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THE STRATIGRAPHY OF SUPRACRUSTAL ROCKS, GRANITIZATION AND TECTONICS IN THE PRECAMBRIAN TELEMARKE AREA SOUTHERN NORWAY

Guide to excursions no. A 10

by

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Key map: see back cover.

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GENERAL PART

By Johannes A. Dons

INTRODUCTION

Telemark county

Telemark, one of the 18 counties of Norway, is an interesting area, not only from the geologist's point of view. The scenery is varied and often of striking beauty. For ages, no doubt even since prehistoric time, the county has produced a great number of gifted artists who have endowed their home territory with monuments of artistic and folkloristic value. No wonder that nowadays a considerable number of painters, sculptors, authors and others have moved to such inspiring surroundings and settled in Telemark.

Formerly great parts of Telemark were not easily accessible, and the impulses of the outside world only slowly penetrated. Thus the elements of European culture before being accepted, got ample time to be remoulded and fit into the life and taste of the farmer of the mountain valleys, where, therefore, a characteristic local culture could develop and survive with many archaic features preserved even now.

The impact of the industrial revolution only lately reached Telemark with full power. Hydroelectric plants followed by industrial undertakings nowadays grow up at accelerated speed, welcomed by the sober industrialist, though received with mingled feelings by the romanticist. In the mind of the geologist a conflict will accordingly reign

Telemark county covers 5 per cent (15 300 km²) of the total country. Forests cover 5600 km² and lakes 1050 km²; the rest is mountain pasture, bogs, and high, bare mountains.

For the sake of simplification Telemark may be subdivided into three major topographic units. In the north the great "vidder" (plural of "vidde" *i.e.* mountain plain) at about 1000 m.a.s.l. As a second unit follows towards SE a landscape of U-shaped valleys

directed SE with steep sides and many narrow lakes. Lastly the coastal area still further SE, where innumerable islands, islets, sounds and bays form the "skjærgård" ("rim of skerries").

The topographical maps at 1:100 000 were published 1935–1959. Maps covering the NW part of the area are still in preparation. In densely populated areas and near dams, hydroelectric plants, etc. detailed topographical maps have been made.

The bedrock noticeably influences the topography and, particularly in the higher mountain districts also the character of the soil. Gneiss granite and quartzite over great areas yield poor soil, whereas gabbroid rocks yield good soil for trees. The cultivated soil is found on ground and lateral moraines in the upper valleys, on fluvio-glacial material and marine clay deposits in the lower parts of the county.

The original means of livelihood, agriculture, forestry, and sea fishing, are still of great importance. 85 % of the forests are owned by local farmers and 15 % by forest owners. Hunting and lake fishing have importance now mostly as sports. In the autumn there is controlled hunting of the wild reindeer and moose, and in the mountain lakes and streams there is good fishing for trout (several genera are represented).

The towns

Skien (pop. 16 000), Porsgrunn (pop. 10 000), Brevik (pop. 2400), Langesund (pop. 2200), Stathelle (pop. 1000), and Kragerø (pop. 4700), all located at or near the sea, have grown up primarily on the basis of commerce, shipping, and the timber industry. Recently (since 1905) two inland towns have come into existence, Rjukan (pop. 6500) and Notodden (pop. 6700), which are based on local hydroelectric power for, among other things, chemical industry.

Mining in Telemark is not new. Gullnes Kobberverk (copper works) near Seljord was founded in 1538. At the present Åmdals works (copper), Søftestad mines (iron), and many feldspar quarries in the Kragerø area are in operation. Whetstones have been quarried in Eidsborg (near Dalen) from the ancient past until the present.

The large lakes have always been of importance for communication and the transport of goods, in the summer by boat and in the winter by horse drawn sleigh on the ice. Since 1892 locks have enabled ships from the sea to reach Dalen (72 m.a.s.l.), a

distance of ca. 150 km. The railroad from Oslo reached Bø, in 1924. Roads—of a sort, at least—are ancient; the old ones have been rebuilt and rerouted and new ones are under construction. The development of hydroelectric power has necessitated the building of roads up the valley sides and into the mountains. Many farms which were previously isolated and often deserted therefore now lie along roads.

During the period 1835–95 there were 35 000 emigrants from Telemark to the U.S.A. due to difficult conditions. Later people have migrated to the industrial cities. In the last 30–40 years, cheese farming (*seter-drift*) has sharply declined. Young girls find it too strenuous, uninteresting, and poorly paid. Genuine *geitost* (goat cheese) becomes steadily more difficult to obtain.

Much of the old and valuable local culture is preserved in Telemark, *e.g.*, building, domestic industry, folk music and poetry, language, customs, and practices.

“To do a Telemark” is an internationally known expression for a particular turn on skis and “the cradle of modern skiing” was in Telemark, specifically in Morgedal.

The rocks.

The excursion in Telemark is devoted to the Precambrian “Telemark suite”, a sequence of supracrustal rocks (sediments, lavas and tuffs) with a maximum thickness of about 4000 m. Attention will also be paid to tectonics and the problems of age and genesis of the gneiss granites and the granites. See Plate 1.

The Telemark suite

Although the original basement of the supracrustals is virtually unknown, it is assumed that it was gneiss granite. After the formation of the supracrustals this gneiss granite was probably rejuvenated by a granitization, which in some places has transgressed the former boundary of the gneiss granite, invading the supracrustals, partly through granitizing processes, partly as palaeogenic granite penetrating the old gneiss granite as well as the supracrustals.

Within the weakly metamorphosed areas (central part of map area) the supracrustals have retained many primary features. Here one gets the impression of being in a geologically young area.

Absolute age determinations based on minerals from quartz veins and granite pegmatites which cross-cut the youngest sediments give 950–620 million years. The reader is referred to the section “The Telemark supracrustals and associated rocks” (Dons) in *The Geology of Norway* (ed. O. Holtedahl, 1960). Only a few, short, remarks will be given below. In the stratigraphical column (Tab. I)—where, incidently, nearly all names of stratigraphical units are new—are given reference symbols for each unit. These are used in the road log as, *e.g.*, U 1, U 2, U 3 etc.

The Rjukan group. There are a number of different acidic lava types in the *Tuddal formation*. Wyckoff (1934), within a small area, was able to distinguish five types, one of them rather a flow breccia containing large fragments, some of which showed ripple marks. Certain lava flows have been found at corresponding stratigraphical level in places more than 30 km apart. The *Vemork formation*, composed of basic lavas, tuffs, biotite schists, and pebbly arkoses in places grading into quartzites, was recently established as a separate formation near Rjukan. No angular unconformity has been observed between the Vemork formation and the underlying Tuddal formation. The lower part of the sedimentary sequence S of Lifjell and westward to Kviteseid may belong to the Rjukan group.

The Seljord group. This group seems to be most completely developed and is also best studied in the northern part of the map area S and SE of Rjukan, where its thickness has been estimated as more than 2000 meters. There is an angular unconformity between this group and the underlying Rjukan group. The lowermost unit, the Gausta quartzite, gradually wedges out SW wards from Rjukan. The thick conglomerate in the Seljord–Brunkeberg area may possibly be correlated with the Gausta quartzite.

The Bandak group. The sequence is well studied north of lake Bandak (mapped at 1:25 000). There is an angular unconformity between this and the underlying Seljord group. The sequence seems to be most completely developed in the west, because when passing through the synclines and anticlines eastwards some of the lower units disappear. Field observations have so far not confirmed the proposal that the rocks of the Bandak group are identical with those of the Rjukan group, and form a great thrust mass which,

with a movement northwards, has overridden the Seljord group (cf. however p. 8). Observations of crossbedding, ripple marks etc. show that the Bandak group is not generally inverted.

Basic sills

Basic sills are abundant in the Seljord group, but they are lacking or nearly lacking in the Bandak group. It is tempting to postulate that one and the same magma contemporaneously produced the sills in the Seljord group and the lavas of the Bandak group. The metamorphic grade varies but generally increases towards the south.

