

THE AMERICAN MINERALOGIST

JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

Vol. 22

APRIL, 1937

No. 4

THE GRANITE PEGMATITES OF SOUTHERN NORWAY

HARALD BJØRLYKKE, *University of Oslo, Oslo, Norway.*

INTRODUCTION

The rare minerals of the granite pegmatites of southern Norway have been studied especially by Brøgger (7, 8), Schetelig (8, 12), and Vogt (8). However, recently many new pegmatites have been opened for feldspar production, and the use of x -ray spectrographic methods has made it possible to study the composition of a larger number of their minerals.

The results given in this paper are based on field observations of the granite pegmatites of southern Norway made during the summers 1931-36, and laboratory investigations of the materials collected. Most of the minerals collected were only small fragments of crystals, or irregularly formed nodules, and many of them could not have been identified without the use of special methods. To this end x -ray spectral analyses were used. The x -ray spectrograms give positive identification of most of the rare minerals and, since an amount of 2-3 mg. of the mineral powder suffices, very small mineral particles can be studied and classified. They also give a good survey of the variation of the chemical components in each mineral specimen. For identification purposes, also Debye-Scherrer diagrams were used to some extent. A total number of about 400 x -ray spectrograms from Norwegian granite pegmatites have been made. The classification of these pegmatites is based chiefly on a study of several hundreds different pegmatites in Sørlandet (Iveland county and the coastal region) and Østfold (Region E. of the Oslofjord). Mineralogical descriptions of the material used, as well as a description of the laboratory methods, have been published in previous papers (4, 5, 6).

ORIGIN OF THE PEGMATITES

It is generally accepted that granite pegmatites carrying rare minerals represent residual granite liquors enriched in volatile components and characteristic rare elements. According to Goldschmidt (9), the enrichment of rare elements is caused by the fact that the ionic radii of these elements are different from those of the common rock-forming elements of the granite. In the Norwegian granite pegmatites the following rare

elements are characteristically present: Ti, Nb, Ta, W, and Be. However, the amounts of these rare elements vary within wide limits in the different pegmatites. In some large pegmatite dikes no minerals of rare elements have been encountered, while in others they occur abundantly. At the same time, pegmatites differing in their content of rare minerals may be very similar in their content of the principal minerals. It seems impossible, therefore, to find any relationship between the main composition of the pegmatites and the amount of rare minerals.

Investigations of Norwegian granite pegmatites carried on during the last six years, especially in Iveland, have shown that, generally speaking, pegmatites containing insignificant amounts of rare minerals form rather regular, dike-shaped bodies, while irregular or lens-shaped pegmatites almost always contain rare minerals in considerable quantities.

Coarse granite pegmatites must have been subjected to slow cooling, and since they usually form relatively small bodies or dikes, the neighboring rocks must have maintained a temperature near that of the crystallization interval of the pegmatites for a long time. It is assumed, therefore, that such pegmatites were formed at a certain depth where the pressure was large enough to keep the volatiles in solution, and where the temperature was approximately that of the crystallization of the pegmatites.

If a granite pegmatite magma has been intruded into rocks with a temperature above the temperature of crystallization of the pegmatite no crystallization could take place, and this pegmatite magma should remain in a liquid condition until the temperature of the surrounding rocks was low enough to permit crystallization. Such a lowering of the temperature of the native rock may be effected by denudation.

As previously pointed out by Andersen (1) and Barth (2, 3) the granite pegmatites often occur as lens-shaped or irregular masses without any traceable connection with other granite bodies, and Andersen, therefore, assumes that the pegmatite magma filling these spaces was intruded along small cracks or channels in the surrounding rock. It is a common phenomenon that the surrounding rock has developed a schistosity parallel to the pegmatite bodies. Since microcline and quartz of the pegmatites usually exhibit no sign of pressure, the deformation of the adjacent rock must have taken place before the crystallization of these minerals, i.e. while most of the pegmatite magma still was in a liquid condition. It seems unlikely that this pressure was caused by the intrusion of the pegmatite magma through narrow cracks or channels in the surrounding rock. It seems more probable that the pressure was caused by stress forces subsequent to the intrusion, but before complete crystallization of the pegmatite magma. This view is supported by the fact

that many granite pegmatites contain strongly deformed crystals of the early mineral phases: beryl, tourmaline, euxenite, columbite, and biotite (incidentally the mechanical deformation of these minerals is a further indication of their magmatic origin); whereas the mineral phases of the principal stage of crystallization: feldspar, quartz, etc., seldom show any trace of deformation.

