

ON THE DEVELOPMENT OF GRANITE PEGMATITE IN GNEISS AREAS

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A b s t r a c t. In South Norwegian gneiss areas granite pegmatites are nearly always much poorer in Sr and Ba than are large granite bodies. Based on these and other observations the origin and emplacement of such pegmatites is discussed.

Certain aspects of this problem will be discussed here, mainly by means of the distribution of Sr and Ba in the feldspars of granites and pegmatites.

Sr and Ba were determined spectrochemically. The procedure has been described in some detail in an earlier paper [1]. It is well known that consistent spectrochemical determinations of Sr and Ba are difficult to obtain, because of the very slow evaporization of these elements in the arc. Therefore no high accuracy can be claimed for the results given below. However, as ascertained by a number of parallel exposures, they are relatively consistent. It may be that our figures are systematically too high [1], but this is of no consequence to the following considerations, which are based on relative Sr and Ba concentrations. The standard mixtures and the samples for arcing, as well as the spectrograms, were prepared by Mr. JENS HYSINGJORD, cand. mag.

The examined specimens are all from localities in the South Norwegian gneiss areas.

Granite pegmatite in plagioclase-quartz-gneiss in the island of Justøy.

The plagioclase gneiss complex in question has been the subject-matter of an earlier paper [2]. Granite pegmatite is a subordinate component of the complex and occurs in veins, bands and bodies of varying shapes and sizes. None of them are more than a few meters across, most of them are much smaller, sometimes barely visible in hand specimen. Along the strike direction even narrow pegmatite bands may be very persistent. Some of the bands have clearly been deformed, e.g. torn into boudins, during subsequent tectonic movements. The pegmatite bodies appear as more or less irregular patches and have not been notably influenced by tectonic movements; they must have developed at a later stage than most of the pegmatite bands, actually during the concluding phase of the movement. As pointed out in the earlier paper [2], the metasomatic origin of the alkali feldspar (microcline) is evident from field observations as well as from the constant appearance of myrmekite at the contact between the microcline and the plagioclase of the gneiss. It should be remarked that the gneiss itself, which consists of mainly plagioclase (about An_{30}) and quartz with usually subordinate amounts of biotite, does not contain visible alkali feldspar. It is obvious that the potassium metasomatism in the gneiss has been going on for a long time, and that the various pegmatites now observed demonstrate different stages of development. The incipient stages can be seen in the microscope: scattered microcline grains with myrmekite appear along certain narrow gneiss bands. In the next stage the microcline grains form continuous pink bands clearly visible in hand specimen, the grain size being still less than a millimeter. In the later stages the bands (or bodies) as well as the microcline (and quartz) grains continue growing in size, so that a normal pegmatitic appearance is eventually reached. Certain quite small pegmatite bodies may consist of one or a few comparatively large microcline grains, looking like porphyroblasts or augen in the gneiss. Even if the smallest pink bands or streaks have the appearance of aplite, they obviously do not differ from the larger pegmatites genetically. It is also generally observed that coarse grained pegmatite bodies have fine grained border zones. In the majority of cases the pegmatite is in immediate

Table 1. *Feldspars from the plagioclase gneiss complex of Justøy.*
 n – number of samples examined.

