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THE THERMAL ORVIN SPRING BELOW THE MOUNT GNÄLBERGET (HORNSUND SOUTH SPITSBERGEN)

Abstract

The thermal Orvin spring flows out below the Mount Gnälberget at the foot of the Sofiekammen massif built of carbonate rocks of the Hecla-Hoek formation. The spring flows out of the gravel deposits of a contemporary coastal ridge. The temperature of its water is 12.4°C, with a general mineralization of 98 mg/l. This water is of the type Cl—Na—Ca. The considerable amount of chlorides is due to a mixing of karst water with the saline Hornsund water.

The water of the Orvin spring comes from a zone where cold, surface infiltration water (glacier ablation, precipitation, permafrost thawing) mixes with warm ground water and cold sea water. The waters of this zone have specific physicochemical features.

Fresh waters flows down gravitationally through crevices of tectonic origin while thermal waters are able to penetrate permafrost. Saline water flow takes place through swallow holes at the bottom of the Hornsund fiord. In dependence on the pressure in the karst crevices these holes may also function as fresh water vaucluse springs. The amount of water of different genesis is likely to vary with time.

The infiltration of saline sea waters and their interaction with thermal water as well as with the overlaying, cool, fresh water is limited only to local zones where the tectonic and lithological conditions make such a contact possible.

OUTLINE OF CONTENTS

On the basis of observations of the warm Orvin spring, the circulation pattern of subterranean water in the Mount Gnälberget carbonate massif (South Spitsbergen) is presented.

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Water from snow cover and permafrost thawing predominates in the water circulation and in the balance of the non-glaciated areas of Spitsbergen. In the deeper water-bearing layers circulation has hitherto been found only in the carbonate massifs of the Hecla-Hoek formations developed in the form of marbles, limestones and dolomites [Bieroński, Pulina, 1975; Karwowski, Kozik, 1982; Leszkiewicz, 1982; Leszkiewicz, Wach, Waga, 1982; Pulina, 1977]. They forms a narrow mountain range near the western coast of South Spitsbergen. These rocks show favourable conditions for the development of karst phenomena both in the ice-covered areas (Amundsen Plateau, Kopernikusfjellet, Mefonny Plateau, Vitkovski glacier basin) as the ice-free areas (Sofiekammen massif, Tsjebysjovfjellet, Hilmarfjellet) in the littoral zone, in sea terrace regions and on mountain ridges [Pulina 1977].

In August 1983, during investigations carried out by the members of the scientific expedition of Jagiellonian University in Cracow, under the guidance of A. Krawczyk, brief hydrographical observations were made in the Sofiekammen region where special attention was giving to the Orvin spring.

The Orvin spring is in a karst area of littoral type (Photo 1). It is located below the Mount Gnälberget wall at the foot of the Sofiekammen massif (Fig. 1). Mount Gnälberget as well as the whole Sofiekammen massif is composed of grey, yellowish or whitish, often brecciated marbles and black, grey and light-grey limestone veined with multi-coloured calcite and also of black argillaceous slate rarely inserted by brecciated limestone (Fig. 2). These rocks belong to the Hecla-Hoek formation [Birkenmajer, 1978]. The crevices in zones of tectonic dislocations may be essential agents for the circulation of underground waters.

The Orvin spring flows out of gravel sediments on a contemporary shore ridge. Its water flows into a small bay in diffused streams, seeping through the gravel material. This is why its discharge is difficult to establish. After rainfalls its discharge rises after several hours delay. Then the place of its outlet changes as well with respect to the sea level. During rising tide it is below sea level.

The water temperature exceeds 12°C (on 29-th August 1983, at 02.00 GMT — 12.4°C). This water warms up the sea water in the bay. The temperature variations between the summer seasons are negligible [Pulina, 1977]. In winter the spring feeds the small coastal pond which, owing to the high water temperature, never freezes (oral information from Piotr Trela). This proves that the circulation inside the massif takes place through the whole year. In winter there is probably a permafrost zone in the karst crevices, reaching from the surface to a certain depth, which isolates the unfrozen karst waters inside the massif from the influence of external atmospheric conditions.

The total mineralization of the Orvin water amounts to 98 mg/l. The water is of the Cl—Na—Ca type (Fig. 3). The considerable rate of chlorides results from the mixing of karst waters with the saline waters of Hornsund (Table 1).

