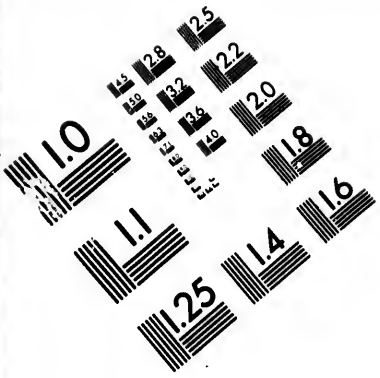

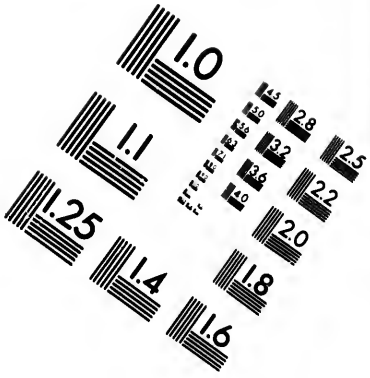

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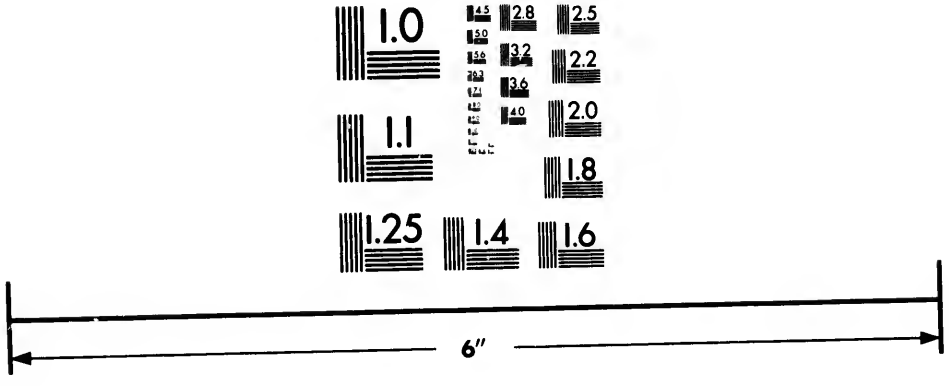

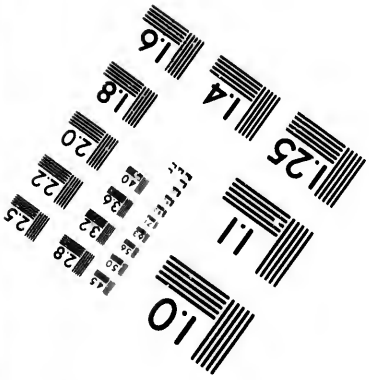

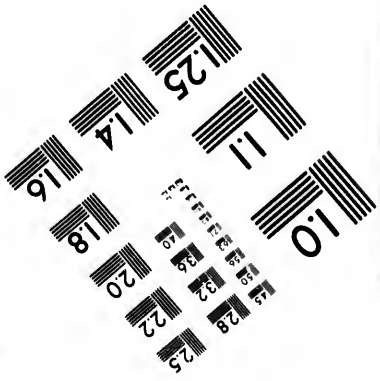

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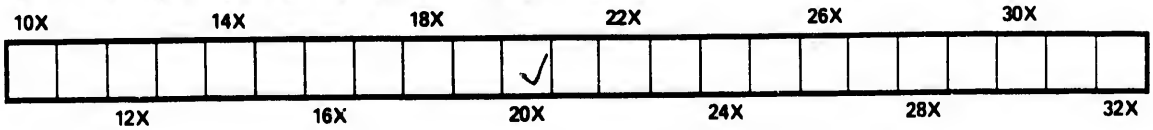

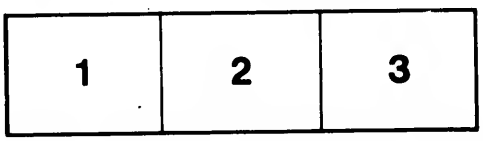

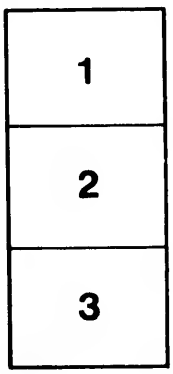

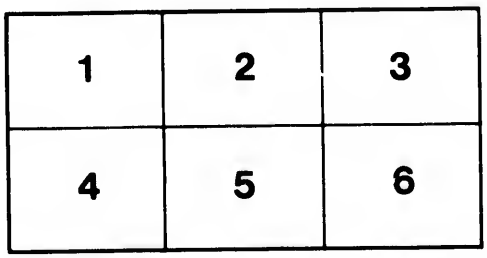

Sold, J. A. Dawes Esq
with the deep respect
of the author.

ON THE PRIMITIVE FORMATIONS IN NORWAY AND IN CANADA,

AND THEIR MINERAL WEALTH.

BY THOMAS MACFARLANE.

(Presented to the Natural History Society.)

Some apology may appear necessary here for the use of a term, regarded by many geologists as calculated to perpetuate false ideas as to the character and origin of the series of rocks which it comprehends. The object of the following paper, however, being merely to point out certain analogies, and possibly, differences, between certain groups of rocks in Norway, and their equivalents in Canada, the name given them is of minor importance; and when it is considered how difficult it is to choose among the various terms which have been proposed and used for designating these formations, the one adopted in the above title may appear excusable, and not perhaps be deemed unserviceable on this occasion.

The groups of rocks, whose equivalents in Norway I propose in some measure to describe, are here known as the Laurentian system, the Huronian and the Metamorphic Silurian series. The first of these is generally designated the Primitive Gneiss formation, (*Urgneiss Formation*) in Germany and Scandinavia, while the two last mentioned groups make up what is termed there the Primitive Slate formation (*Urschiefer Formation*). I propose to describe these groups of rocks as they

occur in Norway, principally in regard to their petrographical and economic characters. I shall follow the order in which they are mentioned above, inserting at the end of each description, a few remarks on their development in Canada. The various facts related in the following descriptions are principally derived from such authorities as Naumann and Keilhau; my personal observations of the districts under notice, having only served to imprint on my mind the descriptions of these and other philosophers. The particulars narrated as to the various mining establishments, are to a great extent however, the results of my own experience and observation. As to the various features touched upon with regard to Canada, my principal source of information has of course been the reports of the officers of the Geological Survey.

I. The Primitive Gneiss Formation.

In Keilhau's "First attempt towards a Geological Map of Norway," as yet the only complete geological map of the country published, there are distinguished three geographical divisions, belonging to the Primitive Gneiss formation, separated from each other by groups of rocks, belonging either to the primitive slate, the eruptive granite and syenite, or to the Silurian series. The first of these is situated high up in Finmark, its most northern point being the North Cape. The second stretches from Beiern-fiord, north of Trondhiem, along the whole coast of Norway, southward to Christiansand, and from thence north-eastward to Kragerö. To this division, the gneiss districts of Kongsberg and Modum also belong. The third division is that lying to the eastward of Christiania-fiord and lake Miosen. These three divisions form only the most westerly parts of the great Primitive Gneiss formation, which extends through Sweden to Finland, and which is the characteristic feature of Scandinavian geology. The rocks which constitute this formation are the following:—

1. *Gneiss* in many varieties, the most common being what is called by Keilhau, *characteristic gneiss*, and which he thus describes. "The rock consists of white or reddish white feldspar, (orthoclase), grey quartz and black mica; the feldspar and quartz being combined with each other granularly, and the mica arranged in this mass in parallel layers; so that the structure is more an alternatively granular and slaty one, than a regularly slaty structure, with quite equal distributions of the three con-

stituents. In this way, there is caused a characteristic streaked appearance, sometimes with broad black or dark grey bands, and sometimes with the same streaks, narrower and farther from each other, according as the mica is more plentifully or more sparingly distributed in the rock. The grains of feldspar, quartz and mica, are mostly rather small in this variety of gneiss, so that it seldom becomes coarsely granular." *Gæa Norvegica*, p. 251. Through a gradual disappearance of the feldspar; the gneiss sometimes changes into mica schist, and through a gradual change in the position of the laminæ of mica, from that of parallel layers, to being irregularly distributed, the gneiss often passes into granite. Of the many varieties of gneiss, one deserves special notice; it has been called Porphyroid gneiss, and differs from the characteristic gneiss in containing lenticular-shaped aggregations of feldspar in a fine schistose matrix. It is this variety which has sometimes been called Eye gneiss.

2. *Hornblende gneiss*, differing from the characteristic gneiss in having exchanged the scales of mica for crystals of hornblende, arranged parallel with each other according to their longest axis. Sometimes however, the hornblende has only partially supplanted the mica, in which case intermediate varieties are formed between the hornblendic and common gneiss. Through gradual disappearance of both quartz and feldspar, the hornblende gneiss often changes into hornblende schist, and sometimes through a change in the structure of the rocks from schistose to granular, syenitic and greenstone rocks are formed.

3. *Granite* of the usual composition. It often occurs as a very coarse grained aggregation of dark red orthoclase with sparingly distributed quartz and mica.

4. *Mica schist*, composed of quartz and mica, with a schistose structure, and often containing garnets. It exhibits transitions into hornblendic schist as well as into gneiss, &c.

5. *Hornblendic schist*, forming transitions into greenstone, and when the structure continues coarse grained, into diorite and diabase.

6. *Chlorite schist*, consisting principally of chlorite and a little feldspar; here and there interwoven with fibres of hornblende.

7. *Talc schist*, mostly quartzose.

8. *Quartz*, as granular quartz rock, forming layers and zones; sometimes slaty, forming quartz slate.

9. *Euphotide*, consisting of brown diallage and white feldspar.

Other rocks allied to this, have been discovered in a good many localities, and described as gabbro.

10. *Serpentine*, sometimes occurs in such considerable masses as almost to entitle it to be regarded as a member of the formation. It is generally of a light yellow colour. The well known deposit of noble serpentine, occurring in the parish of Snarum, comes under this head.

11. *Granular limestone*, as marble, in layers and irregular masses.

12. *Conglomerates* and breccia, mostly the latter. One is described as "a granite-like combination of gneiss and granite," another "angular pieces of gneiss united by a gneissoid cement;" a third consists of "a gneissoid or granitic matrix, enclosing small fragments of other gneissoid rocks."

Besides the rocks above enumerated, there occur numberless varieties, forming transitions between these types of rock, some of which have been already adverted to. Sometimes, as Naumann remarks, "within small spaces, one and the same specific composition shews characters so quickly and so frequently changing, than we soon get accustomed to seek what is similar, only in the specific identity of the constituents, and not at all in the way or quantity in which they are combined." *Beiträge zur Kentniss Norwegens*, I. 188.

As the name Primitive Gneiss formation implies, the most widely distributed rock is the gneiss, either in its characteristic form or its varieties. The next most frequently recurring rocks are granite, mica schist and hornblende schist, or rocks related to these types. Some other rocks which I have enumerated, such as chlorite and talc schists, granular limestone and quartzite, occur in comparatively small quantity, while the remainder of those mentioned must be looked upon as uncommon occurrences.