| | n | log p.p.m. | |
|--|-----|------------|-----|
| | | SrO | BaO |
| I. Plagioclase. | | | |
| a. From typical gneiss 1. | 2 | 4.5 | 4.3 |
| 2. | 1 | 4.5 | 3.3 |
| 3. | 1 | 4.0 | 3.3 |
| b. From gneiss close to pegmatite contacts 1. | 1 | 3.8 | 3.0 |
| 2. | 5 | 3.8 | 2.7 |
| 3. | 1 | 4.2 | 2.7 |
| c. From the interior of larger pegmatites 1. | 2 | 3.8 | 3.2 |
| 2. | 1 | 3.8 | 3.0 |
| 3. | 1 | 3.7 | 2.7 |
| 4. | 1 | 3.3 | 2.2 |
| 5. | 2 | 2.3 | 2.0 |
| II. Microcline. | | | |
| a. From pegmatite boundaries– 1. | 2 | 4.0 | 4.5 |
| 2. | 2 | 3.5 | 4.2 |
| 3. | 5 | 3.0 | 4.0 |
| 4. | 1 | 2.8 | 3.8 |
| 5. | 2 | 2.7 | 3.7 |
| 6. | 4 | 3.0 | 3.7 |
| 7. | 2 | 2.7 | 3.5 |
| 8. | 1 | 2.7 | 3.3 |
| 9. | 1 | 2.3 | 3.3 |
| b. From the interior of larger pegmatites 1. | 1 | 3.3 | 4.0 |
| 2. | 2 | 3.0 | 4.0 |
| 3. | 5 | 2.8 | 3.5 |
| 4. | 1 | 2.8 | 3.3 |
| 5. | 1 | 2.7 | 3.3 |
| 6. | 5 | 2.7 | 3.0 |
| 7. | 2 | 2.6 | 2.7 |
| 8. | 2 | 2.3 | 2.7 |
| 9. | 2 | 2.3 | 2.5 |
| 10. | 1 | 1.8 | 2.2 |
| III. Feldspars in actual contact. | | | |
| Plagioclase } | 3 { | 3.8 | 2.7 |
| Microcline } | | 2.7 | 3.8 |

contact with the normal light plagioclase gneiss. In a few cases a contact pegmatite – amphibolite has been observed; then the amphibolite at the contact has been altered into a biotite-plagioclase-rock very rich in epidote and sphene. A rock of similar mineral composition, looking like biotite schist, occurs in narrow bands and small areas in the gneiss complex; it is supposed that this rock also has been formed from amphibolite by potassium metasomatism.

To some extent it has been possible, by means of the Sr and Ba contents of the feldspars, to follow up the gradual development of microcline pegmatite in the plagioclase gneiss. The results of the spectrochemical determinations are summarized in Table 1, which gives the observed concentrations in units of log parts per million.

Within each of the groups, (I, a) etc., the samples have been arranged according to decreasing contents of BaO. It is seen that this also corresponds roughly to decreasing contents of SrO. The range of concentrations observed is from more than 1% to about 0.01%. The predominance of SrO in plagioclase and of BaO in alkali feldspar is clearly demonstrated.

The plagioclase samples (I, a, 1) are so extremely rich in BaO that some comment is necessary. The rock is a fine grained nearly white gneiss occurring in narrow deformed bands embedded in very biotite-rich and strongly crumpled gneiss. Because of the high Ba content this light plagioclase gneiss might be suspected to contain much alkali feldspar. But this is not the case. In the spectra only moderately strong K lines are seen, and the microscopic examination reveals that microcline is a very subordinate constituent only. In addition this microcline exhibits quite normal refractive indices, far below balsam, so that it can not be anything in the direction of a hyalophane. It must be concluded that the observed BaO content is essentially a constituent of the plagioclase itself, i.e. that plagioclase may in certain circumstances contain as much as 1% BaO. In the present case it suggests itself that this high Ba content of the plagioclase results from an equilibrium distribution of Ba between the light gneiss and the surrounding dark gneiss: the light gneiss bands are only a few cm across, and the biotite of the dark gneiss also contains about 1% BaO. It is probable that the dark gneiss, which contains oligoclase-andesine, quartz, biotite, epidote, and much sphene, has been formed

from an original amphibolite by K metasomatism, which has also affected the included bands of light plagioclase gneiss, some Ba being introduced along with the K.

The specimens (I, a, 2 and 3) are believed to represent well the country rock (ordinary plagioclase gneiss) showing no signs of K metasomatism. The samples do not contain visible microcline. The BaO contents are of the order of 2000 p.p.m. The plagioclase taken from gneiss close to pegmatite bands or bodies (specimens I, b) tend to be poorer in BaO than this, while the SrO contents are roughly on the same level as in the (I, a) samples. This may be due to a diffusion of Ba from the plagioclase into the alkali feldspar crystallizing in contact with it, in consequence of the tendency to establish an equilibrium distribution of the Ba between these feldspars. The alkali feldspars in question (samples II, a) will be discussed below.

