Ms. rec. April 14, 1945.

GEOMORPHOLOGY OF THE RONDANE AREA

BY

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With 6 Text-Figures, 24 Figures on 12 Plates, and 1 Map.

Situation and Introductory Remarks.

The Rondane Mountain Area as circumscribed in the large map lies between 61° 47.1′ to 62° 6.2′ N.L., and 9° 25.1′ to 10 17.8′ E. Gr. (lower margin of map; upper margin 9° 24.8′ to 10° 18.1′), covering about 2030 km². Of this area I have obtained a somewhat detailed acquaintance with 1600 km² during the four summers of 1941 to 1944, and the actual meshes of my routes are rather close within this lesser area. Even if there are stones unturned, I know most of them!

The present paper mainly deals with the Rondane high mountains proper, covering some 400 km², which are on the locational map (A). The map used during the field survey was the original in 1: 50 000, upon which the 1: 100 000 map reproduced is based.

In the following, localities are frequently referred to the 1:100 000 map by their distances in mm from the left and upper margins of the map, given in italics. E. g. the coordinates *212.147* indicate a point 212 mm from the left, 147 mm from the upper margin of the map.

References to figures are only by their numbers (photos on plates), or letter (text figures). Details in figures are referred to by the same mm coordinate system as on the map, only not in italics. The figures themselves have got such full explanations, that they alone might well be regarded as a geomorphological account of the area.

This is the second paper of the Rondane Survey series. In the first one (Strøm 1944) a brief outline of the development and scope of the researches was given. A popular description of the geology and morphology of the area has been published in Norwegian (Strøm 1943).

My sincere thanks are due to the Scientific Research Fund of 1919 for liberal grants toward the work, and to my friends Dr. T. F. W.

Barth and T. Sund, M. A. for good comradeship and hearty collaboration. Many interesting comments were made on a delightful 10-days excursion that I led in 1943, Dr. W. Werenskiold, F. Isachsen, M. A., with twelve young geologists and geographers taking part.

Rock Structure.

A complete petrological account will be written by Dr. Barth in the Rondane Survey series, while there are several valuable observations in the paper by Øyen (1898). Here are only given the data necessary for a geomorphological understanding.

The area within the coordinate lines NS *103, 350,* and WE *110, 285,* that is the whole Rondane high mountain area and surroundings, is exclusively built up of sparagmite, an eocambrian sandstone with feldspar, which superficially has much the character of a quartzite. It has a regular cleavage (18) and jointing, produced by the pressure of overthrusts during the Caledonian folding period, which through differential sliding of layers has caused a very pronounced secondary bedding. Muscovite occurs on the cleavage planes, with friction striae.

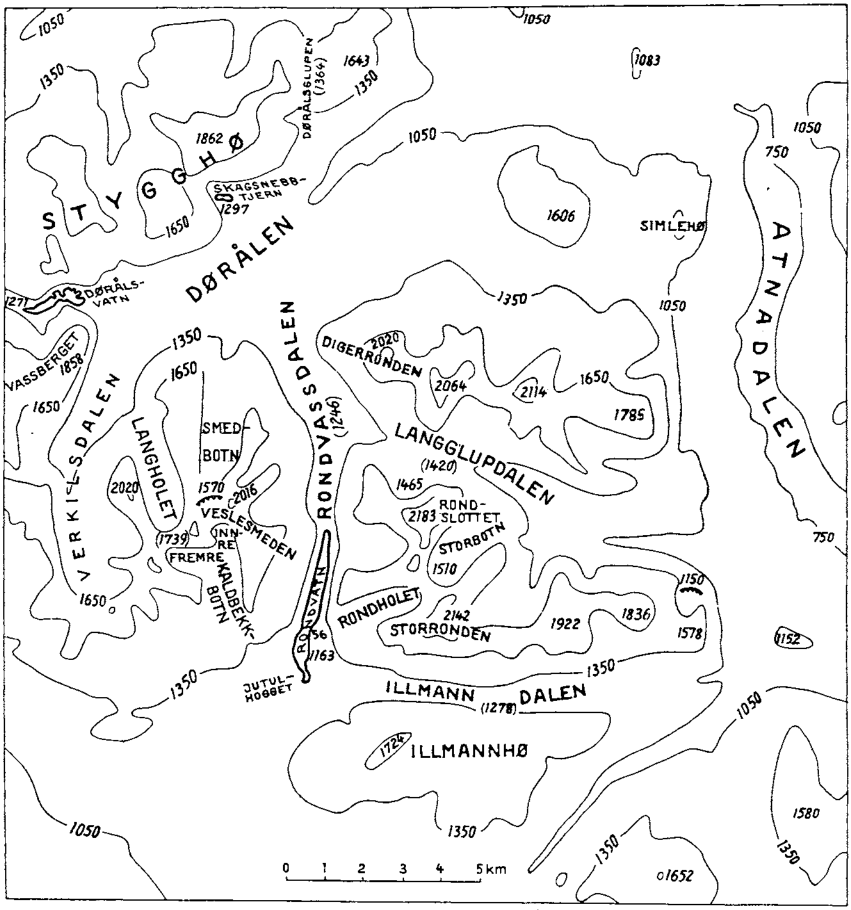
Interspersed in the sparagmite mass there are layers of a strongly deformed quartz conglomerate.

Through mechanical weathering the rock readily splits into mostly narrow rectangular flags. To chemical disintegration it is practically immune.[1]

The layers generally fall towards N and NW, as a rule with a dip of 10 to 20, sometimes up to 30°, but in may places are horizontal. There are zones of pronounced vertical macrojointing in a direction NNE—SSW. Only in one place, visible in the vertical shores of Rondvatn lake (*202.243*) is there a strongly folded section. This is