As to the mode in which these rocks are associated with each other, the whole of them are arranged in parallel layers or zones, side by side, underlying or overlying each other. Hitherto no regular succession of rocks has been marked; they appear to be interstratified with each other without rule. The granitic masses are partly conformable with the parallel masses of the schistose rocks, and partly occur irregularly. It has been remarked that when the granite becomes more or less gneissoid, its masses are regularly interstratified with the other schistose rocks; but where the granite is totally free from all traces of gneissoid texture, the

form in which it occurs deviates more or less from that of layers or beds. A remarkable instance of this is described by Keilhau, as occurring near Norefield. There he saw a mass of granite, which on the whole, was gneissoid and bedded, gradually change at a certain place into a perfect granite, and then, in complete uninterrupted continuity, pierce the rock in the form of a dyke. Another instance is mentioned of a granite rock occurring in the schistose rocks, "partly in very regular layers, partly as isolated knolls and lumps, and partly as a multitude of veins; which in several places run through large portions of the neighbouring mountain as a close net-work." In spite of this however, this granitic rock showed in many places, a gneissoid structure. The relations of the hornblende schists and greenstones resemble those of the granite. The hornblende schist is regularly interstratified with the gneiss, mica schist and other rocks. Where its texture becomes less slaty, the layers or zones are not so continuous, but form, in the direction of the strike, elongated nuclei, which, with their hard masses, often stand out from the general surface, and thus form well distinguished peaks, such as Johnsknuden near Kongsberg, and Fagerlidknatten south-east in Nedenæs. Instances of crystalline amphibolites cutting the strata, occur in the most northern gneiss district, but these appear to have been formed much later than the gneiss. Mention is also made of a diorite, or feldspathic hornblende rock, occurring in veins in a granular mixture of quartz, feldspar and garnet, which latter rock appeared to form a transition into the gneiss.

One of the most striking features seen in the structure of this group of rocks, is the foldings and contortions, which the strata exhibit in all the divisions of the group. This is observed as well where no granitic masses are seen, as in the neighbourhood of such. On the high road from Hougsund to Kongsberg, and shortly before reaching the latter place, the traveller can observe, without dismounting, the most wonderful bends and contortions in the structure of the gneissoid rocks occurring there. Scheerer, in describing these contortions, compares them to the windings figured upon marbled paper. Naumann, in remarking on the same phenomena on the north-west coast, expresses himself as follows: "It is usually said of gneiss, that it is always clearly and regularly stratified. This assumes that the parallelism of the masses, of not too great extent, has a relation to one plane; that the positions of the planes of structure

within small distances, are only subjected to small, and generally gradual and continuous alterations; that these do not frequently shew sudden faults, or leaps in the most varied directions, within a few paces. If we however examine much of the gneiss of northern Bergenstift, we find exactly the opposite of this. Let one only observe the profiles which the play of the waves keeps so clearly and distinctly exposed on the rocky banks of Evenigfiord, Outer Dalsfiord, and especially of Söndelvsfiord. In what absolute indefiniteness, in what indescribable confusion is the structure of the masses exhibited! And yet there reigns the most unequivocal parallel structure within those thousand-fold meandering windings of the single zones, in which no rule, no law is evident, for the wonderful windings appear so lost in each other that neither drawing nor description is able to follow them."

In the presence of such contortions, and of local foldings on a larger scale, it is of course difficult to ascertain the general strike of the strata. It seems however, that in all the principal gneiss regions of Norway, the rocks run most generally north and south, or at least N.N.E. and S.S.W., and this, although there are numerous exceptions, appears to be the general strike. It seems also that a generalisation is possible as well with regard to the dip, as to the strike of the rocks constituting this group. The strata are almost always vertical or nearly so. This is the distinguishing character of the formation, and, *en passant*, let me remark the great difficulty hitherto experienced in all theorizings as to its origin. Horizontal and less inclined strata have indeed been remarked in several places, but they must be regarded as exceptional. The dip is almost always over 45°, generally 60° to 80°, while perfectly vertical strata are often observable. These much inclined strata may be traced continuously many miles on the above mentioned north-easterly strike, and taken together, strike and dip, form a remarkable feature in the architecture of these rocks. As Keilhau remarks, "there lies spread out before us an area of many thousand square miles, which shews only in a few places, any other than steeply inclined strata. In a great many, and indeed we may say in the most and greatest portions of this area, we see these steep strata following some law of regular course. We find them stretching away ten, twenty and often many more geographical miles, according to the same lines, and it appears to us that there where new fields of strike begin, it is still the same parallel masses which we have previously observed, and

which have only changed the direction of their strike." *Gæa Norvegica* I, 375.

The landscape features in the gneiss region vary much. We find in it sometimes tame hills, flat undulating plateaux, in which only the valleys cut into it, have exposed more rugged forms; but sometimes we find zigzag ridges, sharp peaks, and other remarkable mountain shapes. In the gneiss districts of the south, long-drawn, broad massive mountain ridges are most common, but on the north-west coast, the gneiss rises in rugged and fantastic forms above the surface of the water, in the numerous and intricate fiords of that region.

The mineral deposits of these districts are neither few nor uninteresting. Some of these are worked, and produce silver, copper, cobalt, nickel and iron, while others capable of yielding some of these metals or other minerals, remain unwrought or undeveloped. Foremost among the modes of occurrence of metals in this region, must be noticed the so-called *fahlbands*. These are not exclusively confined to the south of the *Fields* which run north-eastward across Norway at its broadest part, but it is there, and especially in the district of Buskerud, that they have experienced their greatest development. From a point to the west of Kongsberg, and near the junction with the so-called Tellemarken group, afterwards to be described, north-eastward to Tyrifiord, or to where the gneiss formation in Modum is overlaid by Silurian strata, there occurs a series of parallel zones of rock, having the same strike and dip as the rocks enclosing them, but distinguishable from these by the decomposed appearance and reddish-brown color which they present on the surface. This peculiar appearance, to which, according to Böbert, they owe their distinguishing name (from *fahl* or *faul*, rotten, as the German miners, who first were employed in their exploration, termed them,) is attributable to the metallic sulphurets which they contain, and especially to iron pyrites; the ferric oxide and the sulphates produced in the oxidation of this being the coloring and decomposing agents. The quantity of metallic sulphurets necessary to produce this coloring and decomposing effect, is exceedingly small, and indeed it is sometimes scarcely possible to distinguish them, so finely disseminated are they through the mass of the rock constituting the fahlband. The sulphurets most generally present are common and magnetic iron pyrites, and copper pyrites; although blende and galena have both been mentioned as impregnating materials,

they are comparatively rare. Besides these, cobalt glance, cobaltiferous arsenical, and iron pyrites, nickeliferous magnetic pyrites, and argentiferous iron pyrites characterise peculiar localities. The impregnation seems to be altogether independent of the nature of the rock; gneiss, mica schist, hornblende schist, &c., being alike found constituting fahlbands. The continuity of these impregnated zones is frequently astonishing, some of them having been traced in the direction of their strike, nearly north and south, upwards of ten miles. Their course is often marked by depressions in the rocks, caused by their greater proneness to decomposition, and these depressions are frequently occupied by marshes and lakes. The thickness of these bands varies from a few feet to several hundred, and they have been frequently observed to split up and throw off side bands, some of which seem to connect with other similar zones. Although, as in the case of the glance cobalt and cobaltiferous mispickel, the impregnating material is sometimes the object of mining enterprise, it is generally on the veins or irregular masses occurring in these fahlbands, that the mines of the district are situated. Concentrations of metallic sulphurets or other minerals in fissures parallel with or crossing the strata, are by no means uncommon, and in some instances have given rise to very profitable mining. The metallic deposits which I propose to notice in connection with those fahlbands, are the silver mines of Kongsberg, the copper mines of Eker, the cobalt mines of Skuterud, and the nickel mines of Ringerike, all of which are at present being worked.

The rocks in which the fahlbands of Kongsberg occur are gneiss, mica schist and hornblende schist; other rocks, such as granite, talc schist and chlorite-schist, granitic gneiss and greenstones occur also in the immediate neighbourhood. Seven different fahlbands or groups of fahlbands have been recognized as existing in these rocks around Kongsberg, on every one of which, at some time or other since the year 1623, more or less mining has taken place. The two fahlbands which have been most minutely examined, have an average thickness, respectively, of 200 feet and 1100 feet. The impregnating sulphurets are iron pyrites, magnetic and copper pyrites; some of which appear to be argentiferous, since the fahlband itself contains one-eighth of an ounce silver per cwt. These fahlbands are intersected throughout the whole extent, about six miles, by numerous veins containing gen-

erally calcspar, fluorspar, quartz and metallic silver, and more sparingly, bitterspar, stilbite, prehnite, harmotome, laumontite, anthracite, fibrous pyroxene, chrysotile, asbestus, actinolite, axinite, adularia, and perhaps albite, auriferous silver, metallic gold, horn silver, metallic arsenic, silver glance, red silver ore, galena, blende, magnetic, iron, and copper pyrites. These cross veins are exceedingly well developed within the fahlband, but beyond its limits they exhibit little distinctness or regularity, and moreover are totally destitute of silver. They do not however, while intersecting the fahlband, uniformly contain that valuable metal; on the contrary its occurrence there is almost as uncertain as that of a valuable ore in any other lode, but only within the limits of the fahlband can one expect to find it. The only rule which seems to have been ascertained to exist with regard to its distribution in the vein, within the fahlbands, is this—that where the latter is most strongly charged with the impregnating sulphurets, the vein at that point is richest in silver.

Such are the characters of the Kongsberg silver veins, striking examples of the influence which the wall-rocks exert on the contents of metallic lodes, and little liable to be neglected in theories regarding the filling of such. The connection between the pyritous impregnation of the fahlbands, and the argentiferous contents of the veins, necessitates the deduction that the silver has been derived from the pyrites, and as these have been found to be argentiferous, the deduction assumes the character of a fact itself. As to the mode in which the silver has been secreted various opinions may exist; the most probable appears to me to be the following:—

Through gradual contact with the waters containing oxygen, percolating through the rocks, the sulphurets, especially the iron pyrites, were decomposed, sulphates of protoxide and peroxide of iron, and sulphate of protoxide of silver being the results. The first named salt would be produced in the earlier stages of the decomposition, and removed; the two latter salts, produced towards the end of the process, can exist simultaneously in solution. On reaching the fissure thus, in solution, they were met by some agent capable of precipitating the silver of the sulphate. The agent which seems to me to have accomplished this, is the sulphate of protoxide of iron, already alluded to as a product of the decomposition of the pyrites. The precipitation of silver salts by a solution of copperas, is a well known chemical reac-

tion, the products being metallic silver and sulphate of peroxide of iron.

The number of veins intersecting the fahlbands at Kongsberg is very great indeed. While the mines belonged to the Danish government, almost the whole of them received some share of attention, an extensive but rather desultory system of mining thus resulting. Since the Norwegian government undertook the working of the mines in 1812, a different system has been pursued, rather the other extreme, of working at too few points. Only three veins, those of *Kongen's Grube*, *Armen Grube*, and *Gottes-Hülfe-in-der-Noth*, have been the subject of mining explorations. However this may be, the mining of the last twenty to thirty years has been eminently successful, and a source of considerable revenue to the Norwegian government. On account of the shortness of the veins, their exploration is pursued chiefly downwards, but as yet, in going downwards, no diminution in richness has been observed. On the contrary, large masses of metallic silver, similar to those which obtained for the mines their celebrity in earlier times, have been recently found. These large masses are of course the exception, the most of the silver which is produced being separated from the vein-stone, in breaking it up, after its extraction from the mines. A large portion is also obtained in the stamping and washing of middle and poor ores at the mines, and in the same operations considerable quantities of more or less argentiferous *schlichs* and slimes are produced. The whole of these products are farther treated in the smelting-house in Kongsberg. The poorer slimes and schlichs, containing from $\frac{3}{8}$ to $1\frac{1}{2}$ oz. per cwt., are smelted with about one-and-a-half times their own weight of a basic slag, containing very much ferrous oxide, from a subsequent smelting, and about half their own weight of iron pyrites. The resulting products are a regulus of sulphuret of iron, containing $3\frac{1}{2}$ or 4 oz. of silver per cwt., and slags, containing $\frac{1}{10}$ oz. silver, which are set aside as useless. The raw regulus is roasted in heaps, and then smelted with one-and-a-half times its weight of rich slags from subsequent operations, containing from 8 to 9 oz. of silver. The regulus from this operation, as it is drawn off from the furnace into the crucible outside, is there stirred up with molten lead, poor in silver. From this results argentiferous lead (which is used over again in the same way, until it contains from $8\frac{1}{2}$ to 10 per cent silver,) and a lead regulus (sulphurets of iron, lead and

silver), containing of silver, 14 oz., per cwt. The slag from this second operation is what is used in the raw smelting. The lumps of metallic iron formed at the same time, and called iron swine, are worked up with the lead regulus, by being smelted together with the litharge and the hearths from the cupellation of the argentiferous lead. This operation produces lead containing only from 1½ to 2 per cent. silver, which is used in the treatment of the argentiferous regulus, as described above.

