THE MINERAL PARAGENESIS AND CLASSIFICATION OF THE GRANITE PEGMATITES OF IVELAND, SETESDAL, SOUTHERN NORWAY

BY

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WITH 17 TEXT FIGURES, 1 MAP, 1 PLATE

Preface.

Some years ago the director of the Mineralogical Museum, Professor J. Schetelig, proposed to me to undertake an investigation of the rare minerals in the pegmatite dikes in Iveland. To this purpose Professor Schetelig placed at my disposal an X-ray apparatus and allowed me with the help of the mechanic J. Andersen at the museum to carry out several improvements on the apparatus to make them more convenient for X-ray spectral analysis of the rare pegmatite minerals. During the work in connection with these investigations Professor Schetelig has always shown the greatest interest and has supported me in the most friendly way, and I have had great advantage of his unique knowledge and experience of pegmatites and pegmatite minerals. I therefore wish to express my heartiest thanks to Professor Schetelig for his valuable support.

By means of grants given to me by the Fritjof Nansen Fund I was able to carry out field investigations during 3 summers. From Universitetets Jubileumsfond I have received a grant which made it possible to me to stay for some weeks at the Physikalish-Chemisches Institut in Freiburg i. Br.

To Professor G. v. Hevesy, the director of the Physikalisch-Chemisches Institut in Freiburg, I wish to express my best thanks for his kind instructions and valuable support during my stay at his institute in the summer 1934.

Most of the photographic and drawing work has been carried out by Miss Lily Monsen.

I am also indebted to the road inspector Olav Landsverk, Iveland, who has helped me with the field work. His great knowledge of the feldspar quarries in Iveland and their minerals has been of great importance for these investigations.

Introduction.

Iveland is a district in the southern part of Setesdal in southern Norway about 50 km north of Kristiansand S.

Geologically the district belongs to the large Precambrian area that forms the southern part of Norway. The geology of this area has lately been treated in several publications by T. Barth (3, 5, 6). The greatest part of the Iveland district is made up of amphibolitic rocks which form an area that extends toward the north into the neighbouring district Evje. These amphibolitic rocks are surrounded by gneisses and granites.

The amphibolitic area of Iveland and Evje is intersected by many dikes and irregular bodies of granite and numerous larger and smaller pegmatite bodies. Near the boundary of this area the amphibolite is strongly intersected by small veins of granitic composition and seems gradually to change into the surrounding gneiss.

Quarrying for feldspar has been going on in Iveland since 1898, and the feldspar production has been of a great economic importance to the district. Most of the pegmatite bodies are very small and have only produced some hundred tons each of first class feldspar, in the largest quarries, however, up to 30 000 tons have been produced from a single pegmatite body. The great costs of transport bring about that only first class feldspar can be shipped, and as by-products occasionally some mica, quartz and rare minerals.

The pegmatites in Iveland are generally rich in rare minerals, and many valuable museum specimens of these minerals have been sold by mineral dealers to mineralogical museums.

The feldspar production and the feldspar quarries from a technical point of wiew have been described previously in the series of publications from The Geological Survey of Norway (Norges geologiske Undersøkelse) by T. Barth (5). Several minerals from Iveland have been studied previously by P. Schei and J. Schetelig.

The Pegmatites.

The pegmatite bodies intersecting the amphibolitic area of Iveland and Evje are very varying in shape and magnitude. Most of them are dikes or lense-shaped and irregular bodies.

The pegmatites usually exhibit sharp boundaries against the adjacent rock and fragments of the surrounding rock which have been imbedded in the pegmatite show no trace of resorption. In some cases small veins of pegmatite from the pegmatite body are seen to transverse the surrounding rock.

The largest dikes occur generally in the periphery of the amphibolite area in the southern and northern part of Iveland and the adjacent parts of Evje. These pegmatites are usually very coarse-grained, with crystals of feldspar up to a weight of 200 tons. In the central district the pegmatites are usually of less magnitude. According to T. Barth (3) the small pegmatite veins are richer in plagioclase than the larger dikes and this is explained by him assuming a transmission of K from the pegmatite to the surrounding rock. An evidence of this transport of K is given by the fact that the amphibolite near the border against the pegmatites is richer in biotite than is usual.

In the larger pegmatite bodies a fine-grained zone often rich in graphic granite may be observed near the boundary against the adjacent rock. In a few dikes, however, this fine-grained zone is wanting and the coarse pegmatite bounds directly to the country rock. One of the pegmatite dikes, namely Tveit 5, intersects a granite with sharp boundaries against this rock, and in some of the dikes bodies of normal granite are found imbedded in the pegmatite. There seems to be a close genetic relation between the bodies and dikes of granite and the pegmatites.

As to the composition of the chief minerals, the pegmatites in Iveland occur in two very different types, the microcline-quartz type and the cleavelandite-quartz type.

1. The microcline-quartz type. This type of pegmatite is the common pegmatite in Iveland. The chief constituents are: microcline, quartz, plagioclase, biotite and muscovite. Besides these minerals the microcline-quartz dikes often are very rich in rare accessory minerals which will be described later. In some few of these dikes no rare minerals have been found, these pegmatites, however, exhibit no difference from the dikes rich in these minerals in regard to the chief constituents. These pegmatites always show a definite sequence of crystallization and seem to be of magmatic origin. In the magmatic pegmatites the phosphoric acid usually is completely combined with the rare earth elements forming monazite and xenotime and these pegmatites thus differ from the ordinary granites in which the phosphoric acid is combined with Ca in apatite.

2. The cleavelandite-quartz type. These pegmatites are very different in apparition and mineral composition from the microcline-quartz type. The chief minerals are cleavelandite and quartz and they often contain some rare minerals which have not been found on the magmatic dikes.

The pegmatites of this type occur as small dikes which usually intersect the normal microcline pegmatite and seem to a great extent to have replaced the minerals of the surrounding pegmatite. In these pegmatites it is very difficult to state any definite sequence of crystallization, it seems as if the minerals have generally grown simultaneously during a rather uniform conveyance of material by hydrothermal and pneumatolytic activity. Cleavelandite-quartz dikes intersecting microcline pegmatite have been described previously from the pegmatite area in southeastern Norway at Ånnerød by W. C. Brøgger (12) who has pointed out that this dike must have been formed by later hydrothermal activity. In this dike, however, no rare minerals were found.

Working Methods.

Field Work.

The Mineralogical Museum of the Oslo University is in possession of a very fine collection of mineral specimens from the granite pegmatites of Iveland. Most of these minerals, however, being bought from different mineral dealers, are not satisfactorily located to be used for a study of the mineral paragenesis of these pegmatites. As location is generally given the name of the farm to which the feldspar quarry belongs, but as the farms usually have many different feldspar quarries it is often impossible to state in which quarry the mineral has been found.

It was therefore necessary to visit the feldspar quarries and collect the minerals at the place itself to be sure of the paragenesis of every pegmatite dike. For that purpose I have stayed in Iveland and Evje in the summers 1931 34 and have visited about 130 feldspar quarries. All these feldspar quarries were searched for rare minerals and in most of them good collections of these minerals were found.

Laboratory Work.

Most of the collected mineral species were only small fragments of crystals or irregularly formed masses and nodules, and many of these would be impossible to identify without special methods. For this purpose was used X-ray spectral analysis. The X-ray spectrograms give an absolutely sure identification of most of the rare minerals, and as only 2 3 mg. of the mineral is necessary for the study, very small mineral particles can be studied and classified. The X-ray spectrograms also give a good picture of how the chemical components vary in the different species and give information of the minor constituents which is of great importance for the geochemical studies of the pegmatites.

For most of the X-ray spectrograms was used a vacuum spectrograph with a camera diameter of 119 mm. The spectrograph has been constructed at the Mineralogical Museum to give a quick and ready determination of the constituents of minerals and gives with a NaCl crystal lines of the elements from 20 Ca to 92 U with good sensibility. The exposure of each spectrogram lasted 3/4 hour over 0 60 degrees. Because of he small dispersiveness of this spectrograph closely adjacent lines are often very difficult to distinguish, and in cases when it was of importance to have a greater dispersiveness an air spectrograph with diameter 344 mm was used. With the vacuum spectrograph about 130 spectrograms of rare minerasl from Iveland have been taken and with the great air spectrograph about 25. For comparison were also made several spectrograms of rare minerals from other parts of Norway.

The results of these X-ray spectrograms will be given with the description of the minerals. They are used for estimating the qualitative chemical composition of minerals from different dikes. No effort has been made to use these spectrograms in making exact quantitative calculations, as this, with the small dispersiveness of the vacuum spectrograph used, will meet with many difficulties, especially with the rare earth elements which cause many coincidences between different lines. The results are generally given as estimated intensities of the lines $K\alpha_1$ or $L\alpha_1$ of the occurring elements, setting aside coincidences which have no significance for the comparison of the minerals. When a strong coincidence makes the use of the α_1 line impossible the intensity of the β_1 line is used instead, for example with Hf.

The vacuum X-ray spectrograph intends to give a quick determination of the chief components of the minerals and no stress has been laid on great sensibility. Elements which occur in quantities less than 0,1 % will therefore generally not be traceable, the sensibility however being somewhat greater for the heavy elements and less for the elements with low atom-numbers.

For the air spectrograph was also used a NaCl crystal. The air spectrograph has the drawback that the softer (long waved) X-rays will be very much weakened by the long passage in the air. The sensibility will therefore strongly diminish for the elements with lower atom-numbers, and the elements with atom-numbers lower than 22 Ti will give no lines at all.

In the summer 1934 I had the opportunity to stay some weeks at the Physikalisch-Chemisches Institut in Freiburg. With the kind assistance of the director of the institute Professor G. v. Hevesy I used this time to study his methods of quantitative X-ray analysis and was allowed to carry out some quantitative determinations of Ti and Ta in columbites from Iveland.

Quantitative X-ray analyses combined with chemical methods will certainly be of the greatest importance for the study of the rare pegmatite minerals. The X-ray analyses are especially useful for the determination of the elements which occur in small amounts and also the elements which are difficult or impossible to separate by means of ordinary chemical methods such as Nb, Ta, Ti and the elements of the rare earths. With the kind help of my chief, Professor J. Schetelig I have had the opportunity to have the apparatus for such analysis constructed by the mechanic at the Mineralogical Museum. It is my plan when the construction of these apparatus is completed to carry out quantitative X-ray analyses of a series of the most interesting minerals from the Norwegian pegmatites.

The Mineral Occurrences.

In southern Iveland, near the farm Tveit are situated 6 feldspar quarries.

1.[1] *Tveit 1.* ("Eliasgruva"). A feldspar quarry about 7 800 m north of Iveland railway station on the southern slope of a high hill near the east bank of the river Ottra. The deposit is a lense-shaped pegmatite which strikes east, dipping at a great angle toward the north, conformable to the structure of the surrounding amphibolitic rock. The dominant minerals are a greyish microcline, quartz, large thin flakes of biotite and a small amount of plagioclase. The biotite flakes and the surrounding microcline and quartz are rich in well developed crystals of fergusonite and xenotime. Cleveite was found as small irregular splashes up to 1 cm in diameter between the xenotime crystals. Specimens of monazite and alvite were also collected. The monazite occurred in tabular crystals up to 4 cm in square and the alvite in radiated crystal aggregates. A fine crystal of ilmenorutile from this pegmatite had been collected by the feldspar workers. The sequence of crystallization of the rare minerals seems to be: alvite, fergusonite, xenotime, monazite and cleveite. The place of the ilmenorutile in this sequence could not be stated as this mineral has only been found as a single crystal; the ilmenorutile, however, on other dikes always belongs to a late stage of the crystallization of the accessory minerals.

2. Tveit 2. A small feldspar quarry about 500 m south of the road Tveit—Dalane. The pegmatite body forms a somewhat irregular almost vertical dike, striking north and cutting the amphibolitic rock. Besides the ordinary pegmatite minerals microcline, quartz, mica and plagioclase, small crystals of alvite, garnet, monazite and magnetite were present.

3. Tveit 3. ("Steli") is a great feldspar quarry situated about 100 m south of the road Tveit Dalane. The pegmatite dike is about 10 m wide and strikes east with a dip to the north not far from the vertical, parallel to the structure of the surrounding amphibolite. The dike consists of large crystals of microcline, usually with well developed crystal faces, separated by masses of white quartz. The pegmatite seems to be a little richer in quartz than usual for this type of pegmatite in the district. Large flakes of biotite often largely altered to chlorite were common. The largest microcline crystals

[1] The numbers refer to the localities laid down in the map.

have crystal faces up to 6 m in length and represent more than 100 tons of feldspar. Small lense-shaped bodies in the pegmatite consist chiefly of plagioclase, garnet and curved muscovite.

The rare minerals occurring were beryl, samarskite, monazite and columbite. Beryl was observed in the wall of the opening as large well-formed crystals up to 1 m long and with a diameter of 15 cm. Some of the beryl crystals were altered to a dark mass in which were imbedded small white translucent crystals of bertrandite. Bertrandite located Tveit, Iveland, described by Th. Vogt (56) is probably from this pegmatite. The samarskite was found as an ill-defined crystal with a diameter of 15 cm. Columbite occurred in well developed crystals reaching a weight of 2 3 kgms.

4. *Tveit 4.* On the top of the hill south of the farm Tveit is a small old feldspar quarry which has not been operated for 30 years. It is therefore badly overgrown and no rare minerals were found on my visiting the quarry last summer. The pegmatite is supposed to be rich in samarskite and columbite and a fine collection of these minerals at the Mineralogical Museum in Oslo located Tveit, Iveland, is probably from this dike. This material has been studied by J. Schetelig (14). It shows parallel intergrowths of samarskite and columbite, previously described by W. C. Brøgger (13) from granite pegmatites in South-eastern Norway under the name of Ånnerødite. In his study of this material J. Schetelig has described a new form of coalescence between the two minerals. The columbite has as usual crystallized later than the samarskite.

5. *Tveit 5.* The hill north of the lake Tveittjern consists chiefly of a great body of a greyish, non-foliated granite. On the west side of the hill this granite bounds the ordinary amphibolite which strikes north with a dip east not far from the vertical. This granite area which has a width of 3 400 m is intersected by a vertical somewhat irregular pegmatite dike about 6 7 m wide with a strike to the north. The border between the pegmatite and the surrounding granite is often distinct, but in some places small pegmatite veins from the dike are seen to intersect the surrounding rock. The mineral assemblage of this pegmatite does not seem to differ from the pegmatite imbedded in amphibolite. The pegmatite is rather coarse and consists of large crystal masses of pink perthitic microcline, quarts and biotite. Plagioclase is only present in small quantities. The biotite flakes contain large masses of magnetite in which were found well developed

Fig. 1. The border between granite and granite pegmatite.
5. Tveit 5. Iveland.

crystals of euxenite. Specimens of orthite, monazite and fine crystals of xenotime were also collected. Crystals of euxenite are often observed to cut the outer part of xenotime crystals. The segregation of the dike seems to have commenced with the crystallization of xenotime and later on the xenotime and the euxenite have crystallized simultaneously.

6. *Tveit 6.* A small feldspar quarry about 200 m west of Tveit 5. The pegmatite dike follows the west border between the granite and the amphibolite and strikes north with dip at a great angle to the east. Besides the ordinary minerals euxenite, monazite and xenotime were present.

7. *Dalane 1.* At the farm Dalane about 100 m south of the farm houses a small pegmatite dike has been mined for feldspar. The dike is vertical and strikes north. The quarry has not been operated for about 30 years and is therefore badly overgrown. The pegmatite consists of the ordinary pegmatite minerals and no rare minerals were found when I visited the quarry.

8. *Dalane 2.* A feldspar quarry about 300 m north of the farmhouses. The pegmatite body is a vertical dike cutting the amphibolitic rock and striking east. Between the feldspar quarry and the

farm houses the ground rock consists of a reddish granite. Besides the ordinary pegmatite minerals, specimens of garnet, beryl, fergusonite, alvite, monazite, xenotime and orthite were collected on the dump. From this quarry a fine monazite crystal weighing 1.5 kgm has been sold to the Mineralogical Museum in Oslo. This specimen was only part of a larger crystal which had gone to pieces.

Frøyså. South of the farm Frøyså on the southern and western slope of the hill Frøysåås are situated five feldspar quarries some of which have produced several hundred kgms of gadolinite. The country rock is an amphibolite.

9. Frøyså 1. A feldspar quarry about 2 km west of the farm. The pegmatite is a 20 m wide irregular body and not well defined as to strike and dip. The outer part of the pegmatite is rich in graphic intergrowths of quartz and microcline. The inner part of the body consists of large crystal masses of a grey perthitic microcline imbedded in white quartz. Large flakes of biotite were common. Besides the ordinary pegmatite minerals garnet, beryl, gadolinite, alvite, fergusonite, monazite and euxenite were found.

In Gilderdalen on the southern slope of the hill Frøysåås 3 pegmatite bodies have been mined for feldspar.

10. Frøyså 2. The western feldspar quarry in Gilderdalen. In addition to the ordinary minerals, crystals of gadolinite were present. The pegmatite was of the ordinary type.

11. Frøyså 3. A feldspar quarry about 20 m east of Frøyså 2. The pegmatite is of the ordinary type mined for feldspar in the district. Besides the common minerals, garnet, fergusonite, alvite, euxenite, magnetite and monazite were observed among the waste rock on the dump. The fergusonite occurred in well developed crystals up to 4 cm in length.

12. Frøyså 4. This feldspar quarry is situated about 100 m north of Frøyså 3. The pegmatite body forms a dike which strikes east and consists chiefly of the ordinary minerals microcline, quartz and mica. The inner part of the microcline crystals is often green and translucent. The green microcline appears under the microscope to be a very fine perthite (string perthite) and is evidently the primary mineral of which the ordinary pink coarse perthite has been formed by alteration. A more explicit description of these minerals is given under the descriptions of the microclines. Other minerals collected were garnet, largely altered to a dark mass of alteration products,

Fig. 2. Feldspar working on a small vertically pegmatite dike.
15. Rosås 2. Iveland.

orthite, fergusonite, alvite, euxenite, monazite, beryl, pyrite, chalcopyrite and molybdenite. The euxenite was found in small irregular nodules. Pyrite, chalcopyrite and molybdenite were abundant in the east part of the dike and here most of the microcline had a green colour and was of no commercial value. The molybdenite was found on microcline crystals penetrating 3 4 mm into the crystal surface. The crystallization of the molybdenite therefore seems to have taken place before the growth of the microcline was completed. In this pegmatite a crystal mass of 30 kgms molybdenite has been found by the feldspar workers.

13. Frøyså 5. A feldspar quarry opened in 1929 on the eastern slope of the Frøysåås. Besides the ordinary minerals large crystals of gadolinite were observed.

Rosås. On the farm Rosås I have visited 4 feldspar quarries.

14. Rosås 1. ("Storegruva") south of the farm near the lake Stemtjern. The pegmatite dike outcrops on the western slope of a hill and appears to strike east cutting an amphibolitic rock. The outer part of the dike is rich in graphic granite. The dike consists of microcline, quartz, large thin flakes of biotite and a little plagioclase. Among the waste rock on the dump specimens of fergusonite, alvite, euxenite thalenite, monazite, xenotime and magnetite were collected. The euxenite and xenotime were only found in small nodules without crystal faces.

15. Rosås 2. A feldspar quarry situated north of the farm. The pegmatite body is a vertical dike 3 4 m wide which strikes about north. Besides the ordinary minerals only garnet and magnetite were observed.

16. Rosås 3. This feldspar quarry is situated some hundred meters west of Rosås 2. It is a small test pit where a few shots have been put in a pegmatite dike. As the surroundings are covered the form and extension of the pegmatite can not be stated. The pegmatite is in regard to its chief constituents of the ordinary type. The opened part of the pegmatite is intersected by large flakes of biotite and between these were found considerable quantities of a deep red thalenite. This thalenite has been studied previously by J. Schetelig (52). The other accessory minerals in this pegmatite were gadolinite, alvite, fergusonite, euxenite and monazite.

17. Rosås 4. North of Rosås 3 a small pegmatite dike has been mined for feldspar. Besides the ordinary minerals the pegmatite was rich in gadolinite, this mineral being found in crystals weighing up to 8 kgms. Other accessory minerals found were garnet, beryl, ytrotitanite and yttrotantalite.

18. Hiltveit 1. ("Grasdalen"). A feldspar quarry 1.5 km north of the farm Rosås. The pegmatite body is a dike which strikes east and cuts a gneiss rock. Besides the ordinary minerals garnet, orthite, fergusonite, euxenite, monazite, ilmenite and pyrite are present in small quantities.

19. Hiltveit 2. ("Feitedalen") is situated about 2 km south-west of the farm-houses. In addition to the ordinary minerals gadolinite and beryl has been found.

Ivedal. On the farm Ivedal I have visited 2 feldspar quarries situated west of the lake Ivedalstjern. Besides these quarries J. Schetelig in 1912 has visited a small feldspar quarry near the farm-houses which contained the rare mineral thalenite (52). This quarry was only a small prospect pit. It is probably now quite overgrown and on my visiting the farm last summer it could not be pointed out.

The minerals found in the dike were collected by J. Schetelig and are now in possession of the Mineralogical Museum in Oslo.

20. Ivedal 1. Near the farm-houses. The paragenesis studied by J. Schetelig (l. c.) is: Fergusonite, xenotime, alvite, thalenite, gadolinite, thortveitite (?), orthite, pyrite, magnetite and spessartite. Fergusonite, xenotime and alvite have crystallized earlier than the thalenite. Simultaneously with the thalenite the gadolinite and the thortveitite (?) crystallized, orthite, pyrite and magnetite later. The fergusonite from this dike has previously been described by J. Schetelig (14).

21. Ivedal 2, is situated west of the lake Ivedalstjern on the south side of the valley Rossedalen. The pegmatite outcrops on the steep valley side as an apparently horizontal dike cutting a dark amphibolite which consists chiefly of hornblende. Near the border of the pegmatite the amphibolite is rich in biotite. The pegmatite consists of microcline, quartz and a small amount of plagioclase but is exceptionally poor in mica. In addition to these minerals beryl, samarskite and magnetite were found in small quantities. The samarskite occurred as a circular splash about 15 cm in diameter in the wall of the opening.

22. Ivedal 3. On the northern side of the valley Rossedalen an irregular pegmatite body has been mined for feldspar. The quarry has not been operated for 20 years and was strongly overgrown. Besides the ordinary minerals beryl and magnetite were found on the dump.

Birketveit. On the property of the farm Birketveit I have visited 6 feldspar quarries, four of which are situated east of the farm on the hill Birketveitåsen. These pegmatites are very similar in regard to their chief constituents, all of them being exceptionally rich in plagioclase feldspar. The plagioclase in these pegmatites usually occurs as large well developed crystals imbedded in quartz. In all of the dikes graphic intergrowths of plagioclase and quartz were abundant. The dikes have only been mined for microcline feldspar.

23. Birketveit 1, on the north side of the Birketveitås. Of rare minerals beryl, gadolinite, orthite, euxenite, yttrotitanite, thorite and xenotime were collected among the waste rock on the dump. Yttrotitanite occurred in crystals up to 15 cm in length. Thorite was only found in small red-coloured nodular masses without crystal outlines between the flakes of biotite.

24. Birketveit 2, situated on the top of the hill Birketveitås. Besides the ordinary minerals crystals of garnet were present. No rare minerals were observed.

25. Birketveit 3. A feldspar quarry on the southern slope of Birketveitås. The pegmatite is a small dike which strikes east. It consists of the ordinary minerals and garnet.

26. Birketveit 4 is situated on the west slope of the Birketveitås near the farm houses. The pegmatite body strikes east cutting an amphibolitic rock. In addition to the ordinary minerals garnets and well developed crystals of fergusonite were collected.

27. Birketveit 5. A feldspar quarry situated west of the main road near the house of assembly ("Ungdomshuset"). The dike which strikes west was an ordinary pegmatite. The rare minerals collected in the dike were euxenite and xenotime.

28. Birketveit 6 ("Spellarhaugen"). This feldspar quarry is situated south of the farm Hiltveit on the hill Spellarhaugen. The pegmatite body is a dike about 4 m wide striking east and cutting the amphibolite. Besides the ordinary minerals a fine crystal of fergusonite was found among the waste rock on the dump.

Ertveit. The feldspar quarries on the property of the farm Ertveit are very uniform as to their mineral associations. They are all of them in regard to the accessory minerals typical euxenite dikes and in two of them relatively large crystals of xenotime were abundant. The microcline of these pegmatites has a deeper reddish colour than usual in the pegmatites mined for feldspar in Iveland.

29. Ertveit 1. This feldspar quarry is situated at the road near the farm and is the largest feldspar quarry in Iveland. The amount of first class microcline feldspar mined in this quarry is estimated to 30 000 tons. The pegmatite is a very large irregular body which outcrops on the northern slope of a hill. The surrounding rock is an amphibolite which strikes north-east almost vertically. A map with description of the quarry has been published by T. Barth (5). The accessory minerals euxenite, xenotime and ilmenite occur sparingly in some parts of the dike. The euxenite occurred in polycrase-shaped crystals grown vertically on large plates of ilmenite, it was also found imbedded in the ilmenite.

30. Ertveit 2 ("Eikeråsen") about 400 m south of Ertveit 1. The pegmatite is an almost vertical dike which strikes west. The major constituents were the ordinary ones, microcline, quartz, mica and a small amount of plagioclase. The microcline has a deep red colour and as it was not approved as first class feldspar the mining was suspended. The centre of the dike was made out of a body of ordinary granite about 4 5 m wide. The pegmatite was rich in large flakes of a very dark biotite and in these were found well developed crystals of xenotime and monazite. Euxenite was present as polycrase-shaped crystals.