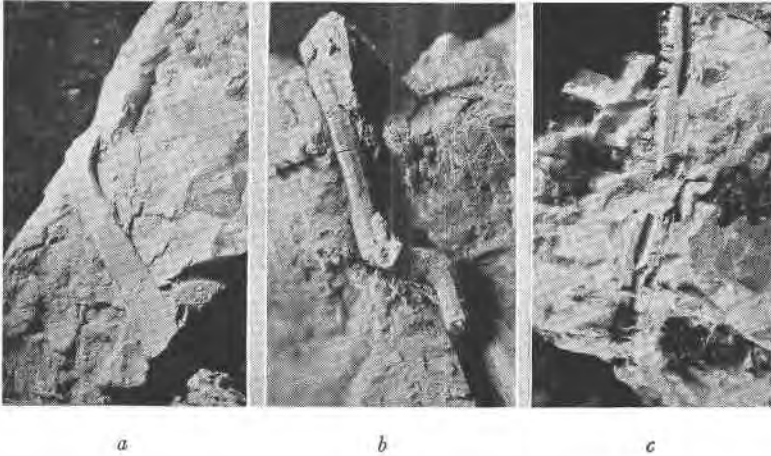


FIG. 1. Mechanically deformed crystals in microcline from granite pegmatite, Torvelona in Iveland ($1\frac{1}{3}\times$); *a* and *b* euxenites, *c* beryl. (For photographic purposes the samples have been whitened with ammonium chloride.)

Some intrusive granite pegmatites in Iveland send forth into the amphibolite small subparallel veins and apophysae that can be traced over great distances. Goldschmidt (9) previously has pointed to the fact that potash extracted from the pegmatite often transforms hornblende into biotite on the boarder of the amphibolite. The small pegmatite veins are richer in plagioclase, therefore, and also richer in quartz than the larger pegmatites. By spectroscopic analyses of the amphibolite Goldschmidt (10) has shown that scandium does not belong to the pegmatite magma but has been extracted from the surrounding amphibolite. It is a characteristic feature that the thortveitite-bearing pegmatites always form small pocket-shaped bodies in the amphibolite.

The relative amounts of the principal mineral phases of the pegmatites vary within wide limits, and according to Barth (3) the granite pegmatites in northern Iveland can be divided into two types: type 1 with 20% quartz and 80% microcline; and type 2 with 50% quartz, 25% microcline and 25% plagioclase.

The contention of the present writer is that the Norwegian granite pegmatites carrying rare elements have been formed as follows: after the injection of the younger pre-Cambrian granites, the residual granite magma, enriched in volatiles and rare elements, was intruded along cracks in the surrounding rocks. The temperature was however still high enough for the magma to remain in a liquid condition in these rocks for a long time. Through orogenic movements the magma was kneaded into the surrounding rock, part of it forming smaller or larger bodies without connection with other pegmatite material. During this time the initial crystallization stage was reached, the early mineral phases thereby becoming subjected to mechanical deformation as previously described, the adjacent rock at the same time developing a schistosity parallel to the pegmatite bodies.

Evidence of a filter press action during the crystallization is afforded by the numerous small veins and apophysae containing none of the early mineral phases of the pegmatite magma. Some granite pegmatites were subsequently influenced by solutions and gases following cracks in the already congealed magmatic pegmatite, thus forming deposits of hydrothermal-pneumatolytic origin (cleavelandite, quartz etc.), which are not of course in equilibrium with the magmatic minerals. Characteristic rare minerals of this low-temperature phase are columbite-tantalite, microcline, spessartite, topaz, and zircon. During this hydrothermal-pneumatolytic stage the magmatic minerals near the pathways of the gases and solutions were partly or wholly replaced by cleavelandite and quartz. Vestiges of this replacement can still be seen: patchy remainders of partly dissolved magmatic minerals, especially microcline, encompassed by cleavelandite or quartz, monazite and gadolinite imbedded in cleavelandite, beryl enclosing fergusonite, etc. However, cleavelandite pegmatites are relatively rare in Norway and occur only as small, distinctly younger dikes and veins in the magmatic pegmatites.