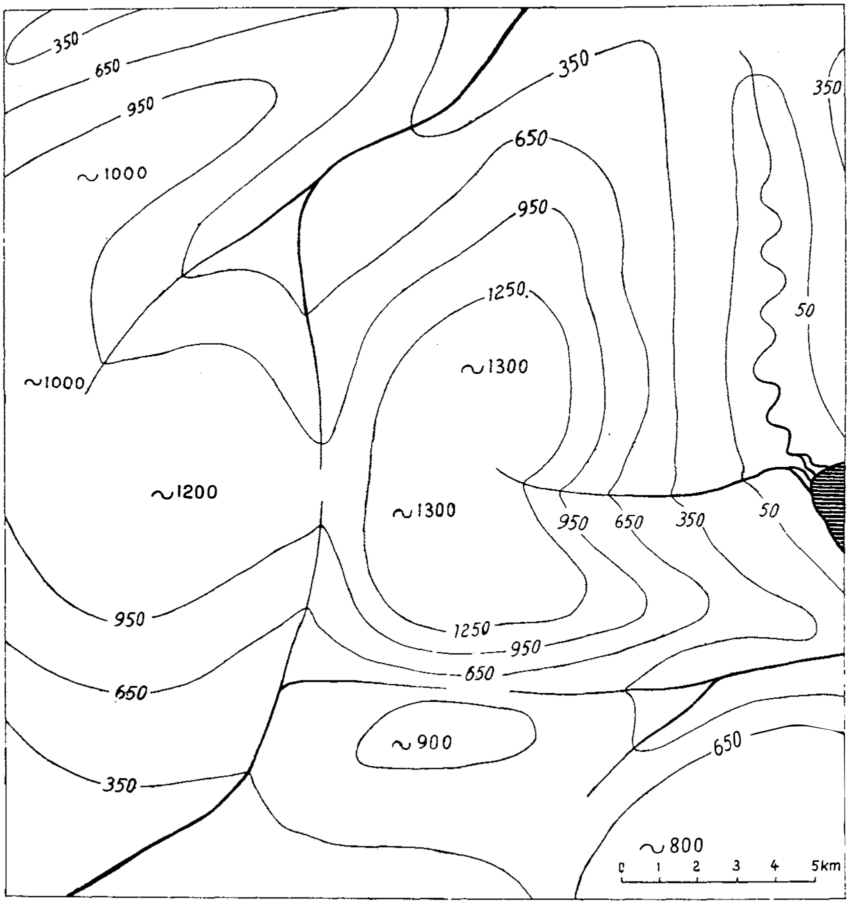
[1] The analysis given by Barth (1938, p. 64) as average composition of unmetamorphic sparagmite is very illustrative:

SiO_2	80.89	MgO	0.04
TiO_2	0.40	CaO	0.04
Al_2O_3	7.57	Na_2O	0.63
Fe_2O_3	2.90	K_2O	4.75
FeO	1.30	H_2O	1.11
MnO	0.00	P_2O_5	0.00
			99.63



A. Locational map of Rondane. Isohypses for 750, 1050, 1350, 1650, and 1950 m. Altitudes in m; pass altitudes within brackets; lake names and depth figure leaning. The two thick, serrated lines are postglacial moraines. Altitudes refer to cirque floors on distal side of moraine.

interesting, as we have here the deepest exposure in the centre of the massif. From the occurrence of a window immediately E of the map margin we know that the subjacent archean cannot be very far below. That a folding zone, evidently caused by resistance from the underlying rocks, exists in the centre of the Rondane bulk, would indicate that the bulk is a repetition of a convexity in the archean surface.



B. A probable preglacial (late-Tertiary) surface. Map covers the same area as the locational map A. Supposed drainage is indicated. Contours and altitudes refer to the possible sea-level for the period suggested (Miocene—Pliocene) of + 1000 m, the land elevation being somewhat under way from the probable Miocene level near Rondane of + 1450 — + 1550 m.

Generally speaking, the sparagmitian rocks of the Rondane area through their homogeneous structure are ideal for a study of geomorphological processes. Even if the conglomerate sheets are harder, the rocks in the NW parts nearer the Caledonian folding zone through a wavy micro-texture more resistant, and the zones of joints more liable to erosion, the uniformity is the striking feature, and possibly unique in a high mountain area.

Surface at the Commencement of the Glacial Cycle.

A somewhat rough reconstruction of a district that has been subject mainly to local glaciation, and where parts of the surface between the cirques are preserved, should be both possible and useful.

The Rondane area must for a very long time have been highlands with mature forms. At the beginning of the Tertiary land elevation, sea level in the west (around the present Jostedalsbre) was probably some 1800 m corresponding to a peneplained surface, preserved over wide areas. (The question of possibly later Tertiary faults within the land region cannot be entered upon here.)

From many indications, this surface in the regions surrounding Rondane may be judged to have lain between 1450 and 1550 m, and above that level Rondane must have emerged up to some 650 to 850 m as mature, rounded hills. From parallelization with the Alps (Götzinger 1912, p. 27 f., v. Klebelsberg 1935, p. 423), and as a mere guesswork, this surface, and the beginning of Tertiary elevation, may be dated as early Miocene. There is another, lower level, at about 1000 m, that cannot be entirely explained by the »in situ« levelling processes of Richter (1896, see post p. 372), and which might be Miocene-Pliocene.

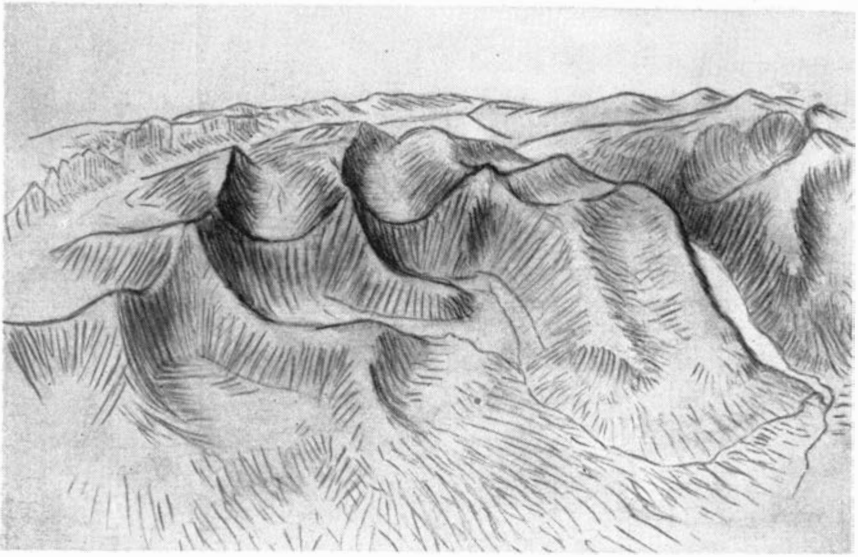
The map B aims at a reconstruction of the Rondane area at that stage. Isohypses and drainage are drawn with due regard to a number of local conditions, which cannot here be specified. The summit level is imagined to be some 100 m above that preserved in the E part, and about 200 m above the highest summits of the W part where no real level has been preserved.

Main Relief, and Forming Processes.

A glance at the map, or the stereogram C, at once fixes the geomorphological character of the Rondane central area, it is a fretted upland, though not in an advanced stage.

The characteristics of the area are thus the initial surface together with the cirques and transectional valleys, as well as several levels of erosion. But interesting are also the character of the foreland, and some erosional forms in the periphery of the area as circumscribed in the locational map A.

