

# HARDANGERVIDDA

A TREATISE ON MOUNTAIN-MAKING IN NORWAY

BY

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ALB. CAMMERMEYERS FORLAG

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In this paper I have tried to find out if possible whether the observations made on "Hardangervidda" by the Norwegian geologists : Brøgger, Bjørlykke, Rekstad and Reusch correspond with my new theory or not.

**W. C. BRØGGER:**

**"LAGFØLGEN PAA HARDANGERVIDDA."**

Yearbook of Norwegian Geological Survey No. 11, 1893.

The late Theodor Kjerulf represented in Norway the old opinion of the eruptive theory. His "foot-granite" with its "swallowing" of lower parts of the Cambro-Silurian formation is quite right, but he too did not know what to do with his "Høifjeldskvarts" and accepted at last in 1878 the new opinion of Brøgger, who considered his so-called "younger gneiss-formation" as the uppermost post-Silurian formation in the Norwegian mountains.

Brøgger who in 1875 and 1877 surveyed "Hardangervidda" had already embraced the modern doctrine of folding as he in 1877 delivered his report to the Norwegian Geological Survey. Kjerulf would not give up his eruptive theory and did not publish the report which at last was printed in 1893 in an enlarged form. This became the standard work of the modern doctrine of mountain-making in Norway. The stratification was for the

future fixed, from below upwards, as primary-granite or Archaean granite ("Grundfjeldsgranit"), phyllite and "younger gneiss-formation." Some years afterwards, in Sweden, the last uppermost formation was considered pre-Cambrian and brought in position by gigantic overthrust (Törnebohm) or, lately, by underthrust (Holmquist). In fact, the gneiss-formation has not been and cannot be explained in a satisfactory way, as long as it is supposed to be the uppermost formation.

The real truth is that the gneiss-formation is lying between granite and phyllite as the second formation in spite of its higher position produced by erosion of the originally overlying phyllite. The gneiss-formation is of real Archaean origin and could only be brought in its present position as loose-broken flakes carried up into phyllite by a younger granitic magma. Brøgger ought to have seen the truth, but he was too preoccupied by the foreign folding-theory to be able to interpret what he really saw.

In the "Snenut" region 1906 I found small pieces or even layers of phyllite still lying fixed upon the gneiss-formation and also upon the so-called younger granite in the mountain-summits. Both must then have been lying under phyllite, and the younger granite is belonging to the so-called Archaean granite. The phyllite was found lying as a covering crust outside the foot-granite and it does never run underneath the gneiss-formation between this and foot-granite. This boundary line is seldom exposed to view, but is mostly covered by overlapping phyllite.

The most famous section in Norway is "Haarteigen", mentioned always as a sure proof of the modern stratification. It is a quite isolated ca. 730 feet high rock of gneiss, resting on nearly horizontal phyllite, and all round with very steep slopes and a narrow more level surface like a teapot-warmer with a kick in the top. Brøgger's own description of this region ought to have warned him: "Round the foot of Haarteigen is running a ca. 144 feet high continuous scree ('Ur') of large blocks and yet in the top of this scree was found the same greenish-gray phyllites as below; the very summit of the rock is full of loose blocks of different rocks (even phyllites like those at the foot!); the blocks are sharp-edged, irregularly mixed together. All round the foot of "Haarteigen" is lying phyllite. Have these phyllitic

blocks in the top of the scree and even on the surface of "Haarteigen" come from below or from above? Brøgger means of course : from below, it is the ice of the Glacial Period which carried the phyllitic blocks up. This would be a most curious thing. The upper surface is exceedingly narrow, and all round in the neighbourhood there are no blocks. If, indeed, it were real glacial boulders, why are the blocks sharp-edged, expressly remarked by Brøgger? The edges ought to be rounded. Why is the scree lying all round on the 4 flanks of "Haarteigen," if it is produced by the Ice Age?

According to Brøgger the gneissose "Haarteigen" is swimming upon phyllite which was already eroded down to its present level when gneiss was deposited upon phyllite over the whole extent of "Hardangervidda." All this sedimented gneiss-formation of gigantic extent is now removed by erosion, and the only thing left behind is "Haarteigen" and a few other mountains far off. Is it possible to believe in this explanation? To the supposed effect of the ice I can but object. If these phyllitic blocks are not brought in position by the ice, the only possible explanation must be that they are from above, are fragments of a phyllitic formation, once overarching the gneiss-formation of "Haarteigen" and now removed by erosion. "Haarteigen" is an originally Archaean flake lifted up by the granitic magma and violently driven into phyllite. Under such a catastrophe the overlying phyllite must have been fractured and severed to a considerable degree; most of it is perhaps thrown aside and at least the erosion had here a easier work to do. Besides it is an impossibility to believe that "Haarteigen" is a rest of post-Silurian sedimentation all over "Hardangervidda," and that these sediments afterwards were crushed down to gneiss by an equally impossible overlying covering of rocks of up to 10 km.s thickness. A reasoning in this direction is not very convincing.