THE ACCESSORY ELEMENTS

Characteristic of the Norwegian granite pegmatites is the absence of minerals containing the elements lithium and tin. According to their ionic radii the characteristic accessory elements of the granite pegmatites may be divided into the following groups:

Group 1, the rare earth elements (yttrium, lanthanum and the lanthanides), Th, and U.

Group 2, Zr, and Hf.

Group 3, Ti, Nb, Ta, and W.

Group 4, Be.

These elements were present in small amounts in the original granitic

magma but were unable to form part of any of the principal mineral phases. They accumulated, therefore, in the residual liquid and crystallized eventually in individual minerals.

Group 1. The rare earths are chemically so closely related that they cannot be separated easily by ordinary chemical methods. However, through fractional crystallization during the congealing of the pegmatites a certain separation was effected, and thus, as first shown by Goldschmidt and Thomassen (11), it becomes possible to distinguish between three chief types of associations of rare earths:

(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.

In most of the minerals containing an appreciable amount of rare earth elements either association (A) or (C) is present, while association (B) is common in minerals with rare earths as minor constituents. Minerals of the A-association (the Ce-group) are monazite and orthite. The C-association, or the minerals with the Y-elements as chief chemical components are: xenotime; compounds with Ti, Nb, Ta, and W: fergusonite, euxenite, betafite, samarskite, and yttrotantalite; silicates: thalenite, gadolinite, hellandite, and yttrotitanite.

In all these minerals Th and U may be present in considerable amounts. (When still larger amounts are present uraninite and thorite are formed.) As minor constituents the rare earth elements occur in apatite, thorite, uraninite, microlite, alvite, and spessartite.

Group 2. The elements Zr and Hf. X-ray spectrograms of Norwegian niobate and tantalate minerals show that the amounts of Zr in these minerals are always lower than 0.1%. Amounts of Zr in these minerals attaining 1% and even more, as given in some older analyses, are probably due to small inclusions of alvite. By far the greatest portion of Zr and Hf present in Norwegian granite pegmatites unites with SiO₂ forming zircon and alvite. Small amounts of Zr and Hf are also present in thortveitite, as previously pointed out by Goldschmidt (11).

Group 3. The elements Ti, Nb, Ta, and W. These elements of similar ionic radii can, at least partially, substitute for each other in a series of minerals. Especially closely related are Nb and Ta which are difficult to separate by ordinary chemical methods. The relative concentration of these elements does not seem to vary much in the various magmatic pegmatites, it probably is about 1 at. Ta:4-5 at. Nb.

In the Norwegian granite pegmatites Nb and Ta have reacted with the Y-elements, Fe, Mn, and Ca, with formation of the following minerals: fergusonite, euxenite, betafite, columbite, samarskite, yttrotantalite, microlite, and tantalite. In all these minerals Ti and W may

be present in considerable amounts. In euxenite the atomic proportion $\text{Nb} + \text{Ta} : \text{Ti}$ varies from 1 to $\frac{1}{3}$. If Ti is present in the magma in relatively larger amounts than that corresponding to the euxenite formula, the excess of this element will enter into ilmenite, or under special conditions into titanite or ilmenorutile. In columbite from Iveland the content of WO_3 may attain 13%.

Group 4. Beryllium. This element is present in the Norwegian granite pegmatites in the minerals beryl, chrysoberyl and gadolinite. Of hydrothermal-pneumatolytic origin is phenakite which is known from two pegmatite dikes near Kragerø.

THE SEQUENCE OF CRYSTALLIZATION

In all magmatic granite pegmatites a distinct sequence of crystallization has been observed. The crystallization of the rare minerals always belong to an early stage. Among the principal minerals we find that the crystallization of biotite began very early and continued over a long period of time. The accessory minerals are therefore usually later than the inner parts, but older than the outer parts of the biotite crystals. Flakes of biotite have therefore often caught rare minerals and hemmed them in during the continued growth of the mica. The wedge-shaped spaces between two plates of biotite are, therefore, preferred loci for rare minerals. In some pegmatites rich in ilmenite large plate-shaped masses of ilmenite may enmesh the rare minerals in the same way as the biotite.

A regular sequence of crystallization is always observed.

- (1) The phosphates of the rare earth 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 proceeded in order of decreasing amounts of these elements. Thus the Y-rich fergusonite always comes before euxenite and betafite, which contain smaller amounts of yttria.
- (3) The niobates and tantalates of iron and manganese (columbite-tantalite) have always crystallized later than the niobates and tantalates of the Y-elements.
- (4) The accessory silicate minerals, thalenite, gadolinite, hellandite, and beryl are always later than the phosphates and the niobate and tantalate minerals.
- (5) The zirconium minerals, zircon and alvite, belong to the earliest crystallizations of the magma.

