Karst and karstification in gypsiferous beds in Mathiesondalen, Central Spitsbergen, Svalbard

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Recent karst forms in gypsiferous beds are reported from Mathiesondalen in Central Spitsbergen, where several sinkholes (dolines) and swallow holes have been formed after the deposition of Holocene raised beach sediments. The bedrock of the area is mostly interbedded gypsum/anhydrite and dolomites of the Carboniferous Ebbadalen Formation.

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Introduction

In the area around Mathiesondalen in Bünsow Land east of Billefjorden (Fig. 1), Carboniferous and Permian beds dip gently to the south. The outer part of the valley is covered by Holocene raised beach sediments in the form of terraces and beach ridges (Feyling-Hanssen 1955; Lauritzen & Salvigsen in press). The valley floor itself is occupied by a braided river system, and small tributary streams have eroded gullies in the unconsolidated sediments. The underlying rocks are mostly interbedded evaporites and dolomites of the Ebbadalen Formation (Cutbill & Challinor 1965), a formation described in detail by Holliday & Cutbill (1972) and Johannessen (1980). The gypsiferous beds in the outer part of Mathiesondalen are downfaulted along local lineaments connected with the Billefjorden Fault Zone (Harland *et al.* 1974) causing almost flat lying evaporites to form the bedrock of the outer part of the valley and on the sides of the mountains further east. The post-depositional tectonic activity has caused prominent cracks and fissures in the bedrock, thus allowing the percolation of surface water.

The geomorphological significance of rock solution in limestone/dolomite areas in Spitsbergen has been discussed by Corbel (1957, 1960) and Helldén (1974). Orvin (1944) described springs in connection with the limestone area near Hornsund in the southern part of Spitsbergen. Elsewhere karst forms are most frequent and best developed in limestone and dolomite, partly because these rocks are more abundant than other soluble rock types (Sweeting 1968). Here we describe karst phenomena in gypsum/anhydrite beds in an area at the mouth of Mathiesondalen.

Observations

Large, closed depressions and other karst features occur in the raised beaches in the outer part of Mathiesondalen. They have a superficial similarity to kettles formed by melting of buried ice. However, several of the depressions contain a drainage into underlying gypsiferous beds. They

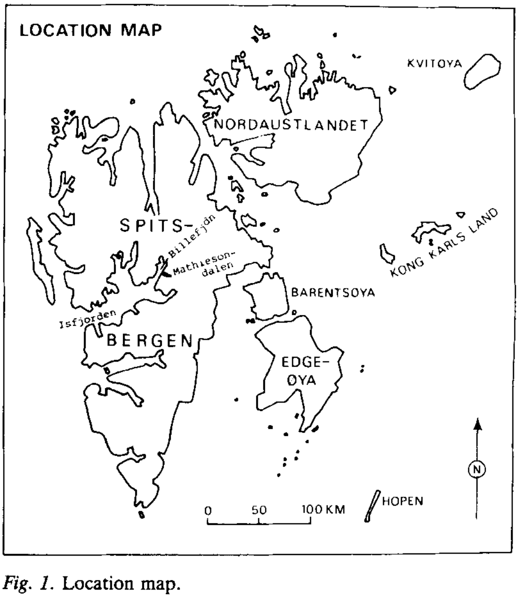

Fig. 1. Location map.

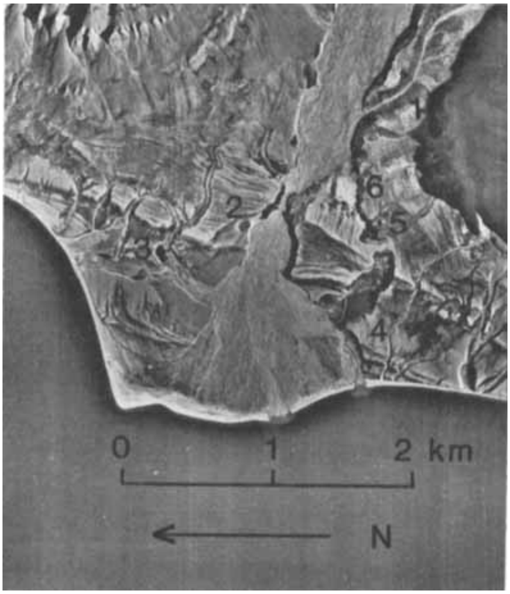

Fig. 2. Vertical air photograph of the Mathiesondalen area. Kapp Ekholm in the foreground. The numbers refer to the karst depressions described in the text as localities 1 to 6. Photo: Norsk Polarinstitutt S61 2959 (23 August 1961).

can therefore generally be characterized as sinkholes (dolines) with associated forms. Six such depressions (Locs. 1–6, Fig. 2) are described, including apparent fossil sinkholes and present-day active sinkholes. These are:

(1) The highest lying depression, about 70 metres above sea level, is a lake on the beach terrace on the south side of the valley, near the talus. This appears to be a fossil sinkhole. The total diameter is about 100 metres, and surplus of water is drained by a surface stream. In late summer-time the pond usually has no visible drainage. Here, the bedrock is not exposed.