Another observation of Brøgger is that the dip of gneiss during the ascension of "Haarteigen" is increasing from 25° to 55° near the cairn. This difference of dip seems rather singular, if the plastic solid granite quietly lifted up the overlying phyllite with its sedimentary gneiss. Could not this difference be more explicable under the supposition of Archaean gneiss

being violently thrust up in phyllite perhaps in a more or less broken condition? A further peculiarity at the foot of "Haarteigen" are the two strata of marble in the phyllite of "Solberget," where the lower one is curved upwards at its inner end, while the upper one has a somewhat different dip. The stratum seems broken in two parts and lifted up in different height, whether by eruption or plasticity of the granite it does not tell.

In this famous section of "Haarteigen" it would be of great interest to settle, if phyllite really is lying below gneiss, and if some small rest of phyllite is yet to be found overlying gneiss. A careful survey of the upper surface and a partial removal of the scree might perhaps solve the second question, while the first one would demand mining at the foot.

A remarkable warning is also given by the observation of Brøgger that in several places the gneiss-formation is found resting immediately upon the granite. Brøgger's explanation of this fact is that it may be a result of the nature of the very centralmassivic pressure upwards. Under the persevering pressure of the plastic granite the phyllitic strata were rolled or pressed out towards the sides, until the granitic mass was pressed quite through the whole phyllitic formation to be at last lying immediately under the gneiss-formation. So unintelligible and absurd such an explanation may seem at the first consideration, nevertheless I do at present stop by this as the most probable one, for the present a very uncertain hypothesis, Brøgger himself adds. Brøgger does not consider this explanation very probable nor do I. The gneiss-formation is in fact always resting upon granite, if not herhaps in a few cases phyllite may be accidentally pressed in between, but very seldom is the real boundary line visible as it is mostly covered by overlapping phyllite. In "Snenut" 1906 I found in its north-western part the boundary line visible where the height of the gneiss-formation was about 1200—1300 feet, while in other places this line was covered by phyllite and snow.—Whether the dip of phyllite is more beneath or away from the gneiss-formation, this is of no consequence as being quite accidental, produced by the violence of the upheaval. In no case does phyllite run beneath the whole gneiss-formation so that gneiss is swimming upon phyllite, as the modern jargon sounds. This is an absolutely

false supposition, accepted as a real fact to explain other false suppositions. Phyllite is always lying as a rind or crust upon granite and gneiss. If Brøgger had simply accepted the fact of gneiss resting immediately upon granite and asked himself why, but this did not correspond with his accepted foreign theory.

Brøgger considered the gneiss-formation as post-Silurian sediments, afterwards crushed down to gneiss by gigantic overlying masses of rocks of up to 10 km.s thickness. Of this absurdity I will not speak as it speaks for itself. Nevertheless he remarks : in "Sandskarnut" as in "Haarteigen" &c. chrystalline schists of an appearance, often not to be separated from old Archaean rocks, are lying over phyllite. He does not admit their really Archaean or pre-Cambrian origin as Törnebohm and rejects his formidable overthrust as an uncertain hypothesis of necessity. Brøgger found no signs of overthrust. In some places the stratification, where it is steeper and folded, may seem to be reverse, but this may be explained, for instance, by inversion. That he, later on, partly has accepted an overthrust is of no consequence, as in fact an overthrust does not solve the question. He says here in his paper that the only possible explanation must be an overthrust, if the gneiss-formation is accepted as pre-Cambrian (Algonkian). This is false, as the only possible explanation is that the gneiss-formation as loose-broken Archaean flakes is lifted up by a real magma, which is such a simple explanation that no geologist has even proposed it. Brøgger remarks that he will not deny the possibility of being once obliged to give up his present opinion and accept Kjerulfs Cambrian or Törnebohms pre-Cambrian one.

The folding theory of German geologists was imbibed by Brøgger. It was an upheaval of a plastic centralmassif and regional metamorphism. Brøgger attributes Kjerulfs adherence to contact-metamorphism to his unacquaintance of regional metamorphism and his want of ability to follow critically a thought into its consequences, otherwise he would easily have avoided his unfortunate "melting down" and "swallowing up," which has no support in nature.—This support in nature is at least found in the Alpine tunnels, where we have excellent proofs of "swallowing up" of overlying sediments in the granite; near "Hallingskarvet" Reusch seems to have seen it without under-

standing it. Dr. Weinschenk speaks in several places of "melting down," and some expressions of Norwegian geologists seem to point in the same direction. Brøgger and his prototypes are to a remarkable degree wanting in self-criticism. Theodor Kjerulf was a genius and on the only right way.