Gneisses and granites

Within the map sheet Nisser (in the south) the foliation of the gneiss granite defines synclines in which there are bands of amphibolite (meta-basalt) and meta-porphyrity.—Around some of the isolated gneiss granite areas are border zones of granitization (N of Tinnsjø), around others intrusive contacts are observed (NW of Dalen and near Øyfjell). Within a part of the granite area at the southern end of Tinnsjøen, *N. C. Carter* has determined temperatures using the Barth feldspar thermometer. Near the boundary the temperature determined was 425°C , while in the center the temperature was below 300°C (unpublished results). In the north-western part of the map (south of Mårvann) mapping has shown a gneiss granite area (old?) farthest west, with a relatively sharp boundary towards a belt of granite with recognizable relics of supracrustals. This belt has a sharp contact with ungranitized supracrustals to the east. Temperature determined from a point in the granite at the last named boundary gave 460°C .

In the gneiss granite area south of Lifjell there are augen gneiss, virtually unfoliated granite, and quartz-rich aplite granites together with a number of transitional types. The minerals are: quartz, alkali feldspar (primarily microcline perthite), plagioclase (albite-oligoclase), muscovite, biotite (hornblende) and sericite. The relative amounts and grain-size vary considerably. A common feature S of Lifjell is that the foliation of the granite is parallel to the boundary towards the supracrustals and thus parallel to their stratification. In some road cuts one can see that the gneiss granite gradually looks more and more "sedimentary" as one approaches the supracrustals. However, one finally finds a completely clear

boundary towards the supracrustals. In the east there are apophyses into the supracrustals, and parallel to the boundary of the large granite area there are also granitic veins and pegmatites in the supracrustals. Sheeting (parallel to the present surface, exfoliation) is well developed in the gneiss granite area in the slope of Lifjell. In many places the sheeting is parallel to the foliation in gneiss granite, but may be oblique or perpendicular to it.

There remain areas which one would wish to understand better. One such key area is in the west near Høydalsmo, where the fault tectonics are especially complicated. In this area the problem of whether the Bandak group and Rjukan group are the same could be solved. It is possible that here and farther west exist even lower parts of the Bandak group than are recorded in Tab. I.

An area along the east side of the map is designated as "granulite", "leptite", etc. It includes conglomerates, agglomerates, acidic lavas and tuffs, basic lavas or sills, sandstones, arkoses, shales, etc. The contacts with other rock groups are faults (fig. 2). The rocks are in part strongly metamorphosed and metasomatized. They may together represent a new stratigraphic group; or some of them may belong to, and others may complete, the Bandak group (less likely the Rjukan group).

Tectonics of the central supracrustal area.

All rocks belonging to the Telemark suite are folded. Angular unconformities between the three groups show that they are separated by periods of folding.

No evidence has been found to prove that the oldest group of rocks—the Rjukan group—has been folded three times or the Seljord group two times. This may be because the directions of the fold axes of adjacent rock groups are nearly the same, as is the case with the Rjukan group and the Seljord group SW of the town Rjukan. That the Bandak group is more intensely folded than is the older, adjacent and underlying Seljord group can be explained by a "plissement de couverture", the Seljord group having been very little influenced.

As a whole, the supracrustals of the large area north of the line Seljord—Brunkeberg (mostly composed of the Seljord group and comprising Vindeggen, Gausta mountain, Tinnsjø) have N-S fold axes as opposed to E-W fold axes in the (smaller) area south of

this line (comprising also Lifjell) Along the boundary between the two areas complicated tectonic deformations have taken place (fig. 3).—In the Bandak group the fold axes form a fan with directions changing from N–S to NE–SW. They plunge locally very steeply southwards.

The intrusion of basic sills in the Seljord group is supposed to be contemporaneous with the main folding of this group.

The folding with E–W axes is thought to be due to the doming of the gneiss granite area bordering the supracrustals in the south, and the N–S folding to be induced by a rise of the gneiss granite area(s) in the W (and E?).

Local irregularities in the fold directions may be ascribed to movements in the gneiss granite which certainly underlie the supracrustals. In some places the gneiss granite has risen so high that small areas of granite are exposed; around these the doming of the adjacent rocks is often evident.

Detailed mapping has revealed complicated fault patterns in many areas, *e.g.*, in the western part of the central supracrustal area near Høydalsmo and Eidsborg. Faults around the granite near the southern end of Tinnsjø seem to be contemporaneous with (and due to?) the granite intrusion. (Similar may be the case near the eastern end of lake Totak.) Numerous faults and fracture lines can be traced from the southern gneiss granite area northwards into the sedimentary sequence, they strike NW and NNE (see also fig. 2).

The contact between the supracrustals and the large western gneiss granite area is for a greater part formed by a fault zone, often in the form of quartz dykes. The valley in which lake Byrte is situated, was eroded along this western fault zone.

Two prominent fault planes, one SW of Gausta mountain and the other north of Hjartdal, may have been folded. This observation may help to establish the chronology of movements, *i.e.*, to determine the interrelation of movements within the various gneiss granite areas.

Important publications earlier than 1935 about the area concerned are by Werenskiöld (1910, 1912), Bugge (1931) and Wyckoff (1934). However, the majority of what is shown during the excursion and is described here has resulted from mapping in recent years. Virtually nothing of this is yet published.

ROAD LOG

1st. DAY, Aug. 5th. Travel directly from *Oslo* to *Bø*. *Bø* and surroundings to Lifjell Turist Hotel (night quarters), with several stops in and along the borders of Telemark gneiss granite.

Oslo-Kongsberg-Bø by train or car (3-3¹/₂ hrs.) (description by J. A. Dons).

From *Oslo* (pop. 448 000, nations capital and largest city) to *Asker* (20 km) one travels through Cambro-Silurian sediments (limestones, shales, and sandstones), folded in late Silurian to early Devonian (Caledonian) time, faulted in Permian time, and locally metamorphosed by great Permian intrusive bodies and innumerable dykes. The Permian lavas, *i.e.* rhombporphyries and basalts, lie topographically higher than the road and railway. They can be seen in the bastionlike hills *Kolsås* and *Skaugum*. After leaving *Asker* the excursion passes through the red, Permian, *Drammen* granite (biotite granite) at *Lierskogen* and in the sides of the valleys leading down towards the industrial city of *Drammen* (pop. 41 500); a port for cellulose and paper products. In *Bragernes-åsen* north of the center of *Drammen* there is a small Permian cauldron; southwest of the city in *Konnerudkollen* there are old mines at Zn, Pb contact occurrences.

From *Drammen* ca. west to *Hokksund*, through the industrialized area along the river *Dramselv* in a valley with fluvio-glacial deposits. To the north is the large Permian *Glitrevann's* Cauldron (1.5 km × 3 km) consisting of Permian lavas and intrusives and surrounded by metamorphosed and folded Cambro-Silurian sediments. The subsidence was 1000 m. At *Hokksund* (pop. 1100, industrial town) the road turns southwards and passes *Haug Kirke* (church) built 1250. A few road cuts in Cambro-Silurian until reaching lake *Fiskumvannet* which is connected to the lake *Eikern*. On the east side of *Eikern* are hills with the classical locality of *ekerite* (Permian *aegerine* granite).

The road and railway run parallel and close to the western boundary of the *Oslo* region which is marked by numerous ca. N-S faults. The Cambrian alum shale (east) lies on Precambrian gneisses (west). One passes either close to or through the mining town *Kongsberg* (pop. 8400), until recently Norway's largest town in area (64.2 km²). The reason for the large size was that king

Christian IV, when the town was founded in 1624, wished all of the future mines to be within its limits. The silver mines were operated (with many interruptions) until 1956. (The excursion will return to Kongsberg on the 9th. day). *Sagrenna* is passed where entrance to one of the largest mines, 1000 m deep (visiting tourists can now be conveyed 2½ km into the mountain).

