Periglacial nivation cirques and local glaciations in the rock canyons of Söderåsen, Scania, Sweden. A discussion and new interpretation

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Present opinions about the genesis of the rock canyons Odensjön, Skäralid and Klöva Hallar of Söderåsen, Sweden are reviewed, and a new theory is presented. It is proposed, that during periglacial tundra periods large amounts of drifting snow collected in valleys of north-south directions. Small glaciers were created, which caused local overdeepening and removal of loose material. These processes were active in tundra periods before and after the main Quaternary glaciations.

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One of the field localities included in the excursions of the »Nordic symposium on periglacial geomorphology« in Lund and Båstad in September 1982, was the scenic point Kopparhatten at the deeply incised rock canyon of Skäralid. The canyon with its steep rockwalls in Precambrian gneiss, its well developed talus slopes and its small stream 100 m down in the valley bottom was considered as a very interesting and intriguing landform by the international group of participants in the symposium. There was a lively discussion about the valley, its genesis and its significance in the Quaternary erosional history of the area.

This paper is included here as a follow-up of the brief discussion we had in the field at the symposium. It caused me to make further field studies and comparisons with other areas and literature.

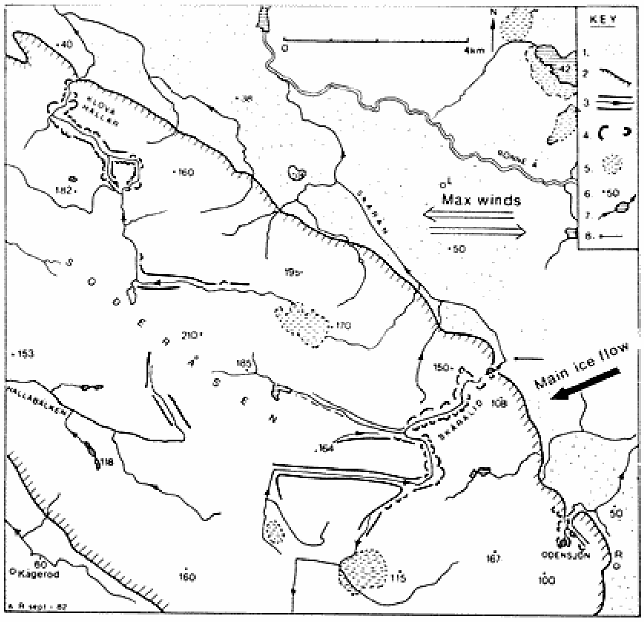

Fig. 1. Map of Söderåsen, a horst block in Scania, south Sweden, with rock canyons and periglacial nivation cirques.
Key: 1. Sandy plains with many ice-wedge casts and wind-polished stone layers (H. Svensson, 1975) from periglacial tundra conditions. 2. Edge of horst block. 3. Rock canyon with straight side walls and a water course. 4. Nivation cirques, large and small, reflecting predominant winds and snow drifting from the east or the west quadrants. 5. Peat bog. 6. Altitude m.a.s.l. 7. Lake and stream.
The main ice flow from the NE is indicated by the black arrow. Abbreviations of place names. L = Ljungbyhed. R = Röstånga.
Fig. 1. Kort af Söderåsen, en horst i Sydsverige, med canyondale og nivationscirques. Den vigtigste isstrømsretning fra nordøst er vist med sort pil. Stednavne: L = Ljungbyhed, R = Röstånga.

Earlier opinions about the three canyon valleys Odensjön, Skäralid and Klöva Hallar

The three canyon valleys Klöva Hallar, Skäralid and Odensjön are cut into the NE-facing part and the plateau of the horst massif of Söderåsen (Fig. 1). The plateau surface of Söderåsen reaches 210 m a.s.l. at Höjehall. From the vicinity of the highest area two valley systems go northwestwards (Klöva Hallar) and eastwards (Skäralid) in zig-zag canyons, partly adjusted to the fracture lines of the bedrock. They reach the horst front at almost right angle in 60-100 m deep canyon-like valleys, 11 km apart (Fig. 1). At the eastern part of the horst front is the third similar valley, however of smaller dimensions. It is about 400 m long, with the small lake Odensjön in the semicircular valley end. The lake level is 40 m below the plateau and its depth in the middle 20 m. (Fig. 2, Fig. 5).

