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Water balance, temperature and mineralization of periglacial waters in Bellsund region, Spitsbergen, summer 1986

ABSTRACT: Preliminary results of hydrological investigations carried through at southern shore of Bellsund are presented. Negative meltwater budget of the permafrost was noted for summer 1986. Temperature and total mineralization of waters are varied in space. Temperature of outflowing meltwaters is related to air temperature. Diurnal rhythm of temperature has been distinguished in springs.

Key words: Arctic, Spitsbergen, permafrost, water budget

Introduction

Water circulation in some drainage basins of the Bellsund region formed the main task of hydrographic investigations carried through in 1986 during the Spitsbergen Expedition organized by the Maria Curie-Skłodowska University. Author paid special attention to outflow formed in different physico-geographical conditions.

Investigated area was located in Calypsostranda, 0.5 to 1 km wide coastal plain with several raised marine beaches, accompanied by mountain massifs and partly glaciated valleys. Central part of the studied area is occupied by the Renard Glacier (Renardbreen) which is the largest in northwestern Wedel-Jarlsberg Land. The seashore plain, 0.5—1 km wide, is composed of several raised marine beaches. Lower ones (at 3—5, 8—10, 12—15 and 20—30 m a.s.l.) are separated by a steep cliff from the higher terraces. The latter, located at 40—60 and 100—150 m a.s.l., are strongly modified by glacial and fluvial processes (Pękala 1987).

The bedrock is composed of Hecla Hoek Formation sediments: tillites interbedded with quartzites, limestones and phyllites. At the Calypsostranda near Calypsobyen these rocks are overlain by Tertiary sandstones and siltstones with coal sheds (Flood, Nagy and Winsnes 1971).

Hydrographic mapping in the scale of 1:50,000 enabled to distinguish two main types of streams. One of them includes glacial streams fed by glacial waters and the others are periglacial streams fed by other meltwaters and by rainwaters.

Discharges were measured in drainage basins of three rivers fed by Scott-breen, Blomlibreen and Tjörnbreen as well as in a periglacial stream escaping to the Recherchefjorden in Calypsobyen. Discharges in a spring, the water of which supplied the expedition base, were measured every day (Bartoszewski 1987a, b, c).

During research the problems of water balance in the active permafrost layer and physico-chemical properties of waters circulating within this layer have arisen. Analysis of these features is important for deduction of water origin in polar drainage basins. Accompanied by balance calculations it allows to define a chemical denudation.

Some physico-chemical properties of permafrost waters

In summer 1986 measurements of temperature and of electric conductivity in waters have been initiated for the area of about 100 km^2 (Fig. 1). Water temperature observations were taken from the last decade of July until the end of August. More than 200 measurements in streams, lakes, marshes and springs have been done. Electric conductivity of waters was defined on the basis of 87 samples collected from 36 sites on August 8 to 31. Repeated temperature and electric conductivity measurements were realized at the water-gauge section of the Scott river, in a spring and a periglacial river of Calypsobyen. Systematic temperature measurements were made every day while electric conductivity every other day. Measurements of electric conductivity were made with a use of the N-571 conductometer with PS-2 electrode. Index of mineralization was calculated according to the formula of Pazdro (1977):

$$M = \frac{G \cdot k \cdot C}{A}$$

in which M is total mineralization in mg/dm^3, G — electric conductivity in simens, k — apparatus constant, C — numerical parameter with accepted value of 720,000 (Pulina 1984), and A is the correction of temperature. Keeping in mind the exploring character of the studies, results are to be considered for approximate, showing a significance of the phenomenon and its space differentiation.