An interesting problem is the way of feeding the poorly mineralized karst waters of the spring as well as the mechanism which causes them to flow out.

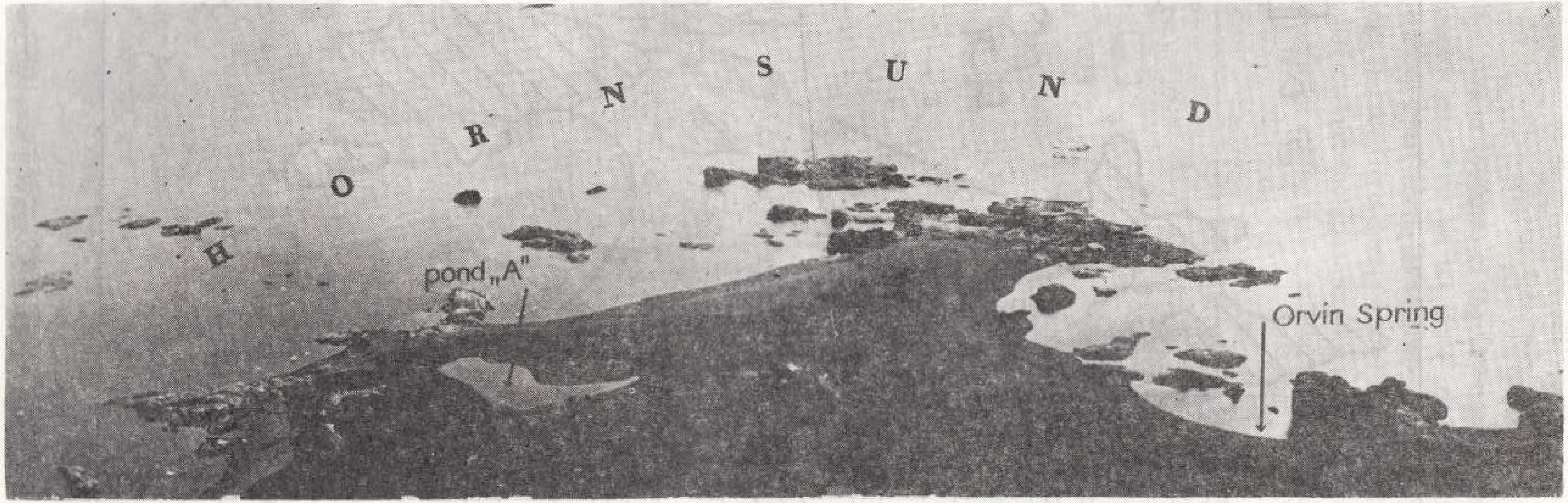

Photo 1. The coast at the foo of Mount Gnälberget (Photo P. Trela)