Brøgger says that Kjerulfs "Høifjeldskvarts" (the gneiss-formation) has an exceedingly large extension, and consequently no local conditions, e. g. adjacent eruptive masses, could metamorphose clay-slates &c. to these extensive crystalline schists, among these even genuine gneisses. This counter-proof of Brøgger is absolutely wrong. Of course, it was not an eruption of a modern volcano or along a fissure, it was a tremendous gigantic eruption where the crust of the earth was broken up in a multitude of extensive flakes, hurled aloft, a quite unknown occurrence in our days. And how can a geologist dare to speak of clay-slates metamorphosed to gneiss? The cause of all the havoc is that the geologists did not dare to look the truth right in the face.

Nowhere any veins from the underlying granite are observed breaking through the phyllitic formation, nor any contact-minerals, which is exceedingly remarkable compared to the district of Christiania. Consequently Kjerulfs contact-metamorphism is impossible. Brøgger seems to have no idea of the necessary difference of metamorphism in intrusive eruption and in extrusive eruption (cfr. my criticism of Weinschenk). Moreover, if there is found a real vein, you will inevitably receive the answer that it is younger granite and not at all Archaean granite; the vein may be found at sea-level or high up, it is always the same answer, perhaps given with an obliging smile. The truth is that there is no Archaean granite, it is all younger granite and not at all two sorts of granite. In all granite you might find fragments of Archaean gneiss or pre-Cambrian Telemark formation, just because the granite is younger; but that is no proof of the granite's primary quality. Every magma must break through disrupted old primary-rocks. But it is of no use, geologists are blind from the time of their examination. The granitic eminences ("Buler"), on "Hardangervidda" seldom and only up to 500 feet but in other places more prominent, seem to speak in favour of eruption and not to be appres-



tures of an old underlying plastic granite. Plasticity of granite is according to recent investigations an absolute impossibility. Likewise in favour of eruption are the observations, where phyllite and bluish quartzite are, in several places, strongly compressed, folded, raised up even vertically or inverted; along the road from "Røldal" to "Seljestad" there are : 1) considerable curvatures of the phyllitic formation, and 2) the gneissose granite protruding under the same in very different heights. Here Brøgger even asks : 3) should the curvatures have relations to this?

The fact that now lower now higher strata of phyllite are found resting upon the granitic kernel is by Brøgger explained, as formerly mentioned, in the same manner as the immediate contact between gneiss and granite. This is improbable; much more reasonable seems Kjerulfs explanation that the eruptive magma incorporated loose-broken lower parts of phyllite. The possibility might not be excluded that the magma peeled off the overlying phyllite in different horizons, whereby the lowest strata of phyllite were left behind lying upon the Archaean substratum. The often large flakes of gneiss, driven up in phyllite, must also have destroyed some part of the lower phyllite. Brøgger remarks especially that on an average the highest surface of granite is just, where the lower strata of phyllite are found most typically developed without overlying higher sections. Here the magma was not hampered by upheaval of Archaean flakes and on account of higher upheaval the uppermost phyllitic strata were more easily eroded, perhaps originally also more disturbed.—Brøggers opinion that the surface of Archaean granite was long ago abraded by erosion, when the phyllitic formation was deposited upon it, is absolutely false.

An objection to contact-metamorphism is also that nowhere on "Hardangervidda" are observed traces of fragments of the overlying phyllite in the granite. In all the Norwegian mountain-literature I have only found one corresponding observation of dr. Reusch in the Yearbook 1902, related later on. In 1906 I found myself in the lower part of "Snenut" and in the summit of "Steinkilsnut" lying incorporated in granite some long narrow stripes of a bluish quartzitic rock, afterwards determined as real bluish quartzite ("Blaakvarts," belonging to phyllite); but in 1907, under a few days stay in these regions in storm

and snowy weather, I came to the preliminary conclusion that it might perhaps be real quartzite from the lowest part of the gneiss-formation. Everywhere here the surely real bluish quartzite ("Blaakvarts") was always grayish but never bluish, while the likeness of the quartzite of the gneiss-formation was striking. This summer I hope to settle that question. If this my opinion is true, it will be a striking proof of the same origin of "Archaean" and "younger" granite, as these stripes were found in both.

Brøgger's result is then that it was a centralmassivic upheaval of Archaean granite on one side and an enormous pressure of the supposed mighty overlying rocks on the other side. The protuberances of granite were perhaps produced where the pressure from above was relatively less. Both the plastic upheaval and the mighty overload are equally impossible, so in real fact there is not much left to sustain Brøgger's result. At present it is exceedingly difficult or even impossible to sustain dynamo-metamorphism and then we must fall back upon contact-metamorphism (cfr. Weinschenk). The critical moment of mountain-making is and will always be the gneiss-formation. This question can only be solved by magmatic upheaval of loose-broken Archaean or pre-Cambrian formations.