The route now passes through the forested region of Meheia. The rocks are primarily dioritic gneisses characteristic of the Kongsberg area which is petrographically closely related to parts of Sørland (the coastal area from Oslofjord to Kristiansand). Immediately after passing *Meheia* station the railway goes on a high bridge over a deep valley. The valley is developed along a breccia zone which can be followed all the way to Kristiansand. The brecciation is originally Precambrian but some brecciation has also taken place later, especially in Permian time. This zone separates the Kongsberg area from the Telemark area. It is believed that the former has been dropped down in relation to the latter. In the Telemark area gneisses, leptites, amphibolites (supracrustal rocks) and "granites" are passed.

The railway runs southwards down to *Hjuksebø* station from which a spur-track goes to Notodden–Tinnoset (ferry used across the lake Tinnsjø)–Mel–Rjukan. The road passes its highest point (455 m.a.s.l.) and goes (westwards) down to *Notodden* (pop. 6700), an industrial center since 1905 (overnight here after the excursion 2nd. day). From Notodden the road runs along the lake *Heddalsvann* (16 m.a.s.l.) southwest past Hjuksebø station and then follows the railway (Sørland railway with end point at Stavanger) past *Gvarv* at the lake *Norsjø* (15 m.a.s.l.). In the valley there are large amounts of unconsolidated material, marine clays, fluvio-glacial sand terraces, and moraines (marine limit 130–150 m.a.s.l.) of quaternary age. (About 16 km further south is the well known "Fen per-alkaline area" with the niobium mineral koppite in carbonatite, surrounded by Precambrian gneisses.) Further to *Bø*, a little "station town" (pop. 700) lying in the center of one of the most intensely tilled areas of Telemark.

1st. DAY (continued) *Bø*–Mount *Lifjell* (description: T. Siggerud).

The main topic of the first and second day is the Telemark gneiss granite and its border relations to the supracrustals. Two sections across this border will be demonstrated. The stratigraphic

position of the strongly metamorphosed supracrustals is uncertain; probably Rjukan group and Seljord group (U 1–U 10). Some units developed in areas further north may be lacking here, others may be present here but lacking elsewhere. The sections to be studied today are seen in road cuts between Bø (90 m.a.s.l.) and Mount Lifjell. At the end of the road (Jønnebu 750 m.a.s.l.), an explosion breccia occurs.

From Bø to near *Bjørnefjell* farm the road climbs out of the lower valley, filled with marine clays up to ca. 150 m.a.s.l. (marine limit), where large deposits of glacial gravel with several kettle holes and rivercut gravel terraces can be observed. In the NW the sheeting (exfoliation) of the granite, is clearly seen (here parallel to the foliation).

Stop 1. Road cut 6 km from Bø, near *Bjørnefjell*. Typical Telemark gneiss granite with some zones of finer grained gneiss (remnants of an older rock complex). Permian diabase dyke (dolerite), 1 cm thick. Pegmatite veins. Mineral composition of gneiss granite: Quartz (undulose extinction) 10 %, increasing to 80 % in quartz aplitic types. The feldspar “augen”, typical for this rock, are fine-grained aggregates of (quartz and) microcline; microcline being the predominant feldspar also in the rest of the rock. Small amounts of plagioclase ([An₁₈]) are found in deeper parts of the gneiss granite, and nearly pure albite along the borders of the mass; Mica (mainly biotite) 5–10 %; Accessories: magnetite, sphene, apatite, zircon.

Stop 2. Lifjell Turist Hotel, lunch.

Stop 3. 2 km upwards from the hotel in road turn. Border between gneiss granite (below) and dark biotite-rich gneiss (above), both showing the same northward dip of foliation. The former is finer grained than at stop 1 and contains no “augen”. Quartz and pegmatite veins occur.—The dark gneiss (quartz, microcline, mica) becomes fine-grained one metre above the junction and shows alternating light and dark bands. Quartz and pegmatite veins.

Continuing by bus through the banded gneiss and the overlying sericitic quartzite schist with amphibolitic (biotite rich) sills, the ascent up the road leads to lower members in the succession, so that the border to the gneiss granite is passed before stop 4 (1½ km ride from stop 3 to 4).

Stop 4. The view westwards shows the geological construction of the area with granite in the south, followed by an intermediate zone of supracrustals and succeeded in the north by pure white quartzite. A few hundred metres further along the road, border (covered) between gneiss granite and biotite quartz-rich gneiss (cf. stop 3).

Stop 5. After having travelled 1 km through gneisses and mica schists etc., a typical sericite-quartz schist with 5–30 cm thick quartzites is reached. Amphibolite bodies showing strong foliation are here conformable with the bedding of the quartzite. In a few other localities in this area, the amphibolites are cross-cutting. The quartzite may be more or less recrystallized.

Stop 6 is reached after a bus ride of 500 m. Here a horizon (2–3 m thick) of very fine-grained porphyry is exposed, composed of quartz and perthitic microcline, grain-size 0.1 mm. Phenocrysts (quartz and feldspar) here not so well developed as elsewhere in the area, are crushed and have no sharp borders. Sericite is common, biotite has grown as porphyroblasts.

Next follows an agglomeratic bed with scattered, deformed boulders in a greenstone matrix, succeeded by an amphibolite sill (?) several tens of metres thick. Biotite has grown in situ, epidote also occurs.

Continuing along the road to *Torkildsstul* the overlying quartz conglomerate is reached. The boulders are flattened into disks aligned parallel to the general northerly dipping foliation. The matrix is gneissic. Thickness at least 50 m. The conglomerate can be traced more than ten kilometres both in E and in W directions.

The conglomerate grades upwards into an amphibolitic rock which again is overlain by quartz schists and quartzites (Seljord quartzite U 10 [?]) which cover large areas to the north.

The view to the east clearly shows the geomorphological features (fig. 1). At the parking space *Jønnebu*, a subcircular phranic explosion breccia (diatreme) 50 by 150 metres, of Permian (?) age occurs. Several fragments consist of quartzites which resemble the local quartzite, but xenoclasts of red schists and black schists are foreign material. Fragments of amphibolite (and porphyry?) are reported, but *no* certain Telemark gneiss granite. Near the contact to

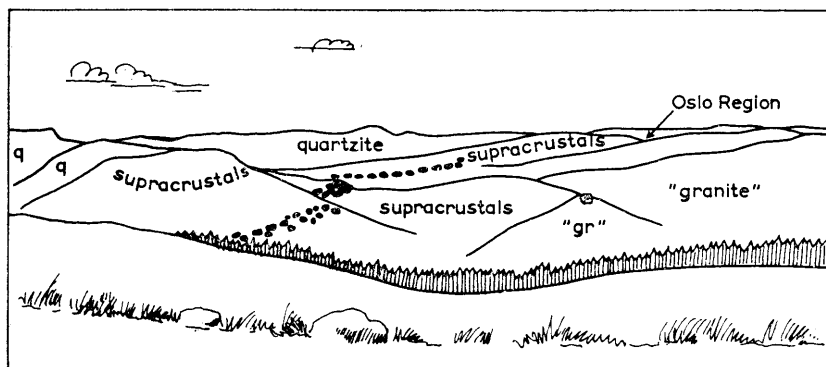


Fig. 1.

View to the E from Jønibu. "Granite" ("gr") in south. The overlying supracrustals (with conglomerate) grade into quartzite (q) in north. In Plate 1 the supracrustals above the conglomerate are included in "Seljordquartzite".

the "pipe", the quartzite country rock is shattered, but the general attitude is maintained. Radiating joints are filled with rock dust and fragments of rock. Joints cutting the strike are steep, the ones parallel to the strike tend to break up the quartzite, the rock material being "intruded" parallel to the layering.

Back to Lifjell Turist Hotel for dinner and the night.

2nd. DAY, Aug. 6th. (description: T. Siggerud). From Lifjell to Notodden 35 km. Once again a cross section from the gneiss granite up into the quartzite. In the slopes down to Heddalen valley porphyries and "leptites" are seen.

From hotel down into the main valley and along the road leading to Notodden (past Reskjem).

