THE FORMATION OF FELDSPAR PERTHITES IN HIGHLY METAMORPHIC GNEISSES

BY

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The feldspar perthites have always been of great interest to geologists. Although a mineralogical problem it is related to the formation of the alkali feldspars, and thus of great petrological significance. The feldspar relations, when thoroughly understood, will be a tool of the highest value in the understanding of rock forming processes.

In Norway these problems have been discussed especially by ANDERSEN (1), BARTH (2, 3, 4), OFTEDAHL (5), ROSENQVIST (6) and VOGT (7). The most modern treatment of these questions is given by LAVES (8, 9) and GOLDSMITH and LAVES (10). The last three papers give an extensive list of literature references.

Andersen separates three groups of perthites according to their mode of formation.

1. Exsolution
2. Rhytmic crystallization
3. Replacement.

Further he distinguishes between:

1. String perthites
2. Film perthites
3. Vein perthites
4. Patch perthites.

He also considers some other perthite classes of minor importance. The four types differ both in form and in orientation.[1] The two first types are believed to result from exsolution in the solid state, while replacement is supposed to be largely responsible for the latter.

Rosenqvist believes that the perthites, regardless of their mode of formation, are results of diffusion. In agreement with other physical properties, low symmetrical crystals will exhibit diffusion anisotropy, and ions diffusing from the center of a crystal will after a while be located at the surface of an ellipsoid which, for monoclinic and tricilnic crystals, will be of the general three axial type. From diffusion experiments he concludes that the symmetry of the diffusion ellipsoid decreases with increasing temperature and he thinks that the high temperature perthites should be of the string type. He suggests that these must have been formed either by exsolution or replacement in the amphibolite facies.

Andersen has based his work on the feldspars from 300 pre-Cambrian pegmatites for the most part situated in southern Norway. The rocks in this region are found in epidