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On the Microcline of the Granitic Rocks of Central Sierra Leone

I.

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Abstract

Microcline of the granitic rocks of Central Sierra Leone is described and its origin discussed. The microcline is the only potash feldspar in these granitic rocks. It is always younger than other constituents of the rocks. It is believed, that by the introduction of potassium, first interstitial microcline will be formed. If the necessary potassium ion concentration is attained, potassium affects plagioclase, at first forming muscovite (and epidote), and finally replacing plagioclase. Furthermore, it is suggested that the formation of microcline is possible under hydrothermal condition below 525° C and if the accumulation takes place during a time long enough.

Introduction

The potash feldspar of the Pre-Cambrian granites of Central Sierra Leone is exclusively microcline, but in spite of that, depending upon the environment it can be of a different appearance. It may occur as interstitial filling or replace the plagioclase; the microcline may be perthitic or rather fresh and homogeneous, cross-hatched or without any grating.

Within the world wide Pre-Cambrian Basement Complex orthoclase has been reported as an essential feldspar only in granites corresponding to the metamorphism of granulite facies (Eskola, 1952), and the microcline has often been explained to be an alteration product of the former. Chayes (1952) believed that the transformation of orthoclase into microcline in certain calc-alkaline granites takes place due to annealing processes. Harker (1954) assumed that at least some of the microcline of the Chuinneag-Ichbae complex was formed from orthoclase, the recrystallization being affected by the later regional metamorphism, which permitted recrystallization at a temperature lower than that at which the orthoclase was formed.

In most cases, however, the metamorphism of the old-Pre-Cambrian granitic rocks corresponds to the amphibolite and epidote amphibolite facies (gneissfacies of ROSENQVIST, 1952). In those granitic rocks the microcline is the only potash feldspar, and there is no proof of the formation of microcline by a re-arrangement of orthoclase.

According to GOLDSMITH and LAVES (1954), the difference between microcline and sanidine (orthoclase) appears in a different degree of the Al-Si-order in the lattice, the triclinic form (microcline) representing a better order and, consequently, the stage of a lower free energy. Furthermore, they noticed that in regard to order and disorder in the lattice, there occur all the intermediate stages between "proper microcline" and "proper sanidine". The most perfect order they found in the microcline of the oldest Finnish Pre-Cambrian granitic rocks. They introduced the conception of "triclinisity" as a measure of the degree of the order in the potash feldspar lattice, believing this triclinisity to decrease with increasing temperature of the formation of microcline.

According to the same authors, microcline, if heated under hydrothermal conditions, converts into orthoclase at 525° C. In conditions available in the laboratories this transition is irreversible. Microcline has not been obtained by any artificial methods.

The investigations of GOLDSMITH and LAVES animated the writer to examine microclines of an area of granitic rocks in Central Sierra Leone, which area is petrologically well investigated.

Description of the Area

The Sula Mountains and Kangari Hills form a north to south stretching schistbelt in Central Sierra Leone, from all sides surrounded by a vast granite and gneiss area.

The enclosing granites are typical synkinematic granites with all varieties from even-grained to coarse porphyroblastic granites, from massive rocks to mica gneiss and migmatites, and from real granites to granodiorites and quartz diorites, often of trondhjemitic composition.

In places Synkinematic concretionary pegmatites are fairly abundant, but especially along the margins of the schistbelt coarse pegmatites occur, often tourmaline-bearing and sometimes containing coarse magnetite as well. These coarse pegmatites are believed to be of hydrothermal origin and latekinematic. Their feldspar is mostly plagioclase, but coarse microcline is usually present too:

The latekinematic granites occur as well, but in an underordinate amount. They form veins and dikes intruding the schists, and in the northern part of the schistbelt they form a boss, assumed to have been formed by doming.

In the south the schistbelt splits into narrow strips intensively interfingering with synkinematic granite. The continuation of the highly granitised schists can be followed within the area of granodioritic rocks several kilometers southward.

The rocks are considered to be very old Pre-Cambrian.

Microcline

Eskola (1954) supposed that all microcline of the Finnish synkinematic granites probably originates from metasomatic processes. Regarding the microcline of the granitic rocks of Central Sierra Leone, the writer came to the same conclusion.