TABLE 1. THE GENERAL SEQUENCE OF CRYSTALLIZATION IN NORWEGIAN
MAGMATIC GRANITE PEGMATITES

Zirconium minerals.....	—
Phosphates of the rare earth elements.....	—
Niobates and tantalates of the rare earth elements.....	—
Niobates and tantalates of iron and manganese.....	—
The silicates of the rare earth elements.....	—
Biotite.....	—
Muscovite.....	—
Ilmenite.....	—
Magnetite.....	—
Beryl.....	—
Plagioclase.....	—
Microcline.....	—
Quartz.....	—

THE CLASSIFICATION OF THE NORWEGIAN GRANITE PEGMATITES

The granite pegmatites may be divided into the following genetic groups: (A) the magmatic pegmatites; and (B) the hydrothermal-pneumatolytic pegmatites.

A. THE MAGMATIC PEGMATITES

The magmatic granite pegmatites exhibit a series of different mineral parageneses which must be due to a differentiation of the rare elements in the magma before the intrusion of the pegmatites. In most of the pegmatites phosphorus has reacted with the rare elements forming monazite or, more infrequently, xenotime. Monazite is encountered in almost all pegmatites carrying rare earths, and it seems to be a stable mineral in nearly all mineral parageneses of the magmatic pegmatites. In some Ca-rich granite pegmatites apatite also occurs frequently.

The most characteristic rare minerals of the magmatic pegmatites are compounds of the rare earth elements with Nb and Ta, the different mineral parageneses in this case being caused by differences in the concentration of these elements in the pegmatite magma. The rare earth elements combine with phosphorus, Nb, Ta, Ti, and with silica. Usually the Y-elements will form various niobates and tantalates, however, in Ca-rich pegmatites, Ca-bearing niobates and tantalates, such as betafite, will form. It is expedient therefore to divide the magmatic pegmatites into two groups: (1) pegmatites poor in Ca, and (2) pegmatites rich in Ca.

1. *Pegmatites poor in calcium.*

The paragenesis of xenotime+columbite shows that the Y-elements under the given conditions have a greater affinity for phosphorus than for niobium and tantalum. On the other hand, columbite has never been found together with silicates of the Y-elements. The Y-silicates can only form, therefore, after the removal of niobium and tantalum from the magma through reaction with yttrium. Thus the mineral parageneses of the pegmatites are chiefly controlled by the ratio of the concentration between the Y-elements and Nb+Ta (in which may enter certain amounts of Ti and W). The atomic proportions of the common niobates and tantalates of the Y-elements are as follows:

Y-elements: Nb+Ta max. 1:1 fergusonite.

Y-elements: Nb+Ta max. 0.5:1 euxenite, ytrotantalite.

Y-elements: Nb+Ta max. 0.3:1 samarskite, betafite.

If the number of atoms of the Y-elements present in the magma (not counting the amounts combined with phosphorus as xenotime) be called Y and the number of Nb (+Ta, Ti, W) be called M , the variations in the proportions of these quantities will give rise to different mineral parageneses.

$Y:M > 1$. The excess Y will form the Y-silicates thalenite or gadolinite.

$Y:M = 1-0.5$. The total amount of Y will react with M and the orthoniobate fergusonite will be the first to form.

$Y:M = 0.5-0.3$. The amount of Y is not sufficient to form orthoniobates. The next niobates and tantalates to form are the meta-compounds and pyro-compounds, euxenite, ytrotantalite and samarskite.

$Y:M < 0.3$. The excess Nb and Ta will react with Fe and Mn forming columbites.

The elements Nb, Ta, Ti, and W are able to replace each other only to a certain extent in the various minerals. The relative concentration of these elements is, therefore, another factor governing the nature of the minerals to form. The atomic ratio between Nb and Ta seems to be fairly constant for the various magmatic pegmatites and is, therefore, of but small importance. The proportion Nb+Ta:Ti is subject to great variations and will, therefore, give rise to different mineral parageneses. The pegmatites may thus be divided into 3 groups:

- (a) The ratio Nb+Ta:Ti is too high for the formation of euxenite minerals. In these pegmatites Nb and Ta will react with the rare earth elements forming samarskite and ytrotantalite.
- (b) The ratio Nb+Ta:Ti corresponds to that of the euxenite minerals. In these pegmatites euxenite will be the characteristic mineral, but there will be no excess of Ti to form other Ti minerals.