Stop 1. 8½ km from Hotel, N of Stormyr. Between the road and the river, large outcrops of Telemark gneiss granite with some quartz veins. Exfoliation (sheeting) well developed. Diabase dykes are numerous in this eastern area, some of them show "en echelon" emplacement and stoping. Ice scouring, crescentic fractures.

Stop 2. Slåttedalen farm. Biotite gneiss (amphibolite) in gneiss granite (the latter is seen nearby). All structures are parallel to

main foliation. Feldspar lenses in biotite gneiss look as if they have been squeezed out by pressure from the north. Apparently rotated lenses have been observed.

Stop 3. 500 m south of *Lona farm* (new road southwards). Uppermost part of gneiss granite and border to supracrustals. The gneiss granite here contains more muscovite than biotite and is exceptionally light in colour near the contact. Diabase dyke. Several quartz veins parallel to the foliation. $\frac{1}{2}$ m above the boundary (which is covered) fine-grained gneiss with quartz lenses parallel to the foliation, which is common for both gneiss granite and grey gneiss.

The excursion continues by bus through the sequence studied the day before at Lifjell. The sediments are nearly flat-lying, but folds, flexures and faults have been observed.

Stop 4. *Jørgedal bridge*, side road. Road cuts in (amphibolite and) a strongly deformed quartz conglomerate (cf. first day stop 6) at least 100 m thick. The matrix is quartzite and porphyry debris. The stratigraphical position of this doubtful conglomerate corresponds to obvious conglomerate beds in the vicinity.

On the way to the next stop amphibolite sills and quartzite schist containing up to 25% sericitized feldspar. Some beds contain fuchsite (Cr).

Stop 5. 500 m north of Reskjem. Massive quartzite with large ripple marked surfaces. A disconformity between ripple marked beds and pigmented layers has been observed. This could indicate a secondary origin of the pigment layers.

Further north along the road, the boundary between quartzite and the overlying (?) rock series of the Notodden–Heddal area (Bandak group?) is crossed. The border relations are obscured by numerous faults (fig. 2).

Stop 6. Ca. 500 m E of the highest point on the road, *Reskjemheia*. Porphyry with easily visible phenocrysts of feldspar (strongly sericitized) and quartz. These “blue quartz eyes” are mostly of primary origin; although some of them seem to be phenoblasts. Further down the road the phenocrysts disappear but the rock (a tuff?) is the same. Flow structures (?) may be seen. Continuing down the road one gets the impression of a gradual transition into granulitic rocks (“leptite”); although radioactivity measurements indicate a sharp boundary (the porphyry containing 50% more radioactive material).

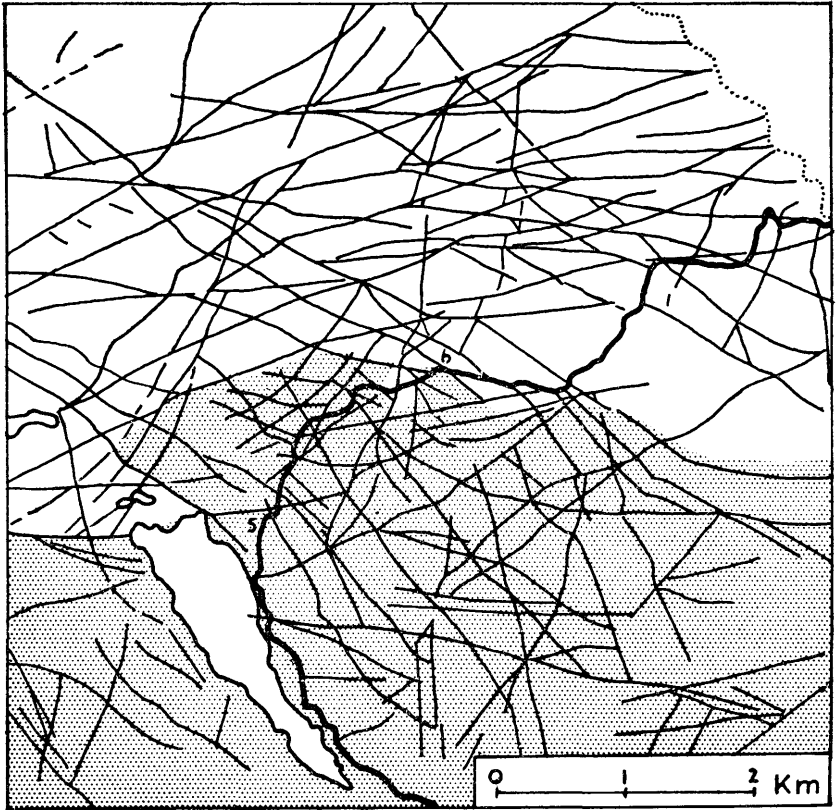


Fig. 2.

Faults and joints in the Reskjem-lake area, field and aerial observations. The quartzite is shown by shading. Location of stop 5 and 6 marked.

The granulite consists of strongly metamorphosed supracrustals, *i.e.* quartz schists, mica schists and gneisses. Retrograde metamorphism has caused some epidotization.

Stop 7. 1 km W of *Strupa bridge*. Outcrops of “gneissified” granulite (leptite) with alternating dark and light layers. Colour difference is due to varying mica content.

Stop 8. On the other side of the valley. The leptite is more gneissic and contains quartz and feldspar veins. Locally (not seen at the stop) these rocks are almost migmatites.

Stop 9. Heddal stave church, the largest of the old Norwegian wooden churches. Built about 1200 A. D., now very carefully restored (1952–54). For 750 years, there has been a service here every Sunday.

To Notodden for dinner and the night.

3rd. DAY, Aug. 7th. (description 3rd. to 5th. day: J. A. Dons).

Notodden–Morgedal Turisthotel (80 km). “Leptites” along the Tuddal-road; upper part of Rjukan group and lower part of Seljord group along the Hjartdøla river and the road to Seljord–Brunkeberg. (The Bleka area (stop 2, 3, 4) has been studied by S. Svinndal.) Stop 8, 9, 10, 11 may be taken fourth day if necessary.

From Notodden along the main road leading to western Norway. In the open “U” shaped valley with marine clay one again passes the Heddal stave church. At Ørvella where the road to Bolkesjø branches off, a great fluvio-glacial delta, formed in front of a glacier, which during the deglaciation period ca. 10 000 years ago came down here from the Tinnsjø valley. The present drainage of Tinnsjø is farther east. At Løvheim (22.3 km from Notodden), to the right on the road leading to Tuddal.

Stop 1. Road cut from 2.1 to 3 km from Løvheim. Polymictic conglomerate (agglomerate ?) with elongated pebbles (quartzite, acid lavas etc.). Strong epidotization, current bedding may be seen in the rocks which originally may have been a fine-grained feldspathic sand, partly limy argillaceous. These rock types which cover a large area—comprising Heddal–Notodden, have an unknown stratigraphic position (Bandak group ?). In the higher part of the sequence (continuation along the road) the rocks become gradually richer in quartz and grade (?) into the quartzites of the Seljord group. Faults are frequent here.

Back to Løvheim and 17 km by bus past the hydroelectric Hjartdøla plant at Hjartsjø lake to Flatland bridge near Hjartdal church. Up to the right (construction road, direction Breivatn) to the top of the former waterfall of Hjartdøla river.

Stop 2. Road cut along the *Hjartdøla river*. 1.3 km walk down to *Årus bridge*. White porphyry U 1 (Vemork formation) with large lithophysae and flow structure to 500 m downwards. Then follows (after 150 m alluvium) agglomerate (?) = Maristi-conglomerate U 2

(divided in two by a 5 m thick zone of detrital material) with huge fragments (blocks) overlain by a tuff 25 m. In road cut down to Årus bridge follows the red porphyry U 3 with prominent flow structure (welded tuff?), the highest part of Vemork group. The phenocrysts, (partly corroded) are made up of quartz and feldspar (microperthite and albite). Dark spots are magnetite dust. The fine-grained to submicroscopic groundmass is of sericite, quartz, and biotite. The contact to the overlying Seljord group is not exposed here.