Concerning the mode of occurrence of microcline, the following kinds are most typical:

1. replacing the plagioclase (Fig. 1);
2. accompanied by muscovitisation of plagioclase and formation of myrmekite (Fig. 2);
3. filling interstitial spaces between other minerals (Fig. 3);
4. in pegmatites with poorly developed cross-hatching and often perthitic (Fig. 7);
5. in graphic intergrows with quartz (Fig. 5).

As already mentioned, the granitic rocks of Central Sierra Leone vary in their composition; quartz diorite and trondhjemite are followed by microcline-rich granites and correspondingly the amount of microcline differs very much; while some varieties contain hardly any, microcline is the sole feldspar of others. In all synkinematic granitic rocks, the plagioclase also varies in its composition but a little; in most cases it contains 24—28% An, exceptionally in dioritic rocks up to 38%. The latekinematic granites, on the contrary, are of entirely different composition, and their plagioclase contains seldom more than 12% An, usually 8—10% and exceptionally 2% An only.

Although the microcline is varying very much in appearance, the differences in its lattice structure are rather small. On the writer's request

Dr. Julian R. Goldsmith of Chicago University investigated some of the microclines of Central Sierra Leone. He used X-ray methods and found that all microclines sent him by the author — representatives of syn- and latekinematic granites, of granitic portions of migmatites, of both the syn- and the latekinematic pegmatites, of microcline granites and granodiorite — showed all the most perfect order in the lattice (Al-Si), hence they had a triclinisity of approximately the maximum value for microcline.

The *a*-axis spacing, which is a measure of Na content according to Goldsmith, in all of the above-mentioned samples indicates no or little Na in solid solution, which is typical of microcline. In his mentioned investigations Dr. Goldsmith used a high-resolution camera (Nonius quadruple focussing camera, radiation monochromatized with a bent quartz crystal). Only a small fragment was used for each picture.

Microcline Replacing Plagioclase

One of the most typical features of microcline of the synkinematic granites of Central Sierra Leone is its tendency to replace plagioclase. Such a replacement must be considered to result from the introduction of potassium, and in general it is believed that especially the albite of the

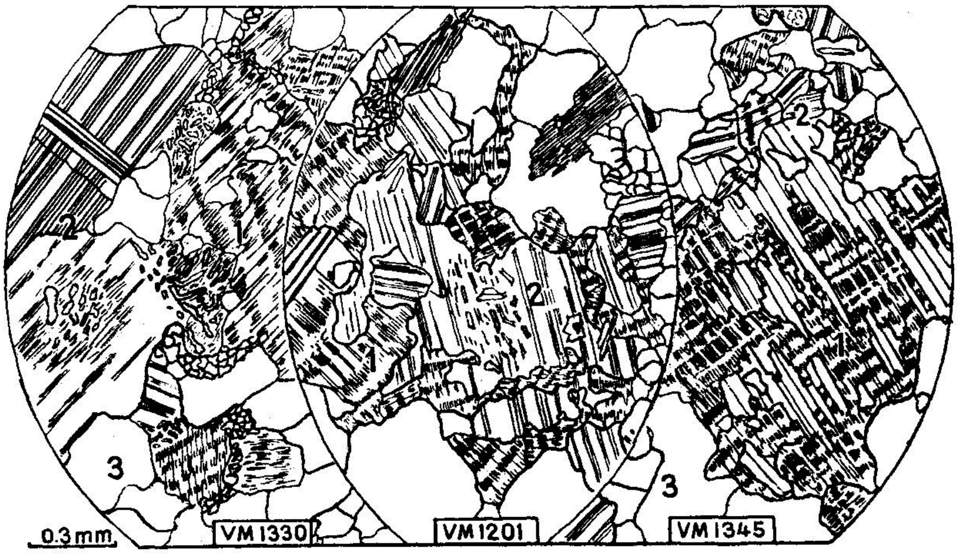

Fig. 1. The replacement of plagioclase by microcline.
1 = microcline; 2 = plagioclase; 3 = quartz.
Kangari Hills, Sierra Leone. Two Nic.

plagioclase is then replaced, the plagioclase of myrmekite being more anorthitic than that of plagioclase grain surrounded by myrmekite (Edelman, 1949, and Seitsaari, 1951).