The surface initial to the glacial cycle can only be summarily reconstructed, as has been attempted, but an "old" surface is found in

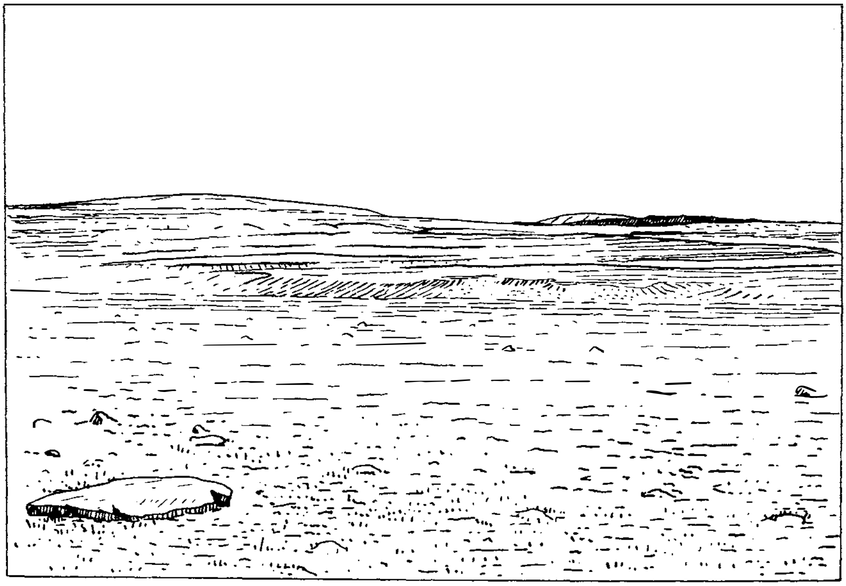


C. Stereogrammetric representation of W Rondane from S. After original (reproduced Mannerfelt 1940, Strøm 1943) by E. Laurell & C. Mannerfelt.

many places. This old surface has been pared down by weathering, and run over by the inland ice, probably even after the last wholesale cirque erosion at the commencement of the last ice age, but in spite of that must be regarded as conforming to the Tertiary relief.

An example of the paring and weathering down is given in 17 (*78.145*) where hard conglomerate rocks protrude about 25 m above a well-rounded surface. A little farther to the N (*83.127*) there is a widespread occurrence of similarily protruding olivine rocks. In the first case the conglomerate lies between sparagmite rocks to the right and phyllites to the left (geologically it is basal to the phyllites), in the second case the country rock is phyllitic. It is possible that the "härtlinge" and their surroundings have not for ages had a common surface, but more probably the protuberance is a measure of general denudation during a certain length of time, which cannot now be specified.

In the E part of central Rondane there are flat, or gently curving summit surfaces (4, 8, 14). In the W part E of Verkilsdalen the frettage is too great (1, 3, 8), so that an old surface is nowhere preserved. But W of Verkilsdalen the mountain plain (really plateau,



D. Vassberget—Steinbuhø old surface. From Steinbuhø (90.190, 1573 m) towards Vassberget (140.173, 1858 m. Level summit left 1753 m). Drawn by R. Smit after photo by K. M. Strøm.

since the layers are practically horizontal) of Vassberget—Steinbuhø (*98.164, 142.160* to *100.230, 132.217*) which shows so well in D and 10, constitutes the largest part of the old surface preserved. It continues W of an intervening valley in Sletthø (*62.162, 58.180, 88.164*) which is so flat that the summit altitudes only vary from 1577 to 1593 m over an area of some 4 km². Styggħø, N of central Rondane, even if rather dissected, has a comparatively level skyline of 1750—1850 m (2).

The cirques in Rondane are very characteristic both of the mode of erosion, and rock structure. A typical picture of a comparatively round and short cirque is 6. This may be regarded as the classical type. But the Rondane cirques are often much elongated, and form finger valleys. Langholet (8) is characteristic of this type, and is also noteworthy as being a hanging valley in relation to the Verkilsdalen finger valley. All those transitional stages are well illustrated in the central part of the map. The reason for the Rondane cirques being thus relatively long, and very flat-bottomed (5), with no real cirque lakes, is doubtless the character of the sparagmite rocks, which shatter so easily that the back wall recession is very rapid, and no rock thresholds are preserved, the only instance being a quite abortive one (7), damming no lake. The contrast against cirque glacier work in the tough plutonics of Moskenesøy (Strøm 1938), where in the generally short cirques are small lakes overdeepened to more than 170 m (one lake with a surface of 0.87 km^2 has a maximum depth of 168 m) is very striking. In the one case one has the impression of drills working horizontally, in the other vertically.

The altitudes of Rondane cirque floors are most typically 1450 to 1600 m, but even neighbouring cirques may differ much (3).

Where the frettage has proceeded far, the cirques are separated only by saddle-edges, as is mathematically inevitable when two cirques approach each other through progressive erosion. This has been demonstrated by Hobbs (1910, p. 162, fig. 19), the intersection of two truncated cones representing the cirques being a parabola. The argument of Mannerfelt (1940, p. 38) that the saddle-shape of edges is evidence of an erosion by inland ice therefore does not hold good, whereas the rounding of the saddle-edges from cirque to cirque must probably be the result of an overflow. But this overflow might simply have been a coalescence of the two cirque glaciers, not necessarily an overflow by the inland ice.

Very interesting is the fact, appearing in the map (*143.168, 151.238, 185.165*) that the finger valleys from W central Rondane towards N have a steep W side, and a more gently sloping E side. Unhappily circumstances are complicated by the structure of the rocks, there being a WNW dip of up to some 30°. But I regard it as highly probable, even if on account of structure a complete demonstration is not possible, that this is due to a well-known climatic factor, névés and glacierets commencing earlier and persisting longer on the W than on the E side, the sunshine from the E being less effective than that from the W, after the daily air warming. While prevailingly W winds through differential snow accumulation may play a part towards the same orientation in an incipient stage, this factor should be of no consequence in an old, deep cirque. Forbes (1938, p. 113, fig. 116) has a magnificent air photo of the same phenomenon from the Torngat mountains in Labrador at 59° N. L.

The time for the main formation of the cirques must be at the beginning of each glacial sub-cycle, when alpine glaciation commenced in the highlands, the very first incipient glaciers being merely névés on the old surface. For each erosion period the cirques were deepened and lengthened, transforming topography from the "biscuit-board" to the groved, and finally the fretted type. The farthest incised cirque, Verkilsdalen finger valley, is 7.5 km long, the highest back wall (N of Rondslottet, 15, *230.210, 230.203*) more than 700 m high. The conception of the important function of meltwater in cirque formation, convincingly put forward by Lewis (1940), certainly helps much towards an understanding of such extended erosion, the easily shattered Rondane sparagmite as previously mentioned being especially liable to destruction by sapping.

In many cases, postglacial sapping has played an important part in keeping the edges of cirques sharp. Nearly everywhere when extremely steep walls and sharp edges appear (contours merging on map) there are, or have recently been, glacierets or névés (4, 6), these cirques with rejuvenated forms being markedly different from those where no such sapping has recently occurreed. The exception is the E side of Vassberget, where the steep wall has a somewhat different character with the numerous couloirs, and is kept steep through hard horizontal layers appearing high up, the highest immediately below the summit (10).