31. Ertveit 3 is situated 100 m west of the farm houses on a dike which strikes west. Besides the ordinary minerals euxenite (polycrase), monazite and magnetite were present.

32. Ertveit 4 ("Lille Øigard") is a small feldspar quarry south of the farm Ertveit. The pegmatite was of the ordinary type with the same accessory minerals as Ertveit 3, euxenite, monazite and magnetite.

33. Ertveit 5. About 20 m north of Ertveit 4 a small pegmatite dike has been opened with a few shots. The dike strikes west and is exceptionally rich in quartz. Besides the ordinary minerals only small nodules of magnetite were observed.

34. Nateland. To the farm Nateland belongs a feldspar quarry situated on the top of the hill south of the farm houses. The pegmatite is an irregular dike striking about east and cutting the amphibolitic rock. This dike is the only known occurrence of chrysoberyl in granite pegmatite dikes in Norway. The chrysoberyl from this pegmatite has been studied previously by J. Schetelig (48). The major constituents of the dike were microcline, quartz, mica and a small amount of plagioclase. Other, accessory, minerals collected in the quarry were gadolinite, fergusonite, alvite, euxenite, xenotime, monazite, and molybdenite. Euhedral crystals of gadolinite were found imbedded in crystals of chrysoberyl, which mineral must belong to the latest stage of the crystallization of the accessory minerals. The first crystallized minerals in the dike were fergusonite, xenotime, alvite and euxenite.

35. Tjomstøl. North of the farm Tjomstøl, near the main road, a small lens-shaped pegmatite body has been mined for feldspar. The pegmatite consists chiefly of the ordinary pegmatite minerals. On my visiting the quarry I found as accessory minerals, garnet, pyrite, alvite, euxenite and monazite. The euxenite occurred in brown coloured nodules without crystal outlines. In this quarry have also been collected a few crystals of thortveitite which are in possession of the Mineralogical Museum in Oslo.

Thortveit. To the farm Thortveit belong 3 feldspar quarries all of them being known to be very poor in rare minerals.

36. Thortveit 1 ("Thortveitholtane") a feldspar quarry north of the farm, near the farm houses. The pegmatite is a dike which strikes south-west and consists of the ordinary minerals. As accessory minerals only small amounts of magnetite and pyrite were found.

37. Thortveit 2. North of the farm near the swamp Thortveitmyren a small pegmatite dike has been opened for feldspar mining. The pegmatite was of the ordinary microcline-quartz type. Besides the main constituents only a little pyrite was seen among the waste rock on the dump.

38. Thortveit 3 ("Thortveittunnellen"). This pegmatite outcrops as a horizontal dike on the face of a cliff north of the farm, on the southern slope of the hill Solheia. At the opening of the quarry the dike is about 3 m wide but peters out at the west and the east. Besides the ordinary minerals specimens of euxenite, monazite, garnet and pyrite were collected.

Skripeland. On the hill Varaheia 1.5 km west of the farm Skripeland are situated four feldspar quarries two of which belong to Skripeland and the others to the neighbouring farm Landås.

39. Skripeland 1. A small experiment pit on the eastern slope of the hill Varaheia where a few shots have been put in a dike in search for feldspar. As no quantities of microcline were found the mining has been suspended. The pegmatite forms a small lens-shaped body about 3 m wide surrounded by large quantities of graphic granite. The extension of the graphic granite could not be stated as the surroundings were covered with glacial drift. The pegmatite is of a type which is very rare in Iveland, consisting chiefly of an albite with a particular platy structure, called cleavelandite, and quartz. The other minerals occurring in the dike were microcline, a green coloured muscovite, small laminated crystal aggregates of a lilac coloured muscovite, spessartite, topaz, beryl, black tourmaline, microlite, tantalite and zircon. The microlite was found in well developed cubic crystals up to 1 cm in diameter imbedded in cleavelandite and quartz. The crystals were often seen to be intersected by blades of cleavelandite. Topaz occurred in crystals of up to 20 cm long. This dike is in regard to the mineral paragenesis exactly analogous to a dike on the farm Landås called Landås 1. Dikes of this type are very different from the ordinary pegmatites and their

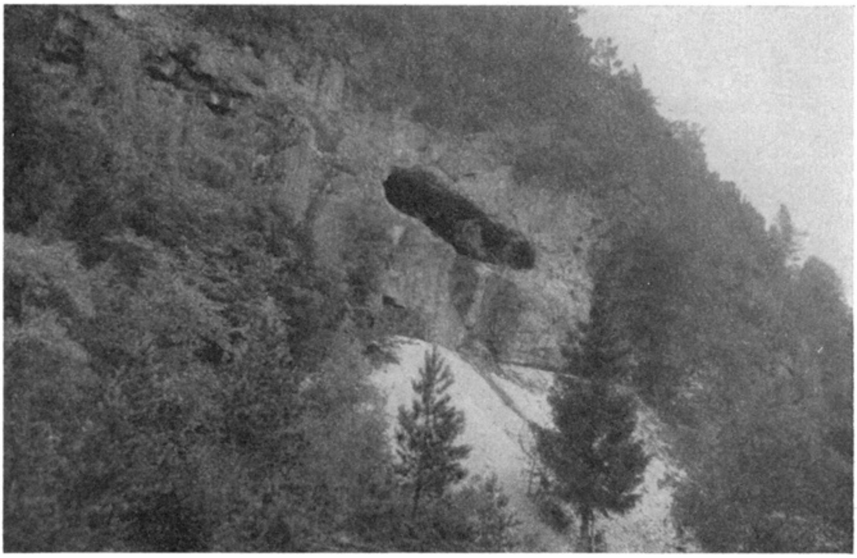


Fig. 3. Feldspar quarry on a pegmatite dike cutting an amphibolitic rock. 38. Thortveit 3. Iveland.

mineral paragenesis indicate that they were formed under the influence of pneumatolytic and hydrothermal activity.

40. Skripeland 2, a feldspar quarry situated 100 m south or Skripeland 1. The pegmatite forms an irregular dike cutting a dike-shaped area of granite which seems to strike east. The pegmatite is of the ordinary type consisting chiefly of microcline, quartz, mica and a small amount of plagioclase. The accessory minerals were garnet, beryl, euxenite (polycrase), and magnetite.

Landås. To the farm Landås belong 7 feldspar quarries situated on the eastern part of the property.

41. Landås 1. A small test pit opened with a few shots in search of microcline feldspar on the eastern slope of the hill Kolås. The pegmatite is a magnetite-bearing microcline-quartz pegmatite, rich in graphic intergrowths of microcline and quartz. It strikes north dipping slightly to the west. The lower part of this dike, however, is intersected by a younger dike of the same type as Skripeland 1 with main constituents cleavelandite and quartz and obviously formed in the same way under the influence of pneumatolytic-hydrothermal activity. The minor constituents were the same as in Skripeland 1 namely beryl, green and lilac-coloured

Fig. 4. The microlite and tantalite-bearing cleavelandite-quartz dike. 41. Landås 1. Iveland.

muscovite, zircon, garnet, tantalite, microlite, topaz and black tourmaline. This dike was the first known finding-place of microlite on the pegmatite dikes in Southern Norway. The microlite and the mineral paragenesis of this dike has previously been described by the author (10).

42. Landås 2, a feldspar quarry on the northern part of Varaheia. The dike has only been opened with a few shots. The pegmatite is of the ordinary type. As accessory minerals beryl and samarskite were observed. A large beryl crystal about 30 cm in diameter was seen in the footwall, the samarskite occurred in crystals about 2 cm in length.

43. Landås 3, is situated on the northwestern slope of Varaheia. In this pegmatite large flakes of muscovite occurred abundantly and besides the feldspar considerable quantities of this mineral has been produced from this quarry. As accessory minerals beryl, samarskite and monazite were found among the waste rock.

44. Landås 4, a feldspar quarry about 200 m east of Varaheia. The pegmatite is a horizontal lens-shaped body striking east and cutting an amphibolitic rock which strikes vertically to the north. As accessory mineral only a specimen of euxenite was found.

45. Landås 5 ("Landåstunnellen I"). This feldspar quarry is situated about 500 m east of the farm. The dike has been opened as a tunnel about 25 m long and 4 m high. Besides the ordinary minerals euxenite, monazite, garnet and beryl were found among the waste rock. The pegmatite seems to be somewhat richer in plagioclase than usual.

46. Landås 6 ("Landåstunnellen II"), about 150 m west of Landås 5. These feldspar quarries are very similar, both of them are opened as a tunnel and the same accessory minerals have been found in these pegmatites.

47. Landås 7 ("Beinmyr"). A feldspar quarry situated north-east of the farm. The pegmatite body seems to be lens-shaped and is of the ordinary microcline-quartz type. In addition to the ordinary minerals garnet, beryl, samarskite, monazite, xenotime and pyrite were found.

Støledalen. Near the farm Støledalen two pegmatite dikes have been mined for feldspar.

48. Støledalen 1, situated west of the farm houses. The pegmatite body is a dike cutting amphibolitic rocks. The chief constituents are a reddish microcline, quartz, mica and a small amount of plagioclase. The pegmatite is rich in accessory minerals of which garnet, thalenite, fergusonite, alvite, euxenite, monazite, magnetite and molybdenite were collected. The thalenite of this dike has been studied by J. Schetelig (52). Fergusonite and alvite are the first crystallized accessory minerals of the dike. The fergusonite was found in relatively large crystals up to 5 6 cm in length. The euxenite generally occurred in small irregular nodules without crystal faces.

Fig. 5. Fragments of amphibolite in granite. At the upper left a granite pegmatite dike. 40. Skripeland 2. Iveland.

49. Støledalen 2, is situated north of the farm houses. The pegmatite is of the ordinary type. The accessory minerals were gadolinite, beryl and ilmenorutile. The beryl is partly strongly altered to a mass which seems to contain bertrandite, partly is the beryl very clear and transparent, the crystals are, however, always minutely fractured and are therefore of no value as gem stones. The ilmenorutile was only found as a small crystal fragment which was identified by means of X-ray spectroscopic analysis.

Omdal. On the property of the farm Omdal I have visited two feldspar quarries. The country rock is an amphibolite.

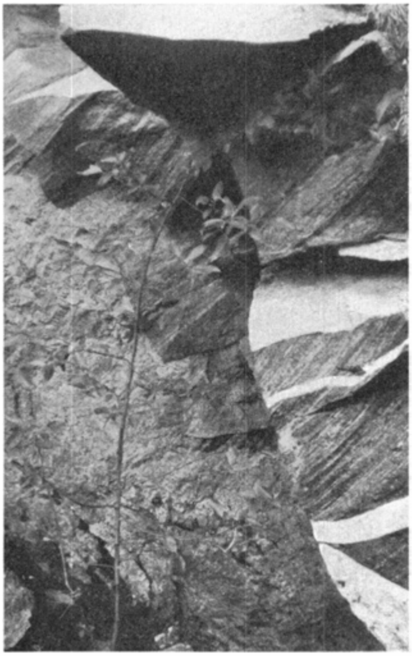


Fig. 6. Fragments of amphibolite imbedded in granite pegmatite. The amphibolite is intersected by small veins of pegmatite. 52. Mølland 1. Iveland.

50. Omdal 1 ("Omdalsstedje") about 1 km south-west of the farm houses on the western slope of a hill. The pegmatite body is a somewhat irregular dike striking north-east. Besides the ordinary minerals small amounts of euxenite, monazite, xenotime, orthite and magnetite were found. The euxenite had a yellow colour and occurred in well developed crystals.

51. Omdal 2 ("Omdalsholtane") is situated about 500 m north of the former Omdal 1. The pegmatite body is a small dike striking about east. In addition to the ordinary minerals euxenite and xenotime were found in small well developed crystals.

Mølland. To the farm Mølland belong 11 feldspar quarries some of which are rich in rare minerals, especially fine museum specimens of monazite.

52. Mølland 1, is situated on the eastern slope of a hill about 200 m south of the farm houses. The pegmatite body is an irregular dike which strikes east about vertically. The dike cuts an amphibolite and small veins and veinlets of granite aplite from the pegmatite were seen to intersect the surrounding rock. The pegmatite was of the ordinary type with microcline and quartz as chief constituents. Of rare minerals specimens of euxenite and xenotime were collected.

53. Mølland 2. A feldspar quarry on the eastern slope of the hill 150 m south-west of the farm houses. The dike was of the ordinary type. On the dump specimens of magnetite and euxenite were found. The country rock was an amphibolite.

54. Mølland 3 ("Horja"). On the northern side of the hill Horja near the farm houses a pegmatite dike has been opened for feldspar mining. The pegmatite body was of the ordinary composition and outcropped as an almost vertical dike striking to the south.

Beryl occurred in large crystals up to 25 cm in diameter traversing the quartz and the microcline. Monazite was found in well developed sharp-edged crystals. Xenotime was present partly in single crystals and partly in radiated crystal aggregates forming globular nodules. A dark euxenite-like mineral which was found in irregular nodules between the flakes of biotite appeared by X-ray spectral analysis to be a samarskite.

55. *Mølland 4* ("Vermdokka"). This feldspar quarry is situated 1/2 km south of the farm on the southern slope of a hill. The pegmatite is a dike-shaped body striking to the north with a dip at a great angle to the west, conformable to the structure of the surrounding amphibolite. It is rather largely segregated with large crystals of microcline and thin flakes of biotite. In addition to the ordinary minerals an euxenite mineral and monazite were present.

56. *Mølland 5*, a feldspar quarry about 150 m west of the south end of the lake Kjettevann. This feldspar working is a small almost vertical dike of the ordinary type and striking south. The dike cuts a pyrrhotite-bearing amphibolite and about 200 m north of the dike a prospect pit for nickelbearing pyrrhotite has been opened. The accessory minerals were: euxenite, monazite and magnetite.

57. *Mølland 6*, situated west of the middle part of the lake Kjettevann. The pegmatite is a very small dike striking south and is of the ordinary type, perhaps somewhat richer in plagioclase than usual. As accessory minerals were noted: Euxenite, monazite, magnetite, orthite and ilmenite. The ilmenite occurred as large plate-shaped masses often orientated conformable to the flakes of biotite. Small euhedral crystals of euxenite were seen imbedded in the ilmenite.

58. *Mølland 7*. A very small feldspar quarry near the northern end of the lake Kjettevann. The pegmatite is exposed as an irregular body on the southern face of a cliff. The border of the dike consisted of large masses of graphic granite. The feldspar of the graphic granite was partly a microcline and partly a plagioclase. The accessory minerals were: fergusonite, euxenite, monazite, xenotime, magnetite, ilmenite and orthite. The fergusonite is one of the first crystallized minerals of the dike, the euxenite has crystallized partly before the monazite, and crystals of monazite and xenotime were found imbedded in orthite. The orthite was present in large ill-defined crystals. Ilmenite occurred in plate-shaped masses.

Rostadheia. On the hill Rostadheia feldspar has been produced in 4 different quarries. These pegmatites form irregular bodies and as the hill is strongly overgrown the extension of the pegmatite bodies is difficult to state. The association of both the ordinary and the accessory minerals is very similar in these quarries and seems to indicate a connection between the pegmatites. The dikes are especially known for having produced many fine museum specimens of monazite. The monazite from these dikes has previously been studied by J. Schetelig (48).

59. Mølland 8 (Rostadheia 1), is a quarry which has been opened as a tunnel. Besides the ordinary pegmatite minerals fergusonite, alvite, euxenite and monazite were found among the waste rock.

60. Mølland 9 (Rostadheia 2) is situated east of the tunnel and contains the same minerals as this quarry.

61. Mølland 10 (Rostadheia 3) west of the tunnel. Of accessory minerals euxenite, monazite, and magnetite were present.

62. Mølland 11 (Rostadheia 4), is a pit now filled with water and is situated south of the tunnel. The accessory minerals were: fergusonite, euxenite and monazite.

Ljosland. The property of the farm Ljosland is very rich in pegmatite dikes and 14 different dikes have been opened for feldspar mining. The country rock is a very dark amphibolite.

63. Ljosland 1 (Ljoslandsjordet I). A feldspar working on a pegmatite body which outcrops on the southern slope of a hill 200 m west of Nedre Ljosland. The pegmatite is of the ordinary microcline-quartz type. The accessory minerals were: garnet, monazite and columbite. The columbite occurred in relatively large crystals up to 15 cm in length.

64. Ljosland 2 (Ljoslandsjordet II), is a small feldspar quarry situated 50 m north of Ljosland 1. The dike differs from the former in regard to the rare minerals. The rare minerals collected were euxenite, monazite and orthite.

65. Ljosland 3 ("Ljoslandsåsen"). On the hill Ljoslandsåsen west of Nedre Ljosland an almost vertical pegmatite dike strikes east cutting the amphibolite and can be traced for a distance of about 200 m. This dike has been opened for feldspar mining in several places. The pegmatite consists of the ordinary chief minerals but seems to be a little richer in quartz than usual.

A considerable part of the dike is made up of graphic intergrowths of microcline and quartz. The accessory minerals were beryl, samarskite, columbite and monazite. Parallel intergrowths of columbite

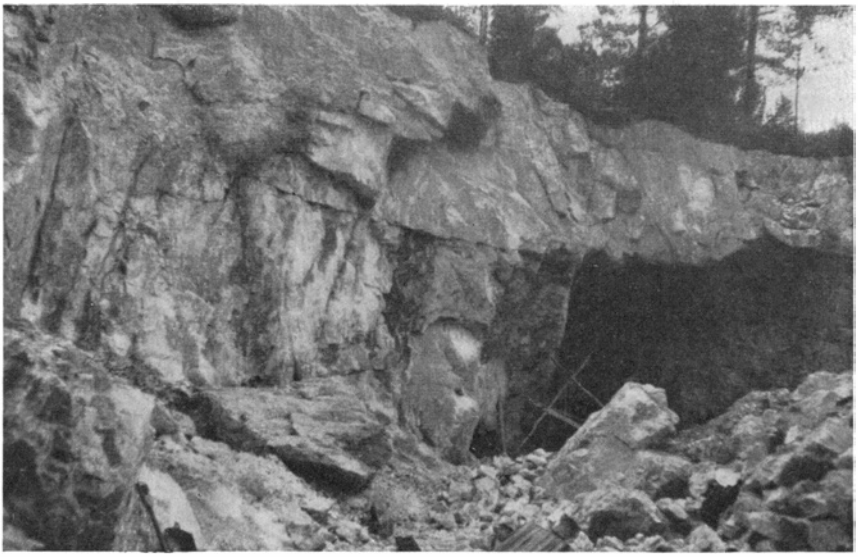


Fig. 7. Feldspar quarry at Rostadheia, Mølland, Iveland. Large crystals of microcline are seen in the wall of the opening.

and samarskite were observed. The samarskite has always crystallized earlier than the columbite.

Knipan. On the south-western slope of the hill Knipan, two pegmatite dikes have been opened in search of feldspar, one of these being famous as the first finding-place of the rare mineral thortveitite.

66. Ljosland 4 (Knipan 1). This thortveitite-bearing dike is a small irregularly-formed pegmatite body rich in quartz, which seems to be an offshoot of a nearby situated larger dike. The pegmatite and its minerals have been explicitly studied by J. Schetelig (49, 50). The sequence of crystallization is according to Schetelig: euxenite always older than the thortveitite; monazite, alvite, ilmenorutile and xenotime are in small grains older than the thortveitite, in larger masses partly younger. Beryl is generally younger than the thortveitite and the other minerals magnetite, biotite, muscovite, feldspars and quartz have all of them crystallized later than the thortveitite.

67. Ljosland 5 (Knipan 2) a small test pit about 100 m south-east of the thortveitite-quarry. Besides the ordinary minerals fergusonite, alvite and magnetite were found.

Ljoslandsheia. On the Ljoslandsheia around the swamp on the northern side of the hill Knipan 6 pegmatite dikes have been mined for feldspar. Five of these dikes are situated on the north side of the swamp and strike to the north. All of these pegmatites are of the ordinary microcline-quartz type but differ in regard to their accessory minerals. The amphibolite is a dark massive rock without distinct structure.

68. Ljosland 6 ("Ljoslandsheia 1") situated north of the east end of the swamp. The accessory minerals found were: garnet, beryl, samarskite, columbite and monazite.

69. Ljosland 7 ("Ljoslandsheia 2"). This feldspar quarry has been opened on a pegmatite dike south of Ljosland 6. The only accessory mineral found was euxenite.

70. Ljosland 8 ("Ljoslandsheia 3") situated west of the former Ljosland 7. Large flakes of dark biotite intersect the exposed part of the pegmatite. The accessory minerals were: euxenite (polycrase), monazite, xenotime and ilmenite. The ilmenite was present in large thin flakes which often intersected one another.

71. Ljosland 9 ("Ljoslandsheia 4") about 20 m west of Ljosland 8. The pegmatite is very rich in large crystals of blue and green coloured beryl. A large beryl crystal about 70 cm long and 10 12 cm in diameter was exposed on the wall of the opening (fig. 8). The other accessory minerals were euxenite, monazite and magnetite.

72. Ljosland 10 ("Ljoslandsheia 5"). A feldspar quarry on a pegmatite dike at the west end of the swamp. The pegmatite consists of the ordinary chief minerals but is richer in plagioclase than usual. Besides the ordinary minerals beryl, euxenite, betafite, monazite, xenotime, yttrotitanite, apatite, chalcopyrite, magnetite and chalcocite were found among the waste rock on the dump. Chalcopyrite was seen imbedded in euxenite. The monazite and xenotime have crystallized partly later than the euxenite minerals. In some parts of the pegmatite apatite was abundant between the flakes of biotite, less frequent in the microcline, as green transparent prismatic crystals. They often intersected the yttrotitanite, and the apatite is therefore on this dike evidently a primary mineral. Some fine specimens of cleveite at the Mineralogical Museum in Oslo, located Ljoslandsheia, are probably from this pegmatite dike. I have, however, visited the quarry 4 times without finding any trace of this mineral and it has therefore probably only occurred in certain parts of the dike which are no more available. This pegmatite dike differs from the ordinary pegmatites in Iveland in being exceptionally rich in calcium. This great content of calcium has caused the formation of the calcium minerals apatite, yttrotitanite and betafite which are very rare in the pegmatite dikes in the district.

Fig. 8. Beryl crystal in the wall of a feldspar quarry. 71. Ljosland 9. Iveland.

73. Ljosland 11. About 100 m south of the swamp on Ljoslandsheia a small pegmatite body has been mined for feldspar. The quarry is a pit which was filled with water when I visited the place and the extension of the pegmatite could therefore not be stated. Among the waste rock on the dump specimens of beryl, garnet, euxenite, monazite and ilmenite were collected. The beryl was present in small beautiful crystals intersecting the quartz and less frequently the microcline. The crystals were generally blue coloured and transparent, they were, however, too much fractured as to have any value as gem stones. The ilmenite was abundant as large thin flakes in the same way as the biotite. Between the flakes of ilmenite and imbedded in this mineral occurred polycrase-shaped crystals of euxenite.

74. Ljosland 12. ("Tarald Fidjelands brudd"). A small feldspar quarry about 100 m south-east of the former. The quarry is a pit now filled with water. The accessory minerals found among the waste rock were: euxenite, gadolinite, xenotime, beryl, magnetite and orthite. In regard to the chief constituents the pegmatite was of the ordinary type.

75. Ljosland 13. About 30 m south of Ljosland 12 some experiment pits have been opened in a small pegmatite dike of the ordinary type. The only accessory mineral found in this dike was a euxenite.

76. Ljosland 14 ("Torvelona"). At the road about 200 m east of Øvre Ljosland a small pegmatite dike has been exposed in the road cut and some rock from this dike has been mined and used as road material. The pegmatite is a small irregular body about 4 5 m wide and has a somewhat unusual mineral composition. Plagioclase seemed to be the dominant feldspar in the exposed part of the dike. It contained numerous crystals of beryl and garnet and at some places a black tourmaline. The garnet occurred partly as euhedral crystals and partly as irregular intergrowths with quartz. The garnet and the tourmaline were also observed imbedded in well developed crystals of beryl. The microcline showed no crystal outlines and seemed to be partly replaced by plagioclase. Muscovite was sparingly present. The quartz occurred chiefly as finer and coarser intergrowths with microcline and plagioclase. Besides these minerals mentioned euxenite and a single crystal of thortveitite have been found in the dike. This pegmatite differs in its mineral composition considerably from the ordinary granite pegmatites in Iveland; the mineral paragenesis and the structure of this dike indicate that it has been influenced by hydrothermal-pneumatolytic activity. Cleavelandite which generally is the characteristic mineral of the hydrothermal-pneumatolytic dikes in the district has, however, not been observed on this pegmatite.

Håverstad. On the property of the farm Håverstad 7 pegmatite bodies have been mined for feldspar.

77. *Håverstad 1.* A small feldspar quarry at the road side about 50 m from the farm houses. The pegmatite forms a small irregular body with the ordinary chief constituents. The microcline is an ordinary reddish perthite, plagioclase occurred very sparingly. Biotite in large thin flakes was abundant. When an old dump of waste rock was removed to be used as road material many fine crystals of thortveitite were found by the road surveyor Olav Landsverk, and during the last years some thortveitite crystals have been collected in the pit. The other accessory minerals of the dike were euxenite, alvite, monazite, xenotime, ilmenorutile, orthite and apatite. The thortveitite occurred usually in the microcline near the biotite flakes and has crystallized later than the euxenite but earlier than the ilmenorutile. The apatite occurred very sparingly as small slightly green coloured translucent crystals.