The plagioclase specimens taken from the interior of larger granite pegmatites (samples I, c) exhibit highly variable Sr and Ba contents. Some of them (1, 2, 3) correspond closely to plagioclases of the groups (I, a) and (I, b) in this respect, while others (4, 5) tend to be much poorer in Sr and Ba. These plagioclases obviously did not originate in the same way. One would expect that they were all true constituents of the granite pegmatite, but this can hardly be the case. Field observations show that broader pegmatite bands often contain remnants of plagioclase gneiss bands in their interiors, and much of the plagioclase found in the pegmatites really belongs to the gneiss. Possibly some of this plagioclase has recrystallized in contact with microcline. At any rate it has to be expected that much of the plagioclase within pegmatite bands really belongs to group (I, b), gneiss in contact with pegmatite. This must be the case with samples (I, c, 1, 2, 3) and possibly (4). Probably only the samples (I, c, 5) are true constituents of pegmatite interiors. The matter will be further discussed below.

Among the *m i c r o c l i n e* samples taken from pegmatite boundaries (II, a) number 1 is exceptional. It contains something like 1% SrO and 3% BaO. The specimen is a small lens-shaped body, a few cm in size, of rather coarse grained pegmatite, coated by a layer of biotite. This biotite, like that referred to above, is also rich in Ba, containing about 1% BaO. The very high Ba content of the microcline is obviously

in equilibrium with that of the biotite. A look at the table shows that exceptional quantities of Sr and Ba were present during the formation of this small pegmatite lens.

The other microclines of group (II, a) exhibit BaO-concentrations varying from about 1% to about 0.2%, and SrO-concentrations varying from about 0.3% to about 0.02%, the variations for the two elements being roughly parallel. They probably represent various stages in the development of the pegmatite.

In the microclines from the interior of larger pegmatites (group II, b) the SrO and BaO contents vary in nearly the same way as in (II, a), but here still lower concentrations – down to about 0.01% for both elements – are rather common. The higher concentrations within this group may be interpreted as really belonging to microclines of group (II, a), microclines which have, it is true, been taken from the interior of pegmatites, but which are in contact with remnants of plagioclase gneiss, – see the above discussion of group (I, c).

A few samples of plagioclase-microcline-pairs, each taken from one hand specimen of a gneiss-pegmatite-contact, yielded fairly consistently the distribution of SrO and BaO between the two feldspars shown in (III). The plagioclase contains nearly 1% SrO and about 0.05% BaO, in good agreement with the plagioclases of group (I, b), and the microcline contains nearly 1% BaO and about 0.05% SrO, in fair agreement with the intermediate microclines of group (II, a). In some cases, not quoted in the table, the microcline yielded a higher percentage of SrO, but this seems to be due to a contamination of the samples by plagioclase. I consider the results given in Table 1 to be fairly representative of the equilibrium distribution under the conditions of formation in question, which correspond to low amphibolite facies. It may be of interest here to point out that similar Sr and Ba distributions have been observed between the feldspar phases of several large granite bodies (1). Table 2 illustrates this. The data are not very numerous, and in some cases very pure plagioclase samples could not be prepared. But it is seen that in each case the SrO content of the plagioclase is similar to the BaO content of the alkali feldspar, and vice versa, even if the levels of concentrations vary. It has been pointed out earlier (1) that this distribution of Sr and Ba seems to be fairly independent on the temperature of crystallization of the various

Table 2. Concentrations in units of log p.p.m. n-number of samples exam.