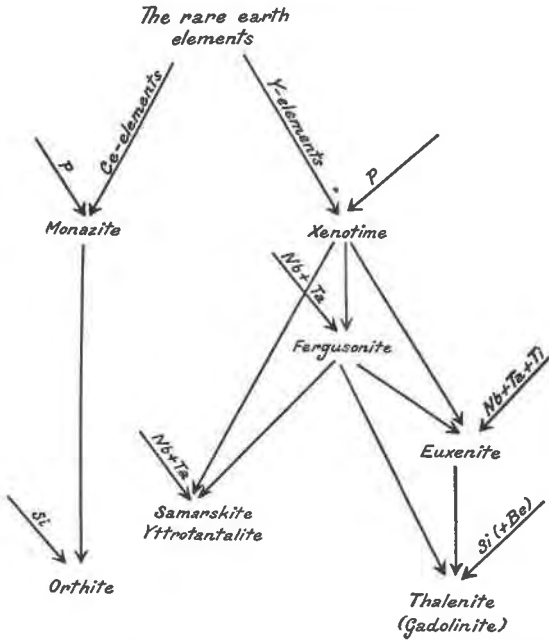


FIG. 2. Sequence of crystallization of the rare earth element-bearing minerals in the Ca-poor magmatic pegmatites.

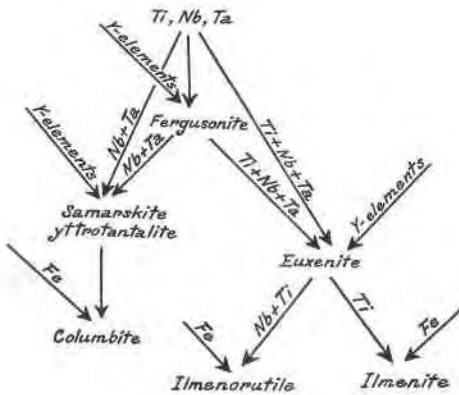


FIG. 3. Sequence of crystallization of the Ti, Nb, and Ta bearing minerals in the Ca-poor magmatic pegmatites.

- (c) The ratio Nb+Ta:Ti is lower than in the euxenites. These pegmatites will have an excess of Ti, which will cause the formation of ilmenite or ilmenorutile.

According to their content of rare minerals the Norwegian magmatic granite pegmatites poor in Ca may be divided as follows:

1. THE THALENITE—GADOLINITE TYPE

(a)	(b)	(c)
Characteristic minerals	Characteristic minerals	Characteristic minerals
<i>Thalenite</i>	<i>Thalenite</i>	<i>Thalenite</i>
<i>Gadolinite</i>	<i>Gadolinite</i>	<i>Gadolinite</i>
Fergusonite	Fergusonite	Fergusonite
	Euxenite	Euxenite
		Ilmenite
		Ilmenorutile

2. THE FERGUSONITE TYPE

(a)	(b)	(c)
Characteristic minerals	Characteristic minerals	Characteristic minerals
<i>Fergusonite</i>	<i>Fergusonite</i>	<i>Fergusonite</i>
Yttrotantalite	Yttrotantalite	Euxenite
Samarskite	Euxenite	Ilmenite
		Ilmenorutile

3. THE EUXENITE (SAMARSKITE) TYPE

(a)	(b)	(c)
Characteristic minerals	Characteristic mineral	Characteristic minerals
<i>Samarskite</i>	<i>Euxenite</i>	<i>Euxenite</i>
Yttrotantalite		Ilmenite
		Ilmenorutile

4. THE COLUMBITE TYPE

(a)	(b)	(c)
Characteristic minerals	Characteristic mineral	Characteristic minerals
<i>Columbite</i>	<i>Columbite</i>	<i>Columbite</i>
Samarskite		Ilmenite

In pegmatites of the thalenite-gadolinite type, thalenite has never been found together with beryl. It is obvious, therefore, as first pointed out by Schetelig (12), that the formation of thalenite is possible only if the amount of Be in the magma is insufficient for the formation of gadolinite. These minerals will react according to the following scheme: thalenite + beryl → gadolinite.