78. *Håverstad 2* ("Knotten") is situated at the main road north of the farm. The pegmatite body is an irregular dike which strikes about east and is composed of the ordinary chief minerals. The

accessory minerals were: garnet, euxenite, monazite and xenotime. The xenotime was present in radiated crystal aggregates forming globular nodules up to 2 cm in diameter.

79. Håverstad 3 ("Heia"), a small feldspar quarry north of Håverstad 2 near the main road. The pegmatite body is a dike striking south-east. The mineral composition is the ordinary one. As accessory minerals, garnet, euxenite, monazite and xenotime were present.

80. Håverstad 4 ("Tuten"). A feldspar quarry situated about 500 m east of the farm. The pegmatite outcrops as a dike on the southern face of a small cliff. The pegmatite is of the ordinary type. Of rare minerals only orthite and monazite have been found.

81. Håverstad 5. About 1 km east of the farm Håverstad a small dike has been opened for feldspar mining. The pegmatite consists of the ordinary chief constituents but is unusually rich in graphic granite. Garnet is the only accessory mineral which has been found in the dike.

82. Håverstad 6 ("Salegruva"). On the hill Salane about 3 km east of Håverstad the amphibolite is intersected by several pegmatite dikes striking east. The pegmatite is of the ordinary type and contains as accessory minerals beryl and garnet.

83. Håverstad 7. On the western side of the small lake Klepptjønn near the main road a small pegmatite dike which outcrops on the top of a cliff has been mined for feldspar. Besides the ordinary minerals beryl is present in large crystals.

E p t e v a n n. On the property of the farm Eptevann I have visited four feldspar quarries.

84. Eptevann 1. A feldspar quarry situated about 1 km south-east of the farm, near the main road. The pegmatite is of the common microcline-quartz type. Monazite, euxenite and magnetite occurred sparingly.

85. Eptevann 2. A small test pit about 50 m west of the main road. The pegmatite is very rich in quartz and outcrops on the northern slope of a hill as a small lense-shaped body surrounded by a coarse-grained amphibolite. The dike was too small for feldspar quarrying but as the rare mineral thortveitite was found in considerable quantities in the dike a few shots were put in the dike in search for this mineral. When I visited the dike it had not been operated for 20 years and was badly overgrown, by a close inspection of the waste rock, however, some small crystals of thortveitite were found. The mineral paragenesis was very similar to that of the other thortveitite-bearing dikes, namely: a reddish microcline, quartz, small amounts of plagioclase, biotite in large black flakes, beryl, monazite, xenotime, euxenite, ilmenorutile and thortveitite. The euxenite was the first crystallized rare mineral of the dike. The thortveitite from this dike is often very fresh and translucent. It has previously been studied by J. Schetelig (49).

86. Eptevann 3. A feldspar quarry about 100 m east of the farm. The pegmatite is of the ordinary type. A specimen of pegmatite with monazite and cleveite located Eptevann in possession of the Mineralogical Museum in Oslo is probably from this dike.

87. Eptevann 4 ("Hovåsen"). On the eastern slope of the hill Hovåsen a very large pegmatite dike has been mined for feldspar. The pegmatite is segregated on a gigantic scale and is of the ordinary type. When I visited the quarry in the summer 1933 a huge beryl crystal weighing about 1 ton had recently been mined out and the sharp-edged impression of this crystal was seen in the wall. Monazite and columbite have been found in relatively large crystals.

The pegmatite dikes in northern Iveland.

In the northern part of Iveland the amphibolite is intersected by numerous pegmatite dikes, most of which strike to the north-west. These dikes are generally larger than the pegmatites in the southern and central parts of the district and are usually visible in the landscape as lower ridges and hills, as the ground rock here is more sparingly covered with glacial deposits. These pegmatites are also generally segregated in a larger style than those hitherto described. It is therefore very difficult to state the mineral paragenesis by studying the quarries, the rare minerals generally being segregated in large crystals only in particular parts of the dike, and thus often very great quantities of pegmatite rock may be examined without finding any trace of rare minerals. The dikes in northern Iveland are generally very uniform as to their mineral paragenesis, most of them containing as rare minerals large crystals of gadolinite only and they are thus not so interesting from a mineralogical point of wiew as the pegmatites in the southern and central part of the district.

A few dikes, however, are exceptions with very interesting mineral parageneses. The pegmatite dikes in this area have been very explicitly described and mapped out by T. Barth (5). Besides feldspar the pegmatite dikes in northern Iveland have produced considerable quantities of gadolinite and some euxenite minerals, most of which have been sold for export to Germany.

Frikstad. On the property of the farms Frikstad are situated many feldsparquarries, 11 of which will be mentioned in this description.

88. Frikstad 1 ("Klystra"), about 200 m west of Nedre Frikstad. The pegmatite forms a large rock knoll surrounded by swamps. The pegmatite was of the ordinary microcline-quartz type. As accessory minerals only some crystals of garnet were observed.

89. Frikstad 2 ("Kjørka"). About 1 1/2 km west of Nedre Frikstad are situated several small pegmatite dikes which have been opened as small test pits in search for rare minerals. I have not found occasion to visit these quarries but the minerals occurring in these dikes have been collected for the Mineralogical Museum by O. Landsverk, Iveland. These minerals were: microcline, plagioclase, cleavelandite, beryl and garnet. According to this mineral composition these dikes must belong to the hydrothermal-pneumatolytic type.

90. Frikstad 3 ("Tuftane"). A feldspar quarry about 700 m west of Nedre Frikstad, which has been opened for feldspar mining with 3 cuts. Besides the ordinary minerals only garnet was found.

91. Frikstad 4 ("Dauren"). The hill Dauren about 200 m north of Øvre Frikstad consists of a large pegmatite dike. The pegmatite is of the ordinary type and no accessory minerals were observed.

92. Frikstad 5 ("Stifjell"). A feldspar quarry about 200 m south of Vestre Frikstad. The pegmatite is a dike of the ordinary type. As accessory minerals were found: gadolinite, ilmenite and magnetite.

93. Frikstad 6. This feldspar quarry is situated about 400 m south of Østre Frikstad. Only the ordinary minerals were found in the dike.

94. Frikstad 7 ("Slobrekka"). About 200 m north of the farm Vestre Frikstad on the hill Slobrekka a large pegmatite dike strikes east parallel to the southern slope of the hill. The dike has been opened with two cuts and consists of the ordinary minerals with large crystals of microcline. This pegmatite is probably the richest in accessory minerals in Iveland. Some years ago a gadolinite crystal weighing about 500 kgms was mined in this dike. The crystal was seen on the rock surface and was mined out with one shot. Probably about 2 tons of gadolinite and several hundred kgms of blomstrandine have been produced on this pegmatite. The gadolinite occurred partly in large ill-defined crystal masses and partly in small well developed crystals up to 5 10 cm in length, usually imbedded in the microcline. The other accessory minerals were: a brown coloured blomstrandine (priorite), a black blomstrandine brilliantly vitreous and submetallic, a polycrase-shaped euxenite, alvite, monazite, xenotime, orthite, garnet, magnetite and ilmenite. The xenotime occurred as irregular nodules without crystal faces. The magnetite was found in globular nodules which often included euhedral crystals of euxenite.

95. Frikstad 8. A feldsparquarry situated about 300 m èast of Østre Frikstad. In addition to the ordinary minerals garnet and gadolinite were found.

96. Frikstad 9 ("Steli"). This feldspar quarry is operated on a very large dike which forms a hill about 100 m broad and has been opened with several pits and cuts. The pegmatite is unusually coarsely segregated, some of the microcline crystals containing more than 200 tons of feldspar. A gadolinite crystal of 200 kgms has been mined in this dike. On my visiting the place a crystalline mass of pyrite weighing about 100 kgms was found in one of the pits.

97. Frikstad 10 ("Stemyr"), a feldsparquarry situated east of the former. The pegmatite is highly segregated and consists of the ordinary chief minerals. As accessory minerals occur: gadolinite, orthite, molybdenite and pyrite.

98. Frikstad 11 ("Småliane"), about 1 1/2 km north of vestre Frikstad. This pegmatite is also very coarsely crystallized and is of the ordinary type. Among the waste rock on the dump crystals of garnet, gadolinite and orthite were collected.

Kåbuland. On the property of the farm Kåbuland I have visited two feldspar quarries.

99. Kåbuland 1 ("Amerika") is a large, very coarse-grained pegmatite dike about 2 km north of the farm. The pegmatite body seems to be irregularly shaped but the extension of the pegmatite could not be stated. It cuts the amphibolitic rock, and small veins and veinlets from the pegmatite body are seen to traverse the surrounding rock. The chief minerals were: microcline, quartz, mica and a small amount of plagioclase. The microcline was partly green and translucent with microscopic perthite lamellæ, and this type was evidently the primary mineral most of which was altered to the ordinary reddish coarse perthitic microcline. The pegmatite is very rich in blomstrandine which has been found in masses up to a weight of 500 kgms. This mineral has been described previously by the author (7). Orthite was abundant in large ill-defined crystals. Monazite and xenotime were present in small quantities.

100. Kåbuland 2. This pegmatite dike is situated north of Kåbuland 1. The pegmatite is very coarse-grained and consists of the ordinary minerals.

Birkeland. Near the farm Birkeland, 3 pegmatite dikes have been mined for feldspar.

101. Birkeland 1. About 200 m north of the farm. The pegmatite is of the ordinary microcline-quartz type. The accessory minerals were: garnet, gadolinite and magnetite. In this dike several hundred kgms of gadolinite have been produced.

102. Birkeland 2. A small test pit about 200 m north of Birkeland 1. Here a microcline-quartz pegmatite consisting chiefly of graphic intergrowths of microcline and quartz has been intersected by a younger dike of the cleavelandite-quartz type very like those of Skripeland and Landås. The cleavelandite pegmatite is very rich in topaz and a large crystal of this mineral with a weight of 80 kgms from this dike has been acquired by the Mineralogical Museum in Oslo. The topaz is generally colourless and transparent, it is, however, always strongly fractured. It is often surrounded by a lilac-coloured muscovite. Microcline occurred sparingly without crystal outlines and seemed to be partly replaced by cleavelandite. Gadolinite was present in plate-shaped crystal aggregates. A red coloured garnet occurred partly in euhedral crystals and partly as irregular plateshaped masses between the cleavelandite blades. In the cleavelandite were as usual found small cavities or pockets up to 15—20 cm in diametre. In this dike large masses of bismuthinite weighing up to 2 kgms has been found by J. Schetelig.

103. Birkeland 3. A feldspar quarry on the northern slope of the hill north of the farm. The pegmatite dike was an ordinary microcline-quartz pegmatite which was, however, intersected by a small younger dike of the cleavelandite-quartz type. In addition to cleavelandite and quartz the dike contained garnet, topaz, a lilac-coloured and a green muscovite and was very similar to the former Birkeland 2.

Katterås (Vegusdal). The farm Katterås is situated about 1 1/2 km west of Birkeland but belongs to Vegusdal, a neighbouring district to Iveland. On the property of this farm 3 pegmatite dikes have been opened for feldspar mining. Two of these feldspar quarries are situated on Øigardsheia about 500 m north of the farm on a pegmatite hill about 150 m long and 40 50 m broad, consisting chiefly of graphic granite.

104. Katterås 1. The southern feldspar quarry on the hill Øigardsheia. The pegmatite is of the hydrothermal-pneumatolytic type and consists chiefly of cleavelandite and quartz. No microcline of commercial value has been produced from the dike. The microcline is partly blue coloured. This cleavelandite-quartz dike is surrounded by large masses of graphic granite. The accessory minerals were: garnet (spessartite), topaz, beryl, apatite, columbite and monazite.

105. Katterås 2, about 20 m north of Katterås 1. The pegmatite is here of the microcline-quartz type rich in graphic intergrowths of microcline and plagioclase with quartz. Besides the ordinary minerals, specimens of garnet, euxenite, monazite and magnetite were collected among the waste rock on the dump.

106. Katterås 3. This feldspar quarry is situated about 500 m east of the farm. The pegmatite is of the ordinary type. The accessory minerals are: beryl, monazite and columbite.

Evje. The district Evje, situated north of Iveland, is very rich in granite pegmatites in which large quantities of rare minerals have been found. Most of these feldspar quarries, however, have not been operated for many years and are therefore badly overgrown. It is thus very difficult to state the mineral paragenesis of each dike. Two of the feldspar quarries in this district, in which the mineral paragenesis is well known shall be included in this description.

107. Høgetveit. A feldspar quarry situated about 100 m north of the farm houses. From this dike about 17 000 tons of feldspar and large quantities of quartz have been produced. The pegmatite is of the ordinary type with chief minerals microcline, quartz, biotite and small amounts of plagioclase. The accessory minerals were: fergusonite, xenotime, monazite, alvite, gadolinite, thalenite, orthite, pyrite, magnetite and garnet. The mineral paragenesis and the sequence of crystallization has previously been described by J. Schetelig (52). A study of the fergusonite of this dike has been published by P. Schei (47).

108. Landsverk. This feldsparquarry is situated about 500 m north of the farm, near the road. The dike is about 20 30 m wide and intersects a dark gabbro rock. Part of the pegmatite forms a breccia consisting of fragments of pegmatite and the surrounding gabbro, cemented with quartz. The pegmatite is chiefly of the ordinary microcline-quartz type with some biotite, muscovite and relatively much plagioclase. The accessory minerals are: fergusonite, alvite, euxenite, monazite, xenotime, thorite, uranothorite, betafite, orthite, garnet, epidote, magnetite and calcite. This mineral paragenesis shows that the pegmatite is unusually rich in calcium. The ordinary magmatic pegmatite is intersected by a small hydrothermal-pneumatolytic dike consisting of cleavelandite, quartz and green and lilac-coloured muscovite.

Mineral Description.

Microcline.

Microcline is the leading mineral of the ordinary pegmatites in the Iveland district. In some pegmatites especially rich in quartz the microcline may be developed as single, huge well-shaped crystals imbedded in quartz, in most of dikes, however, the microcline crystals are worked into each other. The microcline is always perthitic and usually the albite veins are visible to the unaided eye. The colour is generally reddish or greyish. The crystallization of the microcline belongs to a late stage of the solidification of the pegmatite, only the quartz has crystallized later, and the microcline therefore often encloses euhedral crystals of other minerals, especially rare minerals, beryl and garnet.

The feldspars from the granite pegmatites in Norway have especially been studied by J. H. L. Vogt (52) and Olaf Andersen (1). Vogt emphasises the process of exsolution as the cause of all ordinary perthites and that this exsolution has taken place in the solid phase owing to the diminishing solubility of Ab and An in Or, and of Or in Ab + An at decreasing temperature. Olaf Andersen (1), however, has by his study of the feldspars of the granite pegmatites come to the conclusion that the microcline perthites during their formation to a great extent have been influenced by replacement processes. Andersen has in the same paper described the different types of perthites as string perthite, film perthite, vein perthite and patch perthite.

The ordinary microcline of the magmatic pegmatites in Iveland is a coarsely perthitic mineral belonging chiefly to the type which Andersen has called vein perthite. Under the microscope it proves to be very coarsely cross-twinned. According to Andersen the composition of the microclines of Norwegian pegmatites varies from 15 Naf. 85 Kf. to 32 Naf. and 68 Kf. with very little Caf.

The amount of perthite-substance in the microclines from Iveland was found by T. Barth (3) to vary between 13 and 23 % in 17 different dikes. The central part of the perthite-veins is according to Barth generally richer in An than the outer zone.

In some of the dikes in Iveland small quantities of a green translucent microcline without macroscopically visible albite veins are also met with. Under the microscope this feldspar exhibits very fine twinnings, and the albite forms very small regular strings in the microcline. This type of perthite O. Andersen has called string perthite, and in his opinion it has been formed by exsolution in the solid state at an early stage of the evolution of the feldspar.

This green translucent microcline generally forms the inner part of the crystals and is irregularly surrounded by microcline of the ordinary coarse vein perthite of a reddish colour, which is apparently formed by alteration of the former. Fig. 9 shows a picture of the border between these feldspars. The alteration has begun along cracks in the feldspar which run vertical to the base and form about 30 degrees with 010. The coarse albite veins are orientated in a direction about vertical to the cracks. Microscopic studies of the border between these two types of feldspar give a good picture of how this alteration has taken place. The vein perthite seems to have been formed by a gradual gathering of the small perthite lamellæ in the string perthite. At the same time the microcline looses its peculiar fine twinning and has attained the appearance of the ordinary crosstwinned type. The microphotographs on Pl. 1 exhibit the different phases in this alteration.

Such transition of string perthite into vein perthite has been described previously by Andersen (1) in feldspar from Stene Sannidal near Kragerø. Andersen concludes that "also those perthites in which no trace of string perthite is visible may have originated as string perthites, the recrystallization in such cases being complete, producing

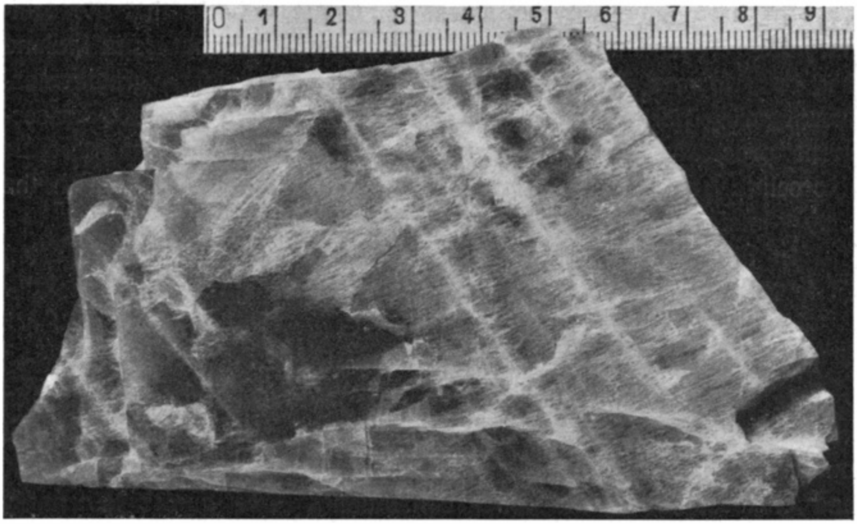


Fig. 9. Green translucent microcline perthite
surrounded by microcline of the ordinary coarse perthitic type.
99. Kåbuland 1.

a vein perthite with its associated film perthite." During this transition O. Andersen assumes that also replacement processes by means of circulating solutions have taken place.

As the other minerals in the magmatic microcline pegmatites of Iveland exhibit no distinct trace of real replacement processes, this explanation seemed to be unlikely for these pegmatites. In order to state if a change in composition due to replacement processes has taken place during the transition from string perthite to vein perthite I have made chemical determinations of K_2O and Na_2O in the two types of microcline.

The analysis gave as result:

	K_2O	Na_2O	Kf.	Naf.
Green translucent string perthite	11.84 %	3.22 %	70.16 %	27.32 %
Reddish vein perthite	11.92 „	3.32 „	70.64 „	28.17 „

The result shows that the difference in composition between the two feldspars lies within the limits of the error of the analysis. The lower calculated percentage of feldspar in the string perthite may be due to small inclusions of quartz. No evidence of replacement processes can therefore be stated.

In the opinion of the writer it seems probable that the ordinary coarsely perthitic microcline of the magmatic pegmatites in Iveland has been formed chiefly by transformation of a primary green translucent string perthite which has taken place without traceable replacement processes. The formation of the ordinary coarse perthitic microcline in Iveland therefore seems to be in accordance with the theory maintained by J. H. L. Vogt.

In Finland Eero Mäkinen (38) has come to the same conclusion as to the microclines of the granite pegmatites at Tamela.

Quartz.

In the magmatic granite pegmatites in Iveland quartz is next in abundance to microcline. It occurs as large masses without crystal outlines as the last crystallized mineral of the dikes, and surrounds and encloses all of the other constituents. The quartz is usually milky white but is also often clear and transparent. It may often be intersected on the cross and recross by thin veins representing fractures which later on have been filled with quartz substance. On the cleavelandite-quartz dikes the quartz varies from colourless to milky or smoky. It is often present in euhedral crystals generally intersected by blades of cleavelandite.

According to T. Barth (4 p. 119) the quartz in the granite pegmatites in Southern Norway always is a β quartz.

Plagioclase.

Plagioclase occurs in all the magmatic dikes in Iveland but to very varying amounts. In some pegmatites the plagioclase is found very sparingly, in other pegmatites it may be present in large crystals. It is also often found as graphic intergrowths with quartz especially near the contact. The plagioclase from the pegmatites in Iveland is usually an oligoclase. According to T. Barth (3) these plagioclases vary in percentage of An from 6 23 % in 19 different dikes in northern Iveland.

Albite.

According to private information from Professor J. Schetelig small transparent crystals of albite has been found on small cavities in some of the pegmatites in Iveland. In the dike Ljosland 10 small masses of a finegrained albite have been observed.

The platy variety of albite, cleavelandite, is the most characteristic mineral of the pneumatolytic-hydrothermal pegmatites in Iveland. It has a blue or white colour, and is usually translucent. The crystals are twinned on the albite law and the mineral occurs in sheaves of plates and fan-like aggregates. Cleavelandite has previously been described by W. C. Brøgger from granite pegmatite at Ånnerød, southeastern Norway (12). This mineral is often seen to replace earlier minerals especially microcline and beryl, it may also have filled open spaces in the surrounding rock.

The minerals generally associated with cleavelandite in the pegmatites in Iveland are quartz, green and lilac muscovite, spessartite, topaz, tourmalin, tantalite and microlite. Crystals of all of these minerals are often intersected by blades of cleavelandite.

Biotite.

Biotite is a prominent constituent in most of the magmatic pegmatites in Iveland but the quantity varies within wide ranges in the different dikes. The mineral generally occurs in rather thin flakes often several meters in extension. In dikes where biotite is abundant the microcline usually has a reddish colour. The rare minerals in the pegmatites generally occur near the biotite flakes or imbedded in this mineral. Often the crystals of these minerals have grown on the biotite flakes and with the vertical axis about vertical to these.

The crystallization of the biotite has apparently taken place during a long period of the solidification of the dike. Parts of the biotite appears to be older than the rare minerals fergusonite, euxenite and monazite. In some dikes the biotite is largely altered to chlorite.

Muscovite.

Muscovite is present in all the pegmatite dikes in Iveland. In the dikes belonging to the magmatic phase the amount of muscovite is very variable. The mineral may occur throughout the pegmatite but a concentration near the contact is often observed. In most of the dikes the books of muscovite are of a moderate size, in some few dikes, however, the mineral occurs in large thin flakes in the same way as the biotite. The colour is silvery white.

In the quartz-cleavelandite pegmatites, the muscovite usually differs in appearance from that of the magmatic phase. The muscovite that accompanies the cleavelandite generally has a greenish colour and also a lilac muscovite occurs in these dikes. The lilac muscovite often forms a thin layer between the topaz crystals and the surrounding cleavelandite. It may also form a thin coating around the blades of cleavelandite and fill small cavities in the albite. In larger masses this muscovite forms fine micaceous aggregates. It shows no flame reaction on Li.

Garnet.

Garnet is a common accessory mineral in the pegmatite dikes in Iveland. It occurs in both the magmatic and the pneumatolytic-hydrothermal pegmatites. All the studied specimens are spessartites.

In the magmatic dikes the spessartite generally has a dark red colour and occurs in well developed euhedral crystals up to 15 cm in diametre. The ordinary form is the icositetrahedron.

It usually contains considerable amounts of rare earth elements.

In the pneumatolytic-hydrothermal cleavelandite-quartz dikes the spessartite is always clear and transparent with a hyacint-red colour. In these dikes it generally occurs as irregular masses in the quartz and between the cleavelandite blades; euhedral crystals are very rare. These spessartites are also generally richer in manganese than those of the magmatic phase and rare earth elements have not been detected by X-ray spectral analysis of them. The same is also observed with spessartite from a cleavelandite-quartz dike from Gjerrestad near Kragerø, Norway.

Table 1.

Spessartite.

Estimated intensities of the lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	Coincidences
Y	K α_1	3	0.2	-	
Fe	»	10	10	5	
Mn	»	6	10	10	
Cp	L α_1	0.1	-	-	Dy L β_2
Yb	»	3	-	-	
Tu	»	0.1	-	-	
Er	»	0.5	-	-	
Ho	»	-	-	-	
Dy	»	4	-	-	Mn K β_1

1 Spessartite. 11. Frøysâ 3. Vacuum spectrograph. *2* Spessartite. 73. Ljosland 11. Vacuum spectrograph. *3* Spessartite. 41. Landås 1. Vacuum spectrograph.

In table 1 are given the results of the X-ray spectral analysis of 3 spessartites from Iveland. The dikes 11. Frøyså 3 and 73. Ljosland 11 belong to the magmatic phase. 41. Landås 1 is a cleavelandite-quartz dike.

Tourmaline.

Tourmaline has not been found in the typical microcline-quartz pegmatite dikes in Iveland.

In the hydrothermal-pneumatolytic dikes this mineral occurs sparingly. The colour is always black. Usually it is met with in dark, small masses often included in beryl crystals; euhedral crystals are very rare.

Topaz.

Topaz occurs frequently as a characteristic mineral in the cleavelandite-quartz pegmatite dikes but has not been found in the microcline-quartz pegmatites. It is usually colourless or slightly yellow and is mostly present in euhedral crystals to a weight of up to 80 kgms. The crystals are always strongly fractured.