Fig. 1 illustrates different stages of the replacement of plagioclase by microcline. VM 1330 shows fresh plagioclase (An_{26}) and fresh microcline, but on the margins between both feldspars myrmekite occurs whereever plagioclase and microcline are in contact with each other. In VM 1201 the myrmekite is sparse, but, instead, along cracks and fissures microcline has proceeded into plagioclase; in VM 1345 the process of replacement is very advanced, and the microcline crystal contains raggy remnants of enclosed, "eaten" plagioclase (An_{26}). In the last-mentioned specimen, however, there occurs a new feature: the upper part of the figure shows minute grains of entirely fresh plagioclase (An_{16-20}) evidently younger than the replaced plagioclase, and it seems that it is younger than the microcline, as well. Here it represents, assumably, the re-deposited plagioclase, which was formerly pushed away by the advancing potash metasomatism — microclinisation. The anorthite content of the newly-formed plagioclase indicates that not only the albite was replaced by microcline, but the anorthite component as well. Such instances are not very common, but they hardly can be stated to be rare either. It seems, that in a certain environment both microcline and plagioclase can be formed more or less simultaneously, a case exactly similar to that described by Marmo and Hyvärinen (1953) in molybdenum bearing synkinematic granites of Rautio, Finnland. This finding is in good agreement with the experimental works of O'Neill (1948), who observed that under quite similar conditions and depending only on the amounts of K and Na ions in the hydrothermal solutions, the albite may be replaced by potassium feldspar or the latter by the albite. The more or less simultaneous replacement of plagioclase by microcline and the re-deposition of plagioclase may be reasonably explained by assuming that the "microlinisation" takes place after the concentration of K ions exceeds a certain value within the plagioclase crystal. The sodium released during the replacement moves away from the crystal and in such manner outside of the replaced crystal; in front of the formation of microcline, a Na ion concentration will be attained, where the formation of plagioclase is possible again.

It is noteworthy that in such cases the microcline is always intensively cross-hatched, hence it seems that the formation of replacing microcline was immediately accompanied by the twinning of growing microcline.

The Muscovitisation of Plagioclase

The replacement of plagioclase by microcline indicates an introduction of potassium in such concentration that a complete removal of the cations of plagioclase is possible. Fig. 2 shows an example of a replacement where this concentration evidently was insufficient and therefore

Fig. 2. The muscovitisation of plagioclase.
1 = muscovite; 2 = biotite; 3 = apatite; 4 = epidote; 5 = allanite; 6 = magnetite; 7 = sphene; 8 = microcline; plagioclase (to some extend serizitised). Kangari Hills, Sierra Leone. One Nicol.

muscovite was formed (sericitisation). In VM 256 A the plagioclase is intact with the exception of minute muscovite laths within the plagioclase; in VM 444 the muscovite either forms orientated patches within the plagioclase (right-top) or appears as a fine-grained sericite patch in its central part. In addition there occur a little myrmekite and antiperthite, but also almost always epidote in abundance.

If small amounts of potassium affect the plagioclase, it may be assumed that then only the albite of the plagioclase will be replaced by the microcline, but, according to Barth (1952), potash feldspar and the remaining anorthite may also react:

(1) $$4\,CaAl_2Si_2O_8 + KAlSi_3O_8 + H_2O = 2\,Ca_2Al_3Si_3O_{12}OH + KAl_3Si_3O_{10}OH + 2\,SiO_2$$
zoisite muscovite

This equation explains the co-occurrence of muscovite and epidote as a result of potassium metasomatism. Regarding the formation of sole muscovite (VM 444) inside the plagioclase, reaction between albite and potassium (in hydrothermal conditions) must be assumed:

(2) $$6\,NaAlSi_3O_8 + 2\,K^+ + H_2O = 2\,KAl_3Si_3O_{10}OH + 6\,Na^+ + 12\,SiO_2$$
muscovite

Interstitial Microcline

In most cases when there occurs muscovite in the manner described above, there also occurs interstitial microcline, that is potash feldspar occupying the intergranular spaces, as one can see in Fig. 3. It seems that corresponding to low free energy the microcline has there deposited in cracks, fissures, and other places.