No cirque, with one possible exception (post, p. 376), has however been filled by glaciers since the melting of the inland ice (Mannerfelt 1940, p. 26).

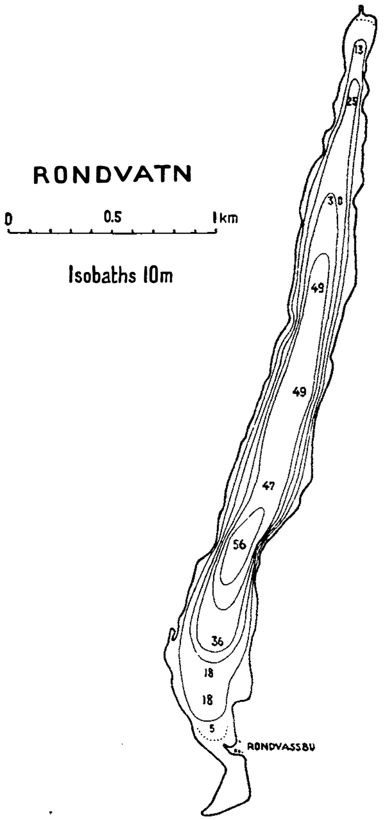
There are various stages to be seen in the formation of transectional valleys. The first one is when the cirques begin to join, and the saddle-edge or col separating them is much lowered. This is the case with the col between Langholet and Kaldbekkbotn (*171.220*) which is only 1739 m, and which has certainly also been overflowed by the inland ice. The next stage is when the cirques have fully joined, and form a valley with a graded ascent from each side (Langglupdalen, pass alt. 1420 m). Finally a full transectional valley is formed (2, *111.157* to *145.160,* W of Dørålsvatn, pass alt. 1340 m). The transectional valleys Illmanndalen (pass alt. 1278 m) and Rondvassdalen (pass alt. 1246 m) are probably tectonically conditioned as well. This is demonstrably the case with Rondvassdalen, where the pronounced vertical macro-jointing is visible on the E side, and which has an "uncalled-for" continuation in the Dørålsglupen glen N of Dørålen (12, *197.103*).

How great is then the work of the inland ice? While having generally pared down the land surface (ante, p. 365) its erosional effect is not to be compared with that of local glaciation. This is easily to be understood when we realize that at least during the later part of the last glaciation period the main ice divide passed immediately over Rondane. On the surrounding valley bottoms there are deposits, certainly dated as of the last interglacial period or older through the occurrence of mammoth remains, and moraines that have been judged to belong to a glaciation older than the last (Strøm 1943 A p. 288).

During the maximum of the last glaciation it seems probable that the summits of the Rondane mountains were just buried. Through lateral drainage channels from the melting period there is clear evidence of the ice reaching up to 1600 m (on Steinbuhø—Vassberget). That the Langholet—Kaldbekkbotn 1739 m col was overflowed by inland ice is seen not only from its smoothing in a transverse profile, which could be dependent upon local glacier coalescence, but upon the indications of a strong iceflow out of Kaldbekkbotn, where the only roches moutonnées (18, 19) occur, and the flow out Fremre Kaldbekkbotn has helped to form and preserve the abortive rock threshold of Innre Kaldbekkbotn (7) with its then relatively stagnant ice. But a complete overflow cannot be proved, only autochthonous rocks occurring on the highest summits. What is known of the inland ice height limit towards the west, and its rising towards Rondane, makes, however, the overflow at the last glaciation maximum seem certain.

Such a great thickness of ice (at least 1000 m above the valley floor), even if slowly moving, has caused an overdeepening in the Rondvassdalen transectional valley (1, 13, along E side of valley and lake from *207.198* to *203.255,* Strøm 1944, p. 6, fig. 1). This valley is also the only NS gap for a very long distance. The overdeepening is continued in Rondvatn (E), which adds some 50 m (max. depth 56 m), the total overdeepening being at least some 150 m. Erosion has been concentrated towards the deep, in places forming a trough-in-valley.

This example of directed erosion may be contrasted by cases of selective erosion. Apart from the more or less easily eroded tectonical zones, which are responsible for the whole Rondvassdalen

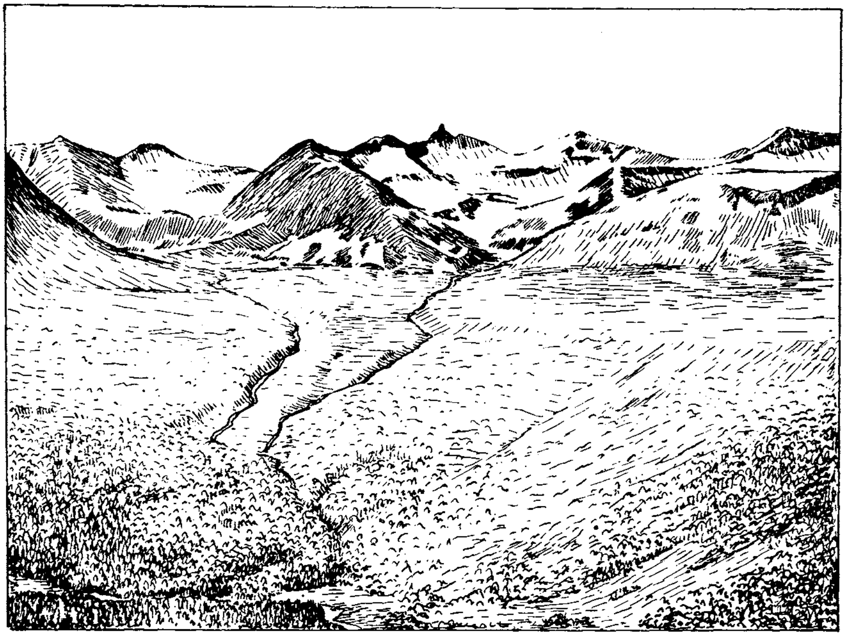


E. Depths in m. Only the deepest sounding is shown for each traverse. Areas inside the dotted curves are very shallow. From Strøm 1944.

system, we see selective erosion brought out through the formation of ledges from hard materials in cirque and valley walls (2, 10). In areas with weak erosion there may be preserved knobs, such as one covered by the hard quartz conglomerate (*232.187*), but the general impression (ante p. 363) is that of Rondane as built up of a highly homogeneous material.