Beryl.

Beryl is a common mineral in the pegmatite dikes in Iveland. In the magmatic microcline-quartz pegmatites, the beryl is present in euhedral often very large prismatic crystals reaching a weight of up to 1000 kgms. The colour is green, blue or yellow and the crystals are partly opaque and partly transparent but are always strongly fractured. The crystals often exhibit a zonar structure and may enclose small crystals and irregular masses of feldspar, quartz and mica. The crystallization of the beryl therefore must belong to a late stage in the segregation of the accessory minerals. Beryl occurs frequently in the varying types of magmatic pegmatites in Iveland with exception of the thalenite-bearing dikes. Thalenite and beryl have not been found in the same pegmatite, as previously pointed out by J. Schetelig (50). This is in accordance with the opinion maintained by Schetelig that the occurrence of thalenite is only possible when the amount of Be present is insufficient to transfer all of the yttersilicate into gadolinite. In some of the pegmatites

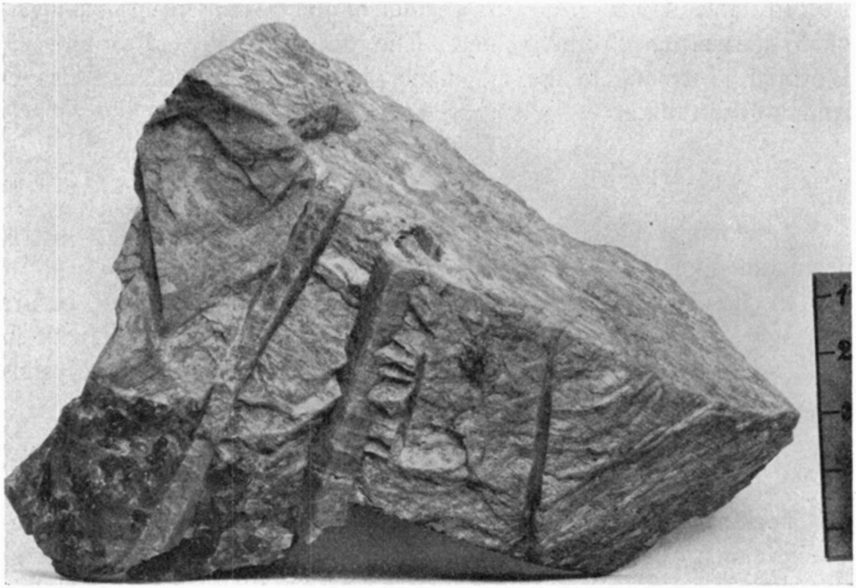


Fig. 10. Beryl crystals intersecting microcline and quartz.
73. Ljosland 11.

the beryl may be strongly altered to a decomposition mass containing the beryllium-mineral bertrandite. It has previously been described by Th. Vogt from a pegmatite at Tveit, Iveland (54).

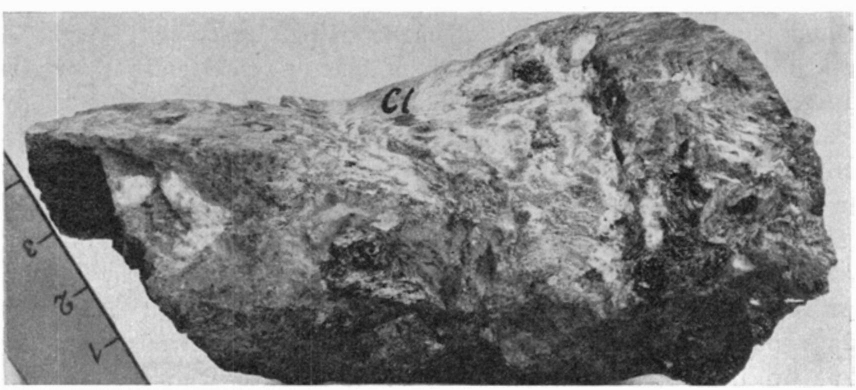


Fig. 11. Etched beryl, partly replaced by cleavelandite (Cl) and spessartite (S).
The cleavelandite-quartz dike 41. Landås 1.

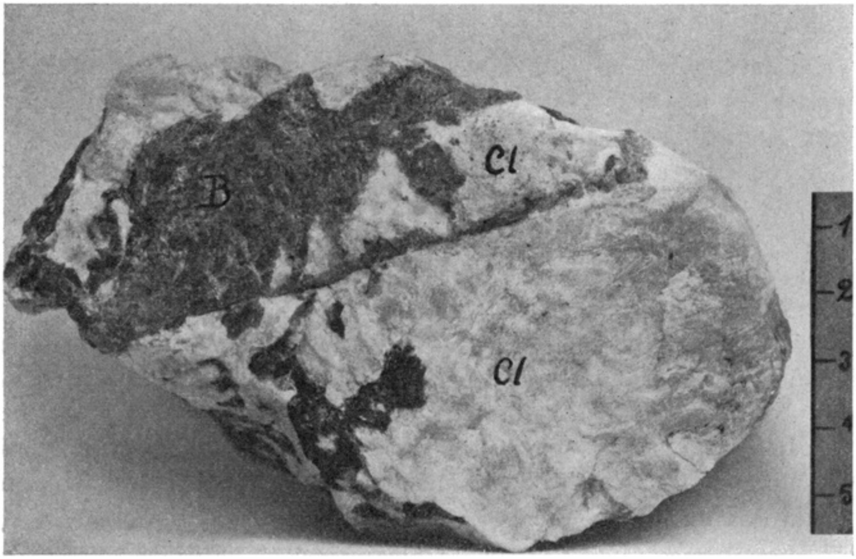


Fig. 12. The inner part of a beryl crystal partly replaced by cleavelandite, while the outer part of the crystal is preserved. 39. Skripeland 1.
B beryl substanz, Cl cleavelandite.

In the cleavelandite-quartz dikes the beryl is also a common mineral. In these dikes, however, the mineral has not been found in sharp-edged crystals as is usual in the magmatic pegmatites; the beryl crystals here usually have an etched and resorbed apparation and parts of the original crystals are often filled with cleavelandite and garnet and seem to have been replaced by these minerals. It is therefore probable that this beryl has been formed during an earlier magmatic phase and later on been partly dissolved and replaced by hydrothermal-pneumatolytical activity. These etched forms of beryl from cleavelandite-quartz dikes have been described previously from Central Maine by K. K. Landes (30) as "pocket" beryl. Some beryls of these dikes also occur in irregular masses and are very transparent. This beryl may probably represent the beryl material that has been resorbed and recrystallized during this hydrothermal-pneumatolytic activity.

Chrysoberyl.

Chrysoberyl has only been found in one pegmatite dike in Iveland, at the farm Nateland. This mineral and the paragenesis has been studied by J. Schetelig (47).

The pegmatite is of the ordinary microcline type. The other accessory minerals are fergusonite, euxenite, monazite, xenotime, alvite, gadolinite and molybdenite. Euhedral crystals of fergusonite and gadolinite have been found included in the chrysoberyl crystals.

The chrysoberyl has crystallized later than all of the before mentioned minerals. Beryl has not been observed in the dike.

According to V. M. Goldschmidt (21) the chrysoberyl must be regarded as a typical plumasitic Be-mineral, and the occurrence of this mineral probably indicates a relatively great excess of Al in relation to Na + K in this pegmatite.

Gadolinite.

Gadolinite occurs in Iveland especially in the southern and northern part of the district. In the central part of the area gadolinite-bearing dikes are very rare.

Gadolinite from Kåbuland, Eptevann, Ivedal, Nateland, Birkeland and Frikstad in Iveland has previously been described by J. Schetelig (14).

During my investigations in Iveland, I have found this mineral in 19 different dikes in the district; the paragenesis of these dikes will emerge from table 18. In the largely segregated pegmatites in northern Iveland the gadolinite crystals may reach enormous dimensions up to a weight of 500 kgms. The colour is black or brown and the mineral is often coated with a thin white layer of the carbonates of the rare earth elements, tengerite. The crystals are usually partly or completely in a metamict condition.

In table 2 are given the intensities of the α_1 lines of the elements in the spectrograms of the mineral powder. In addition to the chief constituents the gadolinite also contains small amounts of U and Th. The proportions of the chief chemical compounds in the gadolinites studied do not show any great difference, the distribution of the rare earth elements, however, exhibit some variation in the different species. In the gadolinite from Frikstad the rare earth elements have

Table 2.

Gadolinite.

Estimated intensities of lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	*4*	*5*	Coincidences
Y	$K\alpha_1$	8	8	8	8	10	
Fe	„	10	10	10	10	10	
Mn	„	4	4	3	2	3	
U	$L\alpha_1$	-	-	0.5	-	0.2	
Th	„	-	-	-	-	0.5	
Cp	„	2	0.5	2	2	2	Dy $L\beta_2$
Yb	„	3	2	4	4	8	
Tu	„	0.1	0.1	0.5	0.1	1	Sm $L\gamma_1$
Er	„	3	1	3	3	4	
Ho	„	4	2	4	3	3	Gd $L\beta_1$
Dy	„	5	3	5	5	6	Mn $K\beta_1$
Tb	„	0.2	-	0.2	0.2	1	
Gd	„	5	2	6	5	4	Ce $L\gamma_1$
Eu	„	0.2	-	0.2	0.1	-	Pr $L\beta_2$
Sm.	„	4	1	4	4	2	
Nd	„	4	2	6	4	1	
Pr	„	0.5	-	0.5	0.5	-	
Ce	„	2	3	4	2	-	
La	„	-	-	-	-	-	

1 Gadolinite. 102. Birkeland 2. Vacuum spectrograph. *2* Gadolinite. 34. Nateland. Vacuum spectrograph. *3* Gadolinite. 17. Rosås 4. Vacuum spectrograph. *4* Gadolinite. 9. Frøyså 1. Vacuum spectrograph. *5* Gadolinite. 10. Frøyså 2. Air spectrograph.

been studied by V. M. Goldschmidt who has included the distribution of these elements in the mineral under the thalenite typus.

I. and W. Noddack (40) have published quantitative X-ray spectral analyses of some Norwegian gadolinites including gadolinite from Kåbuland, Ivedal, Frikstad and Frøyså? (Iveland) in Iveland, and in these minerals the content of Re was also determined. The analyses show that the gadolinites from Ivedal, Frikstad and Frøyså are especially rich in Yb and Re, with a rhenium concentration of 1 11. 10^{-7}. The Re concentration seems to increase with the content of Yb in the gadolinite and this is in accordance with the opinion generally held that the gadolinites rich in Yb should represent the last fraction of the magmatic crystallization.

From the table 18 will emerge that gadolinite usually occurs in the thalenite-, fergusonite- and euxenite-bearing dikes. In some of the pegmatites in Northern Iveland, gadolinite is found in large quantities as the only rare mineral of the dikes. It is a characteristic mineral of the pegmatites rich in the rare earth elements in relation to the amount of Nb and Ta present, and in the magmatic dikes it has never been found associated with the niobium- and tantalum minerals poor in yttrium elements such as samarskite and columbite.

Gadolinite has also been found in the cleavelandite-quartz pegmatite 102 Birkeland 2. This gadolinite occurs in cleavelandite in tabular crystal aggregates with a characteristic habit, which has been explicitly described by J. Schetelig (14 p. 96). The mineral is anisotrop.

The composition of the characteristic minerals of the cleavelandite-quartz dikes makes it unlikely that this gadolinite should belong to the pneumatolytic-hydrothermal phase, as the minerals characteristic of this phase are poor in rare earth elements. It is in the opinion of the present writer more probable that this gadolinite represents a remainder of a magmatic pegmatite which later on has been replaced by hydrothermal-pneumatolytic activity, and that the mineral during these processes may have undergone a recrystallization.

Thalenite.

This mineral has first been detected and described from Iveland by J. Schetelig (50). In this paper Schetelig gives an explicit account of the chemical composition by means of chemical and X-ray spectral analysis and with a detailed statement of the paragenesis of the mineral. The known occurrences of this mineral will emerge from table 18.

As mentioned on p. 251, beryl has not been found in the thalenite-bearing dikes and according to Schetelig the thalenite is only formed when the amount of Be present in the magma is insufficient to transmit all the yttrium elements into gadolinite. J. Schetelig has also pointed out the fact that thalenite as a rule is associated with fergusonite. This paragenesis is according to Schetelig due to the fact that the fergusonite is an ortho-niobate and -tantalate and therefore requires less Nb and Ta than the metacompounds of the euxenite minerals.

Table 3.

Orthite.

Estimated intensities of the lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	*4*	*5*	Coincidences
Sr	$K\alpha_1$	-	-	-	-	1	
Y	»	2	2	3	5	5	
Fe	»	10	10	10	10	10	
Mn	»	5	2	2	4	3	
Ti	»	1	-	-	-	-	
Ca	»	6	5	5	-	-	
U	$L\alpha_1$	1	0.1	-	-	1	
Th	»	0.5	0.2	-	4	3	
Pb	»	0.2	-	-	0.1	0.5	
Ta	»	-	-	-	-	0.5	
Cp	»	-	0.1	-	0.1	0.1	Dy $L\beta_2$
Yb	»	0.1	2	-	0.5	0.5	
Tu	»	-	0.1	-	-	0.1	Sm $L\gamma_1$
Er	»	-	0.1	-	-	0.1	
Ho	»	-	1	-	0.1	0.2	Gd $L\beta_1$
Dy	»	1	2	0.1	2	2	Mn $K\beta_1$ Th 2 $L\alpha_1$
Tb	»	0.1	0.1	-	-	-	
Gd	»	2	3	0.2	3	2	Ce $L\gamma_1$
Eu	»	-	0.1	-	0.1	-	Pr $L\beta_2$
Sm	»	1	4	2	2	2	
Nd	»	5	5	5	6	3	
Pr	»	4	0.5	2	1	1	
Ce	»	6	5	6	5	6	
La	»	3	0.2	2	2	2	

1 Orthite Ljosland. Vacuum spectrograph. *2* Orthite 58. Mølland 7. Vacuum spectrograph. *3* Orthite 34. Nateland. Vacuum spectrograph. *4* Orthite, brown 12. Frøyså 4. Air spectrograph. *5* Orthite. 72. Ljosland 10. Air spectrograph.

Orthite (allanite).

Orthite is abundant in some of the magmatic pegmatites in Iveland but has not been found in the cleavelandite-quartz dikes. The mineral is black or brown, often strongly altered, and covered with a crust of iron oxides. It usually occurs in large ill-defined crystals up to a weight of 100 kgms and more, or in large black nodules. It may also be met with in small needle-shaped crystals usually intersecting the feldspar; these small crystals are always strongly altered. The results of the X-ray analysis given in table 3 show that the orthites contain strongly varying amounts of U, Th, and Mn. The distribution of the rare earth elements is rather constant and exhibits a characteristic concentration of the cerium elements. This complex of the rare earth elements V. M. Goldschmidt has defined as the certypus 2 or orthite-typus.

The orthite generally occurs together with euxenite minerals in the dikes of Iveland and has not been found in the samarskite- and columbite-bearing dikes. The same is observed in the dikes of Østfold, southeastern Norway. In the dikes of Østfold studied by W. C. Brøgger orthite has only been found in the euxenite-bearing dike at Kråkerøy near Fredrikstad.

This is certainly due to the fact that samarskite and columbite are characteristic minerals of the dikes which are relatively poor in the rare earth elements and under these conditions the total amount of the cerium elements will react with phosphoric acid and form monazite, thus there will be no excess of cerium elements to form silicates.

Thortveitite.

This mineral was first detected by J. Schetelig in 1910, when a crystal fragment found in a dike at Ljosland, Iveland, by Olaus Thortveit was transmitted to the Mineralogical Museum in Oslo.

The mineral was described by J. Schetelig in 1911 (48) and 1922 (49) and given the name thortveitite. Up to that time the thortveitite had been found in 4 different dikes in Iveland and Evje namely Landsverk and Unneland in Evje and Eptevann and Ljosland in Iveland.

In the last years 3 new occurrences in Iveland have been detected by O. Landsverk namely 35. Tjomstøl, 76. Ljosland 14 and 77. Håverstad 1. In table 4 are given the results of X-ray spectrograms of thortveitite from the five known occurrences in Iveland.

All the studied specimens contain considerable amounts of Zr and Hf which elements have previously been found in thortveitite from Ljosland 4 by V. M. Goldschmidt (24). The amount of Mn is somewhat varying in the different specimens. The complex of rare earth elements in the thortveitite is characteristic by being especially rich in Yb and is by V. M. Goldschmidt defined as yttertypus 2 or thortveitite-typus.

The mineral paragenesis is very similar in the different thortveitite-bearing dikes and has been explicitly studied by J. Schetelig. Especially characteristic is the occurrence of ilmenorutile on these dikes. All of the pegmatites in Iveland containing thortveitite are small

Table 4.

Thortveitite.

Estimated intensities of lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	*4*	*5*	Coincidences
Zr	K α_1	2	1	3	2	3	
Y	-	5	2	6	3	3	
Fe	-	4	5	4	5	6	
Mn	-	3	2	0.2	1	4	
Ti	-	0.1	0.1	0.1	0.1	-	
Sc	-	10	10	10	10	10	
Ca	-	1	0.1	0.5	-	-	
U	-	0.1	-	-	-	-	
Cp	L α_1	2	2	2	2	1	Dy L β_2
Yp	-	4	4	5	3	4	
Tu	-	0.1	0.1	0.1	-	-	
Er	-	0.2	0.5	0.5	0.2	0.1	
Ho	-	-	-	-	-	-	
Dy	-	1	1	0.5	0.5	0.5	Mn K β_1
Hf	L β_1	2	2	1	2	0.5	

1 Thortveitite. 76. Ljosland 14. Vacuum spectrograph. *2* Thortveitite. 35. Tjomstøl. Vacuum spectrograph. *3* Thortveitite. 66. Ljosland 4. Vacuum spectrograph. *4* Thortveitite. 77. Håverstad 1. Vacuum spectrograph. *5* Thortveitite. 85. Eptevann 2. Vacuum spectrograph.

dikes, rich in quartz, and seem to represent small offshoots of larger pegmatite bodies.

In regard to the origin of the Sc, V. M. Goldschmidt (23) has maintained the theory that this element does not originally belong to the pegmatite magma but has been leached out of the surrounding gabbro rock.

Zircon and alvite (cyrtolite).

Zircon minerals occur frequently in both the magmatic and the hydrothermal-pneumatolytic pegmatite dikes in Iveland. It is met with in well-developed crystals or in radiating crystal aggregates partly birefringent and partly in a metamict condition.

In the magmatic dikes the zircon always contains considerable amounts of U and rare earth elements and must be referred to the variety alvite (cyrtolite). The rare earth elements in these minerals, according to V. M. Goldschmidt (24), belong to the yttertypus.

The zircon from the cleavelandite-quartz dike 41 Landås 1 (table 5) differs from the magmatic zircons in having no detectable

Table 5.

Zircon.

Estimated intensities of lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	*4*	*5*	*6*	Coincidences
Zr	$K\alpha_1$	10	10	10	10	10	10	
Y	-	3	3	2	3	3	-	
Fe	-	4	3	8	4	5	4	
Mn	-	1	-	-	-	0.5	0.5	
U	$L\alpha_1$	3	1	1	1	3	1	
Pb	-	1	1	1	1	1	1	Hf $L\gamma_1$
W	-	2	1	0.1	0.1	1	-	Yb $L\beta_1$
Ta	-	1	-	-	-	0.1	3	
Cp	-	-	0.5	-	0.1	-	-	Dy $L\beta_2$
Yb	-	2	2	0.1	1	1	-	
Tu	-	-	-	-	-	-	-	
Er	-	0.5	0.5	-	-	-	-	
Ho	-	-	-	-	-	-	-	
Dy	-	0.2	0.5	-	0.5	0.5	-	Mn $K\beta_1$
Tb	-	-	-	-	-	-	-	
Gd	-	-	0.1	-	-	-	-	
Hf	$L\beta_1$	4	2	2	3	2	4	

1 Alvite. Høgtveit Evje. Air spectrograph. *2* Alvite. 35. Tjomstøl. Vacuum spectrograph. *3* Alvite. 77. Håverstad 1. Vacuum spectrograph. *4* Alvite. 1. Tveit 1. Vacuum spectrograph. *5* Alvite. Høgtveit Evje. Vacuum spectrograph. *6* Zircon 41. Landås 1. Vacuum spectrograph.

content of the rare earth elements. It is, however, rich in Ta and also contains some U.

The table 5 also shows that all the zircon minerals studied have given strong lines of hafnium in the X-ray spectrograms. The intensities of the Hf lines are given for the Hf $L\beta_1$ as the line Hf $L\alpha_1$ coincides with the Zr $2K\alpha_1$. The occurrence of hafnium in Norwegian alvites has been described by V. M. Goldschmidt and L. Thomassen (24).

The zircon minerals occur especially frequently in the fergusonite-bearing dikes and belong to an early stage of the crystallization of the pegmatites.

Fergusonite.

The first find of fergusonite in Setesdal was made by P. Schei (46) in a pegmatite dike at Høgtveit, Evje. In 1922 several new occurrences were published by J. Schetelig, namely Ivedal, Mølland, Lien, Ljosland and Rosås. Today fergusonite is known from 16 different pegmatite dikes in Iveland, the localities will emerge from table 18.

Table 6.

Fergusonite.

Estimated intensities of $K\alpha_1$ and $L\alpha_1$ lines in the X-ray spectrograms.

Element	Line	Air spectrograph			Vacuum spectrograph				
		1	*2*	*3*	4	*5*	*6*	*7*	Coincidences
Nb ...	$K\alpha_1$	8	8	7	8	8	8	8	
Y.....	-	10	10	10	10	10	10	10	
Fe....	-	5	5	3	0.5	7	1	5	
Mn ...	-	0.2	0.2	0.3	0.1	0.2	-	1	
Ti	-	-	-	-	-	2	3	6	
Ca....	-	-	-	-	-	0.5	0.2	0.5	
U	$L\alpha_1$	3	4	1	3	1	0.5	3	
Th ...	-	0.1	1	-	0.1	-	-	0.1	
Pb ...	-	2	3	1	2	1	0.3	1	
W	-	4	6	8	0.5	5	6	6	Yb $L\beta_1$
Ta	-	3	8	6	6	0.5	0.5	6	
Cp ...	-	2	4	2	0.2	2	2	2	Dy $L\beta_2$
Yb ...	-	7	8	7	2	7	6	7	
Tu ...	-	0.2	0.5	0.5	0.1	0.5	0.2	0.2	Sm $L\gamma_1$ Ta Ll
Er	-	4	5	7	2	6	4	3	
Ho ...	-	3	3	4	1	5	4	2	Gd $L\beta_1$ U $2L\alpha_1$
Dy....	-	6	7	7	2	6	7	6	Mn $K\beta_1$ Th $2L\alpha_1$
Tb ...	-	0.1	0.2	0.1	0.1	0.1	0 1	0.1	
Gd ...	-	3	3	1	0.2	4	4	2	
Eu....	-	-	-	-	-	-	-	-	Pr $L\beta_2$
Sm ...	-	0.4	0.2	-	0.2	2	2	-	
Nd ...	-	0.2	-	-	-	1	1	-	
Pr	-	-	-	-	-	-	-	-	
Ce....	-	-	-	-	-	-	-	-	
La	-	-	-	-	-	-	-	-	

1 28. Birketveit 6. *2* 11. Frøyså 3. *3* Høgtveit, Evje. *4* Berg, Råde Analyst. C. Blomstrand (W. C. Brøgger). *5* 8. Dalane 2. *6* 1. Tveit 1. *7* 11. Frøyså 3

The crystallographical data of the mineral are given by W. C. Brøgger (13) and P. Schei (l. c.). T. Barth has studied the structure of synthetic, metamict, and recrystallized fergusonite and according to this author these minerals crystallize tetragonally and agree to the formula $YNbO_4$. This is in accordance with a later study of this mineral by F. Machatschki (35).

In table 6 are given the results of X-ray spectrographical analysis of fergusonites from 6 different localities in Iveland and Evje, For comparison is also quoted the spectrogram of the fergusonite from Berg, Råde, southeastern Norway, which has been described by W. C. Brøgger (l. c.) and analyzed by C. W. Blomstrand.

Four of the spectrograms have been taken with the air spectrograph. These are not quite comparable with the vacuum-spectrograms in regard to the lines of the softer X-rays, with wave lengths more than 2500 X, as these in the air spectrograph are considerably weakened by the passage through the air. In this way the lines of the elements belonging to the Cerium-group will give relatively less intensities in the air spectrograph than in the vacuum spectrograph. The air spectrograph therefore is also unfortunately useless for registering the lines of elements with atom number lower than 25, and the elements Ti and Ca which are of great interest to the study of many of the pegmatite minerals will not be registered in these spectrograms.

From the table 6 emerges that the relative amounts of Nb and Y are rather constant. The amounts of Fe and Mn, however, are varying within wide ranges in the minerals from different localities. Likewise the contents of U and Th are very varying. The vacuum-spectrograms show that all the fergusonites from Iveland studied involve considerable amounts of Ti.

The rare earth elements of the fergusonite from Høgetveit have been studied by V. M. Goldschmidt who characterized this complex of these elements as yttertypus 1 or thalenite-typus. The other fergusonites quoted do not exhibit any great difference from this type.