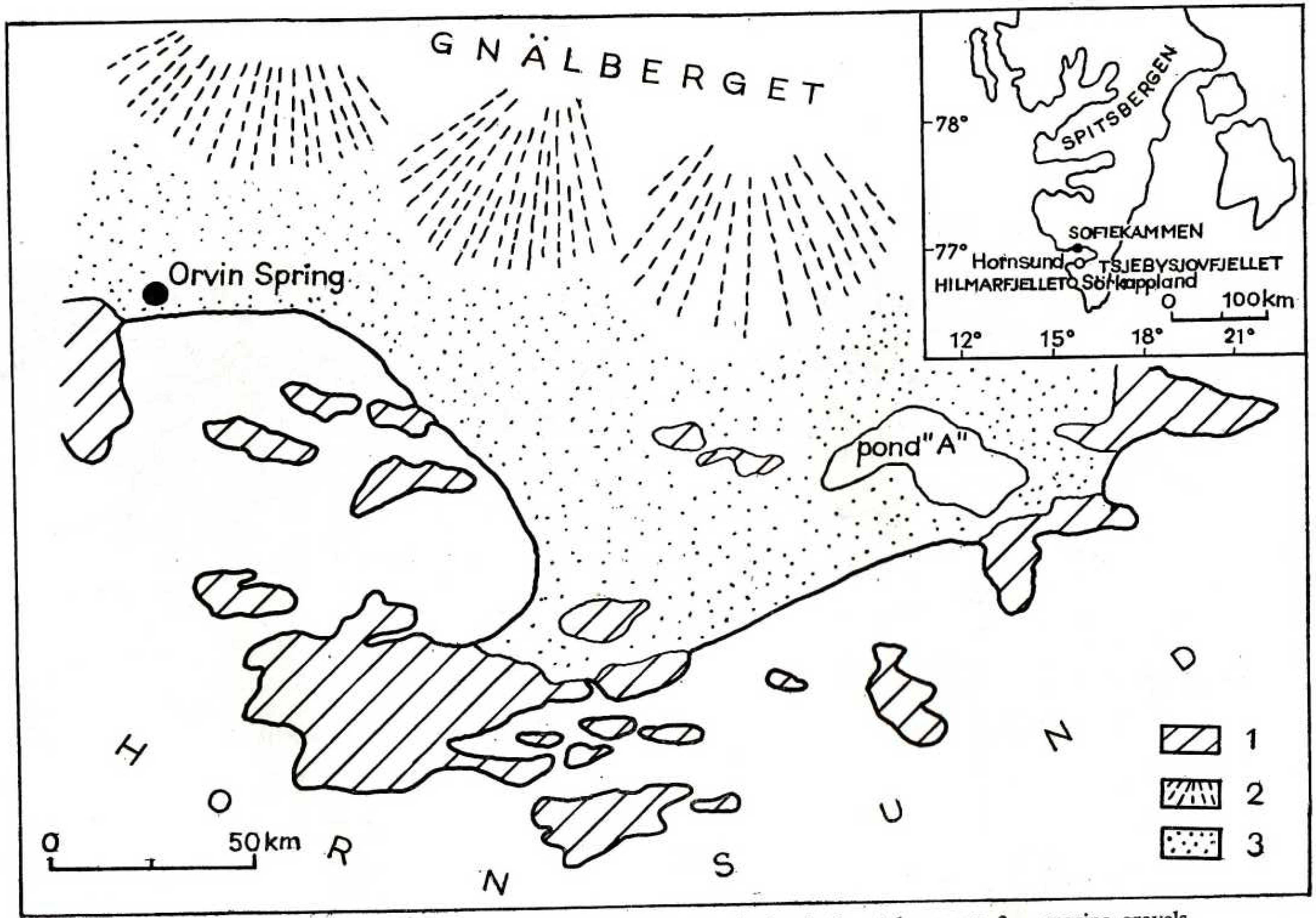

Fig. 1. Sketch showing the Mount Gnälberget region: 1 — badrock, 2 — talus cones, 3 — marine gravels

Forms of outflow similar to those of the Orvin spring have been found at the foot of the Tsjebysjovfjellet and at the foot of Hilmarfjellet (Fig. 1). There exist, however, relatively great chemical and temperature differences between the water of those springs and the Orvin spring water. The water from the Tsjebysjovfjellet spring has a similar chemical composition but a much lower temperature whereas that from the Hilmarfjellet spring has a similar temperature but a different mineralization.