| | n | SrO | BaO |
|-----------------------------------|-----|-----|-----|
| Gneiss-pegmatite contact, Justøy. | | | |
| Plagioclase from gneiss | 3.. | 3.8 | 2.7 |
| Microcline from pegmatite | | 2.7 | 3.8 |
| Grimstad granite. | | | |
| Plagioclase | 1.. | 3.7 | 3.0 |
| Microcline | | 2.7 | 3.5 |
| Birkeland granite. | | | |
| Plagioclase | 2.. | 3.3 | 2.3 |
| Microcline | | 2.7 | 3.5 |
| Østfold granite. | | | |
| Plagioclase | 4.. | 3.3 | 2.3 |
| Microcline | | 2.5 | 3.3 |
| Drammen granite. | | | |
| Plagioclase | 3.. | 2.7 | 2.0 |
| Orthoclase | | 2.0 | 2.7 |

granites. What is of interest at present is that the distribution of Sr and Ba between the feldspar phases of granites in gneiss areas, which must represent equilibrium, is nearly the same as the distribution between pegmatite microcline and the plagioclase of the gneiss in contact with it. This confirms that the latter distribution represents equilibrium. The newly formed microcline crystals in the plagioclase gneiss of Justøy therefore adjust their contents of Sr and Ba so as to be in equilibrium with those of the adjacent plagioclase crystals, and may also take some of the Ba from these crystals in order to approach equilibrium quicker. This of course should establish a Ba-concentration gradient in the near vicinity of the pegmatite, and some of the observations actually seem to confirm that such a gradient exists.

As shown by the series of data (II, a, b) and (I, c) of Table 1, there also exist concentration gradients for Sr as well as for Ba inside the pegmatites, and these gradients are very marked indeed. It is obvious that the larger pegmatites of the area are not at all in equilibrium as a whole as regards the distribution of Sr and Ba. The inter-

pretation is clearly that these pegmatites have grown in size continuously or intermittently during a certain period of time, by introduction into their interiors of new microcline (and plagioclase) crystals. These crystals were comparatively very coarse, and probably formed rather quickly, so that equilibrium with the surrounding crystals could not be completely established. Since some of these large crystals are observed to be very poor in Sr and Ba – something like 100 times poorer than microcline crystals at pegmatite boundaries –, it must be concluded that the pegmatite-forming agent itself did not contain appreciable amounts of Sr and Ba. – The microcline (II, b, 10) of Table 1 would probably be in equilibrium with a plagioclase similar to (I, c, 5). In the field it is difficult or impossible to ascertain whether two pegmatite feldspars have crystallized simultaneously or not.

Since the pegmatite-forming fluid itself appears to have been originally extremely poor in Sr and Ba, the rather high average Sr and Ba contents of the pegmatite microcline must have been taken up from the plagioclase of the country rock. This raises some problems. There is no difficulty about the supply of Sr, since microcline usually takes up a small fraction only of the Sr present in the gneiss it is supposed to replace. On the contrary, if microcline replaces an equal volume of gneiss, incorporating some of the gneiss constituents, there will be a considerable surplus of Sr (and Ca etc.). Now the pegmatites and near environs do not contain any minerals (e.g. basic plagioclase or epidote) which might incorporate this surplus. Therefore the surplus of Sr etc., if it has existed at all, must have disappeared from the rocks forming the present surface. – As to Ba, the difficulty is that most of the pegmatite microcline contains much higher – perhaps on the average 5 to 10 times higher – percentages than the gneiss. Only a small fraction of the Ba actually present in the microcline could be supplied from equal volumes of gneiss. Therefore by far the greater part of the Ba must have accompanied K during the process of metasomatism. This is at variance with the conclusion reached above, that the pegmatite-forming fluid itself must have been originally very poor in Sr and Ba. To explain this discrepancy we may suppose that a K-rich fluid, originally without any Ba and Sr, moved a long way through plagioclase gneiss, possibly continuously crystallizing and recrystallizing, always in contact with plagioclase so that the above equilibrium