In "Grønaut" (page 5) in the boundary between granite and phyllite is observed, resting immediately upon granite, a c.  $\frac{1}{2}$  m. thick Sparagmite-like rock and an enclosed thin schist, different from the overlying phyllite.—The boundary at "Nipavand" (pages 57-59) is remarkable. The gneissose granite here is strongly pressed, rather schistose, often "eye-granite" ("Øiegranit"), often almost gneissoid. Immediately in the boundary of overlying alum-schist the granite is covered by a crush-breccia which clearly shows that the granite as a solid rock has been pressed up in fragments along the boundary against the overlying schist, and that the material of this is kneaded in between the fragments, that lie glued together by a dark hard mass, distinctly material of alum-schist.—At "Børtevand" (pages 89-90) is a mighty crush-breccia with granitic fragments and detritus glued together by white quartz, while the underlying granite is strongly split up by veins of quartz. It is a secondary faulting, where on the one side (to the east) is lying a sunken territory

of Telemark formation. In the district of Christiania Brøgger was the first to point out how the sinking down was the cause of the preservation of the Silurian formation. The Telemark formation (Algonkian) to the east is probably preserved on account of the sinking, while to the west this formation is eroded away from the granite before the alum-slate was deposited upon the granite.

At "Nipavand" we have probably an Archaean gneissose fragment pressed up to and partly into the alum-schist. The whole description of granite here distinctly points upon gneiss and in this case it is not remarkable.—In "Grønanut" it may perhaps be a pre-Cambrian fragment, pressed up apart or adherent to the undersurface of phyllite.—At "Børtevand" fragments and débris were very likely of a similar kind and glued together by quartz of the granitic magma, which was also pressed up between. The Algonkian Telemark formation, east of the fault, is absolutely no sunken territory but only lifted up by underlying granitic magma, while west of the fault the magma had free access upwards. Of course, it is only an absurdity that the Telemark formation formerly was lying upon the granite and was removed before the alum-slate was deposited. The standard instance of sinking of the Christiania district, brought forward by Brøgger, must be a complete mistake. When they do not understand nature, modern geologists take refuge to sinking, which expression has in fact been a real phrase. The supposed sinking of the extensive Christiania plate from "Larvik" to "Mjøsen" and from "Ekeberg" westward can be no sinking at all, the whole plate is lying in its original position, some possible oscillations excepted. It is but some of the surroundings which have been uplifted during the numerous eruptions. In the plate itself the eruptions have vented themselves through numerous faults, while in the gneissose "Ekeberg" these Archaean rocks were lifted up, as the gneissose flake in the rock of "Akershus." In the visible foot of the steep western slope of "Ekeberg" are lying eruptives, particularly Oslo-porphry, and veins are running upwards in the rock; also in "Akershus" are large veins of Oslo-porphry &c.—Both in the case of sinking or upheaval there must be a crush-breccia in the slope of "Ekeberg." These gneissose rocks have, of course, not been origi-

nally in their present position, but are inevitably lifted up from below. In the case of sinking, both "Ekeberg" and the Christiania plate must have been lifted up to about the same level and first afterwards the plate was broken loose from "Ekeberg" and sank down. Would not one catastrophe be enough? Another most curious case of sinking is related by Rekstad in his "Geology of the Folgefonn-peninsula" (Yearbook 1907), where he says: "the phyllitic formation is hanging upon the primitive mountain with a comparatively intense dip toward the 'Hardangerfjord' (on the top of the highest mountain here, 'Sauenut' 1507 m. high, some phyllite is still lying), while on the opposite side of the 'Hardangerfjord' phyllite goes down until below sea-level. This relation shows that the north-western side of the firth is sunken down in proportion to the south-eastern side, at least 12—1500 m." An unscientific man has but one explanation here, it is an upheaval of the Folgefonn-peninsula, while the other side is lying in its original position.—As the subject lies outside my treatise, these few hints may be sufficient.

Albert Heim explains valleys as carved out only by running water. In western Norway, says Brøgger, the narrow valleys are as deep fissures; the upheaval has occasioned the construction of these valleys. How the eroding forces have worked since, of this other signs must bear witness. My opinion is that the upheaval has done all the work and the eroding forces very little.

The white granites in "Sogn" are distinctly younger than both phyllite and gneiss-formation, veins are observed at several places. Also in "Jotunheimen" and further east granites of younger age may probably be found. My own opinion is that it may be a great question, if not the eruptives in "Sogn" and "Jotunheimen" belong to the same enormous eruption which formed the mountains further south.

When did this enormous eruption take place? At least post-Silurian, if not much later. This mountain-making has perhaps something to do with the Ice Age and was, it may be, a cause of the close of the subtropic period at the north-pole.

Brøgger's metamorphism of the gneiss-formation as well as Törnebohms gigantic overthrust is an impossibility and none of these theories is able to solve the problem. Theodor Kjerult

was right, but unfortunately he understood only the first part of the problem.

Up to this day no geologist has found "the key, nor the keyhole."

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**K. O. BJØRLYKKE :**

**"FRA HARDANGERVIDDEN." III.**

Yearbook of Norwegian Geological Survey, Nr. 34, 1902.