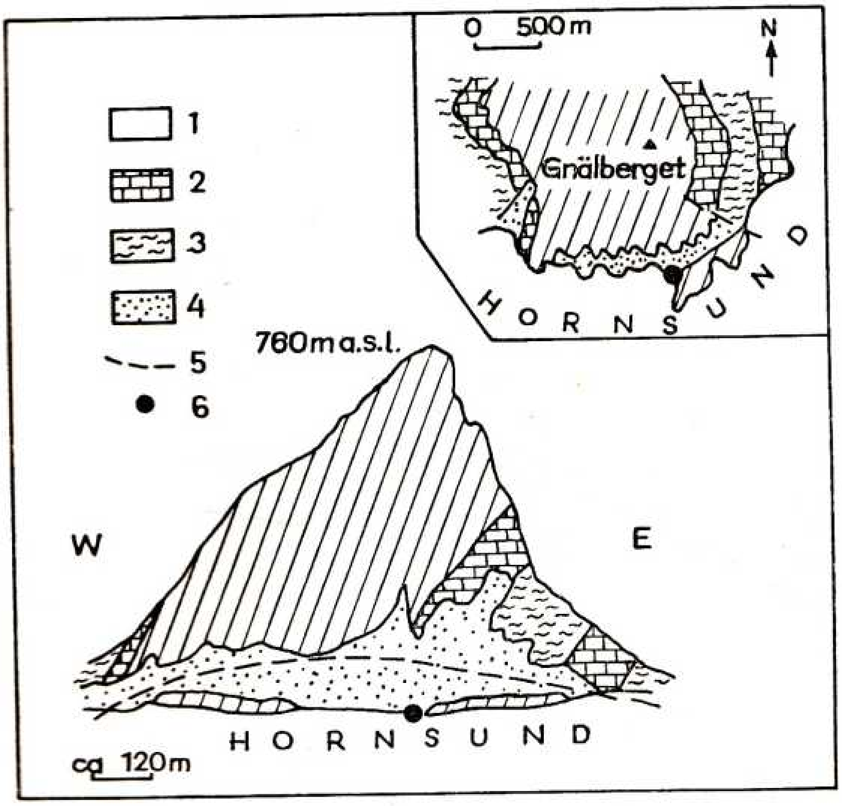

Fig. 2. Geology of Mount Gnälberget: 1 — marbles, 2 — limestones, 3 — shales, 4 — mantle of waste and marine gravels, 5 — fault, 6 — Orvin spring

The water from the springs below the Tsjebysjovfjellet comes from glacier ablation, which has been confirmed by the following facts:

— the temperature of the spring water (3°C) corresponds to the thermal gradient of 0.5°C/100 m, at the 600 m difference in the height of the swallow holes and the springs;

— there is no network of surface run-off on the glacier supplying the karst waters;

— the presence of swallow holes and glacier wells in the vicinity of glaciers situated near the massif;

— the correlation between the changes in mineralization of the vaucluse springs waters and their discharge, air temperature and precipitation [Leszkiewicz, 1982; Leszkiewicz, Wach, Waga, 1982].

The features that the waters of the Orvin spring and those from the spring below Tsjebysjovfjellet have in common are their karst character (carbonate Hecla-Hoek rocks) and their similar chemical composition (a clear predominance of chlorides and a low carbonate content). However, the higher temperature of the Orvin spring water suggests a more complex of water supply and circulation in the Sofiekammen than in the Tsjebysjovfjellet.