(2) A small circular sinkhole pond is found on the terrace north of the river bed (Fig. 3). The height of the terrace is about 35 metres above sea level, and the sinkhole is probably a fossil one. The pond has no visible outlets, and the water depth varies throughout the year. Bedrock was not exposed.

(3) The lowest lying depression is located in the

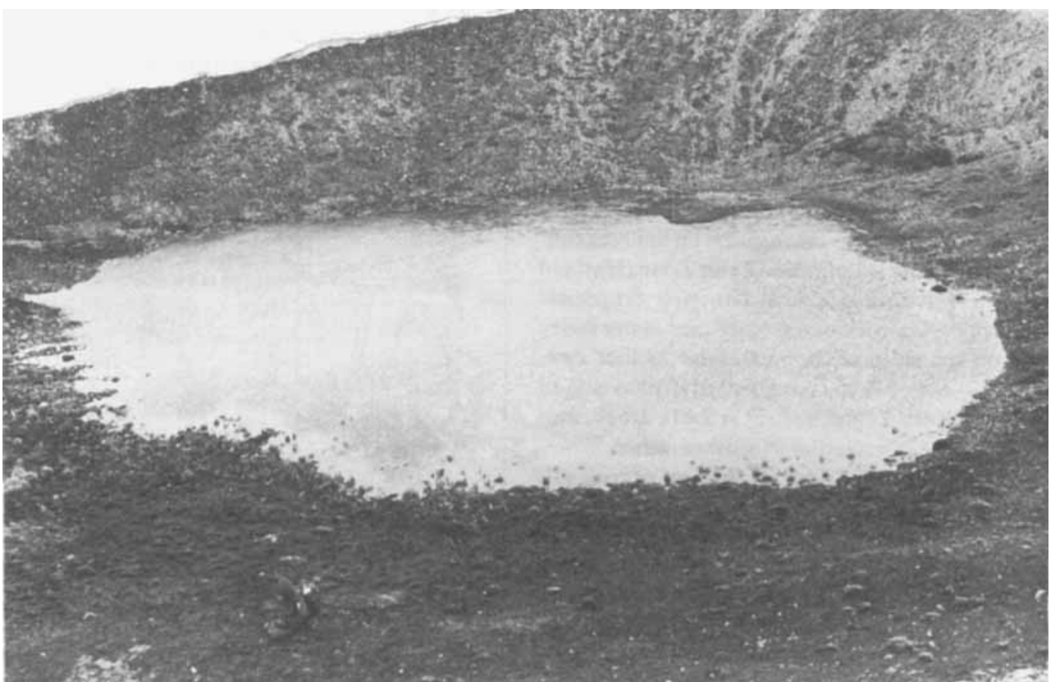

Fig. 3. Locality 2. The small sinkhole pond without any surface outlet. Figure in foreground as scale.

river fan system of Kapp Ekholm about 6 metres above sea level. A small stream flows into the pond, and the outlet is near the inlet. No difference between inflow and outflow could be seen. The walls of the depression show evidence of fresh slides in unconsolidated material. Bedrock was not exposed.

(4) A lake near the southern edge of the delta plain is remarkable. It has a length of about 300 metres and seems to have a considerable depth. The lake is about 6 metres above sea level, and the southern side has fresh slides in terrace sand and gravel. In late July the outlet of the lake was a rapid flowing stream, which was difficult to cross in rubber boots. Obvious sources of water were not apparent and there were no streams running into the lake. We conclude that the lake must be fed by subterranean tributaries, arising partly from the sinkholes and swallow holes observed in depressions at localities 5 and 6.

(5) A small sinkhole pond is found about 32 metres above sea level, 300 metres east of the described lake (locality 4). A small stream flows through it and disappears into a swallow hole in a highly jointed and collapsed gypsiferous wall (Fig. 4) at a level of about 4 metres below the pond level. The cave probably has a connection to the lake previously mentioned (locality 4). This underground outlet has also been observed by Balchin (1941).