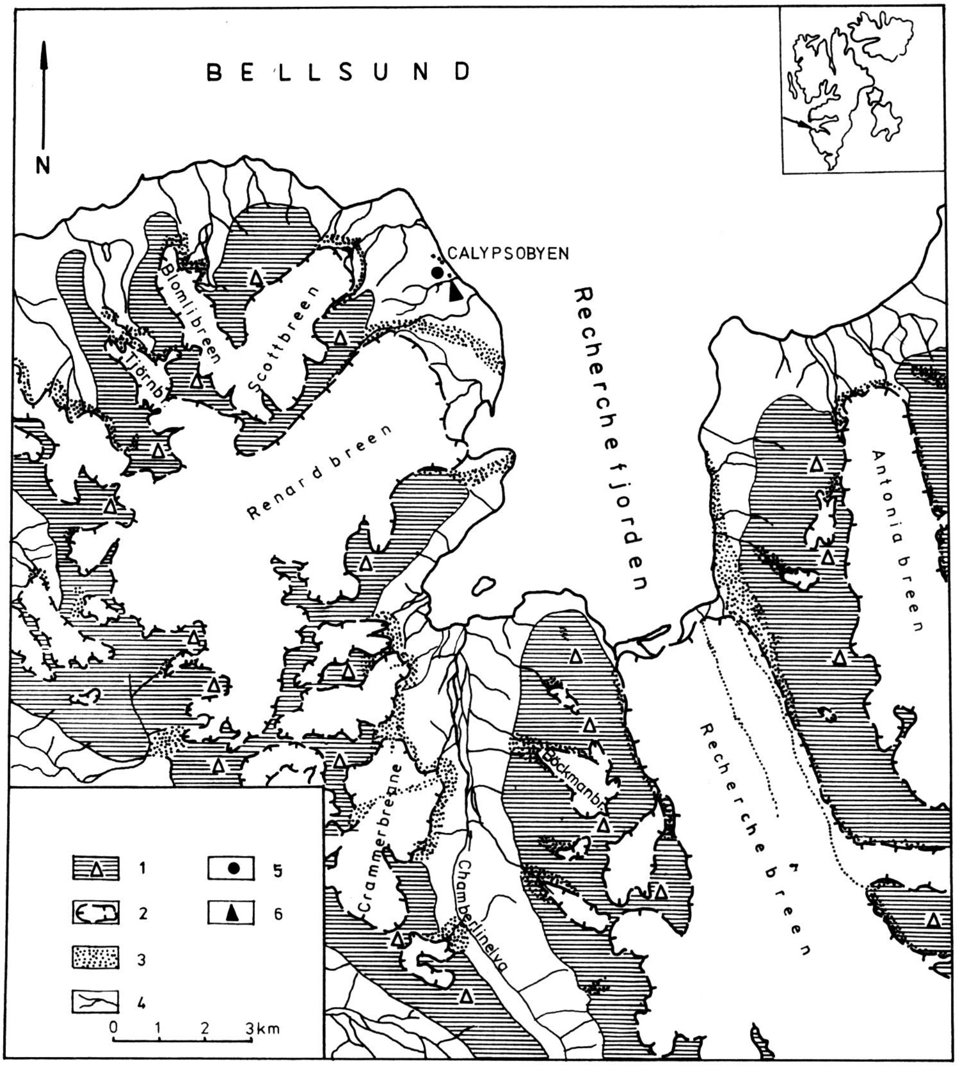

Fig. 1. Investigated area
1 — mountains and their summits, 2 — glaciers, 3 — ice-cored moraines, 4 — streams, 5 — spring, 6 — water gauge

Water temperature

Properties of permafrost waters are most completely indicated in springs. Selection of an adequate object allowed to eliminate accessory features, especially snow feeding which is common in polar drainage basins.

Temperature course, discharge and mineralization are shown in connection with air temperature and precipitation in Calypsobyen (Fig. 2).