Stop 3. Between (before) *Flatland bridge* and *Hjartdal church*. Gausta quartzite U 5 below, cut by amphibolite dyke (offshoot from the great Bleka amphibolite sill) in the higher part of road cut. The Bleka amphibolite sill can be followed many tens of km. Thickness may exceed 600 m. Mineral composition: amphibole (further north also pyroxene) 60 % strongly altered feldspar (mainly oligoclase, subord. perthitic orthoclase and microcline), apatite, magnetite, ilmenite etc. The quartz content varies due to assimilation of quartzite. (At Bleka farm, 5 km to the WSW, orbicular diorite formed by assimilation of quartz(ite) in the same gabbroic magma which formed the sill [C. Bugge 1931].)

By bus along the road 6 km to Svartdal. (In the hillside to the right, Bleka gold mine worked ca. 1880–1900 and 1935–39, on quartz tourmaline veins [tunnels 700 m].)

Stop 4. Road cut *Luten* farm on the road leading to Nørsteteig (900 m from the Svartdal junction). Shales and beds of "hornfels" (quartz, epidote, muscovite, biotite, calcite) U 6 (+7?). Svinndal regards this hornfels as a mylonite whereas Dons looks upon this rock as an metamorphosed calcareous sediment.

By the main road southwards. After 2 km, a splendid view over Flatdal ("the flat valley", 160–170 m.a.s.l.) bordered by Mount Skorve to the right and Mount Mæle to the left.

Stop 5. *Kongehella* (the kings slab) 300 m before *Nutheim*. King Oscar II was present at the road opening 1862. Erratic block (Gausta quartzite?) with ripple marks in two directions. All ripple marks observed in Telemark are of wave and current types. In the road cut U 7, primary bedding dips S, schistosity dips N.

By bus down to Nutheim and 1 km along the Åmotsdal road to *Stop 6*, near *Nutheim*. U 7 with slump structures, cross-bedding and ripple marks.

By bus back to Nutheim and down into Flatdal.

Stop 7. Northern end of lake *Flatsjø* in Flatdal, red quartzite, (higher part of Seljord group) with ripple marks.

One continues by bus through white quartzite, folds plunging NE, along the river (narrow gorge) down to:

Stop 8. Vallar bru, Seljord. Quartzite and quartz conglomerate. Pebbles elongated parallel to fold axis, plunging NE. The locality is situated near the base of the Seljord group. The large quartzite area to the south with fold axes E-W here borders upon the quartzite-porphiry area to the north with fold axes generally N-S. Complicated tectonic features in the border zone see fig. 3.

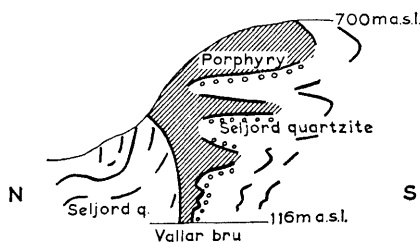


Fig. 3.

Schematic section showing the eastern hillside at Vallar bru, Seljord.

Stop 9. Seljord church built in stone about the year 1100. The village used to be administrative center for the copper-mines at Gullnes (10 km NW of Seljord at lake Sundsbarmvatn) worked on chalcopyrite from 1540 with interruptions until 1900. Monument showing the hymnist and collector of folk songs, Vicar in Kviteseid (1834–39) in Seljord (1840–48) M. B. Landstad (Draumkvedet [a religious poem] from the year 1200).

One continues by bus 7.5 km, direction W (towards Brunkeberg).

Stop 10. Heggveit (side road to Åsgrendi). Conglomerate in lower part of the Seljord group. Quartzite pebbles with linear structures at oblique angle to their elongation, in the micaceous matrix.

Stop 11. Hesteskodiket farm (“horseshoe ditch”) (1.5 km from stop 10) 300 m walk westwards along the main road. Looking back to the east one faces high mountain peaks which are composed exclusively of the conglomerate just seen. Intensive folding and imbricate structures. On both sides of the road, cuts in “leptite” (porphyry of the Rjukan group) in the core of an anticline. Then

follows a rock composed of porphyry debris with scattered pebbles. Further on, the true conglomerate, here polymictic, the basal part of the Seljord group.

In bus one passes Brunkeberg (3.5 km) and by the road to the right one reaches Morgedal Turisthotel (3 nights here) after additional 7 km drive. The border of the Bandak group is crossed near Brunkeberg church (fourth day, stop 4).

4th. DAY, Aug. 8th. Telemark gneiss granite; granitized porphyry; lower part of Bandak group. (The Bandak group is particularly studied by H. Neumann.) Return to Morgedal Turisthotel.

Bus directly past Brunkeberg to Kviteseid old church (built ca. 1100) at Kviteseid vatn. 72 m.a.s.l. On new road (under construction) SE along the SW side of the lake.

Stop 1. Near *Kviteseid old church* (300 m from road junction) two-side road cut. Biotite gneiss granite. "Folds" grade into "faults" with pegmatite. Direction of axes varies. This rock covers great areas.

Stop 2. Snaunes (2.3 km from road junction) a locality situated in a special type of Telemark gneiss granite forming an area of circular outline 6 km in diameter. Great parts of this area are composed of a porphyry granite. The augen have a plagioclase rim surrounding alkali feldspar. Along the borders of the area amphibolite and (not visible here) quartzite beds dip towards the centre of the area, forming an inverted cone. The augen have at least locally grown in amphibolite (a former lava).

Stop 3. Haukom (small bridge) reached by bus drive back again 5.5 km from old church. Junction between "granite" in south (locally pegmatitic) and amphibolite (Vemork or Bandak group) in N (close to the bridge).

By bus down through Kviteseid centre to new church.

Stop 4. Kviteseid new church (built 1915). Large road cut in granitized porphyry (leptite) U 1, 3 etc, epidotized, containing pegmatite veins. Foliation is probably not parallel to the primary structure.

Bus back through Kviteseid and up the hillside to Brunkeberg village.

Stop 5. Brunkeberg. 600 m walk from road junction at the church. Here porphyry (leptite) U 1, 3. After "Post office" porphyry debris

overlain by quartzite U 11 (base of Bandak group) with cross-bedding. The angular unconformity is visible. Upwards in the sequence follows conglomerate with deformed pebbles of quartzite and porphyry. Near the electric transformer, amphibolite U 14. The units U 12 and U 13 are not developed here. The bus continues 3 km through the amphibolite, U 14.

Stop 6. Near Hemnestveit a high and good road cut, amphibolite, U 14, with faint vertical layering and nearly horizontal fissures filled with quartz.

Stop 7. 5.28 km from Brunkeberg, Haugan at Skarstj. Porphyry U 17. The quartz insets are often blue (this rock will also be seen 5th. day stop 2). Bus to Morgedal Turisthotel.

5th. DAY, Aug. 9th. Stratigraphical sequence of the Bandak group in the narrow valley Dalane and W wards to Høydalsmo. Return to Morgedal Turisthotel.

Stop 1. Liberg pensionat at Breivatn (4 km W of Morgedal Th.). White to grey quartzite, U 13, on right side and further along on left side the overlying greenstone, amphibolite U 14.

Stop 2. Mostøyl claim (7.5 km from Morgedal Th.) at the right side of the road under a mast for high-tension line. Quartz vein with chalcopyrite, bornite, malachite, hematite, siderite etc. crossing the border between greenstone U 14 in W and the uppermost of 3–4 “quartzite” beds, U 15, in E. The “quartzite” with angular phenoclasts shows primary bedding and cross-cutting schistosity. Mines and claims on occurrences of this type are abundant in the Bandak group (Vogt 1886, 88).

From Mostøyl the road branching off to S. 7.4 km to Dalen (just before Jusurei).

Stop 3. Dalen farm, grass covered side road down to the river where there are specimens containing native copper (and silver). The material has come from the nearby Spendivegg mine worked in old days and again 1916–20, situated at an impregnated zone between greenstone, U 14, and the underlying “quartzite” band, U 15. Neumann (1944) holds the opinion that the occurrence was formed through impregnation of the underlying sandstone by emanations from the basic lava. No metals are found in the lava itself.