The lead regulus from this last smelting, which contains from 6 to 20 oz. of silver per cwt. is again smelted with lead, and its silver content is thus brought down to 4 or 6 ounces. It is then roasted and smelted with its own weight of poor slags containing 6 to 8 oz. of silver, when there results lead containing 4 to 5 lbs. of silver per cwt., which goes to the second operation; together with slags which are used in the first operation; and a copper regulus, containing 1 per cent silver, and 20 to 30 per cent copper. The latter is repeatedly smelted and treated with poor lead, until it contains not more than ½ oz. silver per cwt., when it is roasted and smelted to black copper.

The lead from the second operation, containing from 8½ to 10 per cent of silver, is cupelled in a German cupelling hearth, in which operation, hot air is used with great advantage. The resulting silver, and the rich silver ores from the mines, are refined in a furnace somewhat like the English cupelling furnace, the hearth of which rests on a well-arranged carriage, on which, after the operation is completed, the hearth is lowered on the one side, and the silver poured into the moulds standing prepared for it. The sweepings of this refinery, and the furnace hearths, are carefully smelted in a small furnace, and the products worked up, according to their contents in silver, in one or other of the operations already described.

The Eker copper mine consists of an irregular mass of iron and copper pyrites, situated on the strike of a fahlband, part of the impregnated rock of which is found to be so richly impregnated with copper pyrites as to be worth smelting. The ores are brought up by hand-picking at the mines, to about four per cent. They are then carted about four miles to the smelting house, where they are roasted in heaps. The roasted ore, with the addition of a little limestone, is smelted in shaft furnaces. The resulting regulus, of about 16 per cent, is concentrated by being again roasted and smelted, yielding a regulus of from 40 to 50 per cent. This

when again roasted and smelted produces black copper, which, being refined on the small hearth to *gahr* copper, is sold in Christiania or Hamburg.

The cobalt mine of Skuterud occurs on a fahlband, which has been traced about five miles, the rock being a quartzose mica schist. Layers of impregnated hornblende and actinolite schists are also of frequent occurrence. The rocks run north and south, and have a dip nearly vertical; sometimes inclined slightly to the east, sometimes to the west. In these rocks the following metallic minerals have been observed; magnetic, iron and copper pyrites, characterising the fahlband; cobalt glance, cobaltine, cobaltiferous mispickel, magnetic iron ore, graphite, and molybdenite are found more sparingly, impregnating the fahlband at certain places. These latter minerals do not occur in veins, but they are sometimes associated with quartz. They seem to form rather a succession of small layers, running parallel with the foliation of the rock. They are by no means generally distributed through the fahlband, and it has only been by taking out the whole mass of this, that the cobaltiferous portions have been got at hitherto. The fahlband itself has a breadth of from one to five fathoms, and it seems, toward the north, to be divided into two different bands, separated from each other by a large mass of dead rock. The mines were discovered in 1772, and have since been uninterruptedly worked, notwithstanding an extraordinary decrease in the value of the products. The treatment of the ores, as at present pursued, is as follows. The rocks are broken and sorted into rich and common ores. In the treatment of the smalls by means of a fall wash-work, washed ore of a very small size is produced, besides the above sorts. The whole of this ore is so finely disseminated, that it can only be advantageously treated by stamping and washing. The stamping mill is of the construction used in Saxony. The resulting stamp meal and slimes are concentrated first on percussion and then on sleeping tables. The rich ore treated in this manner yields per ton 86½ lbs. of *schlich*, containing 17.96 lbs. metallic cobalt. The common ore yields per ton 29 lbs. of schlich, containing 1.88 lbs. of cobalt. The poorer schlichs are further concentrated by being partly roasted, and smelted with an addition of some limestone and slag. The resulting slag is set aside. The regulus (sulpharseniurets of iron, cobalt and copper,) containing about 22 per cent metallic

cobalt, is roasted in reverberatory furnaces, and being mixed with the richer schlichs, which have also been calcined in the same way, forms what is called zaffre, containing about 30 per cent cobalt oxide. This is sent to market in England, where it is manufactured into cobalt oxide and smalt. A small quantity of the former product is manufactured on the spot in the humid way, but this quantity does not exceed one sixth of the whole amount of the cobalt oxide here produced in manufactured and unmanufactured products.

The fahlbands in the neighbourhood of Ertelien, and Ringerike, have not been so carefully studied as those of Kongsberg and and Skuterud; nevertheless it admits of no doubt, that the nickel mines of the former locality occur on impregnated zones of rock like the fahlbands. The deposits are irregular masses of magnetic iron pyrites containing two per cent of metallic nickel. Although a definite veinstone is not observable, it appears from the presence of selvages in various places, that the deposits partake of the nature of veins. Besides the nickeliferous pyrites, copper pyrites is produced at the mines in some quantity, but so contaminated with the former, as to be altogether useless as a copper ore. Occasionally, beautiful crystals of iron pyrites (pentagonal dodecahedrons), have been found, containing two per cent of metallic cobalt. The nickeliferous pyrites is sorted out at the mine, very pure, almost entirely free from rock. It is then roasted in heaps, and smelted in a shaft furnace with the addition of a little limestone. The resulting products are a very heavy slag, with is a basic silicate of ferrous oxide; a regulus of sulphuret of iron, containing about six per cent nickel, and iron swine, which collect in the interior of the furnace during the smelting, and interfere very much with its proper working. The regulus is again roasted in heaps and smelted, a more concentrated regulus with thirty per cent of nickel, resulting. The regulus, as well as the iron swine produced in both smeltings, are farther refined on a hearth similar to that used on the continent for refining copper. A farther scorification of iron takes place in this operation, and a regulus with fifty per cent of nickel and fifteen per cent of copper results, which after being ground to powder, is sent to market. It is mostly sent to Hamburg and sold to German nickel refiners. These mines were formerly wrought, and the pyrites roasted for the manufacture of copperas; it is only during the last fourteen years that they have been wrought for nickel.

Besides the four establishments here described, which are in full operation, there are a good many deposits connected with fahlbands, which are either abandoned, or have not as yet been worked. Of these the following may be mentioned—the cobalt mines of Svartefield, very similar in character to those of Skuterud, the copper works in Sognedalen, and on Kobberbergselven. There are also numerous localities of pyrites containing small quantities of nickel or cobalt, or both. The magnetic pyrites from Höiassen contains three per cent of nickel and six tenths per cent of cobalt; that from Rustand, six tenths per cent of nickel and one per cent of cobalt; that from Olafsbye one per cent of cobalt, and the iron pyrites from Sätersberg one per cent of cobalt.

There are however other deposits of pyrites in this formation, whose connection with fahlbands is more uncertain. Such localities for instance are those of Meinkier Grube, containing copper pyrites, nickeliferous magnetic pyrites and cobaltiferous iron pyrites; and Steenstrup's Kiesgrube, on Lyngdalselven, containing the same minerals. Dahll* looks upon these as contact deposits, and connects them with the intrusion of so-called gabbro.

Closely allied in nature to the fahlbands above described are certain other zones of impregnated rock, occuring in this formation. The impregnating material, however, is magnetic iron ore, the bands containing which scarcely possess such a length in the direction of the strike, as the fahlbands. Moreover the magnetic iron ore, besides occurring in this finely divided state, forms considerable beds in the impregnated zones referred to. It is from these deposits that the iron works of Sweden and Norway are supplied with the material from which their celebrated iron is prepared. These deposits are of frequent occurrence in the south of Norway, especially in the neighbourhood of Arendal, where there exist eighteen different beds of ore, which well repay the cost of working them. They are situated in a narrow straight zone, which runs parallel with the coast for a distance of six miles. The prevailing rock is gneiss, which graduates into mica and hornblende slate. The ore is magnetic oxyd, usually without any admixture of ferric oxide. The minerals most frequently accompanying it are augite, hornblende, garnet, epidote, calcspar, and the three essential constituents of the gneiss, especially mica. Besides these, about thirty other minerals have been mentioned as having been found in the deposits, but these are

* Om Kongsberg's Erts District; Christiana, 1860.

of rarer occurrence. The masses of ore appear flattened, almond-shaped, and drawn out parallel with the foliation of the enclosing rock. In the direction of the strike, they thin out, or branch off and disappear. Their average thickness is from two to six yards, but it sometimes reaches twenty yards. The iron works of Ulefoss, Fossum, Fröland, Näs and others, are all more or less dependent on these deposits for their ores. The situations of these iron works seem to have been chosen, less with a view to economically transporting the ore, than to taking advantage of the magnificent water powers, which exist everywhere in Norway. The fuel is charcoal, mostly from pine, and it has also to be carted considerable distances. The blast furnaces used, are partly similar to those used in Sweden, and partly to those used in Germany. They are thirty feet high, from four to four and a half feet wide at top, and from seven to eight at their widest part. The percentage of metallic iron contained in the mixture to be smelted, ranges from 25 to 42 per cent, and the average production of raw iron from a furnace is 2½ tons daily. 1⅔ tons of charcoal are consumed in the production of one ton of iron. The refining takes place on what are called "frisch hearths," and hammers are used in the further mechanical treatment of the resulting lumps of malleable iron. The iron produced, is like the Swedish, celebrated for its purity. It is shipped to Hamburg, and from thence mostly to America.

Large quantities of titaniferous iron ore occur at Ekersund and Snarum; that from the former locality contains 43 per cent of titanic acid. Phosphate of lime has also been worked and exported from the neighbourhood of Kragerö. With these I must close this sketch of the economical minerals of the primitive gneiss formation of Norway, and turn to compare it in its various features with that of Canada.

The parallelism of the Laurentian formation of Canada with the gneiss of Scandinavia was long ago pointed out by Sir William Logan, and in the more recent reports of the Geological Survey, especially those of 1853–56, we find the features of the Canadian formation fully described. The rocks there occurring are essentially the same as those of Norway. Keilhau's characteristic gneiss corresponds to the granitic or micaceous gneiss of Canada, and the hornblende gneiss of Norway is the syenitic or hornblendic gneiss of the Laurentian formation. Even the *eye gneiss* variety appears to exist here, and from the description, to be syno-

nymous with the reticulated gneiss. In corroboration of this I take the liberty of quoting the following remarks of Sir William Logan:—"In the Reports of the Survey, the Laurentian rocks have been described in general terms, as gneiss, interstratified with important masses of crystalline limestone. The term gneiss, strictly defined, signifies a granite with its elements, quartz, feldspar and mica, arranged in parallel planes, and containing a larger amount of mica than ordinary granite possesses, giving to the rock a schistose or lamellar structure. When hornblende, instead of mica, is associated with quartz and feldspar, the rock is termed syenite, but as there is no distinct specific single name for a rock containing these elements in a lamellar arrangement, it receives the appellation of syenitic gneiss. Gneiss rock then becomes divided into two kinds, granitic and syenitic gneiss, and the word gneiss would thus appear rather to indicate the lamellar arrangement than the mineral composition. Granitic and syenitic gneiss were the terms applied to these rocks in the first Reports; but as granite and syenite are considered rocks of igneous origin, and the epithets derived from them might be supposed to have a theoretical reference to such an origin of the gneiss, while at the same time it appears to me that the Laurentian series are altered sedimentary rocks, the epithets micaceous and hornblendic, have been given to the gneiss in later Reports, as the best mode of designating the mineral composition and lamellar arrrangement, without any reference whatever to the supposed origin of the rocks. (Report 1853–56, pp. 49 and 50.)