Most interesting is the occurrence of levelled areas. A very good example is given in 5, where we see three nearly horizontal levels at 1570, 1740, and 1810 m. Such levels are found in many places, but do never correspond, a proof that they are not preglacial. Indeed possible preglacial levels apart from the old surface could not with the enormous amount of erosion, be expected to be preserved. All levels below the old surface, which I have been able to recognize, are old cirque floors or valley bottoms. Such cirque floor levels are common in many Norwegian mountains, a very good example from outside Rondane is given in F. One could think the cirque floors dependent upon some preglacial levels, as has been demonstrated in the Alps [1] even if these preglacially levelled surfaces were wholly destroyed, and not preserved as in the Alpine example. A consideration of the occurrence of levels in every different altitude, however, indicate that they are levels of special erosion, not of general denudation.

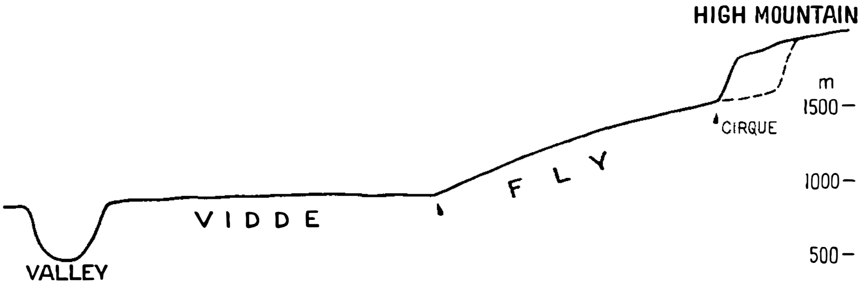
[1] E. g. v. Klebelsberg 1935, p. 424, Karwendelgebirge: "Dabei ist besonders lehrreich daß dieses Niveau (um 2100 bis 1900 m) auch noch abseits der Kare in ausgedehnten Resten erhalten ist."



F. Mountains around Svartnibbo (central peak 1730 m; in Sunnmøre, 62°15′ N. L., 7°30′ E Gr.) towards S. Levelled surfaces on mountain side within cirque glacier region. Drawn by R. Smit after photo by J. Hødal.

For a demonstration of the mode of formation of these levelled surfaces, Rondane supplies one key area (11, 13, *205.169* to *239.165*). The continuation of the cirque floors as projecting bastions, especially the E-most, and the difference of altitude of some 100 m between the two floors, are very important.[1] Thus is given a key towards understanding that the surface of a projecting spur may be an ancient cirque floor, and the occurrence of so many different levels in one neighbourhood. The photo 5 is then fully interpreted by assuming

[1] Final proof of the projecting bastions being solid rock platforms could not be given. They are, however, covered by débris like that elsewhere weathered in situ. In the stream valley *227.157* there was morainic material, but this is only to be expected, as the great ravine is certainly not postglacial, and must have been entirely filled up during the last glaciation, the postglacial brook eroding its way through the loose deposits. The stream head (at *229.161*) is certainly in rock. The ledge and flat-topped, truncated spur 1512 m are not due to an occurrence of harder rock.



G. Ideal section through a mountain region of central Norway.

the horizontal levels to be cirque floors, two ancient ones, and one recent.

Apart from these cirque floor levels, there are in some places old valley floors recognizable. The gently rising 1260—1380 m surface (12) on the N side of Dørålen valley is probably an ancient floor of that valley, the not very clear-cut cirque there being probably "based" upon the ancient valley floor, as the cirques in the Alpine example (footnote p. 370) are based upon old surface levels.

The backward erosion by cirque (or piedmont glaciers) on a large scale much stressed by Holtedahl (1929, p. 16—18, 21 etc.), was first recognized by Richter (1896 p. 17) from observations in Norway. His little paper is certainly one of the foremost contributions to the geomorphology of our country.

As a result of cirque level incisions, overflow by inland ice, and general denudation, we get a somewhat inclined plane abutting against the high mountains,, where the present backward erosion frequently takes place through cirque glaciers.

This inclined surface abutting against higher mountains is in Norwegian called a *fly,* a name which I propose for international acceptance. It is not to be confused with the *vidde,* a somewhat peneplained mountain surface (around Rondane at about 1000 m), which is largely a preglacial level (ante p. 364) that as a rule forms the local base level. In an ideal section of a central Norwegian mountain region we thus get the geomorphological elements indicated in G.

Speaking in a very general way, the "fly" is a kind of rock pediment. The approach from the "vidde" to the high mountains of Western Rondane on a profile from near Mysuseter to Veslesmeden (*170.341* to *181.210*), where the "fly" and high mountains are illustrated on photo 1, is very near to the ideal profile.

Morainic deposits cover most of the ground below some 1300—1400 m, but except when sculptured by fluvoglacial activity during the melting of the last ice sheet (post p. 374), are quite featureless. The cover, e. g. over the "fly" in 1, is, however, nowhere very thick, the streams soon reaching bed rock.

A general view of the high mountains as areas of denudation, and their surroundings as accumulation areas is given in 9.

Besides the results of postglacial fluviatile erosion (post, p. 376) there are some larger features which must at least in part be due to erosion by running water. This is the valley with its tributaries (Bråkdalen, *102.180, 119.180 to 116.250*) draining a W mountain slope and the Vassberget—Steinbuhø mountain plain. While undoubtedly modified by ice, this valley system probably owes its origin to the drainage of the plain. On the less extended high surface of Stygghø there has in postglacial time certainly long been preserved or renewed a plateau glacier. The disproportionately deeply cut drainage valleys, as well as small frontal moraines even at 1300 m on Gravhø (*188.51*) farther north, clearly indicate this. The same must have been the case with Vassberget—Steinbuhø above some 1600 m, where the plateau glacier separated from the main body of ice melting downwards towards the S. At a later stage, a tongue of the main body lay in Bråkdalen, where there are traces of small pocket lakes at about 1420 m, and the drainage must have been under this tongue. But the final melting of the plateau glacier must have sent its large volumes of water through an ice-free valley, and such meltings with correspondingly large drainage certainly have occurred several times during the glacial ages with their (in Scandinavia) two or three interglacial and numerous interstadial epochs.

Features from the Melting of the Last Ice Sheet.

There are very extensive traces, both erosional and accumulational, of fluvoglacial activity arising from the melting of the last ice sheet. As we are not here concerned with the history of ice wasting, it is sufficient to mention that after having had its divide over the Rondane area the inland glacier was dead here throughout this period, and that the ice besides melting downwards also melted backwards from N to S, leaving isolated strips in valley bottoms. (And plateau covers in places outside central Rondane. Ante p. 373). The history of the period will form the substance of an important paper by T. Sund.

Among fluvoglacial phenomena are the traces of drainage, frequently as channels in series below each other along the sides of ice lobes projecting into valleys (5, 16. Illmanhø series 5 are seen in contours *205.264*). These drainage channels are cut in rock or washed out in different materials (15, 16), usually moraine. Sometimes very long canyons are formed by lateral drainage, but more frequent are short canyons forming spillways from a lateral channel towards subglacial drainage. Subglacial drainage channels are very common in places, and whole hillsides covered with moraine may be riddled through by lateral and subglacial drainage (1, contours *193.250*).