2. *The pegmatites rich in Calcium.*

In some pegmatites, especially the pegmatites near Kragerø, the mineral parageneses are different from those hitherto described. These pegmatites contain some Ca-bearing, rare minerals as betafite, yttrotitanite, and hellandite, the formation of which is caused by a relatively larger amount of Ca in the magma. Pegmatites of this type are also

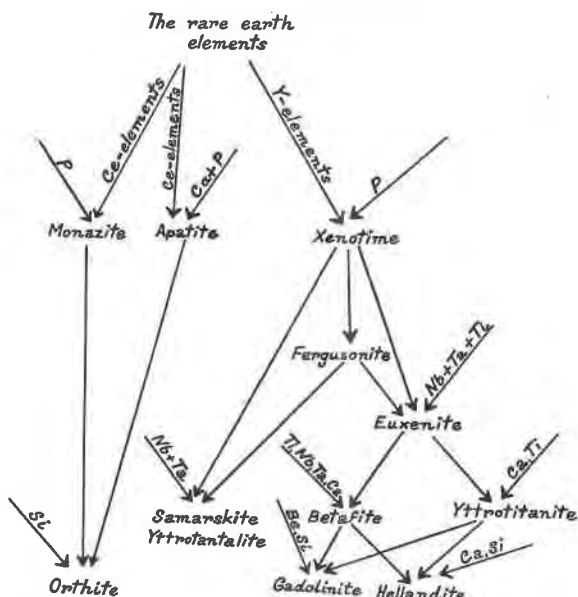


FIG. 4. Sequence of crystallization of the rare earth element-bearing minerals in the Ca-rich magmatic pegmatites.

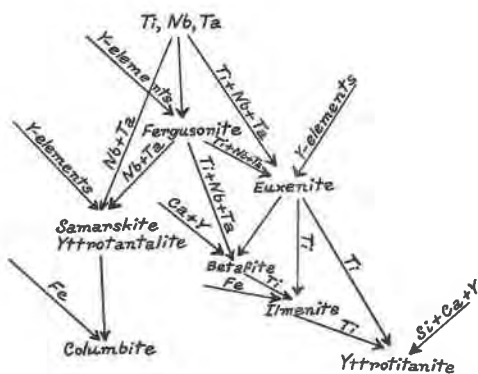


FIG. 5. Sequence of crystallization of the Ti, Nb, and Ta bearing minerals in the Ca-rich magmatic pegmatites.

richer in plagioclase and apatite. In these pegmatites monazite and Ca-silicates become unstable if the Ca-content increases beyond a certain value:



Other minerals characteristic of the pegmatites previously described are, under these conditions, partly replaced by Ca-bearing minerals of similar composition. Thus euxenite is partly replaced by the Ca-bearing niobate, betafite; and thalenite by the Ca-Y-silicate, hellandite. However, like thalenite, hellandite also becomes unstable together with beryl; hellandite + beryl → gadolinite. Hellandite, therefore, can form only if the amount of Be in the magma is insufficient to form gadolinite. The pegmatites rich in Ca may be subdivided into types corresponding to those of the Ca-poor pegmatites:

- | | |
|-------------------------------|-------------------------------|
| 1. PEGMATITES POOR IN CA. | 2. PEGMATITES RICH IN CA. |
| 1. Thalenite-gadolinite type | 1. Hellandite-gadolinite type |
| 2. Fergusonite type | 2. Fergusonite-betafite type |
| 3. Euxenite (samarskite) type | 3. Betafite type |
| 4. Columbite type | |

Thus far pegmatites rich in Ca corresponding to the columbite type have not been encountered among Norwegian pegmatites.

B. THE HYDROTHERMAL-PNEUMATOLYTIC PEGMATITES

These pegmatites occur as metasomatically formed dikes and veins in the magmatic pegmatites. The main mineral components are platy albite (cleavelandite), and quartz. Other common minerals are spessartite, a green and a lilac muscovite, and topaz. As distinct from the magmatic pegmatites, no obvious sequence of crystallization of the minerals was observed. Also in their chemical components the hydrothermal-pneumatolytic pegmatites differ from those of magmatic origin. The scarcity of rare earth elements causes Nb and Ta always to combine with Mn, Fe, and Ca. Some of these pegmatites are especially enriched in Ta, the characteristic minerals then being microlite and tantalite. In others Nb and Ta are present in about the same proportion as in the magmatic pegmatites, and the ordinary rare mineral is therefore a columbite. It is convenient therefore, to divide the hydrothermal-pneumatolytic pegmatites into two groups: (1) the microlite-tantalite pegmatites, and (2) the columbite pegmatites.