Further "The space between them (the bands of limestone) is occupied by gneiss, the banded structure of which is visible in a vast number of places, but a large part of the rock is coarse grained; the feldspar being in individuals, frequently attaining an inch and sometimes more in diameter, while the mica and the quartz, often accompanied by hornblende, and the former sometimes replaced by it, are distributed among the feldspar in such a manner as to give a reticulated aspect to the surface. Beds of this character are sometimes thin, but when thick and massive, which they usually are, they might upon a first inspection be mistaken for igneous instead of altered rocks. Upon a careful study of the case, however, it will be perceived that this reticulated structure is accompanied by an obscure arrangement of the meshes of the net-work, into parallel lines, which are found

to be conformable with the more distinctly banded portion of the strata." (*Ibid*, p. 9–10.)

Besides gneiss, the following rocks are mentioned as occurring in the Laurentian system. A crystalline aggregate of feldspar and quartz, granite in veins, mica and hornblende schists, chloritic gneiss, quartz-rock or quartzite, hypersthenite, serpentine, crystalline limestone, greenstone, hornblende rock, besides syenite and porphyry, which latter intrusive rocks however belong to a later period. These rocks are, on the whole, the same as those occurring in the primitive gneiss formation of Norway. Granite however does not seem to occur in masses running parallel with the other rocks, unless we include under this denomination the above mentioned crystalline aggregate of feldspar and quartz. The hypersthene rocks described by Mr. Hunt in his interesting Report 1855, seem to be of a character similar to those occurring in Norway, and there described as gabbro and euphotide, however much the latter rocks, in their true types, differ from hypersthenite. The confusion existing among mineralogists regarding the nature of these rocks seems still to prevail, notwithtanding the able and exhaustive work of Mr. Hunt on the subject. As a proof of this, I may refer to a recent paper by Dahll on the ore district of Kongsberg, where there is a rock described as gabbro, which is composed of "violet or brownish labradorite and dark green hornblende. The color is that of the hornblende, consequently dark. Diallage, which is known by its shining lustre, is perhaps oftener present than has hitherto been demonstrated; ilmenite is characteristic; and magnetic pyrites occurs frequently; with these, a little brown mica is frequently remarked." *Om Kongsberg's Erts District*, p. 16. Gabbro is commonly described as "a crystalline, granular or sometimes schistose mixture of feldspar or saussurite with diallage or smaragdite;" *Cotta: Gesteinslehre*, p. 53. It is difficult to conceive how the above described rock resembles gabbro; unless as Dahl further remarks concerning it, "labradorite is decisive of gabbro."*

(*Editor's note, by* T. Sterry Hunt.)

* The name of gabbro, originally employed by the Italians to designate a diallagic serpentine, is, by most modern authors, applied to a rock composed of a triclinic feldspar (such as labradorite) with pyroxene. When the latter is of the variety called hypersthene, the rock takes the name of hyperite or hypersthenite, but when it assumes the form of dial. lage or of smaragdite, the name of gabbro is given to the rock. In smar-

The serpentines of the Laurentian formation, are described by Mr. Hunt as of a paler colour than those of the metamorphic series. He failed to detect either nickel or chrome in them, and in his examination of a serpentine said to be from Modum in Norway, (probably that of Snarum, from its being associated with ilmenite), these metals were also absent. This is consequently another point of resemblance between the serpentines of the Laurentian formation and those of the Norwegian gneiss formation, distinguishing both of them from the serpentines of the metamorphic series. The crystalline limestones of the Laurentian formation appear to be much more frequent, and more regularly interstratified than those of the Norwegian gneiss formation, and this is one of the features in which a difference is remarkable between the two formations. In the Laurentian, as in the Norwegian gneiss formation, the gneiss is the prevailing rock, and interstratified with most of the rocks above mentioned. The strike of the strata of the Laurentian formation is most generally N. E. and S. W; or W. N. E. and S. S. W. and the dip much inclined, though perhaps generally less so than those of the Norwegian gneiss formation.

With regard to the economic minerals of the Laurentian formation, the existence of fahlbands similar to those of Norway seems to be uncertain. Still we find in the Geological Reports, descriptions of red-weathering rocks, which bear no slight resemblance to them, and should they be found to possess the character of fahlbands, a search for economic minerals in connection with them, would most likely be successful, because the metalliferous area is limited and well defined. The colour of the rock would assist in tracing it along its strike, and any veins crossing it or occurring in it would be easily recognised. Whether the pyrites of Daillebout occurs in connection with a fahl-

agdite we have an intimate mixture of pyroxene with hornblende, affording a transition to rocks composed of triclinic feldspars and hornblende; in other words to diorite and diabase. Those rocks which consist of such feldspars, with diallage or hypersthene, I arrange under the generic name of dolerite. When the feldspar in these predominates, and is granular or compact, including masses of diallage, the rock has been incorrectly called euphotide. This name was originally given by Haüy to a mixture of diallage or smaragdite with what he called saussurite, a mineral which by modern lithologists has been strangely confounded with compact feldspar, from which it is distinguished by its much greater gravity and hardness, and is, as I have elsewhere shown, a compact zoisite or epidote. The true epidotic euphotides however sometimes in-

band is uncertain; looking to the character of the mineral, which contains nickel and cobalt equivalent to 0·55 per cent of the oxides of these metals, I think it is very probable. The cobaltiferous pyrites of Brockville seems, on the other hand, to be an independent deposit, seeing that it occurs in such extraordinary quantity. I found the compact variety to contain metallic cobalt corresponding to 0.50 per cent cobalt oxide. This result was confirmed by Mr. Hunt, who found 0·52 per cent. In the neighbourhood of the copper mine of Escott, I found no traces of anything resembling fahlbands, so that I am inclined to parallelize this locality with the pyritiferous deposits above described as occurring at Meinkier and Lyngdalselven, independent of the fahlbands. In no particular does the Laurentian formation so much resemble the primitive gneiss formation of Norway, as in containing those enormous deposits of magnetic iron ore, which occur in the townships of Madoc, Marmora, Crosby, Hull, &c. In extent however, the Canadian deposits far surpass the Norwegian. In like manner, the deposits of titaniferous iron of Bay St. Paul far surpass in extent those of Snarum and Ekersund. The phosphate of lime of Burgess and Elmsley, differs from the deposits of the same mineral in Norway, in being associated with crystalline limestone, and in occurring in far greater quantities.

I have thus endeavoured, as far as my knowledge of Canadian geology permits, to parallelize the various features of the Laurentian and primitive gneiss formations. Doubtless many who are more intimately acquainted with the geology of this country will be able to recognize further points of resemblance, and in view of this possibility, I have described the Norwegian formation at greater length. I shall be guided by the same considerations in describing the two other groups of rocks which I have yet to compare with their Canadian equivalents. I cannot however

clude triclinic feldspars, and thus pass into diallagic dolerite or gabbro. The feldspathic rocks of the Laurentian system, above referred to, consist of labradorite, andesine, or some related feldspar, and often include pyroxene, which from a variety like sahlite, passes into hypersthene and diallage, giving rise to hypersthenite, and to the incorrectly named gabbro and euphotide of most modern lithologists. The rock from Kongsberg, as above described by Dahll, except in the substitution of hornblende for pyroxene, agrees closely with a variety of diallagic dolerite common in the Laurentian series. For further illustrations of this subject, see a paper on Euphotide and Saussurite, in the American Journal of Science for March 1859.

leave this division of my subject, without referring to one important difference which exists between Norway and Canada, in regard to the economic minerals of this group.

In the former country, despite its comparative poverty, those deposits are well developed. In Canada they remain dead and unproductive. Why they should be so, it is difficult to say. Canada has the advantage of Norway in having richer mineral deposits, better means of transport by its canals and railways, and a much greater command of capital. With regard to fuel, both charcoal and imported coal, it is equally as well situated as Norway, and although labour is much dearer than in the latter country, there is every prospect of this disadvantage becoming less considerable. The severity of the winter presents no greater hindrances to mining in Canada than in Norway, and Canada is rapidly acquiring the skilled labour essential for successful mining. In view of these considerations therefore, one may hope that the great accumulation of economic minerals in Canada will soon become one of her most important sources of national wealth.

II. The Primitive Slate Formation.

A: *The Quartzose Group.*

The district in which the above-named group of rocks is principally developed is that of Tellemarken, in the south of Norway, celebrated by tourists as containing perhaps the most wild and picturesque scenery in the north of Europe. There exist also northward from Trondhjem, some districts, where the same group seems to prevail, but these cannot be compared with that of Tellemarken, either in extent or economic importance; nor have they been studied or described so minutely.* Naumann entitled this district, the Nummedal and Tellemarken Quartz Formation; Keilhau described it as the Goustafjeld Region, from the mountain which is its most distinguished topographical feature; while Dahll somewhat indefinitely calls it the Tellemarken Slate Formation.

The rocks which constitute this group are the following:

1. *Quartzite or quartz slate.* This, the most widely distributed rock of the group, occurs in the most multifarious varieties. Pure quartz, with a granular structure and glassy lustre, of con-

* According to Keilhau, the district in West Finmark and Quænanger, in which the Alten Copper Mines occur, belongs to this group. It is probable also, that another district to the east of the North Cape is of the same formation.

siderable transparency, and of a white or greyish-white colour, is to be found in beds of great thickness. Fine-grained quartz, with a fatty lustre, and rose-red or flesh-red in color, is also observed in equally powerful beds. The most common varieties are however the splintery, grey, and slightly micaceous quartzites, which are known as quartz slates. Amongst the more impure varieties, talcose, feldspathic, and hornblendic quartzites are to be distinguished.

2. *Mica schist*, differing considerably in general character from that which occurs in the Primitive Gneiss Formation. The broad-leaved very micaceous variety, with garnets, which is common in that formation, has not been observed at all in this quartzose series. In the constitution of the mica schist belonging to the latter, quartz greatly preponderates, and the rock differs from quartz slate, only in containing a somewhat larger quantity of silver-white or brownish-black mica.

3. *Gneiss* may be also said to occur in this group, but of a character widely different from what is usually understood by this term. It is finer grained and less slaty than the characteristic primitive gneiss, while the feldspar and quartz, and especially the latter, greatly preponderate in quantity over the mica. This latter mineral, which plays such an important part in the composition of ordinary gneiss, is very little developed, and hornblende is never found replacing it; so that nothing resembling hornblendic gneiss is found in this group.

4. *Hornstone and hornstone porphyry*, passing into jasper, often occur, and seem to consist of the same minerals, and in the same proportions, as the two last named rocks, but so fine grained that the species are no longer recognizable. The mica schist is seen in some places to pass into a grey, coarse, splintery, quartzose hornstone; while the gneiss gives a red or brown hornstone, with fine splintery, and nearly smooth fractures.

5. *Hornblende slate.*

6. *Talc slate.*

7. *Chlorite slate.*

8. *Clay slate.*

9. *Limestone* has only been remarked at one place in the whole group, where a thin bed of granular yellowish-white limestone, occurs in the quartzose gneiss.