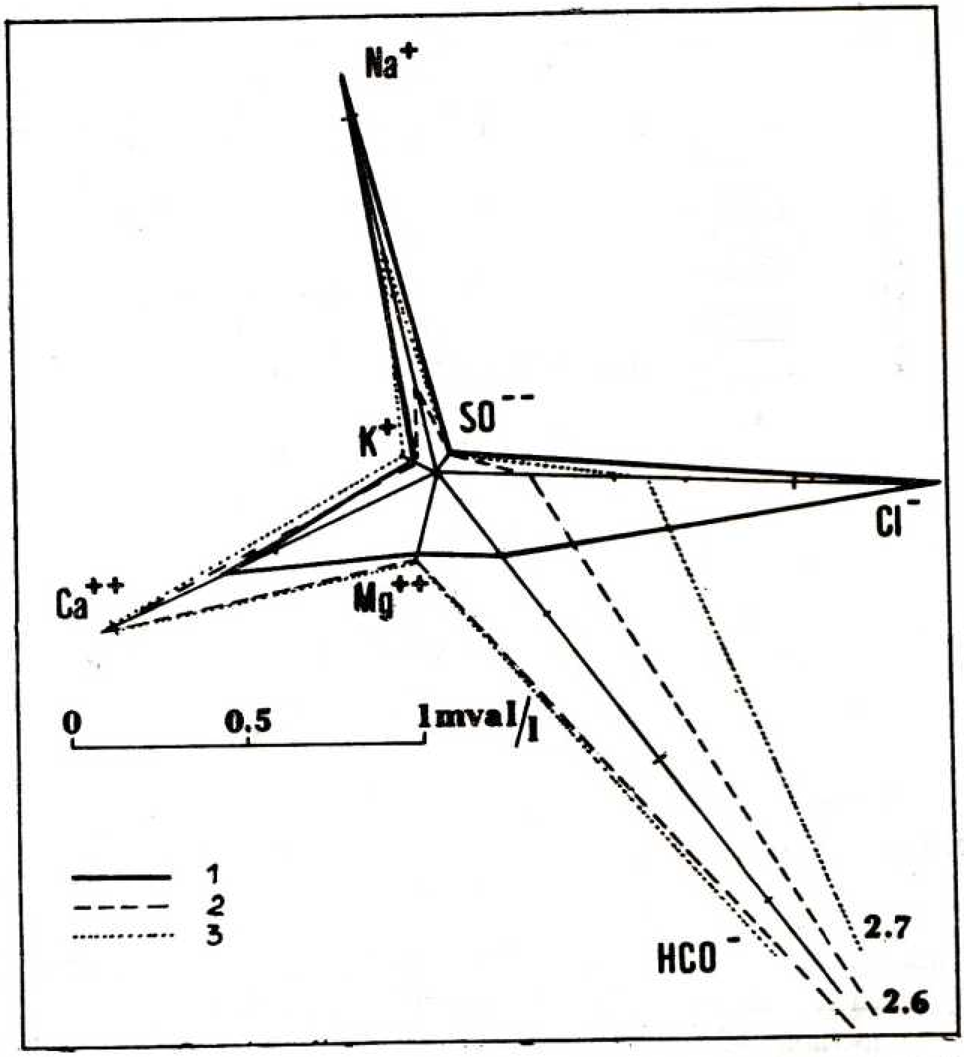

Fig. 3. Chemical composition of the Mount Gnälberget waters: 1 — waters from the Orvin spring, 2 — water from the Gnälberget walls, 3 — water from pond A

Waters of a relatively high temperature have been found in the springs in the southern part of Sörkappland at the foot of the Hilmarfjellet massif built of limestone and dolomites of the Hecla-Hoek series [Pulina, 1977]. The temperature of these waters was 16.5°C in August 1973. With regard to chemical composition they belong to the $Cl-Ca-HCO_3$ type. They are strongly mineralized (1.1–8.6 g/l) and sometimes precipitate white deposits of salts at their outlets. The Hilmarfjellet springs may be related to the circulation of hydrothermal, mineral-forming solutions in

Table 1. Physicochemical features of waters in the Gnälberget region (29 Aug. 1983, 02.00 GMT)

Measuring point	Water temperature [°C]	Ca^{++} [mval/l]	Mg^{++} [mval/l]	K^{+} [mval/l]	Na^{+} [mval/l]	HCO_3^- [mval/l]	SO_4^{--} [mval/l]	Cl^- [mval/l]	PO_4^{---} [mval/l]	Total mineralization [mg/l]
Orvin spring	12.4	0.67	0.23	0.06	1.30	0.30	trace	1.39	—	98
Gnälberget wall	2.5	1.05	0.25	0.05	0.27	2.59	trace	0.28	trace	42
Lake A	4.4	1.05	0.25	0.08	0.67	2.69	trace	0.58	trace	63

the carbonate rocks of South Spitsbergen [Karwowski, Kozik, 1982]. A similar suggestion may be put forward in connection with the Orvin source waters. The much lower mineralization indicates that part of the compounds may have been precipitated inside the massif or that the mineral waters have been diluted by meteoric water as well as by water coming from glacier ablation. The raised temperature of the Orvin spring water may be explained by the geothermal degree. If it is assumed, however, that the geothermal degree for carbonate rocks is 0.5°C (according to Pulina) and that the temperature of ablation water is equal or only slightly higher than 0°C, it may be concluded that the temperature of the spring waters should be about 4°C, whereas actually it exceeds 12°C.

The mineralization of the ablation waters coming down the Gnälberget walls is twice as low as that of the Orvin spring waters, their temperature being 2.5°C. They feed lake a situated between the coast and the talus cones (Fig. 1). This supply is evidenced by the very similar mineralization of the lake water and the water from the Gnälberget walls (Table 1, Fig. 3). Only the chloride content is higher in the lake, which is due to its being situated in a zone reached by the welter of the waves splashes. The water of both the Gnälberget wall and the lake is of $HCO_3-Ca-Na$ type. Both waters contain small amounts of phosphates resulting from the presence of numerous bird colonies (guillemots and mergansers) in the area. It cannot be ruled out that small amounts of these waters infiltrate the ground, passing downwards through the crevices in the substratum and mixing with the karst waters which cool down in the process (Fig. 4). The temperature of the lake water as well as of the water from the Gnälberget walls is related to the air temperature.

The investigations carried out so far in the karst areas of littoral zones make it possible to assume the existance of a zone in which surface waters (precipitation, glacier ablation, permafrost thawing) mixes with thermal waters as well as with sea water (Fig. 5). The waters of this zone are distinguished from the surrounding waters by their specific physicochemical characteristics. They are certainly cooler than the thermal waters flowing out of the massif, but much warmer than the surface and sea waters. Their mineralization is likely to be lower than that of thermal waters, but higher than the mineralization of the surface waters. The dimension of the temporary zone is difficult to establish.