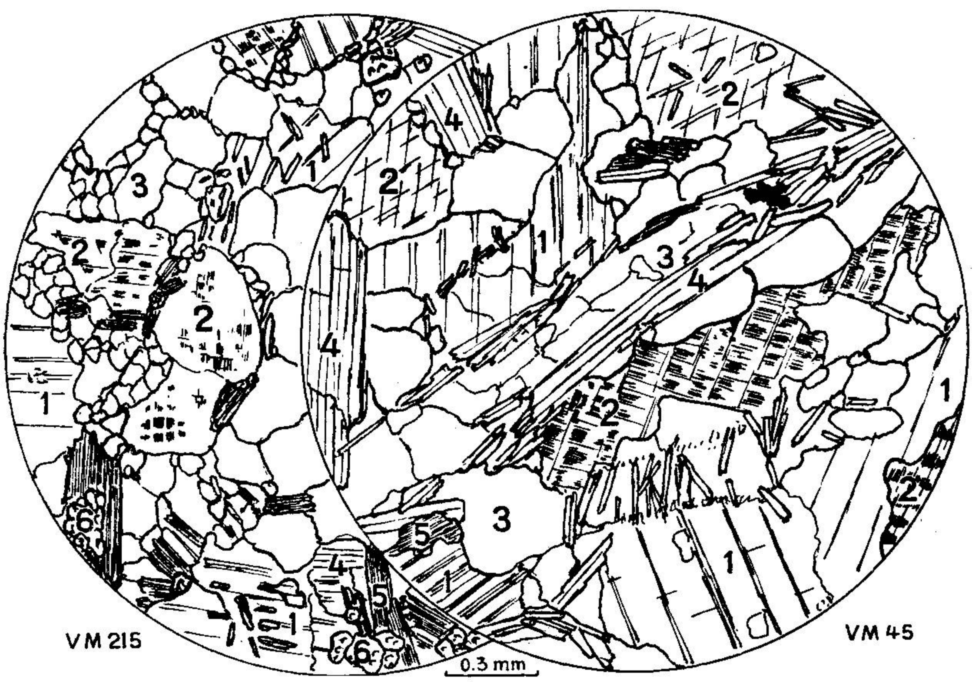

Fig. 3. The microcline forms an interstitial filling.
1 = plagioclase; 2 = microcline; 3 = quartz; 4 = muscovite; 5 = biotite; 6 = epidote. Kangari Hills, Sierra Leone.

In the granitic rocks of Central Sierra Leone the interstitial microcline is the most common kind occurring. In areas occupied by rocks of quartz-dioritic to granodioritic composition there always are patches rich in microcline, hence of potassic granite composition, but such patches are always characterized by shearing, fracturing, often also by mylonitisation. The microcline, however, never shows any signs of kinetic disturbances. The lamellæ of plagioclase, on the contrary, are there often strongly bent and broken. Consequently the microcline must there be younger than the features that caused shearing and fracturing, and the potassium intruded there also the places of low free energy, similarly to that illustrated by Fig. 3.

Conclusively the migration of potassium, tending to move towards the places of lowest free energy, at first produces interstitial microcline, without affecting remarkably any other minerals. Then, if the potassium ion concentration (or pressure) is strong enough, the potassium ions enter the lattices of other minerals as well, and it seems that the plagioclase can easily be replaced by microcline. At first such potassium metasomatism affects only the muscovitisation (and epidotisation) of plagioclase (equations 1 and 2), and if the potassium ion pressure will get still stronger, real replacement of plagioclase by microcline takes place (Fig. 1).

Microcline of Pegmatites

Especially in pegmatites alkali and silica concentrations are high. In the concretionary pegmatites the accumulation evidently happened slowly, in latekinematic hydrothermally originated pegmatites more rapidly, but in both cases the alkali-silica-accumulations favoured the places of lower free energy, and not the environments.