The spectrograms of the fergusonites from Iveland show strong lines of W $L\alpha_1$. Unfortunately both the $L\alpha_1$ and $L\beta_1$ lines of tungsten have strong coincidences. The W $L\alpha_1$ coincides with Yb $L\beta_1$ and the intensity of the observed line therefore, gives no true picture of the content of W in the mineral. The study of the relative intensities of these lines, however, gives as result that tungsten must be present in the fergusonites of Iveland and Evje to considerable amounts. An exact determination of the percentage of tungsten will be carried out later by means of a partial chemical analysis of the mineral.

From the X-ray spectrograms will also emerge that the *fergusonites of Iveland represent a niobate of the rare earth elements of the thalenite-typus in which the niobium to varying amounts is substituted by W, Ta and Ti. The rare earth elements are partly substituted by Fe and Mn.*

The fergusonite represents the compound of niobium and the yttrium-elements which exhibits the largest content of the latter component. Beforehand one should therefore expect to find the fergusonite in pegmatites which are rich in the yttrium-elements in

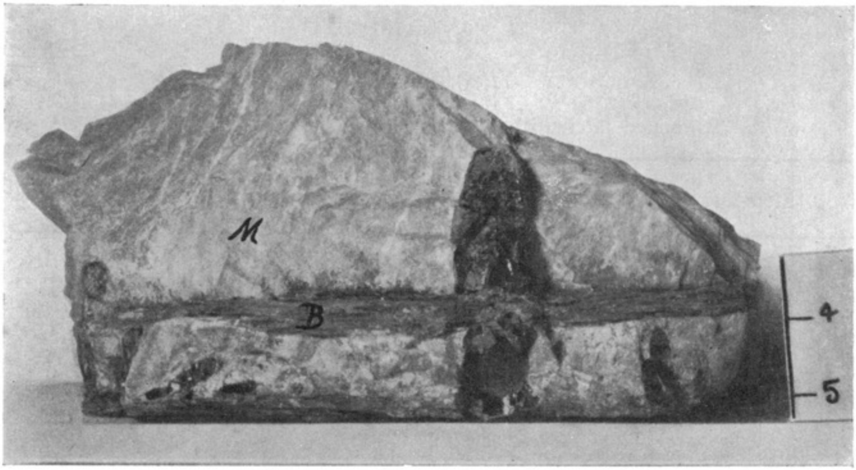


Fig. 13. Fergusonite partly intersected by a flake of blotite (B) 28. Birketveit 6. M microline.

relation to the amount of niobium present. It has previously been pointed out by Schetelig in his study of the thalenites that in granite pegmatite magma with a high percentage of the yttrium-elements these will first react with niobium forming fergusonites and the rest will crystallize as yttriumsilicates, viz. thalenite or gadolinite (when sufficient Be is present).

From table 18 will emerge that these conclusions are in accordance with the observed paragenesis of the dikes in Iveland. The fergusonite has been found in all thalenite-bearing dikes and also in many of the dikes containing gadolinite. Another noteworthy feature of the paragenesis is that the fergusonite-bearing dikes generally are rich in alvite. Other minerals generally associated with fergusonite are garnet, beryl, orthite, euxenite, monazite and xenotime. The fergusonite always belongs to the first crystallized accessory minerals of the dike; it always occurs in euhedral crystals and in a metamict condition.

The fergusonite must be considered, relatively, as a high temperature mineral characteristic of the first crystallization of the magmatic phase of the granite pegmatites rich in the yttrium elements, and has not been found in the dikes belonging to the hydrothermal-pneumatolytic phase.

Fergusonites from Iveland differ from those of South-eastern Norway in being generally rich in tungsten.

Table 7.

Yttrotantalite.

Estimated intensities of lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	Coincidences
Nb	$K\alpha_1$	4	1	2	
Y	-	4	8	4	
Fe	-	3	7	6	
Mn	-	0.5	0.5	1	
U	$L\alpha_1$	6	1	2	
Th	-	0.2	1	0.1	
Pb	-	2	2	1	
W	-	3	10	1	Yb $L\beta_1$
Ta	-	10	8	10	
Cp	-	0.5	1	-	Dy $L\beta_2$
Yb	-	3	4	0.1	
Tu	-	0.5	1	-	Sm $L\gamma_1$ Ta Ll
Er	-	1	3	-	
Ho	-	0.5	2	0.5	Gd $L\beta_1$ U $2L\alpha_1$
Dy	-	2	5	2	Mn $K\beta_1$ Th $2L\alpha_1$
Tb	-	-	0.5	-	
Gd	-	0.2	3	0.5	Ce $L\gamma_1$
Eu	-	-	-	-	Pr $L\beta_2$
Sm	-	0.1	1	0.5	
Nd	-	0.1	0.5	-	
Pr	-	-	-	-	
Ce	-	-	2	-	W $2L\beta_1$
La	-	-	-	-	

1 Yttrotantalite. 72. Ljosland 10. Air spectrograph. *2* Yttrotantalite. 17. Rosås 4. Air spectrograph. *3* Yttrotantalite. Hattevik, Dillingø, analyst. C. W. Blomstrand. Descr. W. C. Brøgger (13). Air spectrograph.

Yttrotantalite.

Yttrotantalite has only been found in two of the magmatic dikes in Iveland namely Ljosland 10 and Rosås 4 and has not previously been described from this district. The mineral is very like samarskite in apparition and occurs in ill-defined strongly fractured crystals, The X-ray spectrograms of these yttrotantalites (table 7) exhibit considerable amounts of tungsten which seem to be a characteristic feature of the niobates and tantalates from the magmatic dikes in Iveland. The yttrotantalite from Ljosland 10 is unusually rich in Nb.

The complex of rare earth elements present in the studied yttrotantalites belongs to the yttertypus.

Table 8.

Titanite and Yttrotitanite.

Estimated intensities of lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	Coincidences
Nb	K α_1	0.1	1	2	
Y	-	-	5	6	
Fe	-	8	10	10	
Mn	-	5	4	4	
Ti	-	10	8	8	
Ca	-	6	6	6	
Ta	L α_1	2	-	-	
Cp	-	-	0.5	0.5	Dy L β_1
Yb	-	-	3	4	
Tu	-	-	0.1	0.2	Sm L γ_1
Er	-	-	1	3	
Ho	-	-	0.2	2	Gd L β_1
Dy	-	-	2	5	Mn K β_1
Tb	-	-	-	.	
Gd	-	-	0.5	2	
Eu	-	-	-	-	
Sm	-	-	-	0.2	

1 Titanite. 72. Ljosland 10. Vacuum spectrograph. *2* Yttrotitanite. 23. Birketveit 1. Vacuum spectrograph. *3* Yttrotitanite. 17. Roså s 4. Vacuum spectrograph.

Titanite and yttrotitanite.

Titanite and yttrotitanite are common minerals in the granite pegmatites in the southern part of Norway. According to W. C. Brøgger these minerals have not been found in the southeastern part of the country. In Iveland the titanite has been met with in 3 of the magmatic dikes and occurs in sharp-edged crystals up to 10 cm in diametre. The results of the X-ray spectrograms (table 8) show that the titanite from Ljosland 10 contains small amounts of Nb and Ta, but no lines of the rare earth elements are visible.

The titanites of Birketveit 1 and Roså s 4, however, show strong lines of the elements belonging to the yttrium group and must be referred to the yttrotitanites. According to V. M. Goldschmidt (24) the yttrotitanites from Setesdal may also contain rare earth elements of the Ce group.

All of the pegmatite dikes in which the titanite has been found are richer in calcium-bearing minerals than is usual, and the occurrence of this mineral seems to be conditioned by a relatively great amount of Ca in the pegmatite magma.

Euxenite minerals.

Under the name euxenite minerals I have also included blomstrandine, priorite, and polycrase which minerals have been described by W. C. Brøgger from the granite pegmatites in south-eastern Norway. For the purpose of this study it has proved suitable to use a group name for these minerals as it would be quite impossible in each case to determine which of these minerals are present.

All of these minerals are very closely related as to the chemical compositions which may all be included in the general formula XZ_2O_6. The cations X are chiefly Y-Ce, Fe, Mn, U, Th and Ca. The anions Z include the elements Nb, Ta, Ti and W.

The euxenite minerals are the most abundant of the rare minerals of the pegmatites in Iveland and have been found in 50 different dikes in the district, all of these being of magmatic origin. They occur partly in well-developed crystals and partly in irregular masses and nodules. In some dikes these euxenite minerals have been found in nearly pure masses to a weight of several hundred kgms. The colour is black or brown to yellowish and the minerals always occur in a metamict condition.

The euxenite minerals from Iveland previously described are priorite from Frikstad described by J. Schetelig with analysis by Dr. Otto Hauser (10) and blomstrandine from Kåbuland 1 lately described by the author (7).

The intensities of the α_1 lines of the registered elements according to the X-ray spectral analysis (table 9) show that the proportion of the anions Nb, Ta, Ti and W varies within wide ranges. These elements may also to a great extent substitute one another in accordance with the proportion between these elements in the magma. Some of the euxenite minerals in Iveland are unusually rich in W. The proportion between the chief anions Y-Ce, Fe, Mn, Ca, U and Th also shows a considerable variation, and the distribution of the rare earth elements is rather different in minerals from different localities. According to V. M. Goldschmidt (24) the rare earth elements in the euxenite should belong to the yttertypus 1 or thalenite-typus.

Chemically the euxenite minerals thus represent complicated compounds in which the components may substitute one another to a great extent.

Euxenite minerals occur in very different types of the magmatic pegmatites. It is often associated with the silicates of the rare earth

Table 9.

Euxenite Minerals.

Estimated intensities of $K\alpha_2$ and $L\alpha_1$ lines in the X-ray spectrograms.

Element	Line	Air spectrograph				Vacuum spectrograph													Coincidences
		1	*2*	*3*	*4*	*5*	*5*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	
Nb	$K\alpha_1$	7	6	8	5	3	3	3	5	5	3	3	3	4	7	5	8	3	
Y	-	10	10	10	10	6	6	6	8	5	5	7	6	5	8	6	10	5	
Fe	-	5	5	8	10	8	10	9	5	8	7	4	10	10	5	10	4	10	
Mn	-	2	-	1	1	0.5	1	0.2	1	3	0.5	-	3	0.5	0.2	0.1	0.1	2	
Ti	-	-	-	-	-	10	10	10	10	4	10	10	10	10	10	10	8	8	
Ca	-	-	-	-	-	0.1	0.1	0.1	0.1	5	3	-	0.3	0.1	-	-	-	0.5	
U	$L\alpha_1$	6	6	6	6	4	6	6	2	2	3	4	4	8	6	7	1	4	
Th	-	2	5	3	5	0.5	0.2	0.1	0.1	-	0.1	1	0.1	0.1	0.5	0.2	0.1	0.1	
Pb	-	4	5	6	5	1	3	3	0.5	0.2	1	2	2	3	3	3	0.2	1	
W	-	6	10	2	6	7	3	2	1	0.1	1	8	2	1	2	1	3	1	Yb $L\beta_1$
Ta	-	6	8	3	3	5	2	4	0.5	10	2	1	7	0.5	1	0.5	3	3	
Cp	-	1	0.1	1	1	0.2	0.2	0.2	0.2	-	0.2	0.2	0.5	0.5	0.2	0.2	0.2	0.1	Dy $L\beta_2$
Yb	-	7	3	3	3	1	3	3	1	0.1	2	1	4	2	2	2	2	1	
Tu	-	1	0.1	0.5	0.5	0.1	0.1	0.1	0.1	-	-	0.1	0.3	0.1	0.1	-	-	-	Sm $L\gamma_1$ Ta Ll
Er	-	5	2	3	4	0.5	2	1	0.5	0.1	1	0.5	1	1	1	2	1	0.2	
Ho	-	3	1	2	3	1	0.5	0.5	1	2	0.5	0.5	1	0.5	0.5	1	0.5	1	Gd $L\beta_1$ U $2L\alpha_1$
Dy	-	5	4	4	6	2	2	2	3	3	2	2	2	2	2	2	2	1	Mn $K\beta_1$ Th $2L\alpha_1$
Tb	-	0.2	0.1	0.5	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	
Gd	-	2	1	3	4	2	0.2	0.5	1	3	0.5	0.5	1	0.2	0.8	0.5	0.5	0.3	Ce $L\gamma_1$
Eu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pr $L\beta_2$
Sm	-	0.5	0.1	0.5	2	1	-	0.1	0.2	2	0.1	0.2	-	0.1	0.1	-	0.1	-	
Nd	-	-	-	0.2	0.2	1	-	-	0.1	0.2	-	-	-	-	-	-	-	-	
Pr	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	
Ce	-	-	-	0.1	1	0.5	-	-	-	0.1	-	-	-	-	-	-	-	-	W $2L\beta_1$
La	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	

1 Brown euxenite. 14. Roså s 1. *2* Priorite. 94. Frikstad 7. Analyst. Otto Hauser descr. J. Schetelig (14). *3* Black euxenite, Alve, near Arendal. Analyst. C. W. Blomstrand descr. W. C. Brøgger (13). *4* Blomstrandine, Hitterø. Analyst. C. W. Blomstrand descr. W. C. Brøgger (13). *5* Black euxenite. 58. Mølland 7. *6* Black euxenite. 23. Birketveit 1. *7* Black euxenite. 72. Ljosland 10 *8* Black euxenite. 58. Mølland 8. *9* Brown euxenite in masses without crystal outlines. 59. Mølland 5. *10* Polycrase. 29. Ertveit 1. *11* Brown blomstrandine. 94. Frikstad 7. *12* Black euxenite. 73. Ljosland 11. *13* Black euxenite. 64. Ljosland 2. *14* Black euxenite. 55. Mølland 4. *15* Black euxenite. 51. Omdal 2. *16* Black euxenite. 34. Nateland. *17* Black euxenite. 77. Håverstad 1 (Thortveitite-bearing dike).

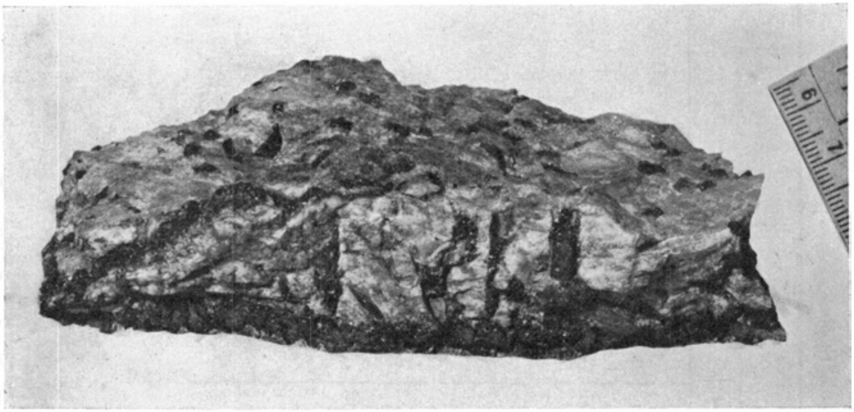


Fig. 14. Euxenite (polycrase) orientated vertically on a plate of ilmenite. 29. Ertvelt 1.

elements as orthite and gadolinite and is characteristic of the pegmatite dikes rich in these elements. Euxenite minerals have not been found on the samarskite- and columbite-bearing dikes. The occurrence of euxenite minerals must in this way be contingent upon a certain amount of the Y-elements and Ti in relation to the amount of Nb and Ta present. When this proportion sinks beyond a certain value these minerals will be substituted by samarskites and columbites.

Samarskite.

Samarskite has only been found in 8 different magmatic dikes in Iveland. This mineral has previously been studied by W. C. Brøgger (13) on the pegmatites in southeastern Norway. On account of two analyses of this mineral from Ødegårdsletten and Aslaktaket by C. W. Blomstrand Brøgger states that the fergusonites may be referred to a general formula XZ_2O_7 where X is chiefly Y-Ce, Th, U, Ca, Fe and Mn and Z is Nb, Ta, Ti.

The samarskite in Iveland usually occurs in irregular masses or ill-defined crystals up to a weight of some kgms. It is also often present as parallel intergrowths with columbite which has been described by Brøgger as Ånnerødite. Such parallel intergrowths of samarskite and columbite has also previously been described by J. Schetelig (14) from a pegmatite at Tveit, Iveland. In apparation the samarskite is often very like the euxenite minerals but is easily distinguished from these by means of X-ray spectral analysis.

Table 10.

Samarskite.

Estimated intensities of K α_1 and L α_1 lines in the X-ray spectrograms.

Element	Line	Air spectrograph				Vacuum spectrograph				Coincidences
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	
Nb....	K α_1	10	8	6	8	8	8	6	6	
Y.....	-	5	6	4	4	6	6	4	4	
Fe....	-	4	10	10	10	10	10	10	10	
Mn...	-	-	3	3	1	3	2	2	2	
Ti....	-	-	-	0.1	0.1	2	2	3	1	
Ca....	-	-	-	2	-	0.1	0.2	1	0.5	
U.....	L α_1	7	6	7	6	5	5	5	5	
Th....	-	2	1	0.1	0.1	0.1	0.1	0.1	0.1	
Pb....	-	0.5	3	4	3	3	3	2	2	
W.....	-	0.5	0.5	0.2	0.2	3	1	3	3	Yb L β_1
Ta....	-	3	10	8	5	10	9	8	7	
Cp....	-	0.1	-	-	-	0.2	0.1	0.1	0.1	Dy L β_2
Yb....	-	1	0.1	0.1	0.2	3	0.5	0.5	0.5	
Tu....	-	-	0.1	-	-	0.2	0.2	0.1	0.1	Sm L γ_1 Ta Ll
Er....	-	0.2	0.5	0.1	-	1	0.5	0.5	0.2	
Ho....	-	0.1	2	0.2	0.1	1	0.5	1	0.5	Gd L β_1 U 2 L α_1
Dy....	-	2	3	2	1	3	3	2	2	Mn K β_1 Th 2 L α_1
Tb....	-	-	1	-	-	-	-	-	-	
Gd....	-	-	4	1	0.1	2	1	2	1	Ce L γ_1
Eu....	-	-	-	-	-	-	-	-	-	Pr L β_2
Sm....	-	-	2	0.2	-	0.1	0.2	1	0.1	
Nd....	-	-	0.5	-	-	0.1	0.1	0.1	-	
Pr....	-	-	-	-	-	-	-	-	-	
Ce....	-	-	-	0.2	-	1	0.5	0.5	-	W 2 L β_1
La....	-	-	-	-	-	-	-	-	-	

1 Samarskite. Aslaktaket. Analyst. C. W. Blomstrand descr. W. C. Brøgger (13). *2* Samarskite. Mitchel County. Analyst. Rammelsberg (13). *3* Samarskite. 3. Tveit 3. *4* Samarskite. 65. Ljosland 3. *5* Samarskite. 21. Ivedal 2. *6* Samarskite. 43. Landås 3. *7* Samarskite. 47. Landås 7. *8* Samarskite. 54. Mølland 3.

In table 10 are given the results of the X-ray spectral analyses of 6 samarskites from Iveland and for comparison are also given the intensities of the spectrograms of the analyzed samarskites from Aslaktaket and Mitchel County.

The relative intensities of the lines in the X-ray spectrograms show that the relative amounts of Y, Th, U, Ca, Fe and Mn exhibit a considerable variation. The amount of U is considerably larger than in the euxenite minerals. The distribution of the rare earth elements is very like that of the euxenites and belongs, according to V. M. Goldschmidt (24), to the thalenite-typus. The samarskites are chiefly niobates but the niobium is to a somewhat varying amount substituted by Ta, Ti and W.

The samarskite of Iveland is usually associated with columbite, beryl and monazite and has always crystallized earlier than the two first mentioned minerals. It has never been found in the euxenite- and ilmenite-bearing dikes and has also not been observed associated with the yttrium-silicate minerals such as thalenite and gadolinite. In the chemical composition the samarskite differs from the euxenite minerals in containing a smaller percentage of the Y-elements and Ti, and is therefore a characteristic mineral of the dikes relatively poor in these constituents.

Betafite.

Betafite is a rare mineral in the pegmatites in Iveland. It has only been found in small quantities in the pegmatite 72 Ljosland 10 and at Landsverk, Evje.

Betafite from a granite pegmatite at Tangen, Kragerø, has previously been described and analyzed by the author (9). This mineral is cubic and Debye-Scherrer diagrams of the heated mineral substance indicate a near relation to the pyrochlore group. In the pegmatites at Ljosland and Landsverk this mineral has only been found as small nodules about 2—3 mm in diametre, without distinct crystal outlines and in a metamict condition. By means of X-ray spectral analysis they could be identified as a betafite mineral very similar to the betafite from Tangen in composition. Debye-Scherrer diagrams of the heated mineral substance also exhibited a cubic structure in accordance with the previously described betafite.

The pegmatites in which these betafites have been found differ from the other pegmatites in the district by being richer in calcium-bearing minerals. In the pegmatite at Ljosland the betafite is associated with large masses of apatite, some yttrotitanite, and the dike is richer in plagioclase than usual. In the dike at Landsverk the betafite occurs together with epidote and calcite.

These parageneses show that the occurrence of betafite seems to be contingent on a relatively great content of calcium in the pegmatite magma.

Two minerals which seem to be chemically and crystallographically related to betafite are ellsworthite and hatchettolite, described by Walker and Parsons. The ellsworthite has been described from

Mac Donald Mine and the hatchettolite from Woodcox Mine, Monteagle Township, Hastings county, Ontario. In his excellent study on rare-element minerals of Canada H. V. Ellsworth (15) gives a detailed description of these minerals and the mineral associations of the dikes.

In the Mac Donald Mine the ellsworthite occurs together with uranothorite, allanite, cyrtolite (alvite), radioactive rare-earth-bearing garnet, calcite and antozonite (fetid fluorite).

The hatchettolite has been found in the Woodcox Mine together with cyrtholite (alvite), columbite, and calciosamarskite.

It is evident that the minerals of the ellsworthite and hatchettolite-bearing dikes are characterized by being rich in calcium, and it seems thus likely that the formation of these minerals also is conditioned by a relatively large amount of calcium present in the magma, in the same way as the betafites of the pegmatites in Iveland.

Microlite.

The microlite is a characteristic mineral of the hydrothermal-pneumatolytic dikes and has not been found in the magmatic pegmatites. It occurs imbedded in cleavelandite or quartz, usually in well-developed cubic crystals to a weight of up to 5 gr. The microlite from 41 Landås 1 has previously been described and analyzed by the author (10). A microlite quite like this in composition has later on been found in the dike 39 Skripeland 1.

The microlite from Landås and Skripeland is chiefly a tantalate of calcium. Besides these chief components it also contains small amounts of Fe, U, Na, K, rare earths, Ti, Nb and Bi.

In both dikes it occurs associated with small well-defined crystals of tantalite.

Columbite.

Columbite has been found in 8 different dikes in Iveland. One of these namely 104 Katterås 1 is of hydrothermal-pneumatolytic origin, the others are magmatic dikes of the ordinary microcline-quartz type. The columbite generally occurs in large ill-defined crystals often covered with a thin layer of muscovite. In some of the dikes the columbite is also found in parallel intergrowths with samarskite. From table 11 of the intensities of the lines in the X-ray spectrograms will emerge that the columbite from Iveland is unusually rich in tungsten. W^{+4} has an ionic radius very near that of Nb^{+5}

and therefore probably partly substitutes this element in the crystal structure. This great content of tungsten in the columbites seems to be characteristic of the granite pegmatites in southern Norway. For comparison I have studied columbites from 5 different localities in the southeastern part of the country and the X-ray spectrograms of all of these showed no lines of this element or only very slight traces. It is noteworthy that the tantalite from the cleavelandite-quartz dike 41 Landås 1 gives no lines of W, while a columbite from a similar dike 104 Katterås 1 exhibits a considerable content of this element.

Table 11.

Columbite and tantalite.

Estimated intensities of the lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	*4*	*5*	*6*	*7*	Coincidences
Nb	$K\alpha_1$	5	6	5	5	0.5	6	7	
Fe	-	10	10	10	6	8	10	10	
Mn	-	6	7	8	10	7	7	6	
Ti	-	2	0.5	2	0.5	0.2	-	-	
W	$L\alpha_1$	6	2	1	3	-	-	-	
Ta	-	4	8	8	8	10	0.2	0.5	

1 Columbite. 4. Tveit 4. Vacuum speetrograph. *2* Columbite. 3. Tveit 3. Vacuum spectrograph. *3* Columbite. 63. Ljosland 1. Vacuum spectrograph. *4* Columbite. 104. Katterås 1. Vacuum spectrograph. *5* Tantalite. 41. Landås 1. Vacuum spectrograph. *6* Columbite, Ivigtut Grønland anal. C. W. Blomstrand. Vacuum spectrograph. *7* Columbite, Ånnerød analyst. C. W. Blomstrand descr. W. C. Brøgger (13). Vacuum spectrograph.

To state the constitution of these tungsten-rich columbites I have carried out an analysis of the columbite from Tveit 4. The analysis was made partly chemically and partly by means of X-ray spectrograms. In the chemical way was carried out a gravimetric determination of Fe, Mn and the total amount of Nb, Ta, W and Ti. No especial determination of Fe^{III} was made.

The percentage of Ta_2O_5, TiO_2 and WO_3 I have determined by means of X-rays spectrograms taken with secondary rays at the Physikalisch-Chemisches Institute in Freiburg, Germany with the kind permission and the instructions of professor G. v. Hevesy, and after his methods (27). These determinations have an accuracy of about 10 % of the amount determined. The determination of Ta was carried out by admixture of CuO to the mineral substance, comparing the lines

Cu $K\alpha_1$ and Ta $L\alpha_1$. The factor of intensity of these lines was under the given conditions found to be 2.10 atoms Ta : 1 atom Cu. Ti was determined by adding $BaSO_4$ to the mineral substance and comparison of the lines Ti $K\alpha_1$ and Ba $L\alpha_1$.