(6) A jointed and collapsed bedrock in locality 5 continues to the end of a short blind valley which branches out from the main river plain (Figs. 5 & 6). Water from the main river in Mathiesondalen feeds a shallow lake in the blind valley. The supply of water is highly variable, and in the summer of 1981 it was small because the main river was on the opposite side of the river plain. In 1981 the water level in the lake varied with the precipitation. Following heavy rainfall the water level rose about 25 cm, and shore marks showed the level to have been approximately one meter higher than normal (see Fig. 5). At this level the blind valley will be filled with water, and surface drainage will start to the river plain of Mathiesondalen. This maximum level had probably been reached in the snow melting period. In

Fig. 4. Locality 5. The swallow hole with stream flowing from left into the base of the white, tilted gypsiferous beds and disappearing into the open fractures. Figure in the upper right corner as scale.

Fig. 5. Locality 6. The lake of the blind valley. Photo taken towards southwest. The outlet into fractured gypsiferous beds is seen on the opposite shore of the lake (see also Fig. 6). Note the shore marks of higher lake levels. Figure on shore as scale.

late July a great part of the blind valley was a lacustrine plain covered by fine sediment. The lake was drained by subterranean outlets in the blind valley. The bedrock is highly jointed and several collapsed tunnels can be seen (Fig. 6). In many places the rock surface has small scale solution features, and newly collapsed tunnels also show that karst processes are still active.

One small scale stream from the main river plain was also observed to disappear before it reached the pond. It disappeared in a 5 metre wide and 2 metre high tunnel in unconsolidated material near the edge of the river plain. During a time span of two weeks, about 10 metres of the tunnel collapsed, but this did not affect the outflow of the stream. No bedrock was seen in the tunnel. The subsurface drainage from this area probably ends in the lake here described as locality 4.

Discussion and conclusion

At localities 5 and 6, water can be observed flowing into caves in the gypsum/anhydrite beds, the one at locality 6 being a 5–6 metre deep collapsed cave. It is therefore obvious that most (probably all) of these described depressions are real karst forms, here developed by the solution of gypsum/anhydrite. Their slopes, however, are moulded by thermokarstic processes in the overlying sediments.

The sinkholes occur in uplifted beach sediments which subside into the depressions. Both the structures and the surface forms of the beach sediments are crosscut by sinkholes (see Fig. 2). We have no observations of fossil sinkholes or cracks in the bedrock filled with till. Two main conclusions can be drawn from these observations:

(1) The sinkholes are mainly formed by collapse of subsurface caves. Where the active permafrost reaches the bedrock, downward solution may also have taken place.

(2) The sinkholes are younger than the beach sediments in which they occur. The caves and tunnels from which the sinkholes were formed

Fig. 6. Locality 6. A collapsed gypsum cave near the subterranean outlet of the lake of the blind valley (see also Fig. 5). Figure above cave as scale.

may be older, but they have collapsed after the formation of the strandlines. The strandlines have been formed more or less continuously from approximately 11,000 years B.P. until the present (Feyling-Hanssen 1965), and thus all sinkholes are of Holocene age. The observed present activity in the sinkholes is also indicative of a young age.

The Svalbard area is subject to permafrost, and a normal model for groundwater circulation cannot be used. The permafrost layer normally acts as a very efficient barrier to groundwater percolation. In the described area the active layer has a maximum thickness of 2 metres; the described subsurface drainage is well below this, and thus in permanently frozen ground. It is difficult to understand how water can penetrate and keep an open passage through the frozen layer. However, a crucial factor in this connection is that the subsurface consists of soluble evaporite minerals in a highly jointed bedrock. Freeze–thaw action in bedrock cracks may allow water circulation in the rock and cause solution.

Liestøl (1977) has discussed the flow of water in permafrost areas and shown that even narrow passages are held open all the year round in connection with pingos and springs. The waterflow in Mathiesondalen, however, ceases during the autumn, and subsurface waterflow will be at a minimum until spring melting starts. Then percolation in the gypsiferous beds can start, causing the development of karst forms.

Gypsum or other evaporite rock fragments are hardly ever seen in the Quaternary sediments, except in the screes where they are very locally derived, and even here the process of disintegration seems more active to the evaporites than to the interbedded rocks, mostly dolomites. The rate of solution of large gypsum blocks has been studied elsewhere, e.g. from Permian beds in England (James, Cooper & Holliday 1981), and factors like water flow velocity, temperature, etc. have been considered. Here, however, we will not try to calculate the rate of solution or the time involved in the dissolution processes but will rather stress the fact that these processes are active in high arctic areas where snow and ice cover the ground most of the year.

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