The three canyon valleys have raised considerable interest among visitors and have been described or commented upon by many scientists (Nathorst 1885, Kjellén 1902, 1903, Hennig 1902, Hadding 1922, von Post 1938, Bergsten 1942, Godlund 1951, Mattsson 1962 and others).

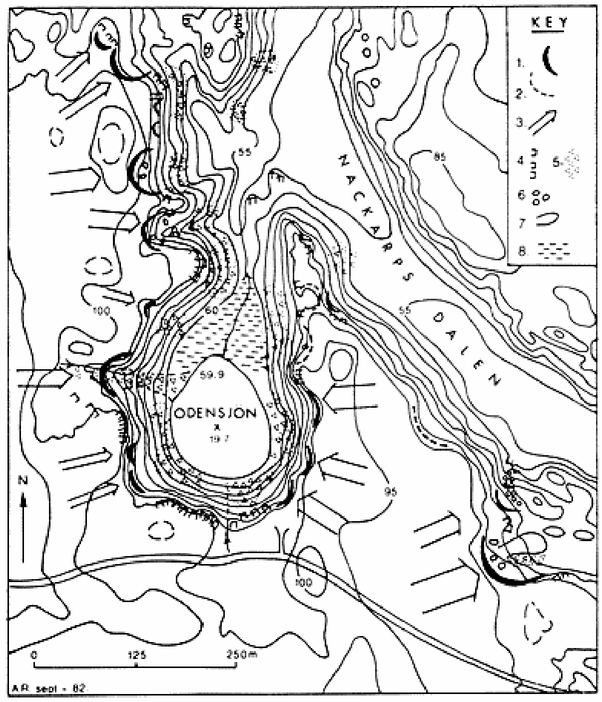

Fig. 2. Geomorphological sketch map of Lake Odensjön and Nackarpsdalen valleys in the SE part of Söderåsen, Scania (Fig. 1) Key: 1. Clear or incipient nivation cirque. 2. Weakly developed nivation hollow. 3. Direction of snow drifting into nivation cirque. 4. Bedrock exposure. 5. Angular rock debris, e.g. talus. 6. Rounded boulders in block streams or single »creeping boulders« in former solifluction material. 7. Debris lobe, possibly from periglacial solifluction. 8. Swamp. Maximum depth of lake Odensjön 19.7 m from Godlund (1951). Map Contours from map concept kindly provided by Mr. Mikael Stern.

Interpretation: Snow drifting from the west (mainly) and the east have widened a fluvial north-south pre-Pleistocene canyon of Odensjön valley, by creating large snow-beds and nivation. The nivation and widening occurred during cold tundra periods before and after the glaciations with complete ice cover from NE. The overdeepened basin of Odensjön was created by a glacial scour from snow, converted into ice in the bottom of thick snow pack of more than 30-40 m. The U-valley, canyon walls and large nivation side cirques were not destroyed by the main glacier flow, because they were filled with ice when the large glacier invaded from the NE.

Fig. 2. Geomorfologisk skitsekort over søen Odensjöen og Nackarpsdalen i Söderåsens sydøstlige del. Odensjöen menes at være resultatet af overdybning forårsaget af en lille cirkusgletscher beliggende i dalens sydlige del.

The interpretations of the genesis of the valleys differ very much. Godlund (1951, p. 179) has listed a number of interpretations of the genesis of the Odensjön valley as follows:

1. Volcanism. Lake Odensjön could be an explosion crater (Kjellén 1902).
2. Tectonic collapse of other type (Nathorst 1885, Hennig 1900, Hadding 1922).
3. Glaciation. Lake Odensjön valley end could be a glacial cirque (Kjellén 1903).
4. Wave abrasion. The Lias sea could have contributed to the valley (Hadding 1922).
5. Glaciofluvial erosion. Meltwater from the Weichselian glacier ice, e.g. from ice-lakes could have drained suddenly through the ice and formed the Odensjön basin as a plunge pool (von Post 1938 and Wennberg 1947).
6. Fluvial erosion. In the densely fractured gneiss a retrogressive erosion could have been stopped at the contact of more resistant gneiss (Hennig 1902 and Bergsten 1942).