The concretionary synkinematic, "migmatitising" pegmatites of Central Sierra Leone are conspicuously sodic, and not seldom the plagioclase (An_{15-26}) is the only feldspar of the pegmatitic "schlieren" of the mica gneisses and migmatites. In the granodioritic portions of such migmatites the microcline is sparse as well, while the concretionary pegmatites of potassium granitic gneisses are on the contrary, usually conspicuously rich in microcline.

The latekinematic pegmatites usually contain both feldspars, and in addition abundant quartz, both micas, and often also coarse tourmaline. In the central part of the mentioned schistbelt, at Bumbuna, the microcline is coarse, does not show any cross-hatching, and not seldom the microcline appears on the surface as hexagonal sections (Fig. 4) and is creamy white. In the same pegmatite, however, there are other pink microcline crystals, graphically intergrown with quartz, and frequently perthitic.

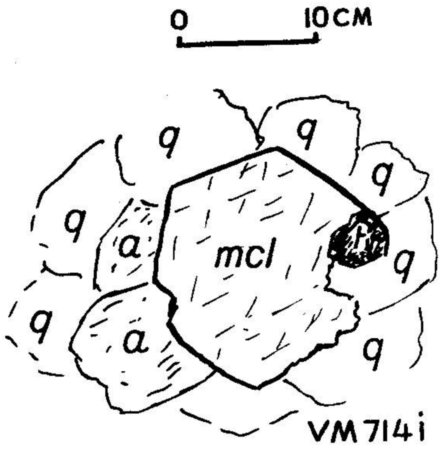

Fig. 4. Large microcline crystal of hexagonal appearence in a mass of albite (a) and quartz (q), containing tourmaline (t). Bumbuna, Sierra Leone.

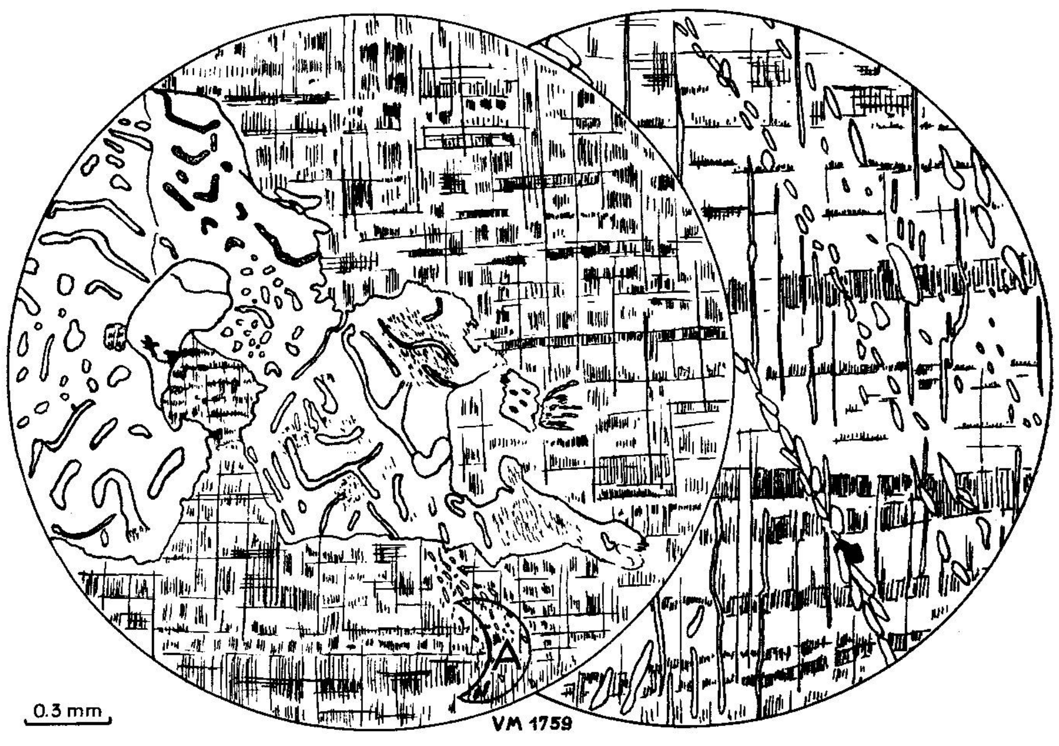

Fig. 5. Microcline of pegmatite. In lefthand figure large grain of albite, intergrown by quartz. The right hand figure illustrates the magnification of area „A" of the lefthand figure. Kangari Hills, Sierra Leone.