Bjørlykke may be the native geologist who has seen or at least described more of the real relations of formations in the Norwegian mountains than any other; he has seen but not understood because he was completely imbibed with the wrong doctrine during his study. As we say in Norwegian, he was always walking like the cat round the dish of warm stir-about, every now and then putting the paw in the warm dish only to burn it, immediately to draw it back again and so go on as a nice boy in the established custom. Bjørlykke is here, in 1900 surveying the south-western district of "Hardangervidden," absolutely fighting for Tørnebohms overthrust. In his latest work "Det sydlige Norges Fjeldbygning," published in 1905, he has already abandoned this theory as he did not find it confirmed. His observations are objective but his explanations are of course subjective.

The so-called Archaean granite, the most predominating part of these mountains, is especially in the central region porphyritic and often very much pressed. Of the old Archaean gneiss much is not preserved; besides as flakes in granite it is, a couple of places, found lying above the granite between this and the phyllite. The Algonkian Telemark formation is penetrated by granitic dykes and veins, a very common observation which is considered as a real proof of the Archaean granite's somewhat younger origin.

The granite along the boundaries contains numerous fragments of gneiss and hornblendic or gabbroid rocks and sends veins into the strata of gneiss or Telemark formation. At "Skare"

and "Lote" the granite is full of sharply edged fragments, but on the other hand it never sends veins into phyllite and phyllitic fragments are never observed in this granite, which must then be, with rather great certainty, indicated as Archaean granite, at least older than phyllite.—In close connection with the granite appear in several places dark-green, hornblendic, often saussurite-gabbroid basic masses, probably a product of differentiation in the granitic magma. They are penetrated by light-coloured granitic veins and are found as fragments in the porphyritic granite and consequently a little older than this. The porphyritic granite at "Lotevand" is penetrated by fine-grained granitic veins. Along the road especially between "Sæim" and "Røldals Hotel" is partly light-coloured granite, partly dark porphyritic one, developed as real breccias commonly with sliding planes, probably on account of vertical faults which also are found elsewhere.—To me it seems not unlikely that at least some of these basic masses are uplifted fragments of old rocks, while others are produced by differentiation in the younger granitic magma.

As the phyllitic formation upon Archaean rocks rests partly upon granite, partly upon gneiss and partly upon the Telemark formation, a longer period of denudation must have occurred between the forming of the old granite and the sedimentation of phyllite. In the seldom visible boundary no littoral sedimentation is observed. At "Berge" the boundary is gneiss while porphyritic granite is near by; the surface of the gneiss has an eroded crushed appearance, partly with a phyllitic touch. The boundary is as effaced; there is a transition zone where some eroded products of gneiss or granite is intermixed among alumschist.—Here in this boundary Bjørlykke speaks only of gneiss, but nevertheless he must also at last put in "or granite," which has nothing to do here.

In the southern part of "Hardangervidden" all is pushed together and altered; in many places one gets the impression that the phyllitic formation in one place is kneaded together as a dough and in other places rolled out as a "Fladbrød" (a thin unleaven cake). Bjørlykke does not doubt that places may be found, where the phyllite is quite pressed away; but such places are difficult to point out without a careful mapping in detail.

My own opinion on mountain-making is to be found in my paper "Mountain-making in the Alps" and needs not be repeated here. The preceding remarks of Bjørlykke speak in many respects in favour of my divergent theory, but even much more remarkable are his following observations, seen with my eyes.

"My (Bjørlykke) investigations leave no doubt that it is really Archaean rocks, consequently mighty Archaean flakes, which by geotectonic processes are brought into their present position above the phyllitic formation. Between the different rocks of the gneiss-formation gneisses are found which impossibly can be separated from Archaean gneisses of the western country and these gneisses are in many places penetrated by ramified granitic veins and pegmatitic ones. It is not only Archaean rocks one finds in these overthrust flakes. Some quartzites and Sparagmite-like rocks may possibly have their origin from the oldest sedimentary strata; but also alum-schists and grayish or greenish phyllites are seen in different places in-baked partly as smaller lenses and partly as rather mighty strata in the overthrust flake. Through two entire pages such places of phyllite in the gneiss-formation are related and at page 64 is even cited : also more to the north between "Hattestenvand" and "Juklevaselven" phyllitic strata appear which possibly belong to the overthrust flake. At page 74 . . . . into these flakes not alone rocks from the deeper lying Archaean rocks enter but also parts of the younger primary-rocks or the Telemark formation and of the lower Cambro-Silurian rocks. The tectonics of the processes, under which the phyllites and quartzites are pressed into the overthrust flakes, are not investigated more precisely. To be able to clear this topic a mapping in detail was necessary, but to that one wants cartographic basis in these regions."