This list is mainly relevant for the valley of Odensjön, but several of the hypotheses have also been considered as influencing upon the formation of the other two sister valleys. Alternatives 5 and 6 are considered as most likely by Godlund, who prefers number 6 in his evaluation.

Mattsson (1962) discusses the valleys in his doctoral thesis and gives the following comment: »Ein Sonderproblem bieten die an kleine Karnischen erinnernden Auskerbungen in den Talwänden; bisweilen gibt es ein ganzes System mit vielen Nischen nebeneinander und sogar stockwerkartig übereinander. Die nicht selten kühn aufgetürmten Felspfeiler auf den zernagten Felsriegeln der Scheidewände können in ihrer jetziger Form keine Vergletscherung überdauert haben. Es ist also möglich, dass Schnee-Erosion (Nivation) unter periglazialen Klimaverhältnissen für die »Karnischen« verantwortlich ist, auch wenn sie komplexe Bildungen mit älteren Anlagen sein können. Das ein herbes Klima wirklich vorgelegen haben muss, beweisen die vielen Funde von Frostbodenstrukturen (zuerst von Johnsson 1956 nachgewiesen) (Mattsson 1962, s. 187).«

The difficulties with all these earlier attempts of explanation of the genesis of the striking valleys were mainly, that none of them could give a reasonable explanation to how the overdeepening of Lake Odensjön had been created, except for the idea that the lake basin was overdeepened by a local cirque glacier (Kjellén 1903). The glacier alternative has so far been regarded as impossible for mainly two reasons: a) it required a very low glaciation limit, close to sea level in Scania and b) it also probably required survival of the deep and abruptly incised canyon valleys under the cover of the continental Weichselian glacier, which advanced over the area and reached western Denmark and northern Germany. These were two obstacles to the theory of local glaciation, which caused von Post (1938) and others to suggest the alternative of erosion by glacial or subglacial meltwater at the last deglaciaton. But also this idea must be rejected, because the loose material damming Lake Odensjön in the narrow outlet of the valley is angular, unsorted gneiss debris. Its lack of characteristics of water transportation from a deep plunge-pool in Lake Odensjön speaks against the plungepool theory. So does also the morphology of the east and west rims of the plateau surrounding the lake basin. A close field check of those has revealed that they show well developed nivation cirques and nivation funnels, according to the interpretation of the present author. (Fig. 2).

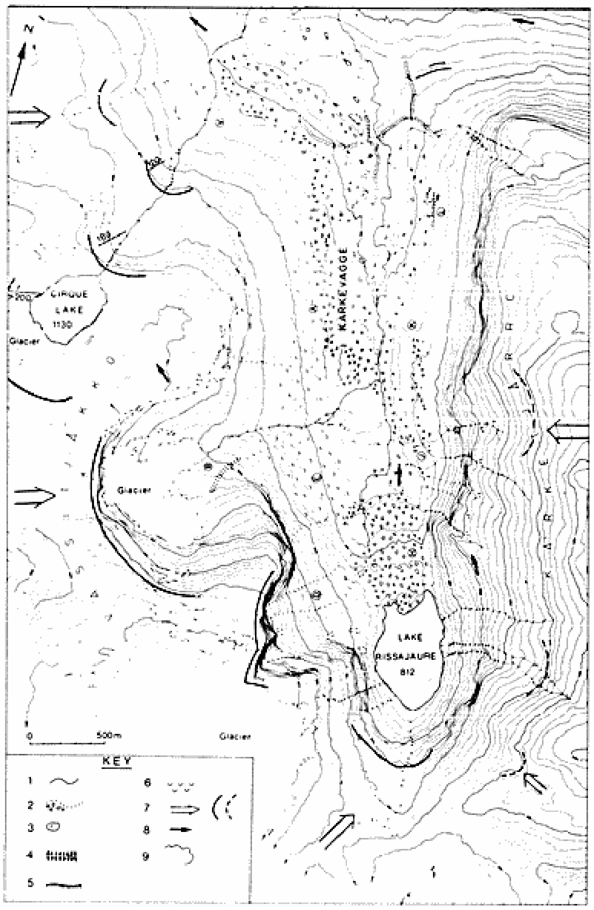

Fig. 3. Map of Kärkevagge valley, N. Lappland, with glacial cirques, oriented by predominant snow drifting from the west, (white arrows), weaker from the east (cf. Vilborg, 1977). Ice flow directions shown by black arrows, from different stages of glaciation. The cirques have clearly survived the main ice flow northwards and westwards. Notice the series of three cirques below each other with decreasing height: 200 m, 160 m and the lowest 120 m high. Map from A. Rapp 1960.