distribution of Ba and Sr between the newly formed alkali feldspar and the plagioclase was readily established, until the position of the present rock surface was reached. In this way all the small pegmatite veins and bodies and the greater part of the larger ones might attain the high Ba contents observed, the pegmatite-forming fluid having been previously enriched in Ba during the passage through much more gneiss than corresponds to the present volumes of the pegmatites. When broad pegmatite bands had been formed, renewed metasomatic activity in the interior of these might be caused by fluids which had moved essentially through deeper parts of the pegmatite itself. New microcline crystals forming from these fluids would be in contact with older microcline crystals. If equilibrium were attained between such old and new crystals they would obviously be equal as to Ba and Sr percentages, that is, new alkali feldspar crystals formed through processes going on within the pegmatite itself only, must be successively poorer in Ba and Sr. In this way repeated formation of new microcline crystals within the larger pegmatites would explain the data presented in Table 1, (II, b). Field observations of bent gneiss bands, wavy biotite bands, and other irregularities within larger pegmatite bands [2], seem to confirm that the pegmatite bands have grown in width by introduction of new coarse material into the interior.

No direct replacement of plagioclase by microcline at pegmatite boundaries can be seen in thin section. What is observed is that myrmekite quartz gradually replaces plagioclase. Thus it appears that dissolution of the plagioclase is the process – or one process – that opens space for pegmatite in the gneiss. Therefore, when constituents of the plagioclase are incorporated in pegmatite minerals, this is probably by way of a fluid phase. Part of the constituents of the dissolved plagioclase must have disappeared from the present sites of the pegmatites.

The conclusion is inevitable that the pegmatites in this gneiss area, apart perhaps from the very narrowest veins and bands, did not originate through metasomatism in situ. Metasomatic reactions between a certain quantity of Ba-poor pegmatitic fluid and an approximately equal quantity of gneiss would not explain the high Ba-contents observed in most of the microcline. The pegmatitic fluid must have acquired practically all of its Ba content before reaching

the present sites of the pegmatites, presumably at deeper levels in the gneiss. This means that the pegmatites, although evidently of metasomatic origin, must have been intruded into their present positions.

Large granite bodies like the Grimstad and Birkeland granites (Table 2), which are generally believed to be of metasomatic origin, also contain more Ba than would be expected to occur in equivalent quantities of the adjacent complex of various gneiss types, even if some of these types are granitic in composition. It is difficult to imagine in this case that the granitic fluids should have extracted Ba from quantities of mixed gneisses much larger than the granite bodies themselves. It is more probable here that the granitic fluid carried sufficient Ba already at deeper levels. Very deepseated igneous rocks generally seem to be rich in Ba (and Sr), even if they are not typical alkali feldspar rocks. Thus all the monzonitic rocks of the Oslo Region [1], which are supposed to have a deepseated origin because of the inferred high temperatures of their magmas, were found to contain about 0.5% BaO (which is something like 25 times the average content of the later granitic differentiates). Also anorthosite from the Egersund Region was found to contain about 0.5% BaO*) (and birkremite even more). The anorthosite usually contains less than 1% K_2O . Therefore, if most of the Ba were to replace K in the alkali feldspar (in antiperthite), this alkali feldspar would have to be a very Ba-rich hyalophane, which is highly improbable and not indicated by observations in thin section. It must be concluded that most of the Ba is incorporated in the plagioclase, which is thus unusually rich in Ba. On the other hand there must obviously be an equilibrium distribution of Ba between the plagioclase and the alkali feldspar of the anorthosite. As shown in Table 2 the distribution coefficient is nearly the same in the various granites, anatectic as well as truly magmatic, the BaO percentage in the alkali feldspar being some 5 to 10 times higher than that in the plagioclase. It is probable that a similar distribution coefficient applies to the anorthosite. In that case the alkali feldspar phase of the anorthosite would contain several per cent, perhaps as much as 5%, BaO. Thus

*) V. M. Goldschmidt (Geochemistry, p. 252) quotes from von Engelhardt some rather low contents of Ba in anorthosite. My figures are much higher, but it is true that Egersund anorthosites are not included in Goldschmidt's list.

ascending K-rich phases originating from anorthosite (and various other deepseated rocks) would be expected to be particularly rich in Ba. This would explain the existence of Ba-rich anatectic granites.