Unfortunately Bjørlykke did not comprehend the enormous importance of solving the question if phyllite is lying above or below the gneiss-formation. When the gigantic overthrust was running headlong across the country upon the phyllitic formation as greasy material, did then phyllitic pieces jump up in the gneiss-formation to rest there for ever? Or, is the real truth, indicated by this fact, simply this hitherto never reflected circumstance that the phyllitic formation is lying over, above the gneiss-formation, but only at present for the most part removed by

erosion? If really the gneissose flakes were driven forcibly up into the phyllitic formation by the granitic magma, this latter must necessarily be kneaded into the gneiss. Why did not Bjørlykke himself draw a new map as I must do in the "Snenut"-complex?

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### I. REKSTAD :

1. "FRA HARDANGERVIDDEN." II.
2. "FRA HØIFJELDSSTRØGET MELLEM HAUKELI OG HEMSEDALSFJELDENE."

Yearbook of Norwegian Geological Survey Nr. 34 & 36 1902 & 1903.

#### 1.

Rekstad, as most Norwegian geologists, maintains a distinct separation between the primary-formation,<sup>1</sup> consisting of Archaean gneiss, Algonkian Telemark-formation and the somewhat younger Archaean granite, and the younger post-Silurian gneiss-formation<sup>2</sup> (also called by others quartzite-gneiss-formation). The oldest formation is always lying below the phyllitic formation, while the youngest one is lying above phyllite. To this youngest formation is also reckoned the so-called "Younger granite" in the summits of some mountains, and this younger granite lies also above phyllite. This distinction does not exist in reality, it is the same rocks, either Archaean gneiss and quartzite or younger eruptive granite. The phyllitic formation is the uppermost and covered originally both the gneissose and the granitic formations, but is now to a great extent removed by erosion so that both the so-called gneiss-formation and "younger granite" seem to lie above phyllite.

Along the steep flanks of "Sørfjorden" is lying Telemark formation with granite at the inner end. On the eastern side from "Espen" upwards in a height of up to 1300 m. the dip

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<sup>1</sup> This primary-formation of Archaean gneiss and Telemark formation is by Rekstad called the gneiss-quartzite-formation.

<sup>2</sup> Called by Rekstad : overlying gneiss-formation. This formation contains usually quartzites in the lower part.



of the Telemark formation is westerly, c.  $20^\circ$  lower down and at the top  $50-60^\circ$ . A little more to the east, upon the tableland, lies the boundary line between Telemark formation and phyllite with quite different dip and strike; here in the boundary the phyllitic stratification is violently disturbed, but a few hundred metres from the boundary the direction of strike is regular as usually in this region. In the boundary the phyllite is lying upon the outcrops of the rather steep quartzitic strata, the difference of strike forming an angle of  $50^\circ$ . This shows distinctly a hiatus between the Telemark formation<sup>1</sup> and the overlying phyllite. The surface of quartzite has prominent sliding striae continuing in under phyllite. At the boundary here some slender quartzitic pieces were also observed within the phyllite. The granite in the neighbouring "Skinnafjeld" sends numerous veins into the Telemark formation,<sup>2</sup> but never into the phyllite; the granite is only in the boundary a little pressed.

There can be no doubt, that these now related cases refer to real Telemark formation. The following related cases longer eastward in the phyllitic formation must on the contrary refer to Rekstads younger gneiss-formation, notwithstanding he really seems to speak of real primary gneiss-quartzite, what in fact is my opinion.

Rekstad relates frequent cases of larger and smaller flakes of phyllite in the quartzite-gneiss-formation, often with signs of great violence. In fig. 8 & 9 at "Juklevarusten" is shown a fault-fissure ("Forkastningskløft") between the phyllite and the gneiss-quartzite-formation; the fault is at least a few hundred metres. The real fact in this case is that there is no fault, but on one side is the Archaean gneiss-quartziteformation lifted higher up as a flake by the magma and the formerly overlying now eroded phyllite exposes to view the Archaean flake, while on the other side phyllite is lying on granite, which only lifted phyllite up to a lower level. In fig. 12, section from "Vivasdalen" to "Medalsrusten," there are two strata of feldspatic quartzite and between these a stratum of phyllite, while above the uppermost stratum of quartzite gneiss is lying in the top. In "Medalen" are 4 phyllitic and 4 quartzitic strata of alternating

<sup>1</sup> Rekstad says : gneiss-quartzite-formation.

<sup>2</sup> Gneiss-quartzite-formation (as before).

levels; a part of the quartzite is often very folded. In "Nups-eggen" is found between phyllite and underlying granite some gneiss and schistose gabbro, penetrated by veins from the underlying granite. In the gabbro is lying a flattened conglomerate. At page 47 stands written: we have then in the South-eastern part of "Hardangerviddan" as in west towards "Sørfjorden" discordance between phyllite and underlying gneiss-quartzite-formation and the same relation of age in both places. The gneiss-quartzite-formation is the oldest, then comes the injection of gabbro, then the granitic eruption and at last phyllite.