Fig. 3. Kort over dalen Kärkevagge i det nordlige Lappland, med angivelse af cirkusdale.

Snow drifting and nivation in the periglacial tundra periods in Scania

After the Weichselian deglaciation had occurred over south Sweden, several cold periods with tundra conditions existed, e.g. the Older Dryas and the Younger Dryas (Berglund & Lagerlund 1981). The plains of Scania and south Halland had several extended periods of permafrost conditions, as shown by the numerous findings of well developed and deep ice-wedge casts (G. Johnsson, 1956 and later, H. Svensson, 1962 and later) and fossil tundra polygons. Well developed wind-polishing of stone layers and also exposures of firm bedrock are also characteristic of this part of Sweden from the periglacial tundra periods (Å. Mattsson 1957, H. Svensson 1972, 1980, G. Johnsson, several papers, Å. Hillefors, 1979). The predominant wind directions of the periglacial wind abrasion of stones and bedrock was from the east and the west quadrants. Based on this evidence, the author has put forward the theory of strong action of snow drifting from the lowland plains of Scania in tundra times, resulting in large lee-side snow drifts and nivation cirques in the canyon valleys of Söderåsen. A comparison with present-day tundra conditions with strong snow-drifting in Kärkevagge, north-

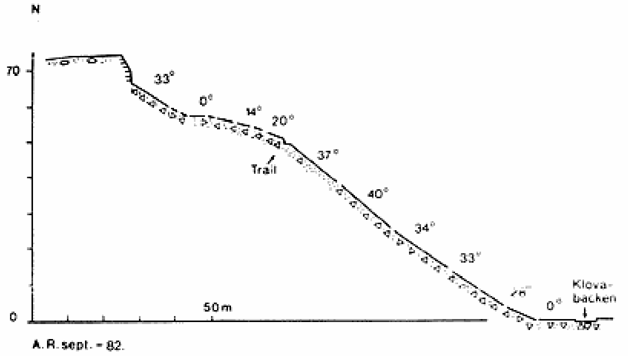

Fig. 4. Slope profile of small nivation cirque with a hanging position and semicircular periphery. Central part of headwall is a cliff of fractured gneiss bedrock and a small talus slope. The cirque floor has a small deposit of debris, which is only a minor fraction of the whole volume of the cirque. The slope of the lower part of the floor is 14-20°, an incipient cryopediment by probable solifluction transport to the lower talus slope. Location: Klöva Hallar, cirque no. 8 on the eastern side. Cf. Fig. 1.

Fig. 4. Skræntprofil gennem en lille nivationscirque i hængende position og med halvcirkelformet omrids. Klöva Hallar, fig. 1.

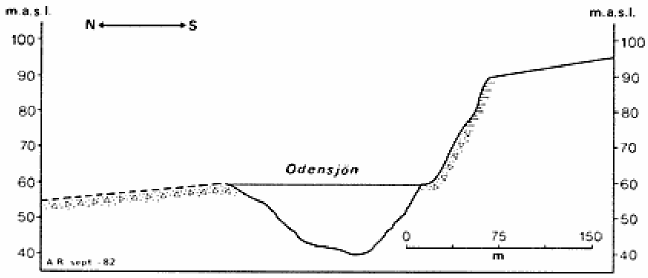

Fig. 5. Longitudinal profile of Lake Odensjön and its valley mouth in S-N direction. The overdeepening of the lake basin according to map by Godlund (1951). At least 6 m deep fine-grained sediments should be added to the deepest part of the basin (E. Lagerlund, oral communication). Gneiss bedrock is exposed at the left end of the profile at 55 m a.s.l. The author interprets the lake basin as overdeepened by cirque glacier flow, in many tundra episodes of local glaciations.