The minerals which occur both in the magmatic and in the hydrothermal-pneumatolytic pegmatites generally are present in different habits, and with different compositions in the two types of occurrences. Spessartite and apatite of the cleavelandite-quartz pegmatites usually occur in ill defined crystals intersected by blades of cleavelandite. They contain no detectable amounts of Y-elements, while those of the magmatic pegmatites usually contain these elements in considerable amounts. The columbites of the cleavelandite-quartz pegmatites differ from those

of magmatic origin by containing more Mn than Fe and they may, therefore, properly be called *manganocolumbites*. In Table 2 are given the relative intensities of the α -lines of the chief elements of columbites and a tantalite of different origin and localities, and the figures give a good picture of the relative variations in their composition.

TABLE 2. X-RAY ANALYSES OF NORWEGIAN COLUMBITES AND TANTALITES
Columbites and tantalites from hydrothermal-pneumatolytic formed
cleavelandite-quartz pegmatites:

	Relative intensities of the line					
	Fe $K\alpha_1$	Mn $K\alpha_1$	Ta $L\alpha_1$	Nb $K\alpha_1$	Ti $K\alpha_1$	W $L\alpha_1$
Manganocolumbite, Tangen, Kragerø	5	10	8	4	2	—
Manganocolumbite, Katterås, Iveland	6	10	8	5	0.5	3
Tantalite, Landås, Iveland	8	7	10	0.5	0.2	—
Columbite from magmatic microcline-pegmatite:						
Southern Norway:						
Columbite, Hulleknatten, Gjerstad	10	6	7	6	0.2	2
Columbite, Brokeland, Gjerstad	10	6	4	6	—	—
Columbite, Ramskjær, Spøndeled	10	6	4	3	5	4
Columbite, Tveit 4, Iveland	10	6	4	5	2	6
Columbite, Tveit 3, Iveland	10	8	8	5	2	1
Columbite, Ljosland 1, Iveland	10	8	8	5	2	1
Columbite, Dalane 2, Iveland	10	5	7	6	2	3
Columbite, Rosås? Iveland	10	5	6	2	0.5	4
Columbite, Håverstad? Iveland	10	5	4	5	0.5	2
Columbite, Southern Norway	10	5	4	2	2	5
Columbite, Hitterø	10	5	5	5	0.5	1
Columbite, Øvre Vats, Ryfylke	10	6	7	5	1	4
Østfold, Southeastern Norway:						
Columbite, Ånnerød, Våler	10	6	0.5	7	—	—
Columbite, Lundebø	10	5	4	7	1	—
Columbite, Kure, near Moss	10	5	5	6	0.5	—
Columbite-tantalite, Karlshus, Råde	10	5	10	2	2	—
Columbite-tantalite, Halvorsrød, Råde	8	7	10	2	—	—

In some of the hydrothermal-pneumatolytic pegmatites are found also magmatically formed minerals as monazite, gadolinite, and beryl. These minerals represent remainders of a magmatic pegmatite which have been replaced by cleavelandite and quartz. Metasomatically formed beryl has been found only in the feldspar quarry at Halvorsrød in southeastern Norway, in small colorless euhedral crystals imbedded in fluorite and quartz.