The analysis of the columbite from Tveit 4 gave as result:

				Calculated:	
Nb_2O_5	52.84 %		Nb	395	
Ta_2O_5	10.00 „		Ta	45	$534 = Z_2$
TiO_2	3.00 „	78.84 %	Ti	38	
WO_3	13.00 „		W	56	
FeO		17.60 „	Fe	244	$282 = X$
MnO		2.75 „	Mn	38	
	Total	99.19 %			

Compared with the formula XZ_2O_6 of F. Machatschki (36) this analysis exhibits a considerable excess of the cations X. This may possibly be explained in that way that a small amount of iron might occur as Fe^{III} and in this form substitute the niobium. A series of X-ray spectrograms of different crystals of columbite from the same dike show that the percentages of W and Mn are somewhat varying in the different crystals.

The columbite from the cleavelandite-bearing dike Katterås 1 shows, in regard to the X-ray spectrograms, a good accordance with the columbites from the magmatic dikes. It may therefore be possible that this columbite originally belongs to a magmatic phase in the crystallization of the pegmatite.

The columbite is a characteristic mineral of the pegmatites which are poor in rare earth elements and is generally met with associated with samarskite, which has always crystallized earlier than the columbite. It has not been found together with euxenite or the Y-silicate minerals as gadolinite and thalenite. The columbite-bearing dikes are often rich in beryl.

Tantalite.

The tantalite is a characteristic mineral of the cleavelandite dikes and has not been found in the pegmatites of magmatic origin. It has previously been described by the author from the hydrothermal-pneumatolytic dikes Landås 1 (10) and has lately also been found in a dike Skripeland 1.

An X-ray spectrogram of this mineral (Table 11) shows that it represents a nearly pure tantalate of iron and some manganese with only very small amounts of niobium.

The tantalite occurs associated with microlite and this paragenesis shows that during the hydrothermal-pneumatolytic phase a concentration of Ta in proportion to the closely related elements Nb and Ti has taken place.

In the dikes of Iveland no columbite-tantalite mineral has been found which, in regard to the chemical composition, forms a connecting link between the niobium-rich columbites of the magmatic phase and the tantalum-rich tantalites from the hydrothermal-pneumatolytic pegmatites.

Ilmenorutile.

This mineral was first detected by cand. min. C. Horneman in a pegmatite in Evje. It has later been studied by W. C. Brøgger (13) and J. Schetelig (47). The ilmenorutile has only been found in magmatic dikes and occurs always in well-defined crystals.

The X-ray spectrograms of ilmenorutiles from different occurrences (table 12) exhibit strongly varying amounts of the minor constituents Mn and W. The ilmenorutiles from Støledalen 2 and Ljosland 10 are interesting by being especially rich in tungsten.

The ilmenorutile occurs most frequently in the thortveitite-bearing dikes.

Table 12.

Ilmenorutile.

Estimated intensities of the lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	*4*	*5*	*6*	Coincidences
Nb	$K\alpha_1$	2	2	3	3	4	2	
Fe	-	10	10	10	10	10	10	
Mn	-	0.5	2	-	-	2	1	
Ti	-	8	8	8	8	8	8	
W	$L\alpha_1$	0.5	0.5	0.5	0.5	7	6	

1 Ilmenorutile. 1. Tveit 1. Vacuum spectrograph. *2* Ilmenorutile. 77. Håverstad 1. Vacuum spectrograph. *3* Ilmenorutile. 66. Ljosland 4. Vacuum spectrograph. *4* Ilmenorutile. 85. Eptevann 2. Vacuum spectrograph. *5* Ilmenorutile. 49. Støledalen 2. Vacuum spectrograph. *6* Ilmenorutile. 72. Ljosland 10. Vacuum spectrograph.

Ilmenite.

Ilmenite is abundant in some of the magmatic dikes in Iveland. It occurs in thin, plate-shaped masses and is by the feldspar workers generally called "plate-iron" (platejern). These plates of ilmenite may be very large up to more than 1 m in extension and usually 4—5 mm thick. The ilmenite plates often intersect the feldspar on the cross and recross in the same way as the biotite flakes, and are generally surrounded by polycrase-shaped euxenite crystals which have grown with their c axes about vertical to the plates. Euhedral euxenite crystals are often observed imbedded in the ilmenite.

The results of the X-ray spectrograms (table 13) show that the percentage of Ti in the studied ilmenites is somewhat varying. Two of the specimens namely from Hiltveit 2 and Mølland 7 give weak lines of Cr.

Table 13.

Ilmenite and magnetite.

Estimated intensities of the lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	Coin-cidences
Fe.....	$K\alpha_1$	10	10	10	10	10	10	10	10	
Mn....	-	4	4	5	4	4	3	1	1	
Cr	-	0.2	-	-	-	0.1	-	-	-	
Ti.....	-	5	5	6	7	8	10	3	0.5	

1 Ilmenite. 19. Hiltveit 2. Vacuum spectrograph. *2* Ilmenite. 99. Kåbuland 1. Vacuum spectrograph. *3* Ilmenite. 73. Ljosland 11. Vacuum spectrograph. *4* Ilmenite. 94. Frikstad 7. Vacuum spectrograph. *5* Ilmenite. 58. Mølland 7. Vacuum spectrograph. *6* Ilmenite. 108. Landsverk, Evje. Vacuum spectrograph. *7* Titanomagnetite. 14. Rosås 1. Vacuum spectrograph. *8* Magnetite. 5. Tveit 5. Vacuum spectrograph.

The ilmenite is nearly always found associated with euxenite and certainly indicates an excess of Ti in proportion to the amounts of Nb and Ta present.

Magnetite.

Magnetite is a common mineral in many of the magmatic pegmatites in Iveland. It generally occurs in small nodules imbedded in feldspar. In the dike Tveit 5 the magnetite is present in large

Table 14.

Uraninites and Uranothorites.

Estimated intensities of lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	*4*	Coincidences
Y	$K\alpha_1$	2	-	0.1	2	
Fe	-	1	0.1	5	4	
Mn	-	-	0.1	-	-	
U	$L\alpha_1$	10	10	4	5	
Th	-	2	3	10	10	
Pb	-	5	3	1	3	
W	-	0.5	-	-	-	Yb $L\beta_1$
Cp	-	-	-	-	-	
Yb	-	0.1	-	-	-	
Tu	-	-	-	-	-	
Er	-	-	-	-	-	
Ho	-	-	-	-	-	
Dy	-	0.1	-	-	-	Th $2L\alpha_1$

1 Uraninite. 1. Tveit 1. Vacuum spectrograph. *2* Uraninite. 86. Eptevann 3. Vacuum spectrograph. *3* Uranothorite. 23. Birketveit 1. Vacuum spectrograph. *4* Uranothorite. Landsverk, Evje. Vacuum spectrograph.

masses between the flakes of biotite and often encloses euhedral crystals of euxenite.

The magnetite from Rosås 1 (table 13) is rich in Ti and must be referred to the titanomagnetites.

Uraninite.

Uraninite is a very rare mineral in the pegmatite dikes of the district. It has only been found in 4 of the magmatic dikes mentioned in this description and only in relatively small quantities. Uraninite from Landsverk Evje has previously been studied by P. Schei (46).

The uraninite in Iveland and Evje generally occurs in small crystals bounded by the faces 100.

The results of the X-ray spectrograms (table 14) of the uraninite from Tveit show that this mineral besides U also contains small amounts of Y, Fe, Th, Pb, W and Yb. The uraninite from Eptevann contains as minor constituents Fe, Mn, Th and Pb.

Table 15.

Monazite.

Estimated intensities of lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	*4*	Coincidences
Y	K α_1	0.2	1	0.1	1	
Fe	„	2	3	1	2	
Pb	L α_1	-	-	-	1	
U	„	-	-	-	0.2	
Th	„	8	0.5	0.5	10	
Ta	„	-	-	-	0.5	
Cp	„	-	-	-	-	
Yb	„	0.1	0.1	0.1	2	
Tu	„	1	-	-	3	Sm L γ_1 Ta L l
Er	„	0.1	-	-	0.1	
Ho	„	2	0.2	3	3	Gd L β_1 U 2 L α_1
Dy	„	2	0.2	0.2	8	Th 2 L α_1
Tb	„	1	0.2	1	2	
Gd	„	6	4	8	6	Ce L γ_1
Eu	„	0.5	0.5	0.5	1	Pr L β_2
Sm	„	10	4	8	7	
Nd	„	10	8	8	6	
Pr	„	4	6	6	6	
Ce	„	8	10	10	3	
La	„	3	6	5	1	

1 Monazite 85. Eptevann 2. Vacuum spectrograph. *2* Monazite 77. Håverstad 1. Vacuum spectrograph. *3* Monazite 104. Katterås 1. Vacuum spectrograph. *4* Monazite 86. Eptevann 3. Air spectrograph.

Thorite.

Thorite occurs as small yellow nodules in the pegmatites Ljosland 10 and Landsverk, Evje.

The X-ray spectrograms (table 14) show that these thorites contain considerable amounts of U and should be referred to the uranothorites. The X-ray spectrograms also show lines of Y.

The mineral paragenesis of the thorite-bearing dikes shows that these dikes are relatively rich in calcium.

Monazite.

Monazite is a very common mineral in all the different types of magmatic pegmatites. It has also been found in the cleavelandite-quartz dike Katterås 1, imbedded in cleavelandite.

This mineral generally occurs in euhedral sharp-edged crystals near the biotite flakes or imbedded in this mineral.

Monazite from Mølland, Iveland has previously been described by J. Schetelig (47).

The lines of the X-ray spectrograms (table 15) show that the monazite from different dikes exhibit a somewhat varying chemical composition. Especially the amounts of Th and Fe are rather varying in the different pegmatites.

The complex of the rare earth elements belongs to the Ce group and according to V. M. Goldschmidt (24) defines the Certypus 1 or monazite-typus.

The monazite from Eptevann 2 is richer than usual in Yb.

The monazite crystals have been formed during an early stage of the crystallization of the pegmatite minerals. In the euxenite-bearing dikes they are partly earlier and partly later than the euxenite crystals and they have always crystallized earlier than samarskite, columbite, thalenite and gadolinite.

The monazite of the hydrothermal-pneumatolytic dike Katterås 1 occurs together with an apatite which in the X-ray spectrogram gave no lines of rare earth elements. According to the chemical composition of these minerals it is probable that they have been formed in different phases of the formation of the pegmatite, and that the monazite might belong to an earlier magmatic phase.

Xenotime.

Xenotime is less abundant than the monazite in the pegmatite dikes in the district. It has not been found in the hydrothermal-pneumatolytic dikes. The xenotime generally occurs in well-defined crystals up to 3 4 cm in square, in some dikes it has also been found in nodular masses. The colour is greyish or brown.

In table 16 are given the results of X-ray spectrograms of xenotimes from 8 different dikes. The spectrograms show that the amounts of Fe and Mn are rather varying in the different localities. The complex of the rare earth elements belongs to the Y-group and according to V. M. Goldschmidt defines the yttertypus 3 or xenotime-typus (24). The xenotime is most abundant in the euxenite-bearing dikes. The crystallization of this mineral belongs to an early stage in the crystallization of the accessory minerals and has usually taken place simultaneously with the crystallization of the monazite.

Table 16.

Xenotime.

Estimated intensities of lines in the X-ray spectrograms.

Element	Line	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	Coincidences
Y	K α_1	10	10	10	10	10	10	8	10	
Fe	-	6	2	6	4	5	8	10	8	
Mn	-	-	-	-	-	-	-	5	5	
Ca	-	2	-	1	0.1	0.1	2	3	2	
U	L α_1	0.1	0.2	0.1	0.2	0.5	2	0.2	3	
Th	-	2	-	0.1	0.1	-	2	0.5	3	
Cp	-	2	3	2	2	2	2	3	3	Dy L β_2
Yb	-	10	6	10	8	10	8	10	10	
Tu	-	1	1	1	0.5	0.5	1	2	0.5	Sm L γ_1
Er	-	4	2	4	3	5	5	5	6	
Ho	-	3	5	6	3	3	4	3	4	Gd L β_1 U 2 L α_1
Dy	-	8	8	10	6	8	6	6	8	Mn K β_1 Th 2 L α_1
Tb	-	0.2	0.2	0.5	0.2	0.1	0.1	0.5	0.5	
Gd	-	5	6	8	4	3	3	5	4	
Eu	-	-	-	-	-	-	.	-	-	Pr L β_2
Sm	-	2	3	4	0.5	-	0.5	3	1	
Nd	-	0.5	1	0.5	0.2	-	0.2	0.5	-	
Pr	-	-	-	-	-	-	-	-	-	
Ce	-	-	-	-	-	-	-	-	-	
La	-	-	-	-	-	-	-	-	-	

1 Xenotime 35. Tjomstøl. Vacuum spectrograph. *2* Xenotime 47. Landås 7. Vacuum spectrograph. *5* Xenotime 58. Mølland 7. Vacuum spectrograph. *4* Xenotime 34. Nateland. Vacuum spectrograph. *5* Xenotime 94. Frikstad 7. Vacuum spectrograph. *6* Xenotime 29. Ertveit 1. Vacuum spectrograph. *7* Xenotime 78. Håverstad 2. Vacuum spectrograph. *8* Xenotime 5. Tveit 5. Vacuum spectrograph.

Apatite.

Apatite has only been found in 3 of the dikes mentioned in this description. Two of these dikes are of magmatic origin, namely Håverstad 1 and Ljosland 10, the third is the cleavelandite-quartz dike Katterås 1.

The apatite from the magmatic dikes has a green colour, is generally translucent, and occurs in well-defined prismatic crystals often intersecting a plagioclase feldspar. In the pegmatite Ljosland 10, large quantities of apatite have been found.

In the cleavelandite-quartz dike Katterås 1 the apatite has a bluish green colour. It occurs in this dike, however, as irregular masses between the cleavelandite blades without definite crystal outlines. Larger masses of apatite are often intersected by plates of cleavelandite. The estimated intensities of lines in the X-ray spectrograms of the apatites were:

	Y	Fe	Mn	Ca
Apatite Håverstad 1 $K\alpha_1$ ..	3	5	3	10
Apatite Katterås 1 $K\alpha_1$ ..	-	1	1	10

The X-ray spectrograms of these apatites show that the apatite from the magmatic dike Håverstad 1 contains considerable amounts of Y, Mn and Fe, and lines of these elements were also present in the spectrograms of apatite from Ljosland 10. The apatite from the cleavelandite-quartz dike Katterås 1, however, gives no lines of Y and is poor in Fe and Mn. This is in accordance with the composition of the other characteristic minerals of the cleavelandite-quartz dikes which indicates that the material supplied to the dike by the hydrothermal-pneumatolytic activity bas been poor in the rare earth elements.

This occurrence of the apatite in Iveland disagrees with the observations of K. K. Landes (30) from the granite pegmatite at Buckfield, Central Maine. According to Landes the magmatic apatite in this dike occurs without crystal outlines while the hydrothermal-pneumatolytic apatites are present in well-defined crystals.

Pyrite and chalcopyrite.

Pyrite and chalcopyrite are present as accessory minerals in some of the magmatic dikes. In the dike Frikstad 9 was found a crystalline mass of pyrite to a weight of more than 100 kgms. Chalcopyrite is less abundant and has only been found in small quantities.

The pyrite and chalcopyrite belong to an early stage in the crystallization of the pegmatites. In the dike Ljosland 10 chalcopyrite was found imbedded in an euxenite crystal.

Molybdenite and bismuthinite.

Molybdenite occurs sparingly in some of the magmatic dikes. In the pegmatite dike Birkeland 2 masses of bismuthinite to a weight of up to 2 kgms has been observed by J. Schetelig.

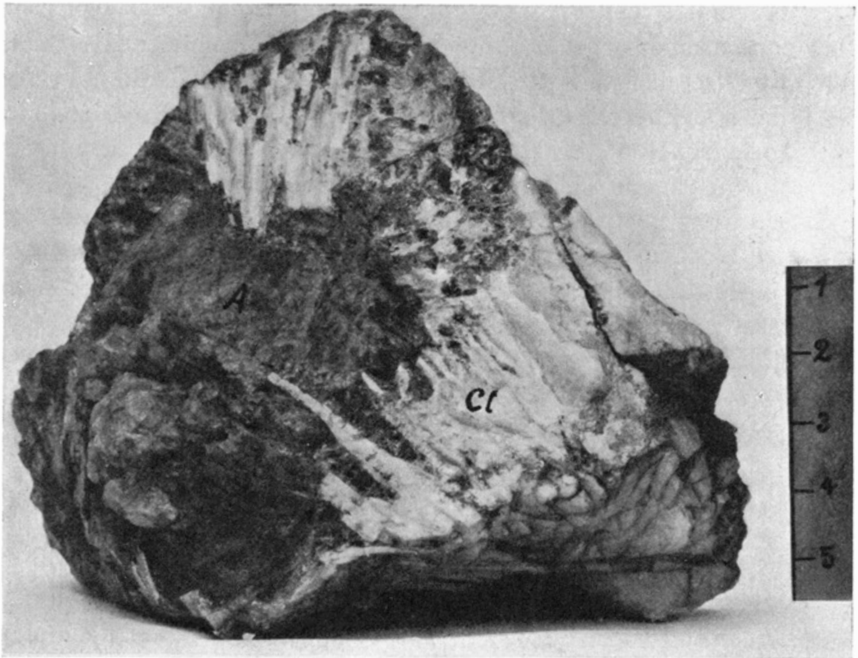


Fig. 15. Apatite (A) and cleavelandite (Cl) 104. Katterås 1.

Chalcocite.

Chalcocite has only been found in small quantities in the pegmatite, Ljosland 10.

Calcite.

Calcite occurs in small quantities in the dike at Landsverk. This calcite may probably be of magmatic origin.

The Chemical Components of the "Rare" Minerals.

Besides the ordinary chemical components of the granite the pegmatites usually also contain many accessory rare elements as mineral-forming constituents.

The total amount of these accessory elements may vary widely in the different dikes and also the relative amounts of these elements are rather varying.

As pointed out by V. M. Goldschmidt (21) and P. Niggli (39), this concentration of the rare elements in the granite pegmatite is due to the fact that the ionic-dimensions of these elements do not agree with those of the chief chemical components of the granite magma.

An evidence of this explanation is given by the associations of the elements in the individual minerals of the pegmatites.

According to this rule, the most characteristic rare elements of the granite pegmatites in Iveland may be divided into 3 groups, in each of which the ionic dimensions of the elements are very similar and these elements therefore may substitute each other to a certain extent. It is therefore suitable for our purpose in many cases to handle these groups of elements as single chemical components.

Group I. The rare earth elements (yttrium, lanthanum and the lanthanides[1]), $\overset{\text{IV}}{\text{Th}}$ and $\overset{\text{IV}}{\text{U}}$.

Group II. $\overset{\text{IV}}{\text{Ti}}$, $\overset{\text{V}}{\text{Nb}}$, $\overset{\text{V}}{\text{Ta}}$, $\overset{\text{IV}}{\text{W}}$.

Group III. $\overset{\text{IV}}{\text{Zr}}$, $\overset{\text{IV}}{\text{Hf}}$.

Our knowledge of the chemical constitution of the complex pegmatite minerals has lately been greatly enlarged, especially by the studies of F. Machatschki (36, 37).

A characteristic feature of the chemical composition of the Iveland pegmatites is a *relative richness in W and the absence of the elements Sn and Li.*

Group I. The rare earth elements, Th and U.

The elements belonging to this group exhibit ionic radii between 1.05 and 1.18 Å and may to a certain extent substitute each other in the lattices of the minerals.

The rare earths are a group of elements so closely related chemically that they cannot be separated by ordinary chemical methods. By means of fractional crystallization, however, these elements may be divided in groups, and by repeated crystallizations the elements also may be individually isolated.

The study of V. M. Goldschmidt of the rare earth minerals (24) shows that such a fractional crystallization has to a certain extent taken place during the crystallization of the granite pegmatites, and

[1] The name lanthanides has been introduced by V. M. Goldschmidt (25) signifying the Ce Cp group of elements.

as a consequence of this process the rare earth elements are usually met with in the minerals in certain associations.

According to this study V. M. Goldschmidt has classified the common associations of these elements in 3 chief groups:

A. Selective associations of the Ce-elements, the Ce-group.

B. Complete associations of the rare earth elements.

C. Selective associations of the Y-elements the Y-group.

Each of these groups is further divided into different types.

The granite pegmatites in Iveland are generally relatively rich in the rare earth elements which are chief components of many of the most characteristic minerals as phosphates, niobates, tantalates and silicates.

Usually the rare earth elements have been differentiated during the crystallization and may be classified as belonging to the Y-group or the Ce-group. The explanation of the near chemical relation of Y to the elements Gd-Cp has been given by V. M. Goldschmidt (25) by the "Lanthanidenkontraktion".

In Iveland the following minerals with the elements of the Y-group as chief chemical component have been found:

Phosphates: Xenotime.

Compounds with Ti, Nb, Ta and W: Fergusonite, euxenite, betafite, samarskite and yttrotantalite.

Silicates: Thalenite and gadolinite.

The elements belonging to the Ce-group form the following minerals:

Phosphates: monazite.

Silicates: orthite.

In the pegmatite dikes in Iveland thus only two minerals with the Ce-elements as chief constituents have been found while the elements of the Y-group form a series of minerals in compound with Nb and related elements.

In most of the dikes nearly all the Ce-elements present occur in monazite. As minor constituent the rare earth elements have been found in: apatite, thorite, uraninite, microlite, yttrotitanite, alvite and spessartite.

The study of the pegmatite minerals shows that in the ordinary magmatic pegmatites all of the phosphoric acid has been combined with the rare earth elements forming monazite and xenotime; apatite has only been observed in a few of the dikes especially rich in Ca. At the same time the excess of the Y-elements present will react with the

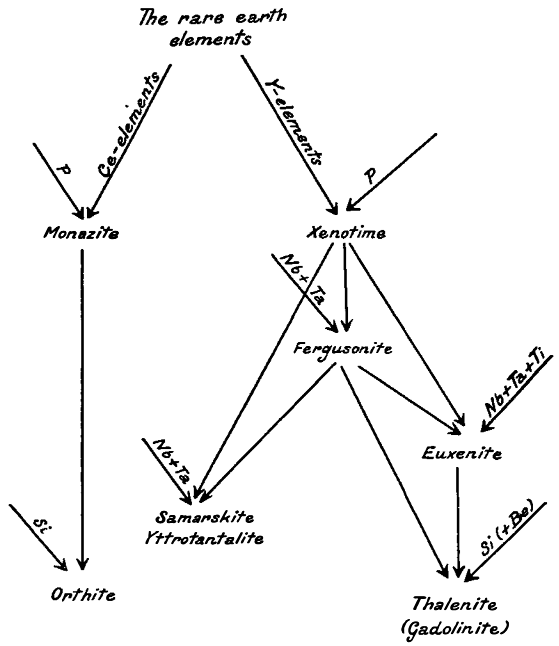


Fig. 16. Diagram showing the sequence of crystallization of the rare earth element-bearing minerals of the ordinary magmatic pegmatites in Iveland.

niobium and tantalum present. In these compounds will also enter some Ti and the minerals formed by this reaction will depend on the relative amounts of the elements present in the magma.

As the last segregation of the rare earth elements the contingent excess of these elements after the reaction with Nb, Ta and Ti reacts with silica and forms the silicates thalenite, gadolinite and orthite,

In each dike there seems to be a balance between the Ce-minerals and the Y-minerals which indicates that the association of the rare earth elements in all the pegmatite magmas has been rather similar. The differentiation of the rare earth elements seems in this way to have commenced with the crystallization of the pegmatite.

In the magmatic pegmatite dikes in Iveland in which no rare earth minerals have been found, apatite is always found to be absent. It thus seems as if the absence of the rare earth elements in a magmatic pegmatite dike is attended by the absence of phosphoric acid in the pegmatite magma. During the differentiation of the granitic residual liquor the rare earth elements thus must have been enriched together with the phosphoric acid.

The characteristic minerals of the hydrothermal-pneumatolytic dikes are poor in the rare earth elements and it is probable that during this phase only very small amounts of these elements have been transmitted to the pegmatite. It thus seems as if these elements have no tendency to enter into the hydrothermal-pneumatolytic part of the granite residual liquor.

In the betafite- and microlite-minerals the rare earth elements substitute Ca and the distribution of these elements in these minerals belongs according to the classification of V. M. Goldschmidt to the complete association of the rare earth elements.

The distribution of the rare earth elements in the different minerals will emerge from the results of the X-ray spectrograms.

In all of the mentioned rare earth bearing minerals $\overset{\text{IV}}{\text{Th}}$ and $\overset{\text{IV}}{\text{U}}$ may be present in varying amounts. In the greatest percentage the Th usually is present in monazite and U in betafite, samarskite and euxenite. When Th and U are present in relatively larger amounts they will crystallize as uraninite and thorite.

Group II. The elements $\overset{\text{IV}}{\text{Ti}}$, $\overset{\text{V}}{\text{Nb}}$, $\overset{\text{V}}{\text{Ta}}$ and $\overset{\text{IV}}{\text{W}}$.