Fig. 5. Længdeprofil gennem Odensjön. Søens bundtopografi efter Godlund (1951). Søen formodes gradvis skabt ved overdybning forårsaget af en cirkusgletscher under tundraforhold i tiden før og efter de kvartære glaciationer.

ern Lappland, is made. (Fig. 3). The nivation cirques in the Söderåsen area have been field-checked by the author in some areas (Fig. 2, Fig. 4). Their distribution and orientation has been preliminarily studied on field checks and by using maps for the orienteering sport in scale 1:10 000 and with detailed contours of 5 m vertical interval, provided by Mr. M. Stern, Lund. Further details in the interpretations are provided by the texts to the illustrations of this paper, Fig. 1-5. The author has also observed local moraine ridges in the valley bottom of Skäralid, which indicate local glaciation from snow drifting.

The study will be continued in order to test the theory, formulated in the summary of this paper. It should be added that the southernmost locality with a supposed local cirque glacier form so far described in modern Swedish literature is a locality in Dalecarlia, middle Sweden above 350 m a.s.l. (Agrell 1977). Of the few detailed descriptions of nivation cirques in the geomorphological literature I wish to refer to E.P. Henderson (1956) as one of the best I know of. Rudberg (1954) and Vilborg (1977) have made thorough inventories of cirque forms in the northern mountains, but like other authors stress the lack of clear nivation cirques in Lappland, probably because the time available for nivation cirques to develop after the last glaciation has been too short.

SUMMARY

Odensjön, Skäralid and Klöva Hallar are three valleys of canyon type, deeply cut (60-100 m) into the horst block of Söderåsen, of fractured Precambrian gneiss rock. It has been shown by other authors that the cold periods after the Weichselian deglaciation were characterized by permafrost and ice wedges on sandy plains in south Sweden. Strong winds caused widespread wind-polishing of stones and bedrock, predominantly from easterly and westerly directions. Based on this evidence, the author presents the theory that large deposits of wind-blown snow were trapped in the canyon valleys of Söderåsen, except for the valleys of east-west directions. The snow was metamorphosed to firn and local, small glaciers, which filled the valleys. The rims of the canyon valleys have in many cases well developed nivation hollows, either steep nivation funnels or gently sloping, semicircular nivation cirques. Odensjøn is a closed, semicircular rock basin, which has been much discussed by scientists earlier, and which seems to fit the theory of creation by nivation from mainly west, but also east, and a local cirque glacier flow northwards causing the overdeepening and removal of loose material. The three valleys mentioned were problably widened and deepened into a series of nivation basins in tundra periods before and after each major continental glaciation. The nivation hollows and the deep canyon valleys were not destroyed by glacial erosion during the Weichselian and earlier Quaternary major ice advances, because the valleys were filled with densely packed snow and ice from snow drifting before the main glacier front moved over them from NE directions. The theory will be further checked by a team of scientists from the Department of Physical Geography in Lund. A comparison is made with cirque forms in present-day mountain tundra conditions in the area of Kärkevagge in northern Lappland, investigated by the author during the 1950's and later.

RESUMÉ

Odensjön, Skäralid og Klöva Hallar er tre canyon-lignende dale, dybt nedskårne (60-100 m) i horsten Söderåsen, der består af prekambrisk gnejs. Andre forskere har i tilgrænsende områder demonstreret tilstedeværelse af permafrost og iskiler i de kolde klimaafsnit følgende Weichsel-deglaciationen. I disse perioder forårsagede stærke vinde en udbredt vindslibning af sten og fast fjeld, især fra vestlige og østlige retninger. Med udgangspunkt heri, fremsætter forfatteren den teori, at store mængder fygesne fangedes i Söderåsens nord-syd strygende canyondale. Sneen omdannedes til firn og små lokale gletschere, som fyldte dalene. Dalenes øvre kant viser mange steder veludviklede nivationshuller, enten i form af stejle nivationstragte eller halvcirkulære nivationscirques. Odensjön er et aflukket, halvcirkulært klippebassin, hvis dannelse tidligere er meget diskuteret, og som synes at passe ind i den fremsatte teori gennem nivation mod især vest, men også øst, og overdybning samt fjernelse af løst materiale af en lokal cirkusgletscher, der var i bevægelse mod nord. De tre ovennævnte dale blev formodentlig udvidet og overdybet i en serie nivationsbassiner i tundraperioderne før og efter hver kontinental glaciation. Nivationshullerne og de dybe dale blev ikke ødelagt ved glacial erosion i løbet af istiderne, fordi de var fyldt af tæt pakket sne og is, hidtørende fra fygesne i tiden inden isskjoldets rand nåede frem fra nordøst. Teorien vil blive efterprøvet af en gruppe forskere fra Instituttet for Fysisk Geografi i Lund. En sammenligning er foretaget med cirque-former i bjerge med recente tundraforhold, ved Kärkevagge i nordlige Lappland, som undersøgtes af forfatteren i 1950'erne og senere.