The amount of water of different origin seems to vary with time, depending on the supply volume of the particular kinds of water. An increase in fresh water supply raises the ground water level, which is made evident by the displacement of the Orvin spring outlet to the upper part of the coastal ridge. Fresh water flows gravitationally through the crevices of tectonic origin, while thermal waters are able to pass even through permafrost [Corbel, 1959]. The flow of saline sea water takes place through the swallow holes at the bottom of the Hornsund fiord. These holes may also function as fresh water vaucluse springs (Fig. 4). This is dependent on the tides and the pressure in the karst crevices. The local geological conditions have a considerable effect on the range and dimension of this zone, that is — the density, width and direction of the crevices as well as lithological structure. The interactions of the three types of

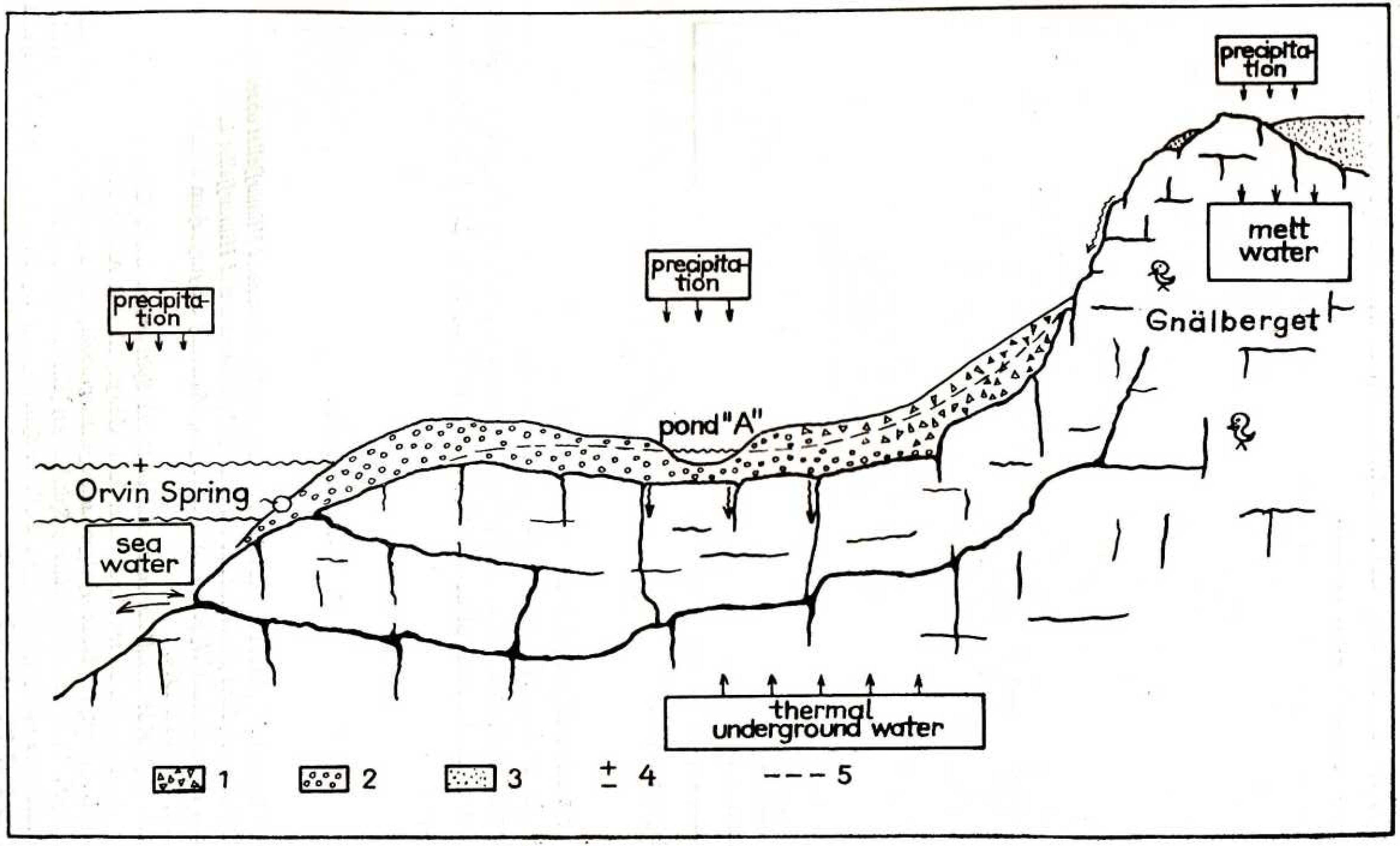