10. *Greenstone and diorite*, composed principally of albite and hornblende, occur in large and important masses.

11. *Granite* does not seem to occur interstratified with the members of this group, but frequently intersects them in the form of veins, and also forms irregular masses.

12. *Conglomerates and breccias* occur in such quantity, and of such peculiar characters, as to constitute a distinguishing feature of the formation. The whole of the rocks already named as forming part of this group, but especially the quartzites, often contain beds or irregular masses, having the aspect of conglomerates; which are made up of fragments of the respectively enclosing rocks, cemented together either by a micaceous or talcose substance. The fragments are more or less rounded, and often of oblong forms; they generally lie parallel with each other, but very often bear little resemblance to boulders.

The rocks just enumerated, form layers, often of enormous thickness, which alternate with each other, forming parallel groups, in which one or the other of them (generally the quartz), predominates. The fine and coarse grained greenstones or diorites of the formation, are most generally in layers running parallel with the other rocks. They sometimes however occur as veins cutting these, and more frequently as irregular masses. The greenstone beds are often of great extent, and pass through gradual transitions into the neighboring rocks. A layer of diorite occurs in the parish of Skafse, having a thickness of 1000 feet. In the middle it is granular, but towards each side, it gradually assumes a slaty texture. It has also been remarked of other greenstone layers in the group, that they assume a slaty structure, as they approach the rocks above or below them. Keilhau has the following remarks with regard to the extent which these greenstone or diorite rocks occupy in the series before us. "We may obtain a good idea of the extent to which this member of the group is developed, from the district west of Bandag Lake. On the road to Mo church, we are surrounded by rugged mountains about 2500 feet high, and these from the bottom of the valley to their summits, consist of the same mass of diorite, which has here a breadth of about two geographical miles."

The conglomerates, of which mention has already been made, have such an important bearing on the question of the origin of the primitive slate formation, that I may be excused for inserting here, at length, a translation of Keilhau's description of them. These conglomerates have been observed: 1. above Hjærdal church; 2. on the road from Fladdal to Manddal; and, 3. on

the road from Guldnæs to Berge, in Morgedal. "The first locality in which the conglomerate quartzites occur in repeated alternations with hornblende rock (diorite), has been described by Naumann (Beitrage I, 79). The quartz layers there consist of what often appears to be a very fine-grained micaceous sandstone; in which harder round or oval concretions, sometimes feldspathic, sometimes quartzose, and sometimes of still more varied natures, are imbedded. The softer cementing matter is frequently worn away, so that the harder masses stand out from the rock, like hemispheres. The smaller and more varied in their nature these concretions (which appear formed exactly like boulders) are, the more talcose the enclosing mass becomes; whereby the slaty texture of the quarzite becomes undulating and confused."

The second of the above mentioned localities is on the Mandœla, a short distance before it falls into the Sillegjord. The bluish-grey, very pure and crystalline quartzite which here occurs, is for a considerable distance around, apparently unstratified, and cannot strictly be defined as quartz-slate. It forms powerful masses, in the midst of which large and indistinctly limited portions, are more or less thickly impregnated with small rounded portions of quartz of the most different shades of color, from white to red and dark-grey. Some of these are quartz, others jasper, while others resemble hornstone; but all of them, even those which most closely resemble their quartzose matrix, are sharply defined, and appear like pebbles cemented into it. The fact that these portions are not arranged as separate layers, but spread out as irregular areas, in the massive and crystalline quartz, is to be regarded as unfavorable to the opinion of the mechanical origin of these conglomerates." "At the third of the above mentioned localities, the conglomerate is also enveloped in a large group of quartzite, which contains besides, only a few isolated masses of greenstone. The perfectly boulder-like concretions of the conglomerate bed, which range from the size of a hazelnut, to that of the human head, are here of the same sort of greyish-white splintery quartz, which forms the strata of the whole surrounding group. A few of them only are reddish, and remind one of the jasper-like masses which appear to be generally associated with these conglomerate quartzites. At the Hjærdal locality, already described, Naumann found whole layers of jasper, close to the conglomerate. The cementing material of the conglomerate betwixt Guldnæs and Berge is argillaceous, and small

in amount; and is certainly to be regarded as analogous to the small beds of clay slate, which occur as regular layers between the thick quartz strata, at other points in this neighborhood. Although the foliation of the pure quartzite is retained in the conglomerate, which is many fathoms thick, this nevertheless, like that below Manddal, does not appear to occupy any well-defined horizon in the stratification. In place of forming a continuous zone along the strike, it appears rather to be a comparatively short and irregular mass.

Occurrences of this sort, which may be regarded as belonging at once to the quartz and to the mica schist, are found to a considerable extent on the northwest of Sillegjord Lake. Here, on the boundary of the primitive gneiss formation, at several points where the quartzite begins to replace the mica-schist, we find layers in which the quartz occurs in the shape of long cylinders as thick as the finger, and rounded off at both ends, as elongated almond-shaped masses; or in the form of boulders, imbedded in a cement of mica schist.

Some time since, Naumann directed attention to the fact that the amount of talc contained in the cement is greater, the more the conglomerate is varied in its composition. I have often confirmed this, and have moreover remarked that the talc seems to stand in some intimate connection with these problematical rocks. This may be the reason why they have nowhere been found more frequently than on the road between Berge in Brunkeberg, and Qvale in Höidalsmo; where the quartz beds are associated with other rocks, and especially with those of a talcose nature. The most remarkable conglomerate of this district, as well on account of its composition, as its thickness, is splendidly exposed in a narrow ravine called Ormebrækjuvet, which cuts across the conglomerate, inclined at an angle of 70°. A road and a rivulet here pass through the ravine, and the rocks are seen in profile on both sides. In a coarse mass of quartzose talc-slate, sometimes more or less micaceous or argillaceous, different varieties of quartz are imbedded; which have the form of small boulders, or are elongated in the direction of the stratification. Besides these, there may be remarked in the slate, a multitude of red and very fine-grained feldspathic concretions, which betray here and there a gneissoid nature, caused by dark mica-like streaks. These feldspathic concretions are the more remarkable, since hitherto, no rock far or near, has been discovered bearing the slightest resemblance to them,

although their oval form, in some parts, and the fact that they are sometimes bent in the direction of the undulations of the surrounding mass of slate, would favor the view that they are pebbles from an older rock. They become still more remarkable when we observe them repeated at very distant points. Exactly similar gneissoid concretions with those of Tellemarken, of which we here speak, have been remarked in the conglomerate rocks of North Trondhjems Amt. The boulder-like fragments in the rock of Ormebrækjuvet, attain the size of a closed fist, and lie usually so near to each other, that they constitute the greater part of the whole rock. Eastward from Holvig, towards Vaæ, down in Vestfjorddalen, conglomerate talcose rocks also are found. Here, in a talcose slate, a layer was observed including larger and smaller kernels of quartz, sometimes almond-shaped, at other times more irregular; and one part, apparently segregations from the slate itself. The foliated portions of the rock are bent and rolled around these masses. On the weathered surfaces of the rock, these irregular, and, as it were, imbedded portions, have a lighter color than the surrounding mass. There is probably some feldspar present in these, as well as in the gneissoid concretions already mentioned, and their lighter colour may be due to kaolin from its decomposition. Southward from Holvig, a layer of similar rock occurs, which belongs to the clay slate."

"Conglomerates which belong to the chloritic rocks in this district, are found at various places in the upper part of Vestfjorddalen, in the neighborhood of the cataract Rjukanfoss. From Vaæ, over and beyond Maristigen, a hard chloritic slate predominates; which appears often as if it had been torn in pieces, and then joined together again, and which contains other very curious aggregations. There may be observed masses like serpentine, portions of greenstone, &c., combined in the most varied manner with the slate; while many phenomena render this place suitable for a more minute study of these conglomerates."

"Farther on, at several points in the neighbourhood of Aamdal, it may be observed that the mica schist contains concretions having the appearance of imbedded fragments, and with an aspect, from which one must believe that it has once been broken up, and its pieces afterwards irregularly joined together. For example, there is exposed between Aamdal Copper-work and Skafse church, a large area of this character. The rock is a fine slaty quartzose mica schist, which, as if by an internal breaking-up,

has acquired a well marked brecciated structure. Only a few of the recemented pieces have rounded angles, the most of them being sharp-cornered. The whole rock, but especially the fragments, contain some feldspar. I will mention one other instance, from which it appears that hornblende schist may also sometimes contain fragments of foreign masses. This is the case on Skafseberg, over which the road leads from Mo to Skafse church. Here the concretions are again feldspathic, and even gneissoid, but most of them resemble rather the rudiments of small bent layers or beds, than fragments cemented into the hornblende schist."*

As before remarked, the quartzites or rocks allied to them, such as the quartzose mica schists and gneiss, constitute by far the greatest portion of the group. Next in frequency and extent, the greenstones or diorites may be placed; after these the hornblende, talc, and chlorite schists, and the clay-slates; and lastly, the conglomerates.

Foldings of the strata in the quartzose group, have been observed in various places, but they do not approach, in intricacy, to the contortions of the gneiss formation. The strata are seldom found horizontal, and generally have a dip of more than 45°; although they do not seem, generally, to be so near to the vertical as those of the gneiss formation. The direction of the strike varies much more than in the latter, but parallel groups have been traced upwards of eight geographical miles, on the strike. In some places, an approach to a regular succession of the rocks has been observed, but the particulars related are by no means conclusive.

As before mentioned, the scenery of this district is of the most wild and rugged nature. The Fjelds, consisting of quartz rock, sometimes present massive peaks, rising in the shape of terraces one above the other; which latter form is caused by the outcrops of the highly inclined quartz beds. Goustafjeld itself, is a huge peak, rising to the height of 7000 feet, and presenting from a distance, a peculiar furrowed appearance, the cause of which is thus explained by Keilhau:—"The upper part of Goustafjeld is formed of two varieties of quartzite, one of which is the preponderating, and the other the subordinate constituent. The former belongs to the purer varieties of the quartzite, and resists de-

* Geæ Norvegica, I. 430.

composition. In the latter, which easily disintegrates to a coarse sand, particles of feldspar are more or less abundantly disseminated. From that part of the mountain where these rocks are found *in situ*, which is about 300 feet perpendicularly beneath the sharp ridge forming the summit, going upwards, there is observable only a succession of very regular beds, having a dip of from 20° to 30°. The mountain is here so sharply peaked, that the beds crop out, as well on the side of the direction of the dip, as on the opposite side. If now the relations of the rocks were as usual, the feldspathic quartzite would be found to form more or less isolated layers, between the strata of the preponderating rock; but in place of this, the feldspathic quartzite extends in an entirely opposite direction through the mass of the prevailing rock. It goes right across the strata, and that without in the least (like veins) interrupting the continuity of the several beds, because these otherwise different rocks, at their junction, run into each other, the pure quartz gradually becoming feldspathic. The consequence of this remarkable relation is very striking. On account of the feldspathic quartzite being so easily disintegrated, and the pure variety, on the other hand, resisting so well, there are produced, where the former crops out, cuts on the ridge, and furrows on the sides of the mountain. On account of the height of the mountain (7000 feet), these furrows remain filled with snow throughout the whole year, and are recognisable from a great distance. Thus Goustafjeld preserves the marked features which distinguish this surprisingly furrowed peak, for those who view it from the heights of Hallingdal or Hadeland."