All mentioned features of microcline occur in the synkinematic, concretionary pegmatites as well. Fig. 5 illustrates a coarse microcline crystal of such pegmatite. The microcline is distinctly grated and contains irregular patches of albitic plagioclase myrmekitically intergrown by quartz (lefthand part of the figure). A larger magnification shows that the microcline is perthitic as one can see in the right-hand part of the figure; there the narrow, fading plagioclase strips a concordant to the

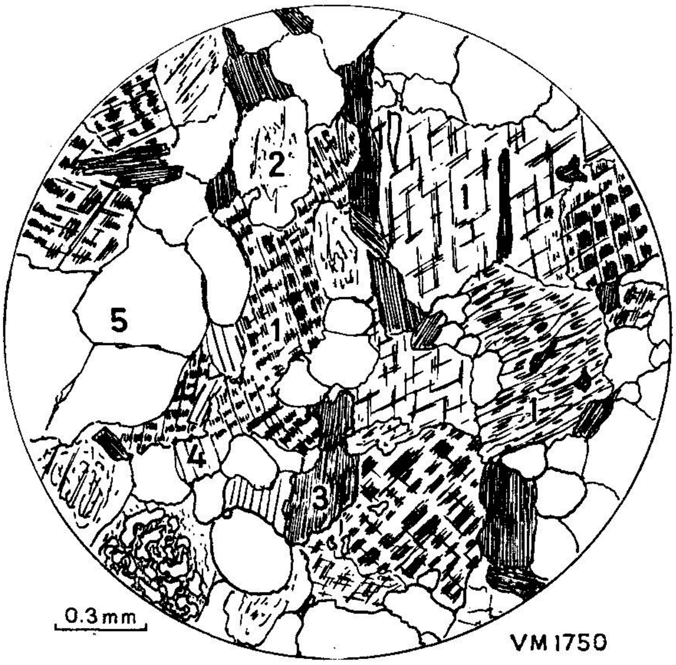

Fig. 6. Granitic portion of a fine-grained granite gneiss.
1 = microcline; 2 = plagioclase; 3 = biotite; 4 = muscovite; 5 = quartz.
Kangari Hills, Sierra Leone.

twinning planes of the microcline, but in addition there are diagonal strips of minute quartz inclusions in parallel arrangement. Fig. 6 shows the microcline of the fine-grained gneiss enclosing the concretionary pegmatite represented by Fig. 5. There the microcline is rather abundant but differs from that of pegmatite being neither perthitic nor graphically intergrown. In the plagioclase, however, myrmekite occurs in the gneiss as well.

Finally, also concretionary pegmatites may contain microcline without any cross-hatching (Fig. 7), but, as determined by Dr. JULIAN R. GOLDSMITH (p. 4), true microcline of highest triclinisity. The microcline is perthitic and along its cracks oligoclase and quartz have been