When the snout of the melting inland glacier lay in Rondvassdalen, this was the only outlet for meltwater over a very long distance. Enormous quantities of outwash were carried towards Dørålen and deposited against the ice left there, which finally consisted only of a wasting strip in the valley bottom. Thus was formed the magnificent fluvoglacial landscape with drainage channels, canyons, pitted and terraced outwash, delta plains, ice contact slopes, and terraces in moraine material, figured 9, 11, 12, 13. For detail one is referred to the descriptions of those figures. While running water is responsible for the formation of these terraces, others seem to have been deposited in "pocket" lakes between the ice and land, but traces of true ice-dammed lakes do not occur in Rondane.

Of more strictly glacial origin are the dead ice deposits, which fill the bottoms of transectional pass valleys, appearing as a knob and kettle landscape with lakelets (Rondvassdalen *206.190,* Illmanndalen *244.257,* and with a more subdued relief in Dørålsvatn valley *139.159,* 2).

In several cases streams have been deflected with lasting effect by the ice or glacial deposits. Noteworthy is the brook figured 1 and 21, which has got a new course with a knee at *194.256,* and the considerable stream deflected from running eastward to a northward course at *317.146* by the glacier tongue in Atnadalen, as instanced by Mannerfelt (1940, p. 31). The preglacial drainage is given on the late-Tertiary surface map B.

Present-Day and Postglacial Change.

The results of recent weathering are everywhere in evidence, as is only to be expected from the effects of frequent frost and thaw upon rocks that shatter so readily as the Rondane sparagmite.

Extrapolated temperature values for Rondvatn (recalculated from Strøm 1944) indicate the large space of time when alternating frost and thaw may occur:

°C	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rondvatn 1163 m . .	—10.4	—9.8	—9.2	—4.5	0.9	6.4	8.3	6.9	3.2	—2.5	—7.4	—10.1	—2.4
Gradient for 100 m	0.4	0.4	0.8	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.4	0.65

Good examples of weathering are to be seen in 10, 18, 19. At the foot of nearly all steep mountain sides there are large tali and as a rule the steep sides are furrowed by couloirs (6, 10, *250.239* and *142.178)*, which in a northern exposition are filled with snow. All more or less level surfaces above some 1400 m are covered by a not very thick layer of rocks and stones weathered in situ; with horizontal layers underneath, the cover frequently consists of great flags lying flat. Where flags are weathered to small pieces, these are sometimes laid down by the snow cover as a pavement (24).

Characteristic pock-marked surfaces due to sapping by snow patches occur, notably on the not very steep, N-exposed mountain flank *168.175*. The sapping activity of even small accumulations of snow is everywhere conspicuous.

Regular rock slides with typical side walls are especially to be seen in Illmanndalen, where one slide has reached across the valley bottom, and conjointly with residual dead ice ridges, dams up a lakelet. The remarkable phenomenon of rock slides taking place upon névés is everywhere to be seen in the cirques (5, 6, 24), and is brought into evidence by the recent melting of névés, leaving ledges of débris along their previous foots (24). In one place (Verkilsdalen *147.200)* really enormous rocks have slid from 2000 to 1200 m on the hibernal snow cover of screes.

There are only a few places where a kind of glaciers occur at present, but one of these glaciers, that in Smedbotn, has left a very conspicuous moraine (23). But this imposing accumulation is certainly mainly formed by the weathering of the back wall with débris sliding across the steep névé of the glacier at the time when it reached the proximal side, the process being somewhat supplemented by glacial movement. At present the much-retired glacier clings immovably to the back wall. The last advance must have been quite recent, probably in the 1740's. This is, however, a phenomenon mainly of the same kind as the sliding on névé everywhere in the "sharp" (p. 368) cirques, only on a larger scale. But there is a much older terminal moraine at a low altitude (*299.228,* at 1150 m, as against Smedbotn 1570 m, see also A) mentioned by Mannerfelt 1940, p. 20) and surveyed by T. Sund, but not by me. This moraine may be paralleled with traces of similar low altitude glacieration mentioned by Mannerfelt (1940, p. 33 ff.) and Holmsen (1915, p. 8 f.).

There are some few landslides in loose deposits, but really more remarkable is the wonderful preservation of the glacifluvial deposits, which in all places where the meteoric water seeps through are as if laid down yesterday.

Solifluction phenomena occur in many places. Most conspicuous is the formation of streaks of stones on mountain sides with suitable material above some 1400 m, these streaks being disposed either horizontally or vertically, according to the steepness of slope and character of material. Overhanging festooned sheets of soil do not occur within Rondane proper, precipitation being too low, the sparagmite also forming poor sliding surfaces, in contrast to e. g. phyllites. Polygon fields are met with in some few localities, on one very slightly sloping level in what could be called the "churchyard" type, elongated "graves" with raised flags as "headstones" (20). Practically all the Rondane high mountain area is above the present limit of peat formation.

Stream erosion is everywhere evident, both in loose deposits (13), and in rock. In rock the larger amount of work is certainly done by weathering and canyons or gorges with vertical sides are formed, the streams carrying away the débris (21, 22). Deposition occurs in lakes (21), and in the flat part of Atnadalen above lake Atnasjø (A, and *332.137* to *362.235*).

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Photos.

In making the necessary selection from between 200 and 300 photos, I have only paid regard to their capacity for illustrating geomorphological features, not to general aesthetic qualities.

Many of the photos are very rich in detail which is only revealed by close inspection, but descriptions go much more into particulars than is usually done. When necessary, localities in landscape are referred to by their distances in mm from the left and upper margins of photo. E. g. 28.35 means 28 mm from the left, 35 mm from the upper margin. Coordinates referring to the map are given in italics, thus *212.147* indicate a point 212 mm from the left, 147 mm from the upper margin of the map.

Photos 1, 2, 7, 8, 10, and 17—24, are by K. M. Strøm; 3, by S. Bø; 4, by H. Østtveit; 5, 6, 9, and 11—16, by T. Sund.

Map 1 : 100 000.

The present map 1 : 100 000 is printed by the Geographical Survey in brown from the contour plate (equidistances between isohypses 30 m), in blue from drainage plate (giving lakes, watercourses, bogs, and permanent snow) of the Rondane sheet issued in 1927. From the locational map, text-figure A, most of the names mentioned in the text can be made out. Approximate altitudes may be ascertained by using the altitudes of summits and lakes there given, and counting the contours, the idea being that nothing should disturb the orographical picture of contours and drainage.

Stippled blue contours indicate permanent snow (glaciers or névés), horizontal blue lines, bogs.

Printed June 1945.