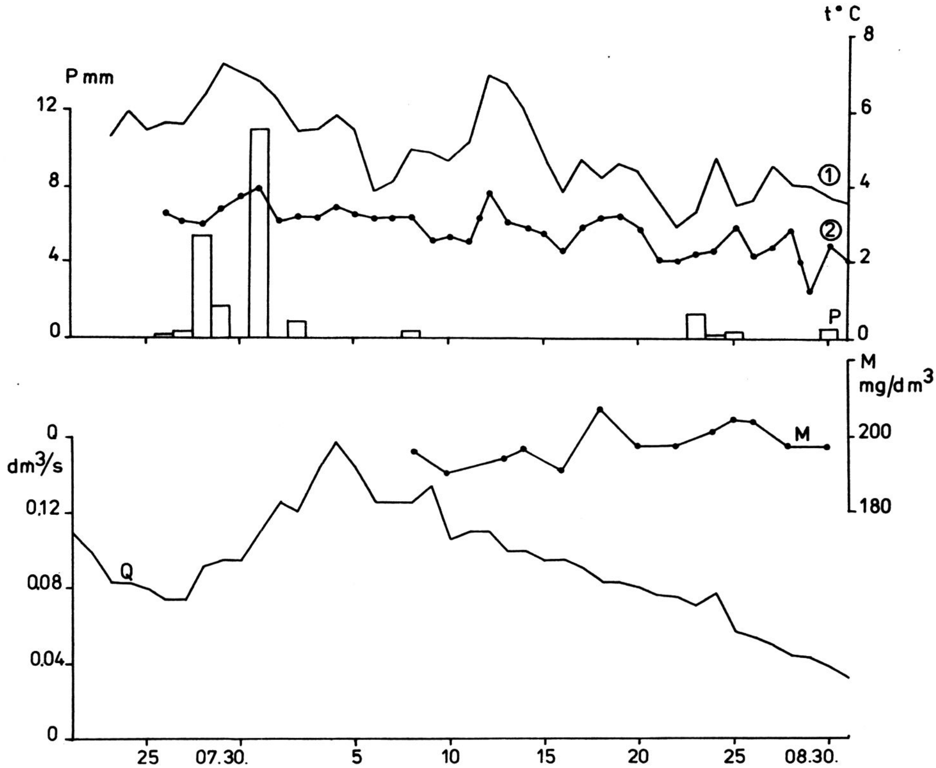

Fig. 2. Curves of discharge, temperature and total mineralization of spring in Calypsobyen in connection with air temperature and precipitation (measurement points marked)
1 — air temperature at altitude of 2 m, 2 — water temperature, P — daily total precipitation, M — total mineralization, Q — spring discharge.

A descending spring located in a mouth of 70 m long valley, cut through a shingle-sandy marine terrace, was analyzed. Temperature course curve shows a decreasing trend. The highest temperature of 3.9°C was noted on July 31, whereas the lowest one of 1.2°C on August 29. Mean temperature during the observation period was equal 2.8°C. A relation of the period with increased discharge and low water temperatures was confirmed. Increased thawing of permafrost seems to be influenced by infiltration of rainwater. More intensive thawing affected increased spring discharge and rise in water temperature. In drainage basin of the analyzed spring a saturation zone was 50 cm thick i.e. half-thickness of the active layer. In such case water temperature seems to indicate thermal conditions within the active layer of permafrost.

Water temperature in the studied spring varied in a daily cycle as exampled by situation on July 26 and 27 (Fig. 3). The highest temperature was measured at 12 while the lowest at 2 LMT. At the end of August the lowest temperatures dropped to 0°C and freezing started.

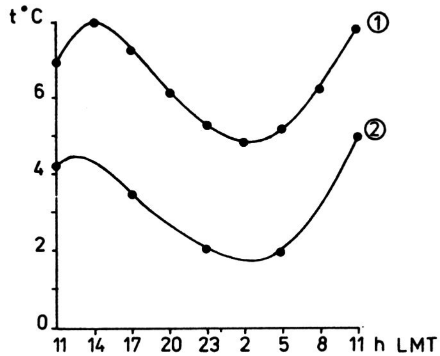

Fig. 3. Daily variation of water temperature in Calypsobyen on 1986.07.26—07.27 (measurement points marked) 1 — periglacial stream, 2 — spring.

Total mineralization

Mineralization of spring waters slightly increased during the observation period (Fig. 2). Average mineralization was 198 mg/dm^3, while 189 mg/dm^3 in a nearby stream.

The meltwaters feed numerous periglacial streams, marshes and lakes in tundra. In August 1986 mineralization in such places varied between 130 and 190 mg/dm^3, with except of a stream near the Antonia Glacier (Antoniabreen) where mineralization was equal 234 mg/dm^3. Lakes in tundra were usually more mineralized than streams.

Periglacial streams are fed by thawing of permafrost, snow melting and rainwaters. Studies of mineralization could be useful to identify the feeding sources. Such identification has been done for draining basin of the Chamberlin river, escaping to the southern part of the Recherchefjorden. Upstream water of this river arises from thawing of permafrost in vast cryoplanation terraces and from melting of residual glacierets and snow patches. In the upper part of the drainage basin a mineralization of outflowing waters measured on August 17 was equal 135 mg/dm^3, with their temperature of 5.4°C. In the middle part of the valley a water discharge from the extensive Crammer Glacier (Crammerbreen) entered the river. Measurements downstream of a terminal moraine showed that water was cold (only 0.9°C) and its mineralization was also low (69 mg/dm^3). Water temperature in the river outlet to the Recherchefjorden was equal 6.0°C and mineralization 102 mg/dm^3.