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Localities visited on Excursions during the Nordic Symposium on Frozen Ground Morphology

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The localities showing periglacial phenomena of various kinds that were demonstreated on September 7, 8 and 10 during the frozen ground symposia are described in this report with text and illustrations. The objects demonstrated were, i.a., periglacial valleys formed chiefly through gelifluction, an ice-wedge cast with infilling of lime, large ice-wedge casts of the most common type in south Sweden, lateglacial aeolian sand underlain by wind eroded stones and boulders, fossil periglacial ground surfaces with overlying sand with small ice-wedge casts and asymmetrical periglacial valleys.

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The Excursion of September 7, 1982

In the afternoon we drove from Lund to Glumslöv via Landskrona. Our first stop was the Hilleshög valley, a broad »bottle-valley« overlooking the island of Ven. From a Swedish point of view this district is quite peculiar because it is the only counterpart we have in our country to the Danish cliff coasts. A prerequisite for such steep cliffs to remain almost perpendicular is that there lies in the storm shore line a hard and tough clay material not too easily eroded by waves, and that landslips and landslides from above are inconsiderable. It is the so called Norwegian till that forms the bed of the lower sediment accumulations at these localities. The Norwegian ice advanced from the north before the main phase of the Weichselian glaciation. The exact date of the advance of the former ice cannot now be established.

Unfortunately there are no good intersections left that can illustrate the stratigraphy of Glumslöv Hills, for all the three clay pits near the coast are filled up now. In the sand and silt above the Norwegian till there were, ealier, localities with the largest and most numerous ice-wedge casts found in the whole of Sweden (Johnsson 1958, 1962 a and b, 1966, Adrielsson 1978, Adrielsson et al 1981).

The Hilleshög valley with its narrow opening out towards Öresund (the Sound) has, in my opinion, been a large dead-ice pit later extended through gelifluction and solifluction resulting in the formation of opening, niches and subsidiary valleys.

ern Lappland, is made. (Fig. 3). The nivation cirques in the Söderåsen area have been field-checked by the author in some areas (Fig. 2, Fig. 4). Their distribution and orientation has been preliminarily studied on field checks and by using maps for the orienteering sport in scale 1:10 000 and with detailed contours of 5 m vertical interval, provided by Mr. M. Stern, Lund. Further details in the interpretations are provided by the texts to the illustrations of this paper, Fig. 1-5. The author has also observed local moraine ridges in the valley bottom of Skäralid, which indicate local glaciation from snow drifting.

The study will be continued in order to test the theory, formulated in the summary of this paper. It should be added that the southernmost locality with a supposed local cirque glacier form so far described in modern Swedish literature is a locality in Dalecarlia, middle Sweden above 350 m a.s.l. (Agrell 1977). Of the few detailed descriptions of nivation cirques in the geomorphological literature I wish to refer to E.P. Henderson (1956) as one of the best I know of. Rudberg (1954) and Vilborg (1977) have made thorough inventories of cirque forms in the northern mountains, but like other authors stress the lack of clear nivation cirques in Lappland, probably because the time available for nivation cirques to develop after the last glaciation has been too short.