Stop 4. Dalen farm (450 m W of stop 3). 700 m walk up the road, starting in porphyry, U 17, at sideroad and 60 m along main road.

Then follows greenstone (amphibolite), schists, sandstone (quartzite), conglomerate (U 14–16). In the greenstone at several places breccia (pillow structure?) with red calcite and epidote. Half way up the hill, the road cuts through an old mine (Haugjuvet mine) situated at the same contact as the Spendivegg mine. The sandstones show cross bedding, the conglomerates are polymictic.

The bus continues 2.6 km to just past the school S of Haugli, crossing an anticline with steep fold axis plunging SW.

Stop 5. School S of Haugli. Porphyry, U 17, with flow structure, blue quartz insets, glacial striae.

Stop 6. Haugli (600 m from stop 5). Near the river nodular beds (fossils?) in schists, U 19. Greenstone, U 18, in road cut. The following complete stratigraphical succession is not easily accessible.

| | | |
|---|-----|---|
| Greenstone U 18 upper part | 200 | m |
| Sandstone with cross-bedding | 30 | – |
| <i>Nodular bed</i> , largest nodules at the top | 1.2 | – |
| Sandstone | 0.6 | – |
| unexposed | 0.7 | – |
| <i>Nodular bed</i> , small nodules | 0.8 | – |
| unexposed | 0.2 | – |
| Greenstone | 0.6 | – |
| <i>Nodular bed</i> , large nodules | 0.4 | – |
| <i>Nodular bed</i> , small nodules | 0.9 | – |
| Porphyry debris | 0.5 | – |
| Quartzite | 1.0 | – |
| Greenstone, aggl. or cgl. | 1.5 | – |
| Greenstone, U 18, lower part | 10 | – |

The nodular beds can be followed at least for several hundreds of meters in both directions. The nodules have ellipsoidal shapes, are 2–4 cm long 0.5–0.7 cm across, are composed chiefly of fine-grained quartz, and have a central coarser grained quartz-filled tube parallel to the longer axes. An inorganic origin (lithophysae, pisolithes or oolithes) seems less probable than organic or organic controlled origin. The name TELEMARKITES ENIGMATICUS has been chosen as a designation for the feature (Dons 1959).

Bus back to Mostøyl again, then to the left, along main road towards Høydalsmo. Stop halfway up the first hill, 250 m from road junction.

Stop 7. Mostøyl old marble quarry, U 20, ca 50 m to the left of the road. Greenstone, U 18, at the point of the road where we stop, polymictic conglomerate and schists a little further on along the road, U 21.—Limestone is seldom met with in Telemark and this is the only pure marble with known stratigraphic position. The bed is 5–10 m thick, white to rose.

Stop 8. Road cut *Mostøyl–Kvåle* school. If time permits the participants may walk 800 m from stop 7. (Attention must be paid to the motor traffic also.)

A good section in quartz schists, U 21, the highest known unit of the Telemark suite, the central part of a syncline. Nice flexures in vertical bedding showing movement of the upper parts towards the W. Flexure axes nearly horizontal. If time is short, the bus will drive along half of the section and then continue from Kvåle school 2.4 km to the farm Nordå, immediately past the sideroad to Fjellet. *Stop 9. Nordå.* Road cut 350 m in flaggy quartzite, U 15, with scattered pebbles of quartzite (and porphyry?). The contact with greenstone, U 14, is exposed and the greenstone, partly tuffaceous (with amygdules?), is followed stratigraphically down (190 m along the road) until a lower quartzite bed (U 15) is met with.

The bus continues 2 km.

Stop 10. Oftevatn (lake), porphyry, U 12. (The quartzite, U 13, on this side of the syncline is reduced to a thin bed of conglomerate seen at the outlet of the lake, accessible with difficulty) Faint flow structure and angular phenocrasts seen on weathered surfaces; the quartz grains are difficult to perceive; feldspar (corroded microcline and plagioclase) diameter often more than 1 cm 72.3 SiO_2 , $3.1 \text{ Na}_2\text{O}$, $4.8 \text{ K}_2\text{O}$ corresponding to 30 % quartz, 55 % feldspar plus epidote, sericite etc (C. Bugge 1931).

The bus returns to Morgedal Th.

6th. DAY, Aug. 10th. Route: Hotel–Høydalsmo–Dalen–Åmot–Høydalsmo–Morgedal Turist Hotel (description: G. Brevig Liestøl).

Whetstone quarry, molybdenum mine, intrusive(?) granite; within the Vinje quadrangle (geological mapping begun 1956, interpretations of the geology tentative).

The supracrustals, mostly belonging to the Bandak group, have fold axes generally plunging southwards. To the west the supracrustals are cut by a N–S fault-zone (quartz dyke). The

area around Høydalsmo exhibits an intricate radial fault pattern. There seems to be a zone of discontinuity from Hovdevn., north-westward to the granite of Vehus. In this area, which is still not studied in detail, the Bandak group and the Rjukan group will adjoin. Two large subcircular granite bodies have penetrated the supracrustals. The gabbro north of Vinje is of ultrabasic composition ($\text{FeO} + \text{Fe}_2\text{O}_3 = 15\%$).

Bus from hotel to road junction Høydalsmo 15 km. Turn to the left, direction Dalen.

Stop 1. Gunnheim (11.2 km from Høydalsmo). Copper minerals in tourmaline dyke.

Stop 2. Brynestein (whetstone), *Eidsborg* (11.8 km from Høydalsmo). Whetstone (in U 21) has been quarried here since prehistoric time. Several quarries in Steinbergnuten (stone rock hill) and Grødnuten south and north of the road. Two vertical joint directions perpendicular to each other, the one in the $\text{N } 10\text{--}20^\circ \text{ E}$ direction corresponds to the primary bedding (?). Irregular horizontal fissures.

The road follows a steep valley E–W developed along a fault which has been mapped for a distance of 15 km. Horizontal displacement ca. 100 m.

One of the largest quarries N of the road will be visited. Short but steep walk along good path.

Stop 3. Eidsborg stave church, first mentioned in documents from 1350 A. D. Probably this wooden church is even older. Well preserved, newly restored. Old farm houses (Museum) near by.

Stop 4. Dalen molybdenum mine, near Borge farm. Worked during World War I, has yielded 110 tons pure MoS_2 . The ore is found in an almost horizontal quartz vein which cuts a sandstone bed (U 15). Smaller occurrences in the adjacent basic lava.

Magnificent view SE along the Bandak lake. During the descent by bus from Eidsborg (500 m.a.s.l.) to Dalen (72 m.a.s.l.) in hairpin turns there will probably be no possibility of stops due to busy traffic on the narrow road—even though the view is nice.

Stop 5. Dalen, shipping terminus of traffic from Skien (150 km). Hydroelectric plant (Tokke) under construction. From Dalen the road along the river Tokke is followed parallel to the strike direction of units U 14 and U 15.

Stop 6. S of Bringsvær farm, on the main road to Åmot ca. 8 km from Dalen. Road section in intrusive (?) granite.

7th. DAY, Aug. 11th. (description: O. A. Broch). Morgedal Turisthotel-Åmot-Arabygdi (at lake Totak)-Skinnarbu Høgfjellstue 110 km. Western border of supracrustal rock suite against "Telemark gneiss granite". Intrusive and tectonic contacts. Types of gneisses and granites near the contact at the road along the northeastern shore of lake Totak (690 m.a.s.l.).

Morgedal Turisthotel-Åmot, see 6th. day. From Åmot upwards along the valley of the river Tokke, mostly through forest. Supracrustal rocks exposed in a few road cuts.

Stop 1. Bratland farm 12.5 km from Åmot. Main geological units seen at a distance towards NW (across lake Totak).-Fracture morphology as developed in granite mountains seen (if illumination favourable) in mount Fløtebunut in WNW.