These elements are chief components of a series of minerals characteristic of the pegmatites in the district, in which minerals they may substitute each other to a certain extent.

The degree to which these elements may substitute each other is very different in the different minerals. The ionic radii of the elements belonging to this group vary from 0.63 to 0.8 Å. The elements Nb and Ta are chemically especially closely related and are difficult to isolate by the ordinary methods.

The study of the minerals of the dikes in Iveland shows that in the magmatic dikes Nb is present to a much larger amount than Ta. The atomic ratio between these elements I have estimated to be usually about 1 at. Ta : 4 5 at. Nb, and there seems to be no very great difference between the relative amounts of these elements in the different magmatic dikes.

In the pegmatite dikes in Iveland Nb and Ta have reacted with the Y-elements Fe, and Mn, forming a series of minerals:

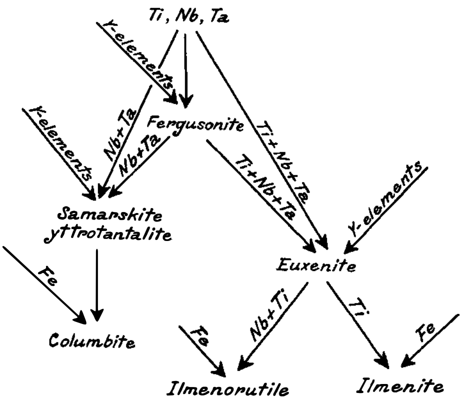


Fig. 17. Diagram showing the sequence of crystallization of the Ti-, Nb- and Ta-bearing minerals of the ordinary magmatic pegmatites in Iveland.

Orthocompounds: Fergusonite.

Metacompounds: Euxenite, betafite, columbite-tantalite.

Pyrocompounds: Samarskite, Yttrotantalite.

In all of these minerals Ti is usually present to considerable amounts as will emerge from the X-ray spectrograms.

To the largest amount Ti occurs in the metacompounds euxenite and betafite. According to previous analysis of euxenite minerals the atomic proportion Nb + Ta : Ti in these minerals may vary from 1 to $^1/_3$. When Ti is present to a relatively larger amount than allowed in the euxenite minerals, the excess of this element will enter into ilmenite or under special conditions into titanite and ilmenorutile.

While the proportion Nb : Ta seems to be rather constant in the different magmatic pegmatites the proportion Nb + Ta : Ti is very strongly varying in the different dikes. A differentiation of these elements must therefore have taken place before the intrusion of the pegmatite magma.

In all of these minerals mentioned a varying amount of W may be found substituting the Nb. The columbites from Iveland exhibit the highest percentage of W, up to 13 % WO_3. In the magmatic dikes only very Nb-rich columbites have been found.

Minerals with tungsten as chief constituent, such as wolframite and scheelite, have not been found in the pegmatites in Iveland and thus all of the W present in the magma seems to have replaced Nb in the niobium-bearing minerals.

The characteristic minerals of the pneumatolytic-hydrothermal dikes, microlite and tantalite, exhibit a proportion between Nb and Ta quite different from that of the magmatic dikes. These minerals are nearly pure tantalates without W and only with very small amounts of Nb and Ti. This fact shows that *during the hydrothermal-pneumatolytic activity a concentration of Ta has taken place.* It seems probable that such an isolation of Ta from the other closely related elements is only possible under the influence of pneumatolytic-hydrothermal activity.

The amounts of Nb and Ta in eruptive rocks have lately been studied by G. v. Hevesy and collaborators (28). These investigations gave as result that Nb and Ta occurred in the equal quantities, namely 4.10^{-7} gram element pr. 1 gram rock as an average value of 133 granites, 9 quartz-diorites, 35 diorites, 82 gabbros, and 23 ultrabasic rocks. In relation to this ratio between Nb and Ta the magmatic pegmatite dikes in Iveland seem to be enriched in Nb, while the hydrothermal-pneumatolytic dikes usually are strongly enriched in Ta.

Group III. The elements Zr and Hf.

Some of the older analyses of niobate- and tantalate-minerals such as fergusonites and euxenite-minerals from other granite pegmatite areas exhibit considerable amounts of ZrO_2. In the analysis of blomstrandite from Arendal by C. W. Blomstrand a percentage of 1.33 ZrO_2 has been determined. The niobates- and tantalate-minerals of Iveland, however, show no amounts of Zr detectable by means of X-ray spectrograms, and in these dikes the Zr together with the Hf almost exclusivly enters into compound with SiO_2 chiefly as the minerals alvite and zircon, which minerals have crystallized at a very early stage in the crystallization of the accessory minerals. Small amounts of Zr and Hf are also found in the later crystallized mineral thortveitite.

The Sequence of Crystallization.

The sequence of crystallization of the granite pegmatites in Norway has first been described by Th. Scheerer (45) from the granite pegmatites at Hitterø, South-western Norway. Later on such investigations of many of the granite pegmatites in Southern and South-eastern Norway have been published by W. C. Brøgger and in the last years especially by J. Schetelig. Schetelig has also studied many of the pegmatites in Iveland as mentioned previously under the description of the mineral occurrences.

The sequence of crystallization of the minerals of the magmatic dikes in Iveland shows that the crystallization of the "rare" minerals belongs to an early stage of the segregation of the pegmatites. As to the ordinary minerals the crystallization of the biotite has commenced very early and seems to have taken place during a long period of the solidification of the dikes. On these early crystallized biotite flakes the rare minerals have crystallized, usually in certain orientations to this mineral. Later on these minerals have been partly inclosed in the biotite as the crystallization of this mineral proceeded.

The sequence of crystallization of the rare minerals is always found to follow some general rules:

1. *The phosphates of the rare elements, monazite and xenotime always belong to an early stage in the crystallization of the pegmatite.*

2. *The crystallization of the niobates and tantalates of the Y-elements takes place in the order of decreasing amounts of these elements present in the minerals.* Thus the yttrium-rich fergusonite has always crystallized earlier than the euxenite which contains a smaller amount of the yttrium elements.

3. *The niobates and tantalates of iron and manganese (columbite-tantalite) have always crystallized later than the niobates and tantalates containing rare earth elements.*

4. *The silicates of the rare earth elements, as thalenite and gadolinite have crystallized later than the other rare minerals.*

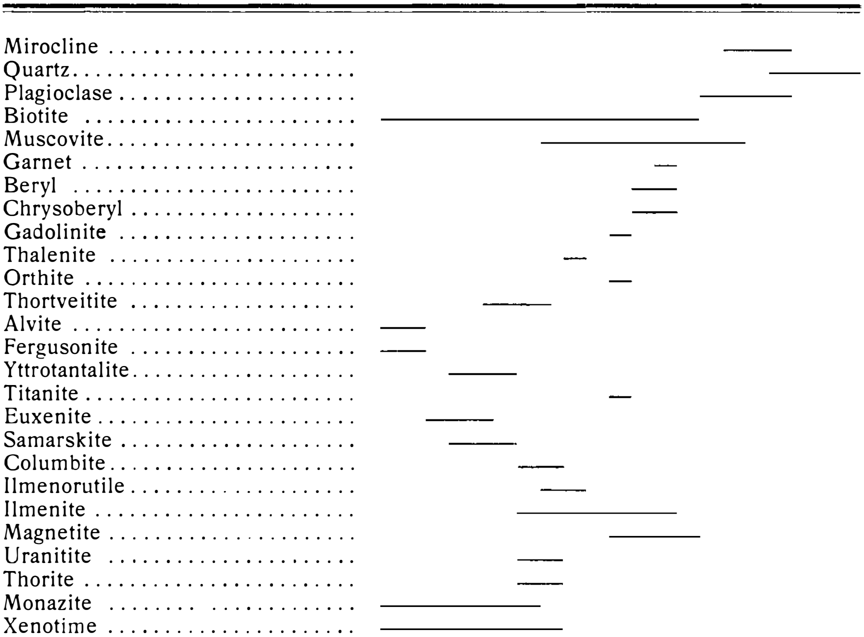
5. *The zircon minerals, zircon or alvite, belong to the earliest crystallizations of magma.*

In table 17 is given a schematical summary of the general sequence of crystallization observed in the magmatic dikes in Iveland.

In the dikes relatively poor in rare minerals usually all of these are deposited near the biotite flakes or imbedded in this mineral. In the dikes, however, in which the rare minerals occur more abundantly some of these minerals also may be observed imbedded in larger masses of microcline or quartz. This is especially observed with gadolinite and thalenite, the crystallization of which belongs to a late stage in the solidification of the accessory minerals. On some dikes especially rich in rare minerals e. g. Slobrekka Frikstad,

Table 17.

The sequence of crystallization of some of the minerals from the magmatic pegmatites in Iveland.



the euxenite minerals may also be found as euhedral crystals in larger masses of microcline.

Monazite has usually crystallized between the biotite flakes or not far from them.

The Origin of the Pegmatites.

The intrusion of the granite magma into the amphibolite body of Iveland has taken place in 3 epochs:

1. The intrusion of granite magma which has crystallized as a normal granite.

2. Intrusion of a gaseous granite magma usually enriched in rare elements. This magma has crystallized as pegmatites.

3. Intrusion of hydrothermal-pneumatolytic solutions which have formed the cleavelandite-quartz dikes.

The ordinary granite forms dikes and larger bodies in the amphibolite and is also found in small bodies imbedded in pegmatite dikes. The granite pegmatite intersects the amphibolite in small veinlets, dikes, lenses and irregular bodies. At Tveit, Iveland a pegmatite dike intersects a large granite body with sharp boundaries against the granite. The pegmatite is thus distinctly younger than the granite. In the periphery of the amphibolite area the amphibolite is especially disseminated with pegmatite veins and veinlets and seems to change gradually into the surrounding gneiss.

The intrusion and crystallization of the magmatic pegmatites have been succeeded by the advance of pneumatolytic and hydrothermal solutions which generally follow cracks and openings in the magmatic pegmatites. During this activity the cleavelandite-quartz dikes were formed partly by replacement of the adjacent magmatic minerals.

W. C. Brøgger was the first to recognise formation of the pegmatites in successive stages, in his work on alkaline pegmatites of 1890.[1] Cleavelandite-quartz dikes at Ånnerød, South-eastern Norway have already been described by Brøgger in 1880.

The theory of hydrothermal replacement as a dominant process in the formation of pegmatites is especially developed by the American investigators F. L. Hess, W. T. Schaller and K. K. Landes; the last mentioned has given an excellent account of the evolution of this theory in his paper on the origin and classification of pegmatites (34).

According to W. T. Schaller (44) the pegmatites may be divided into simple pegmatites which consist chiefly of microcline and quartz and do not contain any quantity of other minerals, and complex pegmatites which in addition to microcline and quartz contain an abundance of one or more of such minerals as albite, beryl, topaz, cassiterite, micas, tourmalines, garnets, lithium minerals, rare earth minerals, the niobates and tantalates, the phosphates and others, many of which contain rarer elements. In the opinion of Schaller the complex pegmatites have been formed of the simple pegmatites by replacement actions of later hydrothermal solutions.

W. T. Schaller says (l. c. p. 150): "If this general sequence of replacement is correct the socalled rare minerals or accessory minerals should not be found in any pegmatite which has not been subjected to the hydrothermal replacement processes."

Landes (l. c. p. 53) "has come to that conclusion that enough evidence has been amassed to cause acceptance of the hydrothermal

[1] Zeit. Kryst. Min. 16.

replacement theory. However, he believes in that in most pegmatites (but little studied because of small size and lack of unusual minerals) a distinctly later hydrothermal phase is absent".

The opinion of the American investigators that the rare minerals exclusively belong to the hydrothermal stage in the formation of the pegmatites is chiefly based on investigations on large, very complicated pegmatites such as the pegmatites in Central Maine which have been studied by K. K. Landes. The results of these investigations have been published by Landes in his classic paper of 1925. This investigation has greatly enlarged our knowledge of the hydrothermal phases of the granite pegmatites.

In Iveland, however, the conditions are more simple, as most of the dikes do not exhibit any distinct examples of mineral replacement and seem to be uninfluenced by hydrothermal activity. And these dikes are usually rich in rare minerals, niobates and rare earth minerals, which in the opinion of the writer must belong to the magmatic stage. One therefore has to distinguish the rare minerals formed by magmatic processes and those of hydrothermal-pneumatolytic origin. This opinion is chiefly based on the following facts:

1. The magmatic dikes show no distinct examples of mineral replacement.

2. In the magmatic pegmatites the rare minerals show a definite sequence of crystallization which has not been found in the hydrothermal dikes.

3. The characteristic rare minerals of the hydrothermal dikes namely microlite and tantalite, have not been found in the magmatic pegmatites.

4. The rare minerals of the magmatic dikes represent a mineral association which, in regard to the distribution of the rare elements, differ from those of the hydrothermal dikes.

5. The magmatic dikes rich in rare minerals do not differ in regard to the other minerals from those in which no rare minerals have been found.

The opinion that the importance of the influence of the post-magmatic hydrothermal activity opon the magmatic pegmatites has been greatly exaggerated by the American theory of replacement has previously been advanced by most of the Europian mineralogists and petrographers and especially by those who have had the opportunity to study some of the Scandinavian granite pegmatites.

P. Eskola (16, p. 13) says: "Many american petrographers, especially Schaller, Hess and Landes, have been led to the conclusion that replacement has played a very considerable rôle in the genesis of the pegmatites explaining even intergrowths like the graphic feldspar as replacement products. In the opinion of the present writer the replacement hypothesis applied in such an extension, is exaggerated, although it is no doubt right as far as many of the so-called rare pegmatite minerals are concerned".

In 1915 J. Schetelig published a paper on scapolite from granite pegmatite in Southern Norway (49). This mineral is known as a secondary mineral of 6 different granite pegmatites in the district Kragerø Arendal. According to the investigations of Schetelig the scapolite of these dikes is formed at the expence of the microcline-perthite, due to thermal effect (circulating overheated solutions of chlorides and carbonates) during the postmagmatic phase after the crystallization of the granite pegmatite. Such alteration of the microcline has, however, not been observed in the pegmatite dikes in Iveland.

As mentioned under the description of the microcline, O. Andersen in 1928 advanced the opinion that some perthites are due to replacement caused by later pegmatic solutions. In a later paper (2, p. 55) Andersen says: "A feature of the granite pegmatites described in this paper is the general absence of strongly marked replacement phenomena. Apart from the universal phenomena of muscovitization and albitization of feldspar the granite pegmatites of Southern Norway show no examples of mineral replacement of the kind so well described from many american localities and indeed very few distinct features that need be ascribed to replacement".

No real evidence is, however, given of a general albitization of the microcline, and it seems unlikely to the present writer that such a process should have taken place in a larger scale without any distinct influence upon the other minerals. According to the investigations of the microcline from Kåbuland it seems likely that the ordinary microcline perthite may be explained by exsolution.

The opinion that the rare minerals belong to the magmatic phase has previously been advanced by J. H. L. Vogt (52, p. 82); he says: "The minerals such as thorite, thoruranite, columbite, blomstrandin, gadolinite etc. present in varying quantities at many Norwegian granite pegmatites occur to a great extent as inclusions within the biotite i. e. the compounds of these minerals may have been present in the magma before the crystallization of the magma begun".

The yttrium-rich magmatic dikes of the gadolinite type occur chiefly as larger dikes in the peripheric parts of the amphibolite area. In the central part of this area the dikes are generally smaller and are usually of the fergusonite- and the euxenite (samarskite) type. It seems likely that the dikes of the thalenite-gadolinite-type represent the earliest intrusions of the rare elements-bearing pegmatite magma, and that the following intrusions have taken place in order of decreasing amount of the rare earth elements in proportion to the amounts of Nb and Ta present.

During the epoch of hydrothermal-pneumatolytic activity gases and solutions have advanced on cracks in some of the already crystallized magmatic pegmatites. Along these vein fissures replacement processes have taken place. In this way the open fissures have been broadened and filled with cleavelandite and quartz which may inclose remainders of magmatic minerals being only partly dissolved by the advancing solutions.

If the material present has not been sufficient to fill the dike, pockets have been formed in the cleavelandite masses, according to the explanation given by K. K. Landes (30).

The adjacent magmatic pegmatite does not seem to have been influenced by this hydrothermal-pneumatolytic activity.

The hydrothermal-pneumatolytic material transmitted to these dikes differs from the magmatic dikes in their content of rare elements. In the former case a concentration of Ta in proportion to the other related elements has taken place and the deposits seem to be poor in rare earth elements. The characteristic minerals of these dikes exhibit a well defined series of minerals.

Besides these minerals, however, some others such as gadolinite and monazite, which in regard to their chemical compositions do not agree with the characteristic hydrothermal-pneumatolytic minerals, have been occassionally found in these dikes. These minerals may, in the opinion of the writer, probably represent remainders of magmatic pegmatites which have been replaced by cleavelandite and quartz.

The Classification of the Pegmatites.

According to V. M. Goldschmidt (21) the pegmatites may be divided into two chief groups, the agpaitic pegmatites in which $Na+K>Al$, and the plumasitic pegmatites with $Na+K<Al$.

The pegmatite dikes in Iveland belong to the last mentioned group, containing characteristic plumasitic minerals such as beryl, chrysoberyl, orthite, muscovite and topaz; corundum has, however, not been found in these dikes.

In his paper on the classification of granite pegmatites, A. Fersman (17) has divided the pegmatites "Reiner Linie" into type I, Proto-pegmatites, and type II, pegmatites containing rare elements. The type I is further divided into 4 groups: a) ordinary pegmatites, b) garnet-pegmatites, c) monazite-pegmatites and d) orthite-pegmatites.

It will emerge from the table 18 of the mineral associations of the pegmatites in Iveland that these dikes can hardly be classified in accordance with this scheme. In all the magmatic pegmatite dikes in Iveland certainly the same rare elements are present, but to very varying amounts and with different ratios between the amounts of the individual elements or the groups of related elements. The magmatic pegmatite dikes certainly are genetically related and a differentiation of the rare elements in the magma must have taken place before the intrusion of the pegmatites.

It seems as if the pegmatites without rare minerals usually occur as more regular dikes than the other pegmatites, and it is therefore probable that these dikes represent the first intruded pegmatite magma in which the rare elements have not yet been sufficiently enriched.

In most of the pegmatite dikes in Iveland some rare minerals have been found by inspection of the material on the dump. When no such minerals, however, were found during one hour of inspection the search for these minerals was usually given up and the dike registered as being without rare minerals. In many of these dikes some rare minerals might probably be found by a closer inspection.

The dikes in which no rare minerals were found did not differ in regard to the chief minerals from the others and there is surely no reason to make a distinction between these dikes.

As previously mentioned the pegmatite dikes may be divided into two chief groups characterized by their ordinary and accessory minerals.

The magmatic dikes. Chief minerals: Microcline, quartz, mica, plagioclase. The characteristic accessory minerals: spessartite (dark, in euhedral crystals containing small amounts of the rare earth elements), beryl (as sharp-edged prismatic crystals), chrysoberyl, gadolinite, thalenite, orthite, alvite (rich in Y-elements), fergusonite, yttrotantalite, yttrotitante, euxenite minerals, samarskite, betafite, columbite, ilmenorutile, ilmenite, magnetite, uraninite, thorite, monazite, xenotime, pyrite, chalcopyrite, molybdenite.

These dikes exhibit a *definite sequence of crystallization* and the rare elements must probably have been present in the magma when the crystallization of the pegmatite commenced. No distinct differentiation of Nb and Ta seems to have taken place.

The hydrothermal-pneumatolytic dikes. Chief minerals: Cleavelandite, quartz, (often in euhedral crystals), and green muscovite.

The characteristic accessory minerals: Spessartite (usually in anhedral crystals and without detectable amounts of rare earth elements), lilac muscovite, black tourmaline (generally without crystal outlines), topaz, beryl (in etched crystals with no definite crystal outlines). Zircon (without detectable amounts of Y-elements), microlite (containing only very small amounts of Nb and Ti), tantalite (representing a nearly pure tantalate of iron and manganese), apatite (without detectable amounts of rare earth elements).

In regard to the structure these dikes are characterized by an extensive simultaneous crystallization of the different minerals. It is *impossible to state any distinct sequence of crystallization*. In these dikes Ta has generally been enriched in proportion to the closely related elements Nb and Ti.

The magmatic dikes.

As mentioned before the magmatic dikes with different assemblages of rare minerals exhibit no great variation in the content of the ordinary minerals. These dikes will therefore have to be classified according to their content of rare minerals which is due to the amount of their chief chemical components present in the magma when the crystallization took place.

These elements are especially those previously described as group I and II.

The Nb and Ta are in most of the pegmatites combined with the rare earth elements or with Fe and Mn. In some dikes, however, as Landsverk and Ljosland these elements partly enter into Ca-rich minerals such as betafite and yttrotitanite. The paragenesis of these dikes shows that they are richer in Ca than the ordinary pegmatites, and also the other betafite and yttrotitanite bearing dikes indicate by their mineral paragenesis that the occurrence of Ca-rich niobates and tantalates and titanosilicates are conditioned by a relatively large amount of Ca present in the magma. In these Ca-rich pegmatites the phosphoric acid has often to a great extent formed apatite and they generally seem to be richer in plagioclase than the other dikes.

The magmatic pegmatites in Iveland thus may be divided into two chief groups:

I. The dikes poor in calcium. The characteristic feature of these dikes is that usually all the phosphoric acid has reacted with the rare earth elements and formed monazite and xenotime. The elements of group II (Ti, Nb, Ta, W) have entered into compounds with the rare earth elements, Fe and Mn. The pegmatites are usually relatively poor in plagioclase feldspar. Apatite has only been found as a rare exception.

II. The calcium-rich dikes. In these dikes the elements belonging to group II partly enter into Ca-rich minerals. The dikes are characterized by:

Calcium-rich cubic niobates, tantalates and titanates belonging to the pyrochlore group, as betafite, or the titanosilicate titanite. Apatite may occur frequently and uraninite and thorite are common minerals. The dikes are usually rich in plagioclase.

The mineral paragenesis of the dikes of group I shows that the rare minerals generally occur in certain associations and some of the minerals have never been found together in the same dike. The mineral combinations which have not been found in the same pegmatite are chiefly:

Thalenite samarskite.
Gadolinite samarskite.
Thalenite columbite.
Gadolinite columbite.
Samarskite euxenite.
Samarskite ilmenorutile.

These mineral associations may therefore under the given conditions be chemically unstable. The occurrence of the yttriumsilicates seems only to be possible when the Nb and Ta present are saturated with the yttrium elements. The rare earth elements exhibit a much stronger affinity to the Nb and related elements than to Si, and the minerals occurring in the dikes will be conditioned by the atomic proportion between the Y-elements and the elements of group II present.

According to the atomic ratio Y-elements : Nb + Ta (in which may enter certain amounts of Ti and W), the common Y-bearing niobates and tantalates may be divided into 3 groups:

Y-elements :	Nb + Ta = max.	1 : 1,	Fergusonite,
—„—	—„—	0.5 : 1,	euxenite, yttrotantalite,
—„—	—„—	0.3 : 1,	samarskite.

Which of these minerals will be formed will depend on the proportions of these elements present in the magma.

If the number of atoms of the Y-elements present in the magma, not counting the amount combined with phosphoric acid as xenotime, is called Y and the number of atoms of Nb (+ Ta, Ti, W) is called M, the variation in the proportions of these quantities will cause the formation of different minerals:

Y : M > 1.	There will be an excess of Y in proportion to the amount of M present and this excess will form yttrium silicates *thalenite* or *gadolinite*.
Y : M 1 0.5.	The total amount of Y will react with the amount of M present and the orthoniobate *fergusonite* will be the first to be formed. No yttrium silicate minerals can occur.
Y : M 0.5 0.3.	The amount of Y is not sufficient to form orthoniobates. The most Y-rich niobates and tantalates formed are the metacompounds and pyrocompounds *euxenite*, *yttrotantalite* and *samarskite*.
Y : M < 0.3.	Most of the elements M will react with Fe and Mn forming *columbite,* which will be the characteristic rare mineral.

The magmatic dikes poor in Ca may thus be divided into 3 groups according to their characteristic minerals conditioned by the proportion between the amounts of Y-elements and Nb + Ta present:

1. *Thalenite-gadolinite type.*
2. *Fergusonite type.*
3. *Euxenite (samarskite) type.*
4. *Columbite type.*

The elements of group II (Ti, Nb, Ta and W) are only able to substitute each other to a certain extent in the different minerals. Which minerals will be formed is therefore also conditioned by the atomic proportions of these elements present.

As mentioned before the proportion between the amounts of Nb and Ta does not seem to undergo very great variations. The proportion between the amount Nb+Ta and Ti, however, is very different in the different dikes.

In the pegmatites poor in Ti in relation to the amount of Nb+Ta, the amount of Ti will not be sufficient for the formation of euxenites, and under these conditions the euxenite will be substituted by samarskite or yttrotantalite.

When, however, the ratio Ti : Nb+Ta is larger than that possible in the euxenites the excess of Ti will enter into ilmenite or ilmenorutile.

In this way each of the chief types may be divided into 3 groups with their characteristic minerals conditioned by the atomic ratio Nb+Ta : Ti.

a. The pegmatites in which the ratio Nb+Ta : Ti is too high for the formation of euxenites. The Nb and Ta will react with the rare earth elements forming samarskites or yttrotantalites.
b. The ratio Nb+Ta : Ti agrees with that of the euxenites being between 1 and $^1/_3$. Euxenite will be a characteristic mineral and there will be no excess of Ti to form ilmenite or ilmenorutile.
c. The ratio Nb+Ta : Ti is lower than in the euxenites. The excess of Ti will enter into ilmenite or ilmenorutile.