Granite pegmatite in other gneiss areas.

The next problem is to explain the origin of very Ba-poor granite pegmatite, which has been shown to occur in the interior of larger pegmatites and obviously represent late stages in the pegmatite formation. It was concluded above that the K-rich fluid forming all of the pegmatite in the gneiss of the Justøy area, was originally very poor in Ba. The study of pegmatite feldspar from other areas might supply a clue. We have examined samples from a number of pegmatite bodies situated in various parts of the gneiss areas of southernmost Norway. The majority of the specimens were collected many years ago by OLAF ANDERSEN from deposits described by him and TOM. F. W. BARTH [3], and kindly placed at my disposal by Professor BARTH, Director of the Mineralogisk-geologisk Museum in Oslo. The results of the spectrochemical analysis are shown in Table 3. Here also the PbO contents of the alkali feldspar have been determined in most cases, and particularly strong Rb lines are shown in a qualitative way. It may be added that PbO was found only in 2 of the microcline samples from Justøy; the concentrations were low, not much higher than 10 p.p.m. Also, these feldspars do not contain unusual amounts of Rb.

The general outcome of Table 3 is that pegmatite feldspars are nearly always much poorer in Sr and Ba than granite feldspars. The Ba content of the microcline from Risøtangen is quite exceptional and must be due to local conditions. At the same time this sample is extremely poor in Sr. On the whole the fairly regular distribution of Sr and Ba between plagioclase and alkali feldspar observed in granites (Table 2) is hardly found in granite pegmatite. The distribution coefficients may be highly sensitive to variations in the temperature of crystallization within the interval in question, or equilibrium may not have been reached at all. I am inclined to believe in the latter alternative in most cases.

The pegmatites of the Iveland-Evje district and of Tørdal, which

occur in gabbroic rocks within the Telemark granite area, are seen to be particularly poor in Sr and Ba and at the same time particularly rich in Pb and Rb. The Halvorsrød pegmatite in Østfold is somewhat similar. The amazonites (Landsverk, Landås, Tørdal) exhibit these properties most markedly. This group of pegmatites is rather opposite in character to the pegmatites of the Bamble-Kragerø district, which are on the average somewhat richer in Ba and Sr, and very poor in

Table 3. *Pegmatite feldspars from various Archaean areas.*

| | log p.p.m. | | | Rb |
|-----------------------------------|------------|-----|------|----|
| | SrO | BaO | PbO | |
| I. Birkeland granite. | | | | |
| Microcline | 2.0 | 2.7 | 1.5 | |
| II. Østfold granite, N. boundary. | | | | |
| Microcline | 2.0 | 2.3 | 2.0 | |
| Plagioclase } | 2.3 | 2.0 | | |
| Microcline } | 1.7 | 2.0 | 1.7 | |
| III. Østfold gneiss area. | | | | |
| Halvorsrød. | | | | |
| Plagioclase } | 1.8 | 1.5 | | |
| Microcline } | <1.0 | 1.2 | 1.5 | + |
| IV. Bamble – Kragerø district. | | | | |
| Kjørstad W. | | | | |
| Microcline | 2.0 | 2.7 | <1.0 | |
| Toner. | | | | |
| Plagioclase } | 2.5 | 1.2 | | |
| Microcline } | 2.0 | 2.7 | | |
| “Båten”, Skåtøy. | | | | |
| Plagioclase } | 2.3 | 2.0 | | |
| Microcline } | 1.8 | 2.5 | <1.0 | |
| Malmtangen. | | | | |
| Plagioclase } | 2.0 | 1.8 | | |
| Microcline } | 1.5 | 2.5 | «1.0 | |
| Lille Furuholmen. | | | | |
| Plagioclase } | 1.5 | 1.8 | | |
| Microcline } | 1.2 | 2.3 | | |
| Risøtangen. | | | | |
| Plagioclase } | 2.5 | 2.0 | | |
| Microcline } | <1.0 | 3.3 | «1.0 | |
| Kalstadgangen. | | | | |
| Microcline | <1.0 | 2.0 | «1.0 | |

