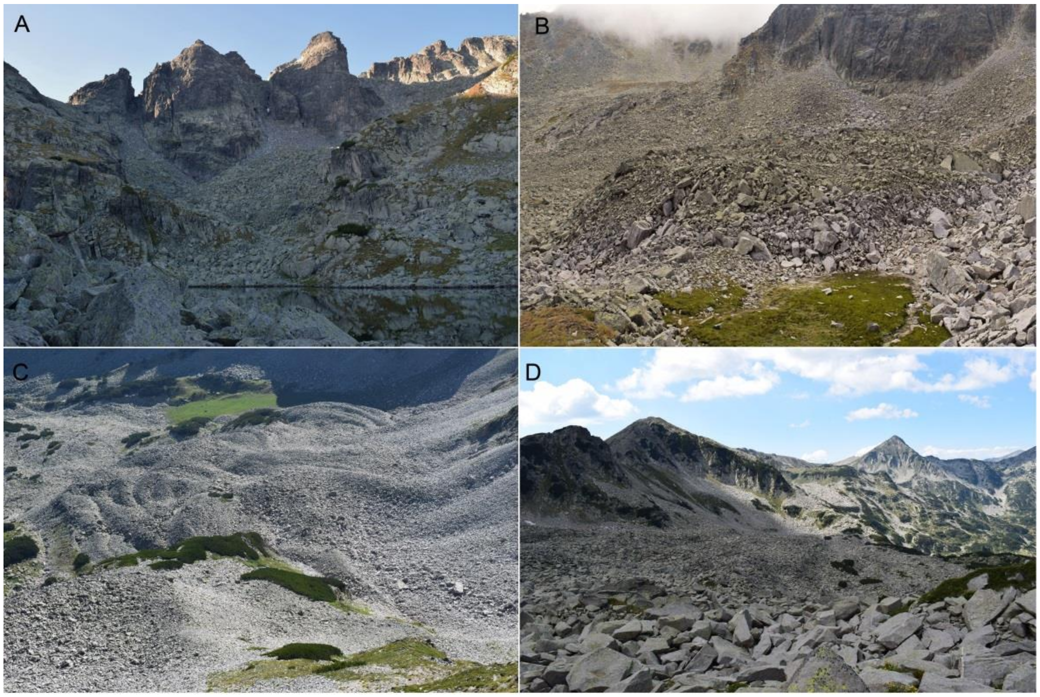

Fig. 1. Selected rock glaciers for observations and measurements within the test sites (A. Golyam Kupen; B. Musala; C. Polezhan; D. Banderishki Chukar).

Two test sites are located in the Rila Mountain and three in the Pirin Mountains. In these sites we started to monitor the ground surface temperature regime of 15 rock glaciers, the annual dynamics of 5 rock glaciers and to perform geophysical investigation on 10 rock glaciers. We will also generate high resolution digital elevation model for 10 rock glaciers. We are also interested to explore permafrost occurrence in the vicinity of the two small glaciers (Snezhnika and Banski Suhodol) and in several rock walls.

2. Installing data-loggers to monitor the temperature of the rock glaciers near-surface

We started in 2016 to monitor rock glaciers near-surface thermal regime and now we extended the measurements. In total we installed 100 thermistors within 15 rock glaciers and in other different periglacial landforms. We placed between 4 and 8 thermistors in each rock glacier and we also placed thermistors to measure air temperature, snow cover timing and temperature of the rockwalls.

To measure the near-surface temperature regime of rock glaciers we used miniature dataloggers (iButton Digital Thermometers DS 1922L). The thermistors were used to register the ground surface temperature every 2 hours. Readings were recorded with a resolution of 0.065^{o}C and less than ± 0.5^{o}C error. The thermistors are designed to measure temperatures between -40 and +85^{o}C. We placed the miniature dataloggers at 5-10 cm beneath the surface of the rock glaciers and we covered the thermistors with pebbles to avoid direct exposure to solar radiation.

In the field we used a portable computer to set the thermistors through a special reader and the 1-Wire Viewer software (fig. 2). The coordinates of the sites where we installed thermistors were saved by a GPS device.

Fig. 2. Installing the dataloggers in the selected test sites.

Based on the `rule of thumb`, permafrost is probable where values lower than -3^{o}C occur in the late winter when the snow depth is thick enough to insulate the ground. Temperature values between -2^{o}C and -3^{o}C suggest the possible presence of permafrost, whereas values above -2^{o}C indicate the absence of permafrost (Hoelzle, 1992).

3. Geophysical investigations

In alpine environments, geophysical measurements have been widely used to get information on permafrost distribution and characteristics. In Bulgaria this is the first time when electrical resistivity tomography (ERT) and ground penetrating radar (GPR) are conducted on periglacial/glacial landforms (fig. 3).