These last citations clearly say, that phyllite is lying upon (above) the gneiss-quartzite-formation; but the granite is an eruptive younger than phyllite. The phyllitic flakes or strata in or between layers of quartzite are no enclosure or intercalated stratum but only a not yet eroded remaining rest of an originally overlying phyllitic formation. All seems to me to speak in favour of my opinion that the gneiss-quartzite-formation is primary-rocks (Archaean and Algonkian), lifted up by the granitic magma and violently pressed up in the phyllite, which by the same magma was peeled off from its Archaean and Algonkian substratum, lifted up and contact-metamorphosed.<sup>1</sup>

The so-called "Kagenuter" (cake-tops), whose foot is phyllite while the top is granite, must be veinlike protuberances of granitic magma up in overlying now partly removed phyllite, which at present is lying round the foot of the granitic kernel as a superficial rind or crust. The fact, that there is found in some places a partly very disturbed stratification of bluish quartzite ("Blaakvarts"), is no inversion or folding but shows only the violent effect of uppressed magma.

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<sup>1</sup> Here in the South-eastern part of "Hardangerviddan" is a great confusion in the stratification, as Rekstad in fact supposes that the same Archaean gneiss-quartzite-formation is found here as in west towards "Sørfjorden," while only the so-called overlying post-Silurian gneiss-formation (also called quartzite-gneiss-formation) is to be found. The reason of this confusion is that phyllite here really is lying upon (above) the quartzitic-gneissose flakes. The real fact here is that phyllite is lying upon (above) so-called younger gneiss-formation; but this is according to modern doctrine impossible, and the result is then that Rekstad calls it Archaean gneiss-quartzite-formation in stead of its real name. It is but a sure proof of my theory.

The related fault-fissures are but an unequal upheaval and erosion.

## 2.

This Eastern part of "Hardangervidden" is a more level tableland where the boundary between granite and phyllite is about horizontal with only a few prominant heights of gneiss-quartzite-formation, protruding out of the phyllitic formation, while especially to the east the much greater part consists only of the so-called Archaean primary-granite. North of "Hallingskarvet" we have a more mountainous region where in several places the summits of the mountains consist of the so-called younger granite which is lying above the phyllitic formation.

The overlying gneissic formation between "Nupseggen" and "Hallingskarvet" consists only of some isolated rests of a supposedly over the whole "Hardangervidde" lying and now eroded gneissic covering; these rests are at present lying as a hood above the phyllite in the highest summits as in "Nupseggen," "Haarteigen," "Hardangerjøkelen" and "Hallingskarvet." First to the north of "Hallingskarvet" the gneissic and granitic covering above the phyllitic formation begins to be more coherent. The same is the case from "Nupeggen" in southern and south-western direction towards "Haukelifjeld" and "Røldal". "Haarteigen" is the most typical instance of one of these eroded rests.

Eastward in the "Moldaadal" flakes of gneissose rocks are often found in Archaean granite which mostly have a great likeness to rocks of the Telemark formation. The old Archaean gneiss appears in the mountainous district between "Røldal" and "Sognefjord" only subordinately in coherent parties below the phyllitic formation; Rekstad cites 3 places.—Between Archaean rocks and phyllite often appears a some few metres thick stratum of an arkose-like sandstone which contains phyllitic débris and upwards not seldom alternates by phyllite. Only in a few places is the contact uncovered, free from loose masses. Rekstad relates several instances. The rounded grains in the quartzite distinctly show that it is a clastic rock.

Bluish quartzite ("Blaakvarts") and phyllite are not seldom strongly folded, while the underlying granite forms a horizontal plane. The folding of phyllite is explained by the strong tan-

gential thrust, while the mighty underlying granite was able to withstand this thrust without being folded.

In the top of "Molnut" is a very coarsely-banded gneiss, where are seen veins of a pegmatitic granite, generally running parallel to the banding. Here the feldspatic crystals of the gneiss often are bent or broken asunder. — In "Dyrehougene" the boundary plane between phyllite and overlying gneiss-formation is mostly undulating, but in some places rather strong foldings exist. The photograph (fig. 14) much more than the schematic drawing (fig. 13) shows the real nature of this boundary. Rekstads supposition is a real impossibility. The photo shows that gneiss is not lying upon phyllite, running beneath the gneiss, but the phyllite is an eroded rest yet lying as a rind or crust outside upon the Archaean gneiss which was lifted up and driven into phyllite by the magma.

The large granitic mass in "Hallingskarvet" is by Rekstad considered as an eruptive rock but of course younger than Archaean granite. Here I may be allowed to cite a remark of dr. Reusch in the periodical journal "Naturen," where Rekstad explains the granitic summits in "Valdersdalen" as rests of a cake-formed melted mass poured out over the phyllitic formation, while Reusch means that they are a result of overthrust. Here dr. Reusch remarks that it is difficult to point out eruption-points. This is quite true, because this "younger granite" belongs to the same later enormous eruption of the "Archaean granite," and consequently there was no points of eruption.