"It is a characteristic trait of this group, as well as of the other sections of the country, analogous with it in geological character, and worthy a mention at the outset, that it is especially well supplied with copper ores."* This great prevalence of copper ores has given rise, since the beginning of the 16th century, to the establishment of six different copper works or mining establishments; all of which however, with but one exception, that of Aamdal, are abandoned. In describing the various mineral deposits, I shall only refer to those of most importance, neglecting altogether the innumerable localities of less value. The mines about to be described are those belonging to the copper works of Guldnæs, Aamdal, Hvideseid, Sauland and Hovindbygden.

* Geæ Norvegica I, 441.

The deposit on which the Guldnæs mines occur, is probably the most important of the whole district. It is situated on the southwest side of Sundsbarm Lake, in the parish of Sillegjord, at least 1500 feet above the sea, and inaccessible, unless to the foot traveller. It has the form of a layer, and lies between a bed of quartzite, and one of clay slate. It has a length of about 100 fathoms, and a breadth of about 100 feet, and is composed of a flesh-red and sometimes greenish-white aggregation of quartz, feldspar and talc; in which purple copper and copper pyrites are more or less abundantly disseminated. The ore is found in irregular nests and veins, quartz accompanying it in the latter. These irregular bunches of ore are frequently found in such quantity, as to render the whole mass of the layer worthy of excavation. There is not much of the rock with finely disseminated mineral, and the ore is much more suited for being dressed by means of crushing and jigging, than by stamping and washing. The latter processes were nevertheless those employed when the mines were being worked, and this may partially account for the unsuccessful result. The copper ores occurring here are argentiferous; the metallic copper resulting from their treatment, containing one per cent. of silver.

The mines belonging to the Aamdal copper works are very numerous; the most important of them being Hoffnung mine, Næsmark mine and Mosnap mine. The works themselves, are situated 1300 feet above the sea, on the river called Værkselven, in the parish of Skafse; which is subordinate to that of Mo. Hoffnung mine lies about 150 feet higher, near the junction of a gneissoid granite, of eruptive origin, with the primitive slates. The two lodes containing the ore, occur on both sides of a layer of hornblende schist; which varies from two to six feet in thickness, and has a fall of from 50° to 60° to the W.N.W. They run parallel with the strata, and the lode underlying the hornblende schist is the most important. It has a thickness of from four to thirty inches; the vein-stone is quartz, and is well filled with copper pyrites, generally massive, seldom finely disseminated. In the deeper workings, the lode almost contains as much purple copper as copper pyrites, with no admixture of iron pyrites, or other mineral, except a little feldspar. The ore, on being excavated, was crushed by flat-faced hand hammers, brought up, by jigging, to 30 per cent., and then smelted or sold. Næsmark mine is like Hoffnung, situated in the immediate neighborhood of the work, on a granite vein,

two fathoms thick, which intersects primitive slates. In this vein, (from which also side veins shoot out into the adjoining slates,) there occur, running in a direction at right angles with its line of strike, numerous lodes of from two to six inches thick, filled with quartz and copper glance; the latter containing six oz. of silver per cwt. The granite in the neighborhood of these quartz veins is also impregnated with copper glance, to such an extent, as to make it amply worth stamping and washing. This mine is a most promising one; is altogether new, and the granitic vein has been discovered at a distance of three miles from it, at Bergland mine; where it bears copper glance in exactly the same manner as at Næsmark. The ore from the quartz lodes of this mine was brought up by hand-jigging to 70 per cent., and then either smelted or sold. The finely divided ore was worked by stamping and washing. Mosnap mine is about 10 miles distant from the work, and probably lies 2000 feet above the sea. The rocks in the neighborhood are the gneiss, mica schist, and hornblende schist, peculiar to the quartzose group. The mine itself is situated on a granitic vein, which contains irregular quartz layers. Copper pyrites, purple copper, and molybdenite are disseminated through it, but are more especially associated with the quartz. The vein itself has a thickness of several feet, and were it more conveniently situated, would doubtless be considered a very valuable deposit. It is only very lately that the ores from these mines began to be treated by crushing and jigging, and then sent to market. They were previously stamped and washed, at least the poorer sorts, and the products were smelted at the works, along with the richer ores. The smelting, however, even after the discovery of a vein of fluor spar, which was used as flux, was carried on but with indifferent success, on account of the highly quartzose natures of the ores. After the introduction of jigging, the ores were treated as follows, at the smelting works:—The copper glance from Næsmark was calcined in a reverberatory furnace, and the silver extracted according to Ziervogel's method; by treating it with water, and afterwards precipitating the dissolved silver by metallic copper. The lixiviated residue from this process, was then smelted together with the rich copper pyrites and schlichs from the Hoffnung mine, (previously calcined in a reverberatory furnace), in a small shaft furnace. From this operation, there resulted a slag, very rich in ferrous oxide, which was rejected; a regulus with 55 per cent. of copper, and a small

quantity of coarse copper. The regulus was roasted and again smelted; coarse copper, and a small quantity of thin regulus being produced. The coarse copper was then refined on the small German gahr hearth.

The two most important mines belonging to Hvideseid copper-works, occur in the parish of Hvides, and are as follows: Haukum mine, situated beneath Brokefjeld, in the neighborhood of a powerful granite vein, wherein orthoclase and oligoclase are observable. This vein intersects primitive slates, and is accompanied by several irregular granitic masses, on the largest of which the mine occurs. The granite mass is more or less impregnated with purple copper, and this is occasionally accompanied by metallic silver in fine threads; which occur in small cavities, with crystals of laumontite and stilbite. The crystals of laumontite form fan-like groups, which are coloured green by the oxyd of copper A very small scale of gold has been found in this mine. The following minerals are also met with: magnetic iron ore, molybdenite, garnet, epidote, and traces of copper pyrites.* Bandag mine is situated on the precipitous south side of Bandag Lake. The surrounding rock bears a strong resemblance to granitic gneiss, but nevertheless differs from it in having a larger quantity of quartz, and, as a consequence, a lighter colour. The ore deposit lies parallel with the stratification of this rock, and consists of a granular mixture of quartz, mica, copper pyrites, purple copper, highly argentiferous galena, zinc blende, and a little feldspar. Metallic silver in threads, has also been remarked in this mine. The ores from these, and other mines, were for a considerable time smelted at the Hvideseid works, and although the smelting was ultimately abandoned, the operation was more successful here than anywhere else in the district, being carried on for a longer time.

The Sauland smelting works were built for the copper ores occurring at Guli, in the parish of Sanland, which is subordinate to Hjærdal. The lode, which occurs in a coarse grained diorite, is sometimes of considerable thickness, and consists of quartz well charged with purple copper. Here, too, the smelting was unsuccessful, even more so than elsewhere in the district.

The ore deposits near Horindbygden in the parish of Tin, are described by Keilhau,† and are the following: I. That of Rödsöe

* Dahll, Om Telemarken's Geologie, p. 27.
† Geæ Norvegica, p. 442.

consists of a layer of quartz, containing partly massive and partly disseminated copper glance. The thickness is about three feet, the strike north and south, and the dip vertical. It is traceable over a length of 200 feet. II. That of Daarudberge contains also some copper glance in a quartz bed, two feet thick, but appears less rich than that of Rödsöe. III. That of Vashoed is a quartz layer of six inches thick, with a strike north and south, and contains some purple copper. The adjacent rock is full of magnetic iron ore, disseminated, and crystallized in very small octohedrons.

A deposit of iron ore has been described by Dahll,* as occurring in Nissedal, between the farms Aarhuus and Söfdestad. It appears to be a vein, and runs from north to south over the hill called Grubeaasen. It dips 30° to 50° towards east, and has a thickness of nine feet on an average. It is exposed for a distance of 210 fathoms, between two small valleys. In the deepest portion, it consists of magnetic iron ore, but on ascending the hill from both sides, the magnetic ore becomes mixed with iron glance, (specular iron ore); the quantity of which gradually increases, until, at the highest part, iron glance alone is present. The surrounding slates are mica schist, containing a little hornblende, hornblende schist and feldspar, and containing portions having a granular structure. The vein is more distinctly separated from the side rock, where it consists of magnetic ore, than when the iron glance is present. The latter penetrates into the side rock, where it replaces the feldspar. It is thus possible to find hand specimens consisting only of iron glance and hornblende. Quartz and desmine are present in the vein. It is impossible to determine with certainty the age of this deposit, but it is intersected by granite veins.

In concluding this description of the quartzose division of the primitive slate formation, and of its economic minerals, as developed in Norway, I think that the following features may be mentioned as characteristic of the group. I. The preponderance of quartzose rocks; II. The presence of conglomerates of a peculiar character; III. The prevalence of copper ores, of a high percentage, unmixed with iron pyrites; the veinstone accompanying them being quartzose, and therefore difficultly fusible; IV. The presence of iron glance in the few deposits of iron ore occurring in the group.

The equivalent of these rocks in Canada appears to be the

* Om Telemarken's Geologie, p. 31.

Huronian formation. In support of this view I shall avail myself of the minute descriptions of the latter to be found in the Reports of the Geological Survey, and particularly in Sir W. E. Logan's Report on the north shore of Lake Huron. The rocks of the Huronian formation are, by these authorities, described as follows:

"The quartzites have sometimes the aspect of sandstones, but at other times lose their granular texture, and become a vitreous quartz. Not unfrequently the quartzite is thin bedded, and even schistose in its structure, and it sometimes holds a little mica, passing into a variety of mica schist.

"These quartzites often become conglomerate, enclosing pebbles of quartz and various coloured jaspers. These pebbles are sometimes arranged in thin layers among fine grained beds. At other times, the conglomerates form thicker beds, which swell into mountain masses; including great portions which contain blood-red jaspers in a white matrix, constituting a very beautiful rock.

"In addition to these, there are conglomerates of a distinctly different character, belonging to this formation. They are composed chiefly of syenitic pebbles, held in a grey argillo-arenaceous cement, which is more frequently of a greenish color, from the presence of chlorite. The pebbles, which are of reddish and grey colors, vary greatly in size, being sometimes no larger than swan shot, and at others, boulders rather than pebbles, measuring upwards of a foot in diameter.

"The quantities in which they are aggregated vary much. They sometimes constitute nearly the whole mass of the rock, leaving but few interstices for a matrix, and sometimes on the contrary, they are so sparingly disseminated through considerable portions, as to leave spaces of several feet between neighboring pebbles; which are still, in such cases, often several inches in diameter. With the syenitic pebbles, are occasionally associated some of different colored jaspers. The matrix appears often to pass on the one hand, into the grey quartz rock, by an increased proportion of the arenaceous particles; and on the other, into a thin bedded greenish fine grained slate, which is sometimes very chloritic. In a third form, the matrix is scarcely distinguishable from a fine grained greenstone In the slate, the stratification is often marked by slight differences of color, in the direction of which, it is occasionally cleavable. The bands in other instances, are firmly soldered together, but in both cases,

joints usually prevail, dividing the rock into rhomboidal forms, which are sometimes very regular."

These slates sometimes approach to argillites, but often, through the chloritic varieties, appear to pass into greenstone or diorite, which, in its typical form, consists of a greenish white feldspar, with dark green or black hornblende. The feldspar is sometimes however, more or less tinged with red, and the rock then occasionally appears to pass into a kind of syenite, by the addition of a very sparing amount of quartz. These two forms of the rock are generally highly crystalline, and not very fine grained. The greenstone, however, sometimes displays a fine texture; and in such cases it frequently holds much disseminated chlorite, giving it a very decided green colour. Portions are found, containing so great a proportion of the mineral, as to yield with facility to the knife.

Associated with these, are three bands of impure limestone, often silicious, and sometimes dolomitic, the uppermost one of which is interstratified with a large amount of hornstone, in very regular beds. The total thickness of the formation on Lake Huron, is estimated about 18,000 feet; of which more than 10,000 feet are quartzites, including the jasper conglomerates. 900 feet of the remainder are limestone and hornstone bands, and the remainder the slate conglomerates, with chloritic and epidotic slates, the whole being interstratified with diorites.