ERT is probably the most applicable geophysical method for permafrost detection, because of high resistivity contrast between frozen and unfrozen materials. The resistivity of permafrost may vary between 10 kΩm and 1000 kΩm depending on ice content, temperature and quantity of impurities (Kneisel and Hauck, 2008). The geoelectrical soundings were performed using a GeoTom MK8E 1000 resistivity meter in the vicinity of Banski Suhodol glacier. For the inversion of measured resistivities we used Res2DINV software.

Fig. 3. Geophysical measurements near Banski Suhodol glacier.

GPR measurements were used to map the internal structure of glaciers and rock glaciers in the selected sites. This technique is based on transmitting high frequency electromagnetic pulses into the ground and measuring the pulse signal travel time form the transmitter to the object that reflect the pulse and back to the receiver. The investigations were conducted using a Mala ProEx system and a 100 Mhz unshielded rough terrain antenna. By now we performed investigations on five rock glaciers and on two glaciers in the Pirin and Rila Mountains. For processing the data we used Reflexw 6.0 software and we followed the protocol for the processing based on the existing literature (Degenhardt, 2009). The results revealed the thickness of the glaciers, the distribution of permafrost in different rock glaciers and near the glaciers and different types of structures in the substrate.

4. Measurements of the spring temperatures in the selected sites

The measurement of spring water temperature during August-September period is an easy and rapid way to get indirect information on permafrost probability in rock glaciers. Generally if the temperature of the water is close to the freezing point (below 2^{o}C) the source of the water might be thawing permafrost (Warhafting and Cox, 1959). In the present study we measured the temperatures of 6 springs in the Rila and Pirin Mountains seeping from the fronts of rock glaciers, using a digital thermometer with ± 0.1^{o}C accuracy (fig. 4).

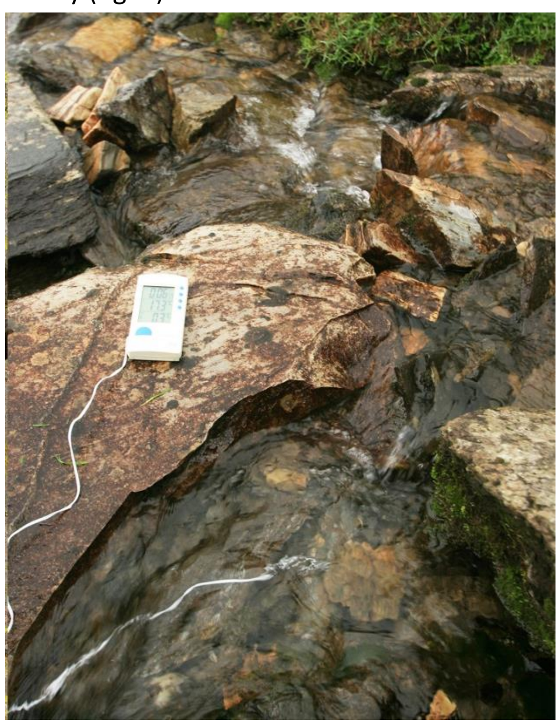

Fig. 4. Measurements of the spring temperatures using a digital thermometer.

The measured temperature values range from 1.7 to 6.7^{o}C, but only in two cases a temperature below 2^{o}C was recorded. In one case the temperature of the spring was measured at 150 m distance from the rock glacier front and is possible that the source of the water to be from the ground too. One spring revealed a low temperature (below 2^{o}C) in 2017 too confirming the probability of permafrost occurrence in that rock glacier.

5. Ground based geodetic measurements for assessing rock glaciers dynamics

We initiated measurements of movement on five rock glaciers in the Rila and Pirin Mountains using a high-precision differential GPS TopCon Hiper V (fig. 5). The accuracy of the measurements is below 2 centimeters for each point we measured. We set up the base antenna in a stable location and we used a rover to receive corrections via radio from the base antenna and to record coordinates for different points within the investigated rock glaciers. We collected between 10 and 28 points on each rock glacier and we marked these points in the field.

Fig. 5. Ground based geodetic measurements using a differential GPS.

One of the main objectives of this project was to realize a database with all the thermal data concerning rock glaciers collected in Rila and Pirin Mountains during the current project and before. We established such a database where encountering three different types of thermal measurements:

a. Thermal regime monitoring at the near-surface of rock glaciers;
b. BTS measurements;
c. Spring temperatures measurements.

We standardized the recording of data and established the attributes for each measurement. We used ArcGIS to create layers with the location of each measurement point. For each point we stored an ID, geographic coordinates, elevation, type of landform, name of the mountain unit, geology and detailed description of the place where the measurements was taken. For the thermistors we also created an .xls file where we stored information on data and time of each measurement, temperature value, daily mean/minimum/maximum, measuring interval, winter equilibrium temperature, mean annual temperature, „zero curtain” interval, freezing and thawing indexes.

Aknowledgement

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