1. W part of Rondane (max. alt. 2020 m), seen from Illmannhø (*209.273*) at 1602 m. A fretted upland dissected by cirque glaciers. In middle ground the inclined „fly“ floor leads up to mountain back wall. Right Rondvatn lake (1163 m) in overdeepened trough with postglacial delta (cp. 21) near outlet. Finiglacial glacier in foreground valley with snout towards lake, has deviated consequent stream in centre to subsequent course from knee (33.46) to delta, and left systems of drainage channels.

2. Dørålsvatn (lake, *139.159*, 1271 m) transectional valley, from N slope of Vassberget at 1723 m. Skyline represents old surface of Stygghø (max. alt. 1862 m). Layers of varying strength dipping NW seen in steep opposite valley-side, which is incised into a maturer surface. Low relief dead ice terrain in valley bottom. Invisible below snow stripe in foreground, small glacier in semi-cirque stretches towards valley bottom.

3. W part of Rondane (max. alt. 2020 m), a fretted upland seen from Digerronden (*220.171*, 2020 m). Two small, elongated cirques high up. Long, deeply incised cirque valley, Smedbotn, from the right (112.43 to 70.32). In the foreground, upper opposite slope of Rondvassdalen transectional valley.

4. Storronden (*236.237*) mountain group (max. alt. 2142 m), from ridge to Rondslottet, at about 1750 m. Right skyline represents old surface. Rejuvenated cirques to the left. Old cirque (Rondholet, *220.236*) run over by ice to the right.

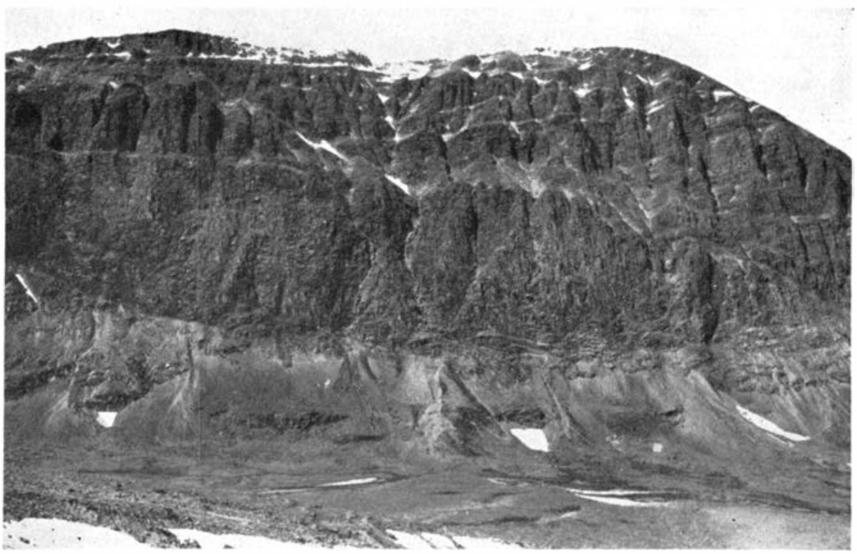
5. Fremre Kaldbekkbotn seen from saddle (*171.220*, 1739 m) towards Langholet. Extremely flat cirque floor 1569 m (lake), level summit right 1795—1830 m, left 1735—1750 m. Through opening is seen Illmannhø with inclined, snow-filled, lateral drainage channels. On cirque floor morainic ridge left of lake, deposited by glacieret between ridge and right side wall,

6. Storbotn cirque (lakelet *234.224*, 1510 m) from Rondslottet at 2070 m. Smal moraines and ledges of débris carried on névé (cp. 24) indicate recent occurrence of glacierets. Snowfilled couloirs on back wall. Edge towards cirque on the right asymmetrical, being rejuvenated after overflow by ice only on the left (Storbotn) side

7. Innre Kaldbekkbotn, the only cirque with a kind of rock threshold across mouth, towards N Cirque floor 1566—1584 m, Veslesmeden summit in background 2016 m.

8. Langholet cirque (lake *161.208*, 1448 m, mountain right of valley 2020 m), from Vassberget 1858 m. In the foreground opposite slope of Verkilsdalen finger valley, towards which Langholet is a hanging valley. In the far distance left skyline of Rondslottet (2183 m) represents old surface.

9. NE part of Rondane (max. alt. 2114 m *256.178*) as denudation, and foreground as accumulation area. (From point *241.102,* 99 m). Glacial and fluvoglacial deposits in middle and fore grounds delta-terraced to different sinking base-levels, corresponding to the wasting of the finiglacial ice strip occupying the foreground valley.



10. Vassberget (*140.173* 1858 m) from about 1400 m on slope towards Langholet (cp. 8). Flat summit continuing in mountain plateau (cp. D) corresponds to old surface. Rock ledges indicating hard layers interrupt the numerous couloirs d'éboulement furrowing upper mountain side. Large scree cones along foot of mountain.

11. NE and E part of Rondane (max. alt. 2183 m) seem from Stygghø (at *188.118*, 1560 m). At 40.19 and 50.22 projecting cirque floors (p. 371). The truncated spur (1522 m, 110.11), better visible in 13, continues level of right cirque floor projection (1512—1517 m). Lower part of landscape filled with pitted outwash derived from snout of melting inland glacier in Rondvassdalen (see 13). River erosional bluff in left foreground conforms to original ice contact slope towards finiglacial ice strip.

12. Dørålsglupen glen (*197.90*, *197.113*, 1364 m, from S) in a system of joints continuing Rondvassdalen across Dørålen valley. On N side of valley gently rising surface (*180.132*, 1260--1380 m) corresponding to Skagsnebbtjern cirque floor 1297--1342 m). Below: Systems of lateral drainage levels in side moraine indicating wastage of ice strip in valley. Foreground: Pitted outwash from Rondvassdalen (cp. 11, 13).

13. Rondane (max. alt. 2183 m) with Rondvassdalen transectional valley (watershed 1246 m) and outwash. (Photo continuation of 11, from Stygghø at *188.118*, 1560 m), 35,28 truncated spur mentioned 11. Left pitted and terraced outwash, right delta-plain in outwash with stream-furrows brought out by vegetation. Delta plain largely eroded by stream from Rondvassdalen, and cut through by transversal stream in foreground.

14. Terrace surface (*313.214*, ab. 900 m) at mouth of Langglupdalen. In the far distance old surface skyline of Rondslottet (2183 m).

15. Lateral drainage channel (*212.178*, ab. 1410 m) along flank of Digerronden. Right background precipice of Rondslottet (2183 m) towards cirque to the N (cirque floor 1465 m).