Fig. 4. Water circulation in the Gnälberget massif: 1 — talus cones, 2 — marine gravels, 3 — snow, glacier, 4 — water level during high tide (+) and low tide (—), 5 — ground water level

water, i.e. cool, saline sea water with the thermal waters and the overlaying, cool, fresh water are limited only the local zones where the tectonic and lithological factors make possible such contact.

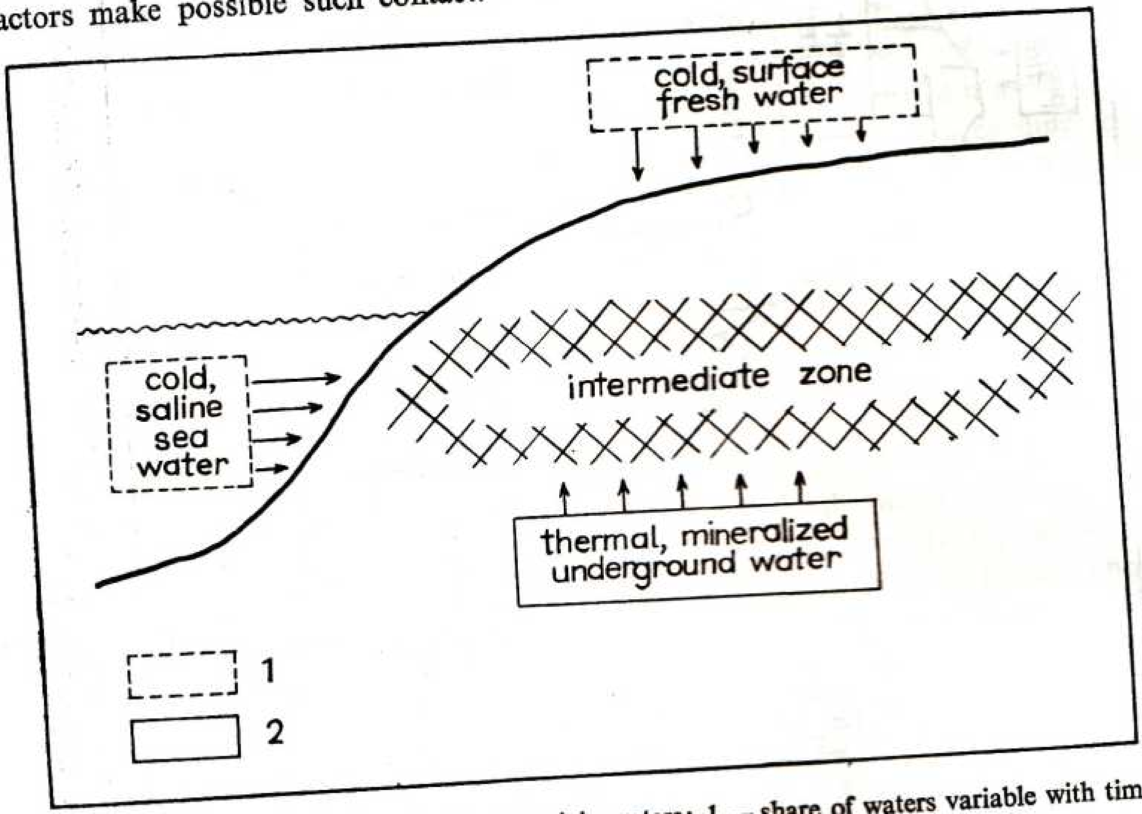

Fig. 5. Diagram of interaction of different origin waters: 1 — share of waters variable with time, 2 — steady share of waters

The presented hypotheses are based on very scanty analytical material. Their verification as well as a full explanation of the circulation mechanism and the genesis of the Orvin spring water and of other springs of this type would require long-term and regular measurements of the chemical composition, temperature and discharge of these springs.

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