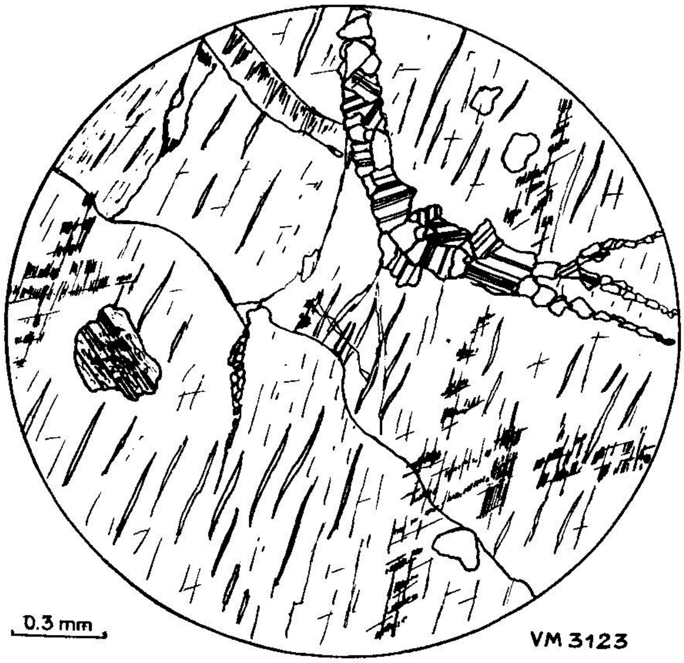

Fig. 7. Microcline of pegmatite without cross-hatching. Kangari Hills, Sierra Leone.

deposited. In such microcline there are always narrow patches, in which also cross-hatching occurs (Fig. 7), and such grated, narrow portions are usually parallel to each other. One gets the impression, that the hatched portions are in some connection with kinematic features and it may be that the at first ungrated microcline became twinned due to slight movement.

On the Origin of Microcline

As mentioned in the introduction, an artifical microcline has never been obtained. All attempts at producing microcline have yielded the monoclinic potash feldspar. Microcline on the other hand under hydrothermal conditions converts into orthoclase at 525° C. Hence it seems that under hydrothermal conditions microcline is not stable at a temperature over the experimentally found transition point, but that orthoclase is stable at any temperature. Consequently in addition to the temperature there must be another factor, necessary for the formation of microcline, which itself represents a modification of a lower free energy than the monoclinic potash feldspar. Evidently this additional factor is the time. Microcline will be formed, if the accumulation of potassium takes place slowly enough to admit an accumulation of ions in a lattice of most perfect order, but if the rate of the accumulation is faster, perfect order will not be attained, and a monoclinic modification will result.

The conditions of the synkinematic granitisation make such slow accumulation very probable, and that may explain that all potash feldspar of synkinematic granites and granodiorites of Central Sierra Leone is microcline. It may be stressed here, however, that within the mentioned area the granulite facies does not occur. In granulites namely, due to their higher temperature of formation, orthoclase would be present, as reported from many Arckaean granulite areas all over the world.

Naturally there could be assumed that the formation of microcline from orthoclase was due to ageing. This implies that in the course of time the primarily monoclinic lattice should have rearranged itself into a triclinic form, corresponding to a lower free energy. Such cases have in fact been reported by several authors (for instance Eskola, 1952), but such an explanation will hardly do for the granitic rocks discussed in the present paper.

One can for instance hardly believe that the microcline replacing plagioclase (Fig. 1) should primarily have been orthoclase, or deny that a slow introduction of potassium — supported by evidences illustrated in Fig. 2 — caused the formation of muscovite at the expense of plagioclase. Furthermore, a complete lack of orthoclase can hardly be expected if the microcline was formed of the monoclinic potash feldspar through ageing. Neither happened such a complete microclinitisation of orthoclase in the granulitic rocks; those are hardly so very much younger than the granitic rocks of the amphibolite facies which does not contain any orthoclase and yet the latter would have to be very much older indeed if all their orthoclase should have turned restlessly into microcline by ageing.

Cross-hatching is more or less universal in granites and granodiorites, but, as shown above, it does not always appear in the microclines of pegmatites. In the case of Fig. 7 slight shearing or any other kind of movement was supposed to be responsible for the development of the grating. This explanation, however, is not appropriate for the case of replacing microcline (Fig. 1). It seems here more useful to try to explain the conditions in which the cross-hatching is lacking. In pegmatites the growing of the microcline is probably much more "free" than in other instances considered in the present paper. In the case of the replacement, the introduction of potassium into the lattice of plagioclase evidently must surmount certain frictional and structural resisting powers causing the grating from the very beginning of the formation of the microcline as also in cases of formation of interstitial microcline. Consequently the grating may be lacking only if there are no hampering factors present, as it is the case only in the formation of pegmatites. But even there, if any stress or shearing or strain takes place, the grating will immediately be developed, as elucidated by Fig. 7.

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