SUMMARY

Odensjön, Skäralid and Klöva Hallar are three valleys of canyon type, deeply cut (60-100 m) into the horst block of Söderåsen, of fractured Precambrian gneiss rock. It has been shown by other authors that the cold periods after the Weichselian deglaciation were characterized by permafrost and ice wedges on sandy plains in south Sweden. Strong winds caused widespread wind-polishing of stones and bedrock, predominantly from easterly and westerly directions. Based on this evidence, the author presents the theory that large deposits of wind-blown snow were trapped in the canyon valleys of Söderåsen, except for the valleys of east-west directions. The snow was metamorphosed to firn and local, small glaciers, which filled the valleys. The rims of the canyon valleys have in many cases well developed nivation hollows, either steep nivation funnels or gently sloping, semicircular nivation cirques. Odensjøn is a closed, semicircular rock basin, which has been much discussed by scientists earlier, and which seems to fit the theory of creation by nivation from mainly west, but also east, and a local cirque glacier flow northwards causing the overdeepening and removal of loose material. The three valleys mentioned were problably widened and deepened into a series of nivation basins in tundra periods before and after each major continental glaciation. The nivation hollows and the deep canyon valleys were not destroyed by glacial erosion during the Weichselian and earlier Quaternary major ice advances, because the valleys were filled with densely packed snow and ice from snow drifting before the main glacier front moved over them from NE directions. The theory will be further checked by a team of scientists from the Department of Physical Geography in Lund. A comparison is made with cirque forms in present-day mountain tundra conditions in the area of Kärkevagge in northern Lappland, investigated by the author during the 1950's and later.

RESUMÉ

Odensjön, Skäralid og Klöva Hallar er tre canyon-lignende dale, dybt nedskårne (60-100 m) i horsten Söderåsen, der består af prekambrisk gnejs. Andre forskere har i tilgrænsende områder demonstreret tilstedeværelse af permafrost og iskiler i de kolde klimaafsnit følgende Weichsel-deglaciationen. I disse perioder forårsagede stærke vinde en udbredt vindslibning af sten og fast fjeld, især fra vestlige og østlige retninger. Med udgangspunkt heri, fremsætter forfatteren den teori, at store mængder fygesne fangedes i Söderåsens nord-syd strygende canyondale. Sneen omdannedes til firn og små lokale gletschere, som fyldte dalene. Dalenes øvre kant viser mange steder veludviklede nivationshuller, enten i form af stejle nivationstragte eller halvcirkulære nivationscirques. Odensjön er et aflukket, halvcirkulært klippebassin, hvis dannelse tidligere er meget diskuteret, og som synes at passe ind i den fremsatte teori gennem nivation mod især vest, men også øst, og overdybning samt fjernelse af løst materiale af en lokal cirkusgletscher, der var i bevægelse mod nord. De tre ovennævnte dale blev formodentlig udvidet og overdybet i en serie nivationsbassiner i tundraperioderne før og efter hver kontinental glaciation. Nivationshullerne og de dybe dale blev ikke ødelagt ved glacial erosion i løbet af istiderne, fordi de var fyldt af tæt pakket sne og is, hidtørende fra fygesne i tiden inden isskjoldets rand nåede frem fra nordøst. Teorien vil blive efterprøvet af en gruppe forskere fra Instituttet for Fysisk Geografi i Lund. En sammenligning er foretaget med cirque-former i bjerge med recente tundraforhold, ved Kärkevagge i nordlige Lappland, som undersøgtes af forfatteren i 1950'erne og senere.

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This article is a preliminary paper presenting the interpretation of nivation cirque forms in southern Sweden and associated local glaciations in tundra times before and after the main Quaternary glaciations. The theory put forward requires further checking by comparative studies of the fossil southern landforms with the active nivation processes in the northern Swedish mountains. I am grateful to many colleagues for stimulating discussions and support, and would like to mention particularly Drs. H. Svensson, G. Johnsson, E. Lagerlund, B. Ringberg and S. Rudberg. Mikael Stern provided me with excellent maps for the orienteering sport. My family helped me in field work. A grant from the Swedish Natural Science Research Council covered some of the expenses for travel and material. Mrs. K. Laszlo made the drawings and Mr. R. Laszlo made the photographic work. Ground photographs can not be taken in most of the field localities in Söderåsen until after the leaves have fallen from the dense deciduous forest. My warm thanks to all persons and institutions mentioned for help and support.

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