TABLE 3. MINERALS FOUND IN NORWEGIAN GRANITE PEGMATITES

MAGMATIC	HYDROTHERMAL-PNEUMATOLYTIC
<i>Microcline</i>	
<i>Quartz</i> , milky or colorless	<i>Quartz</i> , colorless or smoky
<i>Plagioclase</i> (usually oligoclase)	<i>Cleavelandite</i>
<i>Biotite</i>	
<i>Muscovite</i> , colorless	<i>Muscovite</i> , green
<i>Scapolite</i>	<i>Muscovite</i> , lilac
<i>Spessartite</i> , in euhedral crystals usually containing small amounts of Y-elements	<i>Spessartite</i> , mostly in anhedral crystals without detectable amounts of Y-elements
<i>Tourmaline</i> , black	<i>Tourmaline</i> , black
	<i>Topaz</i> , in large crystals
<i>Beryl</i> , green, blue or yellow, in crystals up to 1000 kgms	<i>Beryl</i> , colorless, in small well-defined crystals
	<i>Phenakite</i>
<i>Chrysoberyl</i>	
<i>Gadolinite</i>	
<i>Thalenite</i>	
<i>Hellandite</i>	
<i>Kainosite</i>	
<i>Orthite</i>	
<i>Thortveitite</i>	
<i>Zircon</i>	<i>Zircon</i>
<i>Albite</i> (cyrtolite)	
<i>Fergusonite</i> (and risørte)	
<i>Ytrotantalite</i>	
<i>Titanite</i>	<i>Titanite</i>
<i>Yttrotitanite</i> (keilhauite)	
<i>Euxenite minerals</i> (including blomstrandine, polychrase, priorite)	
<i>Samarskite</i>	
<i>Betafite</i>	
<i>Mossite</i>	<i>Microfite</i>
<i>Columbite</i>	<i>Manganocolumbite</i>
	<i>Tantalite</i>
<i>Ilmenorutile</i>	
<i>Ilmenite</i>	
<i>Magnetite</i>	<i>Hematite</i> (martite)
<i>Uraninite</i> (incl. brøggerite and cleveite)	
<i>Thorite</i> and uranothorite	
<i>Apatite</i> , containing some Y-elements	<i>Apatite</i> , without detectable amounts of Y-elements
<i>Monazite</i>	
<i>Xenotime</i>	

TABLE 3 (Continued)

MAGMATIC	HYDROTHERMAL-PNEUMATOLYTIC
<i>Bismuthinite</i>	<i>Triplite</i> ¹
<i>Native bismuth</i>	
<i>Molybdenite</i>	
<i>Pyrrhotite</i>	
<i>Chalcocite</i>	
<i>Bornite</i>	
<i>Calcite</i>	
	<i>Fluorite</i>
	<i>Parisite</i>

As secondary minerals there occur albite, epidote, chlorite, kaolinite, tengerite, molybdenite and bertrandite.

¹ The first find of triplite in Norway was made last year in the microlite-and tantalite-bearing pegmatite at Landås, Iveland.

LITERATURE

- Andersen, Olaf, Discussion of certain phases of the genesis of pegmatites: *Norsk Geol. Tidsskrift*, B. 7, p. 1-56, 1931.
- Barth, Tom., Zur Genesis der Pegmatite im Urgebirge I: *Neues Jahrb. Min., Beil. Bd.* 58, Abt. A., p. 385-432, 1928.
- Barth, Tom., Zur Genesis der Pegmatite im Urgebirge II: *Chemie der Erde*, 4, p. 95-136, 1928.
- Bjørlykke, H., Ein Betafitmineral von Tangen bei Kragerø: *Norsk Geol. Tidsskrift*, B. 12, p. 73-88, 1931.
- Bjørlykke, H., Norwegische Mikrolithminerale: *Norsk Geol. Tidsskrift*, B. 14, p. 145-161, 1934.
- Bjørlykke, H., The mineral paragenesis and classification of the granite pegmatites of Iveland, Setesdal, Southern Norway: *Norsk Geol. Tidsskrift*, B. 14, p. 211-311, 1935.
- Brøgger, W. C., Die Mineralien der Südnorwegischen Granitpegmatitgänge I: *Videnskapsselsk. Skr. Mat. naturv. Kl.*, No. 6, Oslo, 1906
- Brøgger, W. C., Vogt, Th., Schetelig, J., Die Mineralien der Südnorwegischen Granitpegmatitgänge II. *Videnskapsselsk. Skr. Mat. naturv. Kl.*, No. 1, Oslo, 1922.
- Goldschmidt, V. M., Elemente und Minerale pegmatitsicher Gesteine. *Nachr. Gesellsch. d. Wissenschaften zu Göttingen: Math. phys. Kl.*, p. 370, 1930.
- Goldschmidt, V. M., Drei Vorträge über Geochemie: *Forh. Geol. Föreningen i Stockholm*, B. 56, H 3, p. 385, 1934.
- Goldschmidt, V. M., und Thomassen, L., Geochemische Verteilungsgesetze III: *Videnskapsselsk. Skr. Mat. naturv. Kl.*, No. 7, 1925.
- Schetelig, J., Remarks on thalenite from some new occurrences in southern Norway: *Norsk Geol. Tidsskrift*, B. 12, p. 507, 1931.