Further 3 km to crossroads Krossen (the distance from Krossen is quoted for each stop below). To the left (NW) following road to Arabygdi along Totak. Through poorly exposed supracrustals to *Stop 2* (6.2 km). Near *Nybø* farm. Outcrop of quartz-breccia, traceable as an about 100 m thick plate-shaped body over a distance of at least 5 km, dipping SE to ESE conformably between granite and supracrustals (tectonic border).

Through nearly unfoliated normal granite (red and grey) to *Stop 3* (9 km). Near small torrent *Kvikka*. "Igneous breccia": Red normal granite and pink aplitic granite cutting and containing sharp-edged fragments of basic rock (metamorphosed greenstone).

Along road cut in greenstone and quartzite to *Stop 4* (10.5 km). Old school building at *Aksvik*. Westwards road section in greenstone and quartzite, cut by numerous dykes of pegmatite, also of granite-offshoots from the great granitic dyke of *Aksvik-Dalen*, which at the present locality is covered by morainic drift, but crops out just north of the road.

Stop 5 (11.7 km). *Killingtveit* farm. Zone of augen gneiss between (amphibolitic) greenstone and the gneiss granites to the west. Westwards from this locality the "Telemark gneiss granite" continues into the great South Norwegian gneiss-granitic area.

Stop 6 (13.6 km). Cliff WNW of *Åsheim* farm. Pink aplitic granite with sharp edged inclusions mostly of basic rock, supposedly supracrustals. Border zone of granite against basic inclusions decolorized-impoverishment in potassium, disappearance of red potash feldspar. Also, pink pegmatitic veins are sometimes

bleached when passing through basic rock. Flaky basic inclusions sometimes pygmatic. Formation "en miniature" of arterite through intrusion of pegmatite into basic inclusion. The presence of two or more "generations" of pink aplite suggests spasmodic character of intrusion.

Stop 7 (15.3 km). Immediately south of *Bratsberg* farm. Grey laminated gneiss granite cut by red pegmatite and red aplite. Subordinate amounts of augen gneiss-resembling rock. In the western part of road cut: grey fine-grained granite.

Stop 8 (15.8 km). 150 m NW of *Krossen* farm. Laminated gneiss as above, cut by red aplite. Coarse-grained veined gneiss—possibly arterite, and augen gneiss (cf. stop 6 and 5). Formation of arterite and augen gneiss a stage in the process of granitization?—Conspicuous rectilinear trace of fracture NE–SW across lake Totak.—Soon after stop 8 view towards NW of the mountain Sule with fracture morphology.

Stop 9 (22 km). *Ara-odden*. Basic rock (inclusion?) cut by a swarm of pegmatitic and granitic (aplitic) dykes of different age and appearance. Stage of digestion (granitization)? Mobilisation of basic rock.—On the opposite side of Totak, planar clefts crosswise down the mountain slope (fractures).—From stop 9, 200 m walk to *Stop 10* (22.2 km). Normal "unfoliated" granite.

The excursion continues westwards about 5 km where a look is had at the great prehistoric rock slip in Arabygdi at the north-western end of lake Totak.

Bus travel 58 km via crossroads Krossen and Austbø to Skinnarbu. Between Austbø and Skinnarbu: Rauland Høgfjellshotel in typical "vidde"-landscape.

If possible, visit to a typical mountain farm in Arabygdi and to some protected medieval wooden buildings in Haddeland and Austbø on the route.

8th. DAY, Aug. 12th. (description 8th. and 9th. day: J. A. Dons).

From Skinnarbu along the shore of Møsvatn, then down to Rjukan. Study of the Rjukan group. Lunch at Rjukan Hotel offered by Norsk Hydro. Return to Skinnarbu.

Stop 1. *W of Skinnarbu*, a short walk along the shore (300 m W of a local shop) on rocks of the Vemork formation, U 4, situated in the complicated western limb of an anticline plunging gently southwards. Isoclinally folded beds dipping steeply E. The light

green lava contains amygdules (?) and alternates with beds of tuff and conglomerate (porphyry and quartz[ite] pebbles). Return by bus to shop and 500 m further along the road.

Stop 2. NE of Skinnarbu, left side of road, small scale slumping structures in Vemork formation.

The two dams of Møsvatn (reservoir 1.064 million m³ water) are passed by bus. The first (oldest) one built of concrete, the second (new) one of sand from the "morain", an esker crossed by the main road some few km SW of Skinnarbu, and of greenstone from a quarry nearby. The water passes 5 hydroelectric plants before Tinnsjø is reached (difference in altitude 725 m, distance 30 km).

The first power station Frøystul (23 000 KW) is situated near the bridge, 1.5 km from the dams. Along the artificial lake, Lysnes-hølen, the road crosses the anticline and follows the border between Maristi-conglomerate, U 2, and the overlying red porphyry, U 3. *Stop 3. Risbu* 4.2 km after the Frøystul bridge. Red porphyry, U 3, with lithophysae. Then by bus for 2.1 km until the construction road branches off (back to the right).

Stop 4. Skarsfoss dam. At the caretakers house red porphyry, U 3 (Tuddal formation), and green tuff (locally developed lower part of Vemork formation, U 4). Green lava down to the dry river bed. Strongly porous and agglomeratic rocks are possibly tops and bottoms of basaltic lava streams. On the other side of the river bed (interesting erosion surfaces), well stratified yellow-green tuff (dark grey when fresh) showing slumping structure, and conglomerate (Vemork formation).

The bus returns to main road and follows this downwards, just passing Hjerdøla bridge.

Stop 4. Hjerdøla bridge. White porphyry, U 1 (Tuddal formation), strongly deformed in road cut. Then, along the road follow green lava and agglomerate, U 2, with pebbles of various porphyries, greenstones etc., succeeded by rhyolite, U 3. On the right side (in road turn at the same level, watch out for cars), xenolith of green lava. Encasing red lava shows flow structure parallel to the borders of the xenolith. 50 m further down along the road on the left side, section showing volcanic breccia in rhyolite. Return to bus which continues past Krokkan through the road-tunnel and then turns back on to the old road, outside the tunnel.

Stop 5. Maristien. Agglomerate (conglomerate?), U 2. In fine weather one can look down in the gorge where the waterfall,

Rjukan foss ("the smoker"), once thundered down (105 m free fall). On the opposite side of the valley, beds of the Vemork formation.—Red porphyry, U 3, and green lava, U 4, in the cliff under the road.

In one of the hairpin turns on the way down to Rjukan, view across the valley to the Hydrogen Factory at Vemork (30 000 m³ hydrogene pr. hour) and out the "U" shaped valley to Rjukan. The movement of the great landice was in most of the Telemark area SE. When the thickness of the ice-cap decreased, local topography influenced the movement, leading a branch out through this valley. Ice scouring is observed also in the lowest part of the valley.

Pipe lines from Vemork run parallel to the road down to Rjukan. The sun is not seen from this town from October to March. The aerial railway, Krossobanen on the northern valley side affords easy access to the mountains in the north, which offer sport and other outdoor activities in summer as well as in winter. Rjukan Nitrate Factories (Norsk Hydro) are situated on the right side of the river. From Vemork plant the water is led by tunnel down to Sâheim Power Station (120 000 KW) in Rjukan.

After lunch at Rjukan Hotel return to Skinnarbu.

9th. DAY, Aug. 13th. If weather permits, the bus and a lift will take the participants up to the top of Mount Gausta (pron. approx.: Gowsta[h]) 1886 m.a.s.l. In case of bad weather on the top a visit will be paid to industrial plants at Rjukan. By bus to Kongsberg (Silver mine museum). Train or bus to Oslo.