While the great mass of these greenstones or diorites, is supposed to be altered sedimentary beds,there are other greenstones, which, as well as certain granites in the formation, are evidently intrusive.

The most important mineral deposits of the Huronian series are the copper lodes at the Bruce, Wellington, and Huron Bay mines. The ores are here yellow and purple sulphuret, in veins of quartz, which cut the diorites of the region. According to Sir W. E. Logan's careful examination of the Bruce Mines, made in 1848, about 3000 square fathoms of the lodes were computed to contain, on an average, 6½ per cent. of copper. Since then, about 9000 tons of 18 per cent. ore have been raised from the mine, which has been opened to a depth of 50 fathoms. Attempts were made to smelt the ores, in a furnace erected on the spot, but they are now shipped to Great Britain or to the United States. The adjacent mines appears to be yielding even larger quantities of ore than the Bruce. Copper mining has been attempted also

at Root River, at Echo Lake, and in many other localities in this formation; which, like its Norwegian equivalent, appears to be eminently cupriferous. At the Wallace mine on Lake Huron, copper pyrites occurs, with an arsenical sulphuret of nickel, but the deposit has not been much examined. In the same vicinity, Mr. Murray has described a bed of specular iron or red hematitic ore, and he has shown that the immense deposits of this ore now so extensively wrought at Marquette, in Northern Michigan, belong to the Huronian formation.

From this sketch of the Huronian formation, I think it will appear evident that the same particulars characterize it as the corresponding group in Norway, viz: I. The preponderance of quartzose rocks. II. The presence of conglomerates of peculiar character. III. The occurrence of great masses of interstratified diorites or greenstones. IV. The beds of hornstone or chert. V. The presence of copper ores of a high percentage, unmixed with iron pyrites; the veinstone accompanying them being of quartzose. VI. The presence of iron glance (specular iron ore) in the few deposits of iron ore occurring in the group.

In the absence of organic remains, it seems to me that the only means left of identifying the same group in remote localities, is to compare minutely their petrographical and other physical characters. If this view be correct, there can be little doubt but that the quartzose division of the primitive slate formation in Norway, and the Huronian formation of Canada, are identical.

In conclusion, I have to remark with regard to the development of the mineral resources of both formations, that more appears to have been accomplished in this respect in Canada, than in Norway; seeing that the copper mines on the north shore of Lake Huron have had more permanency than those of Tellemarken. Greater progress is probably attributable only to the greater amount of capital which has been invested in the former mines. The obtacles met with have been substantially the same in both countries: the remoteness and inaccessibility of the region from the ordinary markets, and the difficulties in the treatment of the ores. These however have been overcome in this country, and the principal mines on Lake Huron are now well established, and profitably wrought.

II. The Primitive Slate Formation.

B: *The Schistose Group.*

The second or schistose division of the Primitive Slate Formation in Norway may be said to exist, with certainty, in two distinct areas, the one to the northeast and southeast of Vestfjord, in the Nordlands and the other to the northeast, west, southeast, and south of Trondhjem. Keilhau describes the former of these regions as "The Mica Schist districts of Tromsen and Senjen." The latter region he includes in what he entitles "The Norwegian portion of the central transition territory of the Scandinavian Peninsula," because it appears, through intrusions, to stand in intimate connection with the fossiliferous Silurian strata, which are developed around the northern end of Mjösen Lake. Believing however with Naumann that although the division line between the two formations, may sometimes become very indistinct, nevertheless, "a correct determination of existence will be found in most cases, a rule of demonstration,"* I have assumed, with him, that the strata of the last mentioned region belongs to the Schistose Group of the Primitive Slate Formation.

The rocks of which they are composed are given in the following list, in the order of the frequency of their occurrence.

1. *Mica schist*, "a slaty crystalline mixture of mica and quartz"† occurring most frequently and characteristic in the districts of Tromsen and Senjen. It is, however, often found of a more equivocal character and is then called micaceous schist. It presents numerous transitions into the other schistose rocks of the group. Thus gradually becoming fine-grained, it passes into clay slate, micaceous clay slate, or argillaceous mica schist, and by the disappearance of the mica, through quartzose mica schist, into quartz slate. Similarly, when chlorite and talc occur in it, it often becomes a chloritic or talcose mica schist; the former of these being the most frequent.

2. *Clay slate*, "an impalpable (indistinctly mixed,) distinctly foliated, soft rock; generally of a greyish, greenish, or bluish color,"‡ appears to be, next to mica schist, the most frequently occurring rock. It is however, more developed in the districts around Trondhjem, and is of a more variable character than even the mica schist. Besides the many varieties that may be included

* Lehrbuch der Geognosie II, 281.
† Cotta: Gesteinslehre, p. 140. ‡ Idem, p. 147.

under the general term of argillaceous slate, which is frequently applied to these rocks, there occurs a clay slate, described as being both micaceous and chloritic, (Chloritischer Thonglimmerschiefer); from which it appears that, even mechanically, the same substances are distinguishable in some clay slates, which Sauvage found by chemical analysis to be present in the slates of the Ardonnes; viz., a chloritic mineral which was decomposed by hydrochloric acid, with a micaceous mineral decomposable by sulphuric acid, and quartz.*

3. *Chlorite schist*, "a soft schistose, mostly greenish colored rock, consisting principally of chlorite. Quartz or feldspar, or both together, are however frequently mixed with the chlorite."† It is often found in its characteristic form, but is also frequently described merely as chloritic schist, and occurs principally in the districts around Trondhjem.

4. *Limestone* comes next in frequency. It is developed especially in the districts of Tromsen and Senjen, where its texture varies from granular to impalpable, and its colour from white to dark grey. The limestone of the districts around Trondhjem, is mostly yellowish-white, and of an impalpable, sometimes slaty structure.

5. *Quartz slate and Quartzite*, appear as transitions from mica schist, in the manner above referred to.

6. *Gneiss*, more or less characteristic, occurs in the group, especially towards the junction with the Primitive Gneiss Formation.

7. *Hornblende schist*, occurs in the Trondhjem region, and also in more northern districts. In both, it is connected with, and forms transitions into diorite.

8. *Diorite* and other *Greenstones*. Diorite is "a crystalline, granular mixture of hornblende and albite, sometimes also slaty or porphyritic."‡ Most of the greenstones in this group seem to be diorites. They are, however, often of very variable characters, and by the substitution of diallage for hornblende, graduate into a species of diabase.

9. *Granite and Syenite*, are also eruptive rocks occurring in the group, sometimes intimately associated with the diorites. *Hornblendic granite*, a connecting link between granite and syenite, and *granulite* are also mentioned.

* Ann: des Mines VII, 441.
† Cotta: Gesteinlehre, p. 145.
‡ Cotta: Gesteinlehre, p. 57.

10. *Serpentine* sometimes occurs in considerable masses. It is confined to the schistose districts south of Trondhjem, and consists of the common dark-coloured variety, differing altogether from the light coloured serpentines of the Primitive Gneiss Formation. Chromic iron ore invariably accompanies it.

11. *Euphotide*; a rock thus named is described by Keilhau, as containing large grained diallage or hypersthene. This is however a feldspathic rock, and by reference in a note in a former portion of this paper, p. 17, it will be seen that it is to be regarded as a kind of diabase, and distinct from the true euphotides of the Alps.

12. *Talc schist.*

13. *Steatite or Soapstone.* This, together with the rocks yet to be enumerated, is of comparatively rare occurrence.

14. *Dolomite.*

15. *Conglomerates and breccias*, somewhat resembling in character those already described in the quarztose division of the schistose formation.

The rocks above enumerated form, as already mentioned, two distinct geographical regions, which differ also in petrographical characters. The first is the one already mentioned, of Tromsen and Senjen, where the preponderating rock is mica schist; with which limestone, more or less granular, is very generally interstratified. Besides these, more or less characteristic gneiss, hornblende, chlorite, and talc schist occur as subordinate constituents. Well defined clay slate is of comparatively rare occurrence, although the mica schist often assumes an argillaceous character.

The second region is that spread out to a considerable distance, in the directions before mentioned, around Trondhjem. In this also the mica schist may be termed the preponderating rock, but the interstratified limestone is less frequent. Moreover clay slate and chloritic schist are of far greater frequency than in the first named district, as is also serpentine; which latter rock may be said to be characteristic of the second district, especially of that part of it which constitutes the Dovrefjeld Mountains. The serpentine masses seem to be irregularly interstratified with the slates, and sometimes to graduate into them. The green-stones and granites, besides occurring in distinct beds, often form irregular masses and regular veins, intersecting the schistose members of the group. Here, as in the two groups of rocks already described in this paper, these crystalline rocks, as they approach their limits, gra-

dually assume a schistose structure. Not only does the greenstone, in this way, change into hornblende slate or greenstone slate, and the granite become gneissoid, but the greenstone is found even to graduate into mica schist and clay slate. The more purely granular the greenstones are, the more does the form of the deposit deviate from that of a layer or bed.

Various subdivisions or zones have been distinguished in this group, which greatly differ in their general strike. The principal zone of the Dovrefjeld Mountains, seems to run E.N.E., which is also about the direction of the Dovrefjeld range. The dip varies much, but seems to be, on an average, about 45°. To judge from the direction of the dips given on the geological map, various folds occur in the strata, from their junction with the primitive gneiss, to where they graduate into fossiliferous beds.

In the country south of Trondhjem, the mountain masses of Dovrefjeld and Fillefjeld, consist principally of the micaceous, argillaceous, and chloritic schists, already referred to. They constitute as it were, the pedestal for the higher peaks of these ranges, such as the Jotunfjeld. These peaks are generally of igneous rocks. The Faastenen are, however, composed of serpentine, and Snehætten, of a peculiar sort of gneiss.

The most important mines of the district south of Trondhjem, are the copper mines of Röraas and its neighborhood, the chrome mines on the Dovrefjeld, and the nickel mines of Espedal.

The rocks around Röraas consist of micaceous slates, partly chloritic, and partly argillaceous. They graduate into glossy clay slates, and are sometimes described simply as green slates. These frequently assume the character of fahlbands, being impregnated with pyritous minerals, and weathering red. The deposits of Röraas, which have been worked since 1744, seem to partake of this nature. They form layers in the slates, varying from one to fourteen feet in thickness; the whole of which, however, by no means consists of cupreous minerals, but usually of many small pyritous beds, lying side by side; these being again divided into smaller ones, separated from each other by scales of chlorite schist. The preponderating ores are copper pyrites, and iron pyrites, which are sometimes mixed with magnetic pyrites and zinc blende; while chlorite, brown mica, quartz, garnet, actinolite, and asbestos, also accompany the metallic sulphurets. The ores, as they are delivered to the smelting houses at Röraas and Foldal, average only five per cent., and frequently are as low as

three per cent. They are roasted in heaps, and then smelted to regulus in shaft furnaces; little or no flux being required. The resulting regulus is roasted repeatedly upon hearths, (stadeln) and again smelted, when black copper is obtained, which is refined on the small gahr hearth. The copper is principally sold for home consumption, but part is also sent to the Hamburg market, where it is known as "Drontheimer" copper.