Table 3, cont.

| | log p.p.m. | | | Rb |
|-----------------------------|------------|------|-----|----|
| | SrO | BaO | PbO | |
| V. Iveland – Evje district. | | | | |
| Landsverk. | | | | |
| Microcline | 1.8 | 1.8 | 2.2 | + |
| Høyland. | | | | |
| Plagioclase } { | 2.3 | 1.8 | | |
| Microcline } { | 1.5 | 1.8 | 2.2 | ++ |
| Pålsstien. | | | | |
| Plagioclase } { | 1.7 | ~1.0 | | |
| Microcline } { | 1.5 | 1.5 | 2.2 | + |
| “Salegruben”. | | | | |
| Plagioclase } { | 1.8 | 1.8 | | |
| Microcline } { | <1.0 | 1.5 | 1.8 | + |
| Landsverk. | | | | |
| Amazonite | <1.0 | ~1.0 | 2.0 | ++ |
| Landås. | | | | |
| Amazonite | 1.5 | <1.0 | 2.0 | ++ |
| VI. Tørdal, Telemark. | | | | |
| Høydalen. | | | | |
| Cleavelandite } { | <1.5 | <1.0 | | |
| Amazonite } { | 1.3 | 1.2 | 2.0 | ++ |
| Skarsfjell. | | | | |
| Amazonite | 1.5 | <1.0 | 2.3 | ++ |

Pb and Rb. Now the Birkeland granite and the Østfold granite contain much higher percentages of Sr and Ba than their endogenous pegmatites (Tables 2 and 3), and also less Pb. This confirms that granite pegmatite is impoverished in Sr and Ba and enriched in Pb (and a number of other elements) as compared with its mother granite. The process of development of granite pegmatite from a mother granite may eventually lead to pegmatites extremely poor in Sr and Ba and often rich in Pb, Rb, etc. It seems to me that the Iveland-Evje and Tørdal (and also Halvorsrød) pegmatites must represent very advanced stages of such a development, and the Bamble-Kragerø pegmatites somewhat less advanced stages. As pointed out above it is very difficult to explain the deficiency in Sr and Ba on the supposition that the pegmatitic fluids should have risen directly from great depths.

Large anatectic granite bodies must have formed, presumably below the present surface, and the pegmatites must have developed from them. I believe all the pegmatites discussed in this paper must have formed in this manner, by way of large anatectic mother granites.

SUMMARY

Large presumably anatectic granite bodies like the Birkeland granite contain much more Ba than could in general be derived from equal volumes of mixed gneisses. Such granite bodies may represent K-rich derivatives of very deepseated rocks, e.g. anorthosite and related rocks, which may actually be very rich in Ba. Granite pegmatite bodies endogenous in mother granites have been found to be much poorer in Sr and Ba than the granite proper. Other granite pegmatites are in general still poorer in Sr and Ba. Pegmatites nearly deficient in Sr and Ba seem to represent the most advanced stages of pegmatite formation from a mother granite; these pegmatites are also usually enriched in Pb, Rb, and other pegmatitic elements. It seems justified to conclude that all the pegmatites discussed in this paper must derive from large mother granite bodies, which may themselves be rather rich in Sr and Ba. As to the small pegmatitic veins, bands and bodies in the plagioclase gneiss of the Justøy area, it appears that the pegmatitic fluid was also here originally extremely poor in Sr and Ba, but that most of it absorbed Ba (and Sr) from the plagioclase during the passage through the gneiss, until an equilibrium distribution was more or less established, a distribution similar to those found between the feldspar phases of granites. It is evident that these pegmatites could not have been formed through metasomatism *in situ*; the pegmatitic fluid must have moved bodily through the gneiss, metasomatic processes going on all the time.

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