In accordance with their contents of rare minerals the pegmatites of Iveland may thus be divided as follows:

A. The magmatic pegmatites.

I. The pegmatites poor in calcium.

1. *The thalenite-gadolinite type.*

a	b	c
Charact. min.: *Thalenite* *Gadolinite* Fergusonite	Charact. min.: *Thalenite* *Gadolinite* Fergusonite Euxenite	Charact. min.: *Thalenite* *Gadolinite* Fergusonite Euxenite Ilmenite Ilmenorutile

2. *The fergusonite type.*

a	b	c
Charact. min.: *Fergusonite* Yttrotantalite Samarskite	Charact. min.: *Fergusonite* Yttrotantalite Euxenite	Charact. min.: *Fergusonite* Euxenite Ilmenite Ilmenorutile

3. *The euxenite (samarskite) type.*

a	b	c
Charact. min.: *Samarskite* Yttrotantalite	Charact. min.: *Euxenite*	Charact. min.: *Euxenite* Ilmenite Ilmenorutile

4. *The columbite type.*

a	b	c
Charact. min.: *Columbite* Samarskite	Charact. min.: *Columbite* Ilmenite	Charact. min.: *Columbite* Ilmenite

II. The pegmatites rich in calcium.

The characteristic rare minerals are: betafite or related minerals and yttrotitanite.

B. The hydrothermal-pneumatolytic dikes.

The characteristic rare minerals are: microlite and tantalite.

The other characteristic minerals of these dikes are: cleavelandite, quartz, lilac muscovite, beryl, zircon. With the exception of beryl none of these minerals have been found in the magmatic dikes.

The chemical composition of these minerals indicate that the dikes are poor in the rare earth elements.

The microlites and tantalites are nearly pure tantalates with only very small amounts of Nb and Ta. No lines of W were found in the X-ray spectrograms of these minerals.

By this hydrothermal-pneumatolytic activity Ta has been nearly completely isolated from the closely related elements Nb, Ti and W.

Corresponding Ta-rich minerals have not been found in the magmatic dikes and it is therefore probable, as previously pointed out by the present writer (10), that a separation of the closely related elements Nb and Ta is not possible during the magmatic processes.

The cleavelandite-quartz dikes are very rare in Iveland and have only been observed in 5 different localities in the district. According to K. K. Landes (34) the cleavelandite-quartz dikes belong to the high temperature hydrothermal phase of the formation of pegmatites. Hydrothermal minerals deposited at lower temperatures, such as described by Landes from the granite pegmatites in Central Maine (30), have not been observed in the pegmatites in Iveland.

The cleavelandite-quartz dikes in Iveland differ from those described from America by containing no lithium-minerals and cassiterite.

A Comparison with the Other Precambrian Granite Pegmatite Areas in Norway.

The granite pegmatites of Hitterø, South-western Norway, and their characteristic minerals have been described by Th. Scheerer in 1850 (46). These dikes intersect norite and labradorite rocks and are of the ordinary microcline-quartz type. The rare minerals found in these dikes are xenotime, malacone (alvite), polycrase, kainosite, blomstrandine, gadolinite and orthite, and the dikes are thus apparently very similar to the pegmatites of Iveland.

The pegmatites in South-eastern and Southern Norway have previously been described by W. C. Brøgger (13). At that time, however, the pegmatites in Iveland had not yet been studied systematically. According to his study of the Norwegian pegmatites W. C. Brøgger has classified the granite pegmatites thus:

1. The normal granite pegmatites.
   a. Columbite and samarskite dikes often with monazite. The dikes east of the Oslofjord.
   b. Euxenite (polycrase, blomstrandine) dikes with gadolinite, orthite, yttrotitanite, thorite and xenotime. The dikes from Tvedestrand Arendal, Lister (Hitterø), Setesdal and Stavanger county.
2. The tourmaline dikes in the district around Kragerø.
3. Muscovite-rich granite pegmatites rich in beryl and often with topaz and fluorite. South-eastern and Southern Norway.

Lately the feldspar quarries in South-eastern Norway east the of river Glomma have been described by O. A. Broch (11) in a series of publications on feldspar from the Geological Survey of Norway. This description also gives several particulars of mineralogical interest.

According to Broch the granite pegmatites in this area exhibit a marked zoning and are very poor in rare minerals. The rare minerals found in the pegmatite dikes of this area are: cleveite, orthite, euxenite and columbite. The association of the chief minerals does not differ from that of the pegmatites in Iveland. No cleavelandite-quartz dikes have been observed in this area.

All of the studied Precambrian granite pegmatites in Norway are characterized by being poor in pneumatolytic-hydrothermal products, and by the abscence of Li and Sn in the pegmatite magmas.

X-ray analyses of minerals from a series of localities in the different pegmatite areas show that the pegmatites along the southern coast west of Kragerø and in Setersdal seem to have some general features which possibly indicate a certain genetic relation between these dikes. The general features are especially the richness in W which element seems to a certain extent to substitute the Nb in the Nb-bearing minerals and the average richness of the rare earth elements in relation to the amount of Nb and Ta present, the dikes thus generally being rich in silicates of the rare earth elements. These dikes are also usually relatively rich in Ti in relation to the Nb and Ta present, and the excess of this former element often forms Ti-minerals such as ilmenite, yttrotitanite and ilmenorutile.

The wolframite- and scheelite-bearing dikes at Ørsdalen in the western part of Southern Norway may probably be connected with the W-rich granite pegmatites in this area.

The granite pegmatite dikes in South-eastern Norway also exhibit some general features. In these pegmatites W seems to be practically absent. The average amount of the rare earth elements in relation to the amounts of Nb and Ta present is much lower than in the former area, the silicates of the rare earth elements thus being very rare and have only been found in a few dikes in the district. The Ti-minerals and the euxenite occur very sparingly, and this fact shows that these pegmatite magmas are generally poor in Ti in relation to the amounts of Nb and Ta.

Table 18.

		1. Tveit 1	2. Tveit 2	3. Tveit 3	4. Tveit 4	5. Tveit 5	6. Tveit 6	7. Dalane 1	8. Dalane 2	9. Frøyså 1	10. Frøyså 2	11. Frøyså 3	12. Frøyså 4	13. Frøyså 5	14. Rosås 1	15. Rosås 2	16. Rosås 3	17. Rosås 4	18. Hiltveit 1	19. Hiltveit 2	20. Ivedal 1	21. Ivedal 2	22. Ivedal 3	23. Birketveit 1
1	Microcline	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
2	Quartz	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
3	Plagioclase	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
4	Cleavelandite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Biotite	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
6	Muscovite	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
7	Lilac muscovite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Garnet	-	×	×	-	-	-	-	×	×	-	×	×	-	-	×	-	×	×	-	×	-	-	-
9	Tourmaline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	Topaz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Beryl	-	-	×	-	-	-	-	×	×	-	-	×	-	-	-	-	×	-	×	-	×	×	×
12	Chrysoberyl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	Gadolinite	-	-	-	-	-	-	-	-	×	×	-	×	×	-	-	×	×	-	×	×	-	-	×
14	Thalenite	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-	-	×	-	-	-
15	Orthite	-	-	-	-	×	-	-	×	-	-	-	×	-	-	-	-	-	×	-	×	-	-	×
16	Thortveitite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	?	-	-	-
17	Zircon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Alvite	×	×	-	-	-	-	-	×	×	-	×	×	-	×	-	×	-	-	-	×	-	-	-
19	Fergusonite	×	-	-	-	-	-	-	×	×	-	×	×	-	×	-	×	-	×	-	×	-	-	-
20	Yttrotantalite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-
21	Titanite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	Yttrotitanite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	×
23	Euxenite group	-	-	-	-	×	×	-	-	×	-	×	×	-	×	-	×	-	×	-	-	-	-	×
24	Samarskite	-	-	×	?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-
25	Betafite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	Microlite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	Columbite	-	-	×	?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	Tantalite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	Ilmenorutile	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	Ilmenite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-
31	Magnetite	×	×	-	-	×	-	-	-	-	-	×	-	-	×	×	-	-	-	-	×	×	×	-
32	Uraninite	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	Thorite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×
34	Monazite	×	×	×	-	×	×	-	×	×	-	×	×	-	×	-	×	-	×	-	-	×	-	-
35	Xenotime	×	-	-	-	×	×	-	×	-	-	-	-	-	×	-	-	-	-	-	-	-	-	×
36	Apatite	-			-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
37	Pyrite	-	-	-	-	-	-	-	-	-	-		×	-	-	-	-	-	×	-	×	-	-	-
38	Chalcopyrite	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-
39	Molybdenite	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-
40	Chalcocite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	Calcite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Classification	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II	I	I	I	I	I	II
		2	-	4	4	3	3	-	2	1	1	2	1	1	1	-	1	-	2	1	1	3	-	-
		c	-	a	a	b	b	-	a	b	a	b	b	a	b	-	b	-	c	a	a	a	-	-

Table 18, continued.

	24. Birketveit 2	25. Birketveit 3	26. Birketveit 4	27 Birketveit 5	28. Birketveit 6	29. Ertveit 1	30 Ertveit 2	31 Ertveit 3	32 Ertveit 4	33 Ertveit 5	34. Nateland	35. Tjomstøl	36 Thortveit 1	37. Thortveit 2	38 Thortveit 3	39 Skripeland 1	40. Skripeland 2	41. Landås 1	42. Landås 2	43 Landås 3	44 Landås 4	45. Landås 5	46 Landås 6	47. Landås 7	48 Støledalen 1	49. Støledalen 2	50. Omdal 1	51. Omdal 2	52 Mølland 1	53. Mølland 2	54. Mølland 3
1	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
3	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-
5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-
8	×	×	×	-	-	-	-	-	-	-	-	×	-	-	×	×	×	×	-	-	-	×	×	×	×	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	×	×	×	×	-	×	×	×	-	×	-	-	-	-	×
12	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	×	×	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-
19	-	-	×	-	×	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	×	-	×	×	×	×	-	×	×	-	-	×	-	×	-	-	-	×	×	×	-	×	-	×	×	×	×	-
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25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-
30	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	×	×	×	×	-	-	×	-	-	-	×	-	-	-	-	-	-	-	×	-	×	-	-	×	-
32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	×	×	×	-	×	×	-	-	×	-	-	-	-	×	-	×	×	×	×	-	×	-	-	-	×
35	-	-	-	×	-	×	×	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	×	×	×	-	×
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-	×	×	×	×	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A
	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	-	I	-	I	I	I	I	I	I	I	I	I	I	I	I	I
	-	-	2	3	2	3	3	3	3	-	1	3	-	-	3	-	3	-	3	3	3	3	3	3	1	1	3	3	3	3	3
	-	-	a	b	a	c	b	b	b	-	b	b	-	-	b	-	b	-	a	a	b	b	b	a	b	c	b	b	b	b	a

Table 18, continued.

		55. Mølland 4	56. Mølland 5	57. Mølland 6	58. Mølland 7	59. Mølland 8	60. Mølland 9	61. Mølland 10	62. Mølland 11	63. Ljosland 1	64. Ljosland 2	65. Ljosland 3	66. Ljosland 4	67. Ljosland 5	68. Ljosland 6	69. Ljosland 7	70. Ljosland 8	71. Ljosland 9	72. Ljosland 10	73. Ljosland 11	74. Ljosland 12	75. Ljosland 13	76. Ljosland 14	77. Håverstad 1
1	Microcline	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
2	Quartz	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
3	Plagioclase	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
4	Cleavelandite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Biotite	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
6	Muscovite	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
7	Lilac muscovite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Garnet	-	-	-	-	-	-	-	-	×	-	×	-	-	×	-	-	-	-	×	×	-	×	-
9	Tourmaline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-
10	Topaz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Beryl	-	-	-	-	-	-	-	-	-	-	×	×	-	×	-	-	×	×	×	×	-	-	-
12	Chrysoberyl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	Gadolinite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-
14	Thalenite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	Orthite	-	-	×	×	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	×	-	-	×
16	Thortveitite	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	×	×
17	Zircon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Alvite	-	-	-	-	×	×	-	-	-	-	-	×	×	-	-	-	-	-	-	-	-	×	×
19	Fergusonite	-	-	-	×	×	×	-	×	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-
20	Yttrotantalite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-
21	Titanite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-
22	Yttrotitanite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-
23	Euxenite group	×	×	×	×	×	×	×	×	-	×	-	×	-	-	×	×	×	×	×	×	×	×	×
24	Samarskite	-	-	-	-	-	-	-	-	-	-	×	-	-	×	-	-	-	-	-	-	-	-	-
25	Betafite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-
26	Microlite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	Columbite	-	-	-	-	-	-	-	-	×	-	×	-	-	×	-	-	-	-	-	-	-	-	-
28	Tantalite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	Ilmenorutile	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	×
30	Ilmenite	-	-	×	×	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-
31	Magnetite	×	×	×	×	-	-	×	-	-	-	-	×	×	-	-	-	×	×	-	-	-	-	-
32	Uraninite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	?	-	-	-	-	-
33	Thorite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	Monazite	×	×	×	×	×	×	×	×	×	×	×	×	-	×	-	×	×	×	×	-	-	-	×
35	Xenotime	-	-	-	×	-	-	-	-	-	-	-	×	-	-	-	×	-	×	-	×	-	-	×
36	Apatite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	×
37	Pyrite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	Chalcopyrite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-
39	Molybdenite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	Chalcocite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-
41	Calcite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Classification	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II	II	I	I	I	I
		3	3	3	2	2	2	3	2	4	3	4	3	2	4	3	3	3	-	-	1	3	3	3
		b	b	c	c	b	b	b	b	a	b	a	c	a	a	b	c	b	-	-	b	b	b	c

Table 18, continued.

	78 Håverstad 2	79. Håverstad 3	80. Håverstad 4	81. Håverstad 5	82. Håverstad 6	83 Håverstad 7	84. Eptevann 1	85. Eptevann 2	86. Eptevann 3	87 Eptevann 4	88. Frikstad 1	89 Frikstad 2	90 Frikstad 3	91. Frikstad 4	92. Frikstad 5	93 Frikstad 6	94 Frikstad 7	95. Frikstad 8	96. Frikstad 9	97. Frikstad 10	98. Frikstad 11	99 Kåbuland 1	100. Kåbuland 2	101. Birkeland 1	102 Birkeland 2	103 Birkeland 3	104. Katterås 1	105 Katterås 2	106. Katterås 3	107. Høgetveit	108. Landsverk
1	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	-	×
2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
3	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	×	×	-	-	-	×
5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	×	×	-	-	-	-
8	×	×	-	×	×	-	-	-	-	×	×	×	×	-	-	-	×	×	-	-	×	-	-	×	×	×	×	×	-	×	×
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	×	×	-	-	-	-
11	-	-	-	-	×	×	-	×	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	×	×	×	×	-	-	×	×	-	-	-	-	×	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-
15	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	×	×	×	-	-	-	-	-	-	-	×	×
16	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	×	×
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	×
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	×	×	-	-	-	-	×	×	-	-	-	-	-	-	-	-	×	-	-	-	-	×	-	-	-	-	-	×	-	-	×
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-	-	-	×	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	×	-	-	-	-	-	-	-	×	-	×	-	-	-	-	-	-	×	-	-	-	×	-	×	×
32	-	-	-	-	-	-	-	-	?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×
34	×	×	-	-	-	-	×	×	?	×	-	-	-	-	-	-	×	-	-	-	-	×	-	-	-	-	×	×	×	×	×
35	×	×	-	-	-	-	-	×	-	-	-	-	-	-	-	-	×	-	-	-	-	×	-	-	-	-	-	-	-	×	×
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	×	×	-	-	-	-	-	-	-	-	×	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×
	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	A	A	A	A
	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	-	-	-	I	I	I	II
	3	3	-	-	-	-	3	3	-	4	-	-	-	-	1	-	1	1	1	1	1	3	-	1	-	-	-	3	4	1	-
	b	b	-	-	-	-	b	c	-	a	-	-	-	-	c	-	c	a	a	a	a	c	-	a	-	-	-	b	a	a	-

Summary.

The results given in the present paper are based on field investigations of 108 granite pegmatites in Iveland and neighbouring districts, and on 155 X-ray spectral analyses of their rare minerals.

In the district of Iveland a large amphibolite body has been intersected by the granitic magmas and solutions which have formed granites and granite pegmatites. The pegmatites are generally small dike- or lense-shaped bodies usually imbedded in amphibolite. Sharp-edged fragments of the amphibolite imbedded in the pegmatite bodies show that no magmatic assimilation of the surrounding rock has taken place. Two of the dikes described intersect granite bodies.

The pegmatite dikes may be divided into two chief groups: the microcline quartz dikes which are of magmatic origin, and the cleavelandite-quartz dikes which are formed by later hydrothermal-pneumatolytic activity. The magmatic pegmatites are usually rather rich in "rare" minerals and do not seem to have been influenced by hydrothermal activity.

The microcline of these dikes is usually a coarsely perthitic pink or greyish vein perthite which seems to have been formed by removal of the albite substance in a fine perthitic green translucent string perthite without adding of albite substance by circulating solutions. It is thus, in the opinion of the writer, probable that the ordinary perthite of these dikes is formed by exsolution according to the theory maintained by J. H. L. Vogt.

The rare minerals of the magmatic pegmatites always exhibit a distinct sequence of crystallization which indicates that the rare elements forming these minerals must have been present in the magma when the crystallization of the pegmatites commenced.

The sequence of crystallization of the rare minerals follows some general rules:

1. The phosphates of the rare earth elements, monazite and xenotime always belong to an early stage in the crystallization of the pegmatites.

2. The crystallization of the niobates and tantalates of the yttrium elements takes place in the order of decreasing amounts of these elements present in the minerals.

3. The niobates and tantalates of iron and manganese (columbite-tantalite) have always crystallized later than the niobates and tantalates containing rare earth elements.

4. The silicates of the rare earth elements such as thalenite and gadolinite have crystallized later than the other rare minerals.

5. The zircon minerals, zircon and alvite, belong to the earliest crystallizations of the pegmatite magma.

According to the ionic dimensions the mineralforming rare elements may be divided into 3 groups:

I. The rare earth elements, Th and U.

II. The elements Ti, Nb, Ta and W.

III. The elements Zr and Hf.

In each of these groups the elements may substitute each other to a certain extent.

The magmatic dikes may be divided into two chief groups, namely the ordinary pegmatites which are poor in calcium, and the calcium-rich pegmatites.

The rare minerals which occur in an ordinary magmatic pegmatite are chiefly conditioned by the atomic ratio between the rare earth elements and the elements of group II (Ti, Nb, Ta, W) and by the ratio between Nb + Ta and Ti, present in the magma. On this basis a classification of the rare mineral bearing dikes has been carried out. According to this classification the ordinary magmatic dikes may be divided in 4 chief types: 1. The thalenite-gadolinite type. 2. The fergusonite type. 3. The euxenite (samarskite) type. 4. The columbite type. Each of these types are further divided into 3 groups according to the ratio Nb+Ta : Ti present in the magma.

In the calcium-rich magmatic pegmatites, Ca-bearing minerals occur more frequently and the rare earth elements enter to some extent into Ca-rich minerals such as betafite and yttrotitanite.

In the magmatic dikes the relation between the amounts of Nb and Ta present seems to undergo very small variations and is estimated to be about 1 at. Ta : 4 5 at. Nb.

The Nb bearing minerals from the magmatic pegmatites in Iveland are characterized by usually containing considerable amounts of W, which element seems to substitute Nb in these minerals.

After the crystallization of the magmatic dikes some of these have been intersected by younger hydrothermal-pneumatolytic cleavelandite-quartz dikes. These dikes do not exhibit any distinct sequence of crystallization. They also differ from the magmatic pegmatites in regard to their accessory minerals. The characteristic rare minerals of these dikes, tantalite and microlite, have not been found in the magmatic pegmatites. Zircon, apatite and spessartite from these dikes differ from the same minerals of the magmatic dikes by showing no lines of the rare earth elements in the X-ray spectrograms. Thus the cleavelandite-quartz dikes differ in regard to the chemical composition of the rare minerals from the magmatic dikes by being usually enriched in Ta, and by the absence of the rare earth elements in the spessartite, apatite and zircon found in these dikes. W has not been found in the X-ray spectrograms of minerals from the cleavelandite-quartz dikes. The granite pegmatites of Iveland are further characterized by the abscence of Sn and Li.

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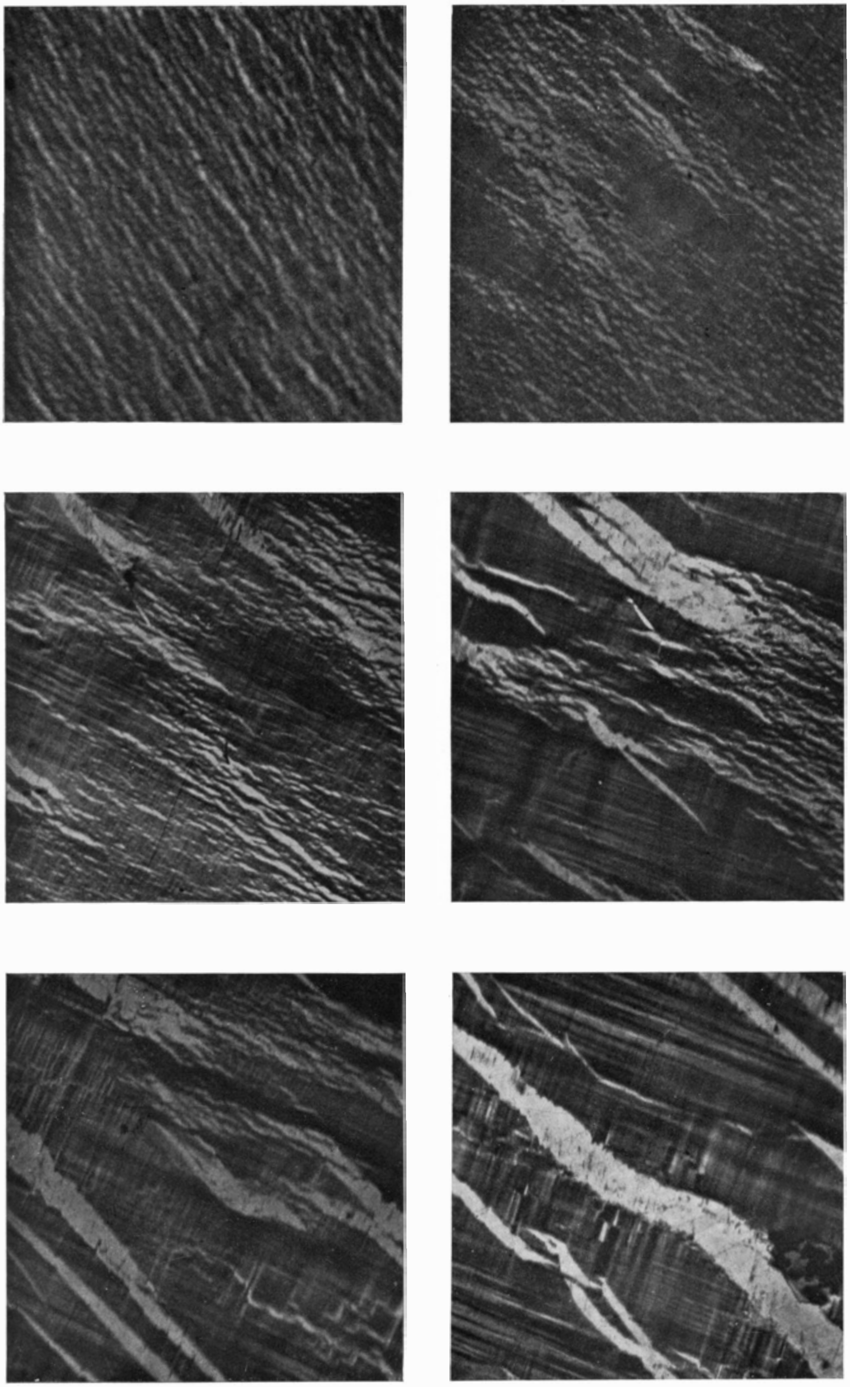
Explanation to Plate.

Microcline from 99. Kåbuland 1, Iveland.

Microphotographs with crossed nicols of sections parallel to 001 from the border between the green translucent, finely crosstwinned string perthite and the coarsely crosstwinned pink vein perthite. The microphotographs show the different stages in the transition of the microcline. The small perthite lamellæ in the string perthite seem to gather and unite into the larger albite veins in the vein perthite, and simultaneously the string perthite looses its peculiar twinning and attains the appearance of the ordinary crosstwinned type.

Magnification about 60.




Map of Iveland
and neighbouring Districts,
showing the localities of the feldspar-quarries where the pegmatite dikes have been investigated.
0 1 2 km.
Landsverk
Högetveit
Aamlands-lonane
Gyvardsheia
Katteraas
Kåbuli
Birkeland
Frigstad
Hovaasen
Eptev
Litj.
Rostad
Omdal
Beinmyr
Kjettev
Salen
Haaverstad
Möll
Stöldalen
Möllandsaasen
Landaas
Skripelandstj.
Varaheia
Skripeland
Solheia
Aasen
Thorveit
Natel
Tjomstöl
Birketveit
Iveland
Hilltveit
Spelahaugan
Rossaas
Rossedalen
Ivedal
Fröisaa
Fröysaa
Paasen
Dalane
Cassefloa
Tveit
Breit
Iveland

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Plate — Map of Iveland.

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