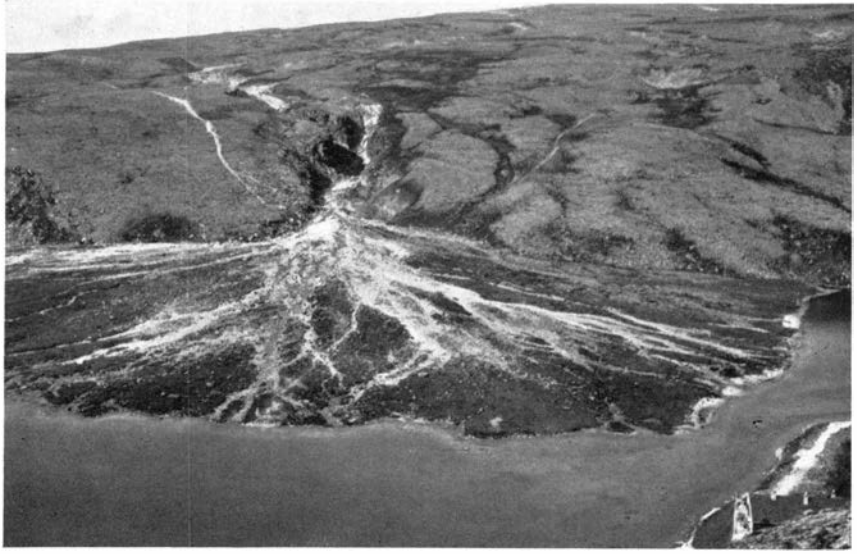
16. System of broad lateral channels (*300.143*, 1080—1020 m; below Simlehø) that drained N along W side of Atnadalen.

17. Hard conglomerate rocks (*78.145*, 1404 m) protruding about 25 m above well-rounded mountain surface.

18. Cleavage surface of sparagmite in Fremre Kaldbekkbotn (*176.127*, ab. 1540 m) representing roche moutonnée somewhat weathered down below original surface as left by glacier.

19. Roche moutonnée on floor of Kaldbekkbotn (*179.127*, ab. 1500 m) disintegrated in situ through weathering. From 35.30 to 55.30 rock débris still arranged in original layers.

20. Faintly sloping polygon field of "churchyard" (graves and headstones) type (p. 376) at *214.145* 1215 m.



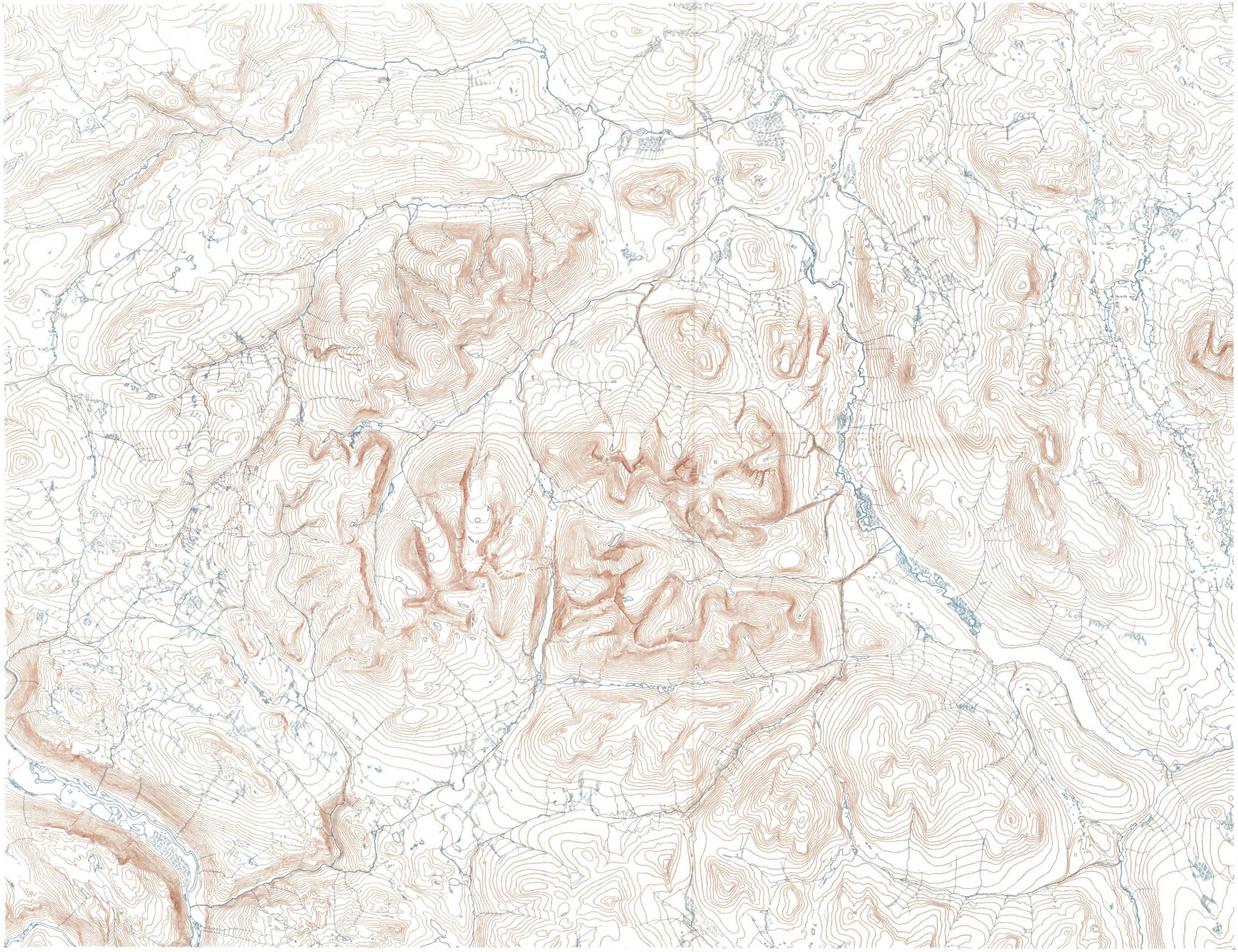
21. Jutulhogget postglacial canyon (*200.253*) with delta flat at S end of Rondvatn (1163 m). From knee in upper left part 23.10 subsequent drainage was caused by snout of finiglacial glacier intruding from left (cp. 1). Systems of glacial drainage channels in slope above delta.

22. Postglacial canyon of Vesle Ula river near Peer Gynt hut. *113.261*, (1110 m) cut along joints in tough, coherent sparagmite.

23. Inner part of Smedbotn with distal side of postglacial terminal moraine (*176.208*), 24.28 to 75.47, about 50 m high. Snow-covered glacieret behind. Lakelet 1568 m, background summit 2017 m.

24. Débris ledges (0.22 to 112.37) along W sidewall of Langholet (*160.214*, floor ab. 1570 m). Rock débris has slid on névés recently melted away, and collected at their foot. At present only localised cones resting directly against sidewall and corresponding to couloirs d'éboulissement are formed. All snow on the photo is annual. Pavement of stones in foreground horizontally laid down by snow cover.

Map 1:100 000



Printed at the Geographical Survey of Norway, Oslo 1945.