Water budget

A formula for the water budget allowed to compare volumes of water supply to drainage basins of periglacial stream and spring in Calypsobyen with the ones lost in the same time for the period between July 23 and August 31.

Water budget was calculated with a use of the following formula:

$$P = H + E + \Delta R$$

in which: P is precipitation indicator, H — outflow indicator, E — evaporation indicator, and ΔR — retention changes.

Precipitation data and values of meteorological elements used for calculation of evaporation after the method of Penman (1948) were collected at a meteorological station in Calypsobyen.

Varying retention is indicated by the difference between precipitation and sum of total outflow and evaporation. Using real data, equations of the water budget are as follows:

periglacial stream: $22 = 47 + 30 - 55$ (mm)
spring $22 = 35 + 30 - 43$ (mm)

During the analyzed period variations in retention were negative. Initial retention was relatively high due to thawing of permafrost and precipitation. In summer 1986 very low precipitation made the volume of meltwaters lower than outflow and evaporation. Therefore gradual reduction of retention was observed. The highest retention level in the active layer of permafrost was noted on August 4, while the lowest one on August 31. Amount of retentioned water calculated according to Maillet formula (Dębski 1970) was equal 44 and 9 mm respectively. Outflow indicator in the stream draining basin was 12 mm higher due to water retention in snow patches (Bartoszewski 1987c). Precipitation and evaporation were the same in the whole investigated area, so there is 12 mm difference in retention in both cases.

Conclusions

Amount of retentioned water within active layer of permafrost depends on meteorological features, namely precipitation and air temperature. A highest retention level occurred on August 4, after the period of the highest air temperatures and relatively intensive precipitation. Several days delay in reaction of active layer for increased feeding has been confirmed. Low precipitation in August 1986 has not balanced evaporation and discharge, so water budget was negative. Temperature and total mineralization of meltwaters are varied in space. Changes of these features within each draining basin separately suggest different feeding sources. This problem is to be still analyzed with special attention paid to hydrochemical background. Temperature of outflowing waters is connected with air temperature and distribution of precipitation. Temperature of meltwaters in springs changes in a diurnal rhythm.

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Streszczenie

W artykule przedstawiono wstępne wyniki badań hydrograficznych przeprowadzonych latem 1986 r. w ramach Wyprawy Instytutu Nauk o Ziemi Uniwersytetu Marii Curie-Skłodowskiej z Lublina. Teren badań obejmował południowe obrzeżenie Bellsundu (fig. 1).

Temperatura i mineralizacja ogólna wód zmarzlinowych jest zróżnicowana przestrzennie. Zmienność tych cech w obrębie poszczególnych zlewni sugeruje zróżnicowanie źródeł alimentacji.

Temperatura wód zmarzlinowych pojawiających się w źródle w Calypsobyen wykazuje w swoim przebiegu związek z temperaturą powietrza i rozkładem opadów atmosferycznych. W następstwie infiltracji wód opadowych występowało przyspieszone tajanie zmarzliny i obniżenie temperatury wód źródlanych. W przebiegu temperatury wody wypływającej ze źródła zaznacza się wyraźny rytm dobowy z minimum ok. godz. 2 i maksimum o godz. 12 czasu lokalnego (fig. 3).

Mineralizacja ogólna wód źródła wykazywała w okresie badań lekką tendencję rosnącą (fig. 2). Średnia mineralizacja wód źródła wyniosła 198 mg/dm^3, a wśród pobliskiego cieku 189 mg/dm^3.

Ilość wody zretencjonowanej w czynnej warstwie zmarzliny zależała od warunków meteorologicznych. Czynna warstwa zmarzliny reaguje na wzrost alimentacji z kilkudniowym opóźnieniem. W okresie 1986.07.23—08.31 zmiany retencji miały znak ujemny: Ilość wód pochodzących z wytapiania zmarzliny i z zasilania atmosferycznego nie równoważyła strat wywołanych odpływem i parowaniem terenowym. W rezultacie następowało stopniowe zmniejszanie się zasobów retencyjnych.