The chromic iron mines of Röraas in Sundal, and in Lessöe, have been, and still are wrought with very considerable success. They all occur in serpentine, and in one year as many as 100 have been worked. Some of these are large and regular deposits, and others are of less extent. The most important of them are situated in the districts to the east of Röraas, Röhammerne, and Feragsfjeldene, and are owned and worked by the proprietors of the chromate of potash manufactory at Leren. Three different sorts of ore are produced at the mine, : No. 1, the best, which is exported to England, although its content in chromic oxide is much beneath what is usually contained in the Baltimore ore; No. 2, an inferior sort, which is worked up into bichromate of potash at Leren; No. 3 is a still poorer quality, which is stamped and washed, the products being also used in the manufacture of bichromate. At the manufactory, the ore in fine powder is simply ignited in a reverberatory furnace, with about 30 per cent. of calcined potash, and little or no saltpetre. The resulting mixture yields, on lixiviation with water, a solution of neutral chromate of potash, which separates as a granular salt on evaporation. It is redissolved, and the solution is treated with a certain quantity of sulphuric acid, when crystallized bichromate of potash is obtained. The sulphuric acid is manufactured in the same establishment. One hundred parts of ore yield about thirty-seven of bichromate, so that the ore used must contain only about twenty per cent. of chromic oxide.

The nickel mines of Espedal, which are now abandoned, furnished an ore much of the same character as those of Ertelien in Ringerike, described in the first part of this paper. The mode of treatment was also similar.

The rocks of the two areas just described, offer, as we have seen, very considerable lithological differences. Those of the northern region do not appear to present any striking resemblances with the Canadian rocks, but the region about Trondhjem strongly resembles that of the Eastern Townships of Canada, and

agrees with it in the very points in which it differs from the mica schist region of Tromsen and Senjen. Among these are the predominance of clay slates, the presence of serpentines, with chromic iron, and the occurrence of ores of copper disseminated in the schists. These rocks of Eastern Canada have been traced from the line of the state of Vermont, for 140 miles north-eastward to the Chaudière River, and thence, at intervals, as far as Gaspé. As described in the Reports of the Geological Survey, they consist in great part of mica schists, passing into a gneiss, sometimes granitoid, on the one hand, and into clay slates on the other. Roofing slates are abundant in this series, and beds of steatite and chlorite slate are not uncommon. Quartzites, sometimes conglomerate, are met with, and limestones, which are very often magnesian, and weather of a reddish or brownish color from the presence of iron or manganese. They are sometimes replaced by carbonate of magnesia. Beds of serpentine are an important feature in this series; they are often mingled with limestone, dolomite or magnesite, and always impregnated with chrome and nickel. These serpentines are sometimes associated with diallage and with feldspathic rocks, which constitute varieties of diorite and diabase. These same rocks are traced southwards in the Green Mountains, through a large part of the United States. All of them find representatives in the Norwegian group around Trondhjem, and in the Dovrefjeld.

This resemblance is still further traced in the metalliferous deposits of the two regions. In the Eastern Townships of Canada, copper sometimes occurs in the native state, in clay slate, but much more frequently in the form of yellow and variegated sulphurets, or of copper glance, disseminated in micaceous or chloritic slates, or in limestone. These deposits are of the nature of fahlbands. Those of Sutton and Ascott, especially the latter, have a strong resemblance to that of Röraas. The copper ores of this region are generally subordinate to the stratification. The short and irregular veins of quartz and bitter-spar, which traverse these copper-bearing strata, sometimes however carry rich ores of copper, occasionally with gold.

Iron schists, which consist of scaly peroxyd of iron, intermingled with various proportions of quartz and chlorite, constitute important beds of iron ore in some parts of this series, as in the townships of Brome and Sutton, where they were formerly wrought to a small extent. These schists resemble the itabirite of Brazil.

Chromic iron accompanies the serpentine in Canada, as in Norway. The deposits of this ore occurring in the townships of South Ham, Bolton, and Melbourne, greatly exceed those of Norway in richness and extent. The deposit in the first named township has been worked, producing an ore containing forty-three per cent of chromic oxide.

As far as regards the developement of the mineral resources of the group, Norway is in advance of Canada. Not only has the mining of copper and chrome ores been long established, but the manufacture of the valuable products obtainable from these, has been long and profitably pursued. The mines of Röraas are beginning to suffer from the scarcity of fuel at the great height, (2080 feet above the sea,) and the chrome mining and manufacturing has had to contend with expensive cartage, and often with high prices for potash, which is to a great extent imported from Russia. In Canada, around the mines of the Eastern Townships, the settler destroys acres of timber, the softer sorts of which he might burn to charcoal; and manufactures tons of potash, which the chrome miner might buy, and use to manufacture his ore into chromate of potash, at a rate alike profitable to producer and consumer. I am not aware of any district where greater advantages exist. May they soon be appreciated, and taken advantage of, as they deserve.

These crystalline rocks in the Eastern Townships are regarded by the Geological Survey of Canada, as a metamorphosed portion of the Quebec group, which belongs to the inferior part of the Lower Silurian series. This view of their age coincides somewhat with that of Keilhau, relative to the similar formation around Trondhjem, which according to him "appears, through transitions, to stand in intimate connection with the fossiliferous Silurian strata."

In the foregoing, I have endeavoured to compare in their petrographical and economic relations, the three groups of rocks mentioned at the commencement of this paper. It was not originally my intention to pursue the subject farther than this; but seeing that the comparison which I have endeavoured to institute would be incomplete without some reference to the mutual geological relations of these groups in Norway, I offer the following remarks before concluding.

The oldest of these groups is the Primitive Gneiss formation. This at least was the opinion of the older geologists, such as Nau-

mann, Keilhau and others, who specially studied the various Scandinavian formations, but Kjerulf and Dahll, to whose researches I have yet to refer, have lately declared themselves opposed to this view. According to Keilhau, the gneiss formation of Kongsberg and of Flesberg, is, to the east of these districts, conformably overlaid by the Tellemarken quartzose group, into the rocks of which the gneiss forms a gradual transition. The same relations are described by Keilhau, as occurring at other points of junction, and he concludes that the Tellemarken quartzose group is to be regarded as filling up a very broad depression in the underlying gneiss formation. The quartzose group is not found in contact with any of the schistose series described, but the analogous quartzose group of Alten and Quænanger is overlaid conformably by the mica schist rocks of Tromsen and Senjen. The relations of the latter to the Dovrefjeld slates are unknown, for where the last mentioned come in contact with strata belonging to the primitive gneiss formation, both the quartzose and mica schist groups are absent, and the slates of Dovrejeld rest conformably on the gneissoid strata. On the other hand, these Dovrefjeld slates form a continuous transition, through less and less crystalline slates, greywacke slates, and sandstones, into the fossiliferous Silurian strata of the district north of Mjösen Lake. It seems therefore that the succession of these groups, in the order of their antiquity, is as follows :—

1. Primitive Gneiss formation.
2. Quartzose group.
3. Micaceous group.
4. Argillaceous and chloritic group.

} Primitive Slate formation.

5. Greywacke slates, sandstones, and limestones.
6. Fossiliferous Silurian strata.

It is to be remarked, that besides these stratified groups, various eruptive formations occur, whose age or place in the above list it is difficult to determine. Among these, the gneiss-granite of Vestfjord, and the granite and gneiss-granite in the southern parts of Bratsbergs Amt are the most important. The relations of the latter to the Tellemarken quartzose group, have been minutely investigated by Dahll, and described in his paper "Om Tellemarkens Geologie." He there unequivocally establishes the following succession, commencing with the more modern formations.

1. Syenite with associated granite, rhomboidal porphyry and augite porphyry.

2. The Devonian formation.
3. The Silurian formation.
4. Gneiss-granite and granite.
5. The slate formations of Tellemarken.

The relations of the latter formation to the primitive gneiss are not touched upon in Dahll's paper; but in another "Om Kongsbergs Erts District," by Kjerulf and Dahll, it is asserted that the gneiss and mica schist of Kongsberg, or as they are called, the Kongsberg slates, "are exactly the same as those which in a more unchanged condition, are spread over large areas in Tellemarken," but separated from these by a band of eruptive gneiss-granite. The primitive gneiss formation is declared to have no existence, but to be resolvable into gneiss-granite, which is eruptive, and into slates, whose two principal types are quartz slate and hornblende slate. It is even said that gneiss "as a petrographical term, in its older and more extended meaning, is no longer advantageous to science, but the opposite." The order of succession in these older groups, according to Kjerulf and Dahll, is as follows, commencing with the oldest:

1. Tellemarken slates.
2. Granite and gneiss-granite. (Eruptive.)
3. Œsterdal slates (which are the same as the Dovrefjeld slates.)
4. Silurian formation.
5. Devonian formation.
6. Younger granite, syenite, &c. (Eruptive.)

That the extreme opinions entertained by Kjerulf and Dahll as to the gneiss formation, are capable of being substantiated, is much to be doubted. At least it seems to me that in their work above cited, nothing very conclusive is brought forward in support of their views, and moreover, no reference is made to the many well substantiated facts, upon which the older view, as to the age of the Tellemarken quartzose rocks, is founded. This total obliteration of the gneiss formation, is perhaps the most extreme point to which the supporters of ultra metamorphism have yet attained.

The views of the Canadian geologists as to the Laurentian and Huronian series are the same as those of the older geologists of Norway, where, as has been shown, these rocks are represented by the Primitive Gneiss, and by the quartzose division of the Primitive Slate formation. The Dovrefjeld slates, with their serpentines, are regarded as more recent, and as closely related to the

adjacent Silurian strata. This is precisely the view of the Canadian geologists, with regard to the Quebec group, except that they include this, with its slates and serpentines, in the Silurian series, regarding it as a peculiar development of the lower part of this, and younger than the Primordial Zone. According to Sir W. E. Logan, this Quebec group was connected with a deep sea, and with movements of elevation and subsidence, the result of which is, that along the outcrop, or the shore line of the original basin, these peculiar strata are wanting. Mr. Sterry Hunt has called attention in a recent paper in this Journal, to the fact that a similar condition of things to that of Canada, seems traceable across the ocean, into Scotland, and probably as far as Scandinavia. In the Scottish Highlands, we find a schistose series, having the lithological characters of the Quebec group and the Dovrefjeld slates. This series has been the subject of much controversy. As in Norway, some have maintained that these strata are older than the lowest Silurian rocks, but Sir Roderick Murchison, with Ramsay and Harkness, seems to have shown that they are really younger than the oldest fossiliferous rocks of Scotland, and that the condition of things described by the Canadian geologists in Eastern Canada, extends across the Atlantic. Can. Nat. Vol. VI, 93.

Thus is it not only in Canada, that the position of the so-called primitive formations is equivocal. Different views prevail as to their age in different countries. In Cornwall, they are considered Devonian, in Scotland, Lower Silurian, and in Bohemia, as in Norway, Pre-Silurian. In Belgium, Rhenish Prussia, Westphalia and Nassau, they are by some geologists regarded as Devonian, and by others as belonging to an older formation. In East Russia, on the western slope of the Ural Mountains, they are supposed to represent metamorphic Lower Silurian strata. A dissimilarity of views will probably continue to prevail as to the position of these rocks, until the question is decided, as to what value, in the absence of fossil remains, the petrographical characters of a group, taken in connection with its stratigraphical position, should have in determining its age. Perhaps there prevails at present, too much of a tendency to attribute extraordinary influences to metamorphic agencies So soon as the true limits and effects of metamorphism are recognized, it will probably be cknowledged that, whatever view may be entertained as to their origin, the schistose rocks above referred to, underlie the Silurian, and all unaltered or metamorphosed fossiliferous strata. Follow-

ing close upon more moderate views as to metamorphism, will probably come the recognition of Werner's old rule, as to the succession of these older rocks; namely that the gneiss groups generally underlie those in which mica schist preponderates, and that the latter are overlaid by argillaceous and chloritic groups. Thus the ground will be cleared for an impartial investigation into the origin of the primitive formations.

Acton Vale, Canada East, 8th April, 1862.