North of "Hallingskarvet" folding becomes stronger and stronger, a region of considerably stronger overturnings. Here also appear granitic rocks of much larger extension above the phyllitic formation, but nowhere has Rekstad observed veins from these massive rocks penetrating phyllite.—In the section of "Bolhøvd" (fig. 16 III) veins from dioretic or more granitic rocks are said to penetrate the gneiss and quartzite. Here also some flakes of strongly quartzose phyllite appear in the interior of the granitic rocks.<sup>1</sup>—In fig. 17 II are lying above phyllite first

<sup>1</sup> This remark of Rekstad is a most remarkable. Phyllitic flakes are found incorporated in granite. But of course this granite is a younger eruptive, not at all an Archaean granite. Rekstad says in "Geology of Folgefonn-peninsula," page 27 (Yearbook Nr. 45, 1907): "between 'Valen' and 'Op-

quartzitic rock and thin gneiss; above this last one in the top of the mountain all the way westward is lying granite in which numerous particles of gneiss and also some of quartzitic rock (Kaldhol) are enclosed.—In many places are found smaller parties of phyllite in the above phyllite lying gneiss-quartzite-formation.

Rekstad's observations concerning "Hardangervidden," seen with my eyes and explained in the sense of my theory, seem to confirm my proper views. Both Archaean and younger granite originated from the same younger eruption, which lifted up loose-broken Archaean flakes and pressed them into the phyllitic formation, where they at present seem to lie above the eroded phyllite. Smaller or larger fragments of Archaean rocks in the consolidated granite have been known long ago as a notorious fact. These old fragments and my extensive old flakes were carried up from below in the same manner, this ought to be understood at last. When the Cambro-Silurian strata were peeled off from their Archaean or pre-Cambrian base by the granitic magma, it might be that sometimes small parts of the base were adherent to the undersurface of the phyllitic formation; but as a rule these fragments were lifted up separately. When the overlying phyllitic formation later on was eroded away, some remnants of phyllite were of course lying behind in different horizons as an external rind or crust upon Archaean or granitic rocks; the modern doctrine, that all these phyllitic remnants always run through the mountains as underlying strata, is of course false. The theory of younger eruption and contact-metamorphism solves all geological difficulties without leaving any or but few riddles. A more complete description is given in any paper "Mountain-making in the Alps."

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sanger' in the southern part of the peninsula the phyllite down at sea is penetrated by veins of a fine-grained, somewhat micaceous granite, which in appearance much reminds of the granulite in the northern part of the peninsula." The whole peninsula mostly consists of "Archaean granite," but Rekstad's answer was : "it is of course younger granite," as I pointed out this remarkable case. Veins in phyllite from Archaean granite do not correspond at all to the accepted false doctrine.

**D<sup>r</sup> H. REUSCH:****“FRA HARDANGERVIDDEN.” I.**

Yearbook of Norwegian Geological Survey Nr. 34, 1902.

Reusch surveyed the northern region of the western more hilly “Hardangervidden” where these hills are the rests of a very old peneplain. He remarks that Brøgger as to the crystalline rocks assumes besides dynamical metamorphism also contact-metamorphism from above by laccolitic eruptive masses which were a continuation from “Jotunfjeldene.” Reusch also sticks to the overthrusts of Törnebohm and explains accordingly.

The phyllitic formation during the overthrust was rubbed asunder, wrinkled, folded and pushed along its substratum. In the whole investigated region he nowhere found a plane of contact with a substratum showing original overlying. The phyllite seems in many places to be folded into or by displacement pressed into the older rocks. Anyhow, it may be a question, if not phyllite and quartzite of a bluish quartzite-like appearance may appear as a part of the Telemark formation. Reusch mentions how in “Ustedalen” below the horizontal alum-schist, which forms the base of “Hallingskarvet,” in the Archaean mountain appear steep strata of a dark clay-slate like rock and quartzite which in the hand-specimen has quite the likeness of bluish quartzite (“Blaakvarts”).

This description of Reusch seems to tell that phyllitic fragments lie incorporated in the eruptive granite which here is the so-called Archaean mountain.

At “Grubeskär” the slightly undulating phyllite lies with a dip of 50° above the Telemark formation; at the boundary here the granite sends veins into the Telemark formation.—The granite at “Helneberg” has a peculiar appearance in the boundary of phyllite (perhaps up to 5-10 m. from this), partly fine-grained, partly porphyritic, and has a darkgray colour. In “Grytingsdalen” the granite just below the phyllite has a strikingly dark colour.—Is this dark colour a sign of the granite having incorporated phyllitic material?

Upon “Grytefjeld” the phyllite which is lying upon granite shows a disturbed stratification and small folding. In the gneiss-

formation of "Nupsdalen" is mentioned that partly also phyllite, perhaps by folding, is kneaded into the gneiss.

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This summary of "Hardangervidda" may be sufficient to prove that Norwegian geologists have seen many important facts in the mountains without understanding their real importance, always sticking to their false doctrine.

10th May 1908.

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