The Gausta trip goes from Skinnarbu, passes Rjukan and at Dale (250 m.a.s.l., 4.6 km W of Rjukan, power station of the Mâr plant) the bus starts climbing the hillside in porphyry of the Tuddal formation to reach Svineroi seter (summer farm) and Langfonn (1200 m.a.s.l.) near the border to the Seljord group. Special permission has been obtained to use the transport-tunnel (horizontal 800 m, sloping shaft (38°) 1030 m, with lift). Gausta is built up to Gausta quartzite, U 5, and basic sills. Permafrost (Average temperature for the year ÷ 4° C at the metrological station on top). Splendid panorama view from the top, overlooking great parts of S. Norway (see key map Plate I). To the north Jotunheimen (distance 180 km) and the ice cap Hardangerjøkelen (distance 114 km); to the east Tryvasshøgda near Oslo; at the skyline in the south, Sweden;

and in the south and southwest the area passed by the excursion. The great synclinal structure comprising Vindeggen (SW) is remarkable. Ripple marks in quartzite at the top of Gausta.

Return to Dale and west to lake Tinnsjø. At its northern end four valleys come down, the western one, Hjerdalen is a hanging valley. Stop between Atrå and Austbygdi at the northern end of the lake. Large body of gneiss granite. In the central part the foliation is faint and horizontal. Along the borders the foliation dips away from centre. There is a transitional border zone of granitized porphyry. Observations of foliation of the porphyry indicate that the gneiss granite body has lifted the encasing rocks.

No stop will be made on the way to Kongsberg. The road passes for the first part between lake Tinnsjø and Mount Blefjell 1370 m.a.s.l. This mountain is composed of quartzite (stratigraphic position uncertain [Seljord group?]). *Kongsberg* (see 1st. day Silver mines from 1623. The workings had their "boom" in 1750. Now the mines are closed. Silver mine museum. Return by bus or train to Oslo.

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Norges Geologiske Undersøkelse, geological maps scale 1:100,000, in print:

Kviteseid by H. Neumann and J. A. Dons.

Rjukan by J. A. Dons.

TABLE I

The main rocks of the central Telemark area.

Gneiss and granite (younger and older than the Telemark suite).

Basic intrusives (mostly sills in the Seljord group).

The Telemark suite.

Bandak group.

- 21 Eidsborg quartz schists with several beds of conglomerate.
- 20 Ormebrekk marble.
- 18-19 Gjuve lava, basic (18) with Haugli schists (19) (fossiliferous?).
- 17 Dalen porphyry (acid lava).
- 16 Bergstøl conglomerate, polymict.
- 14-15 Morgedal lava (14), basic, containing one to four beds of Morgedal sandstone (15) with conglomerate.
- 13 Røynstaulegg quartzite with conglomerate.
- 12 Ofte porphyry, acid lava, locally divided in two with quartzite between.
- 11 Basal quartzite with conglomerate.
- Angular unconformity.

Seljord group.

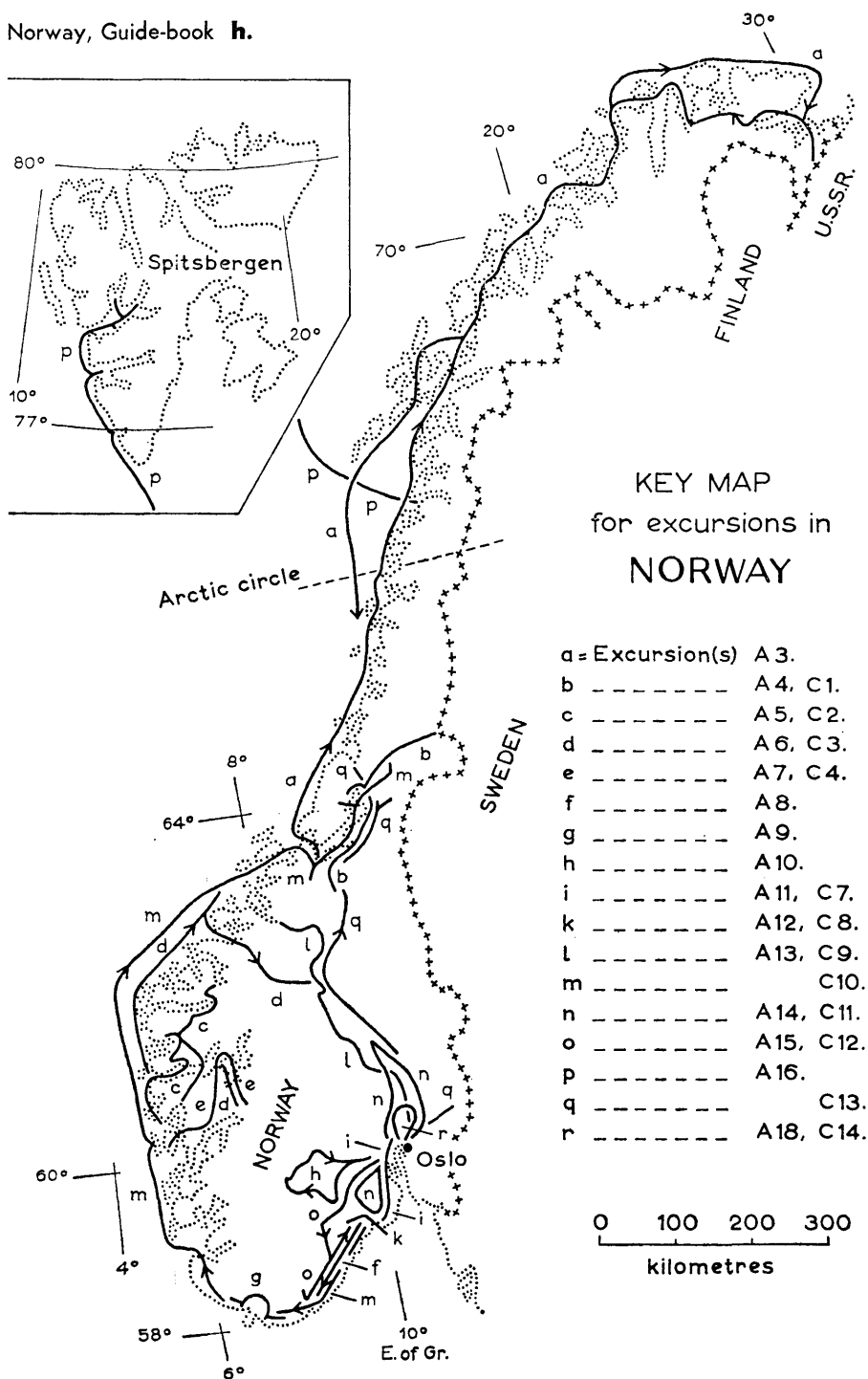
- 10 Brattefjell quartzite, lower part white, upper part red.
 - 9 Vindsjå schists.
 - 8 Skottsfjell quartzite, locally containing conglomerate.
 - 7 Lauvhovd limey quartz schists.
 - 6 Bondal schists.
 - 5 Gausta quartzite, locally containing arkose, conglomerate, and schists.
 - Angular unconformity.
- } Seljord quartzite.

Rjukan group.

- 4 Basic lavas and tuffs, sediments rich in quartz, local conglomerates. } Vemork formation.
- 3 One flow of red rhyolite with flow structure.
- 2 Maristi conglomerate (agglomerate?). } Tuddal formation.
- 1 Acid lavas (and tuffs), top flow: white lava.

Rocks of unknown stratigraphic position in the Heddal-Notodden area: Leptites, porphyrites, agglomerates (conglomerates), amphibolites, quartz schists (Bandak group?).

Notes.



KEY MAP
for excursions in
NORWAY

- | | | |
|-----|--------------|-------------|
| a = | Excursion(s) | A 3. |
| b | ----- | A 4, C 1. |
| c | ----- | A 5, C 2. |
| d | ----- | A 6, C 3. |
| e | ----- | A 7, C 4. |
| f | ----- | A 8. |
| g | ----- | A 9. |
| h | ----- | A 10. |
| i | ----- | A 11, C 7. |
| k | ----- | A 12, C 8. |
| l | ----- | A 13, C 9. |
| m | ----- | C 10. |
| n | ----- | A 14, C 11. |
| o | ----- | A 15, C 12. |
| p | ----- | A 16. |
| q | ----- | C 13. |
| r | ----- | A 18, C 14. |

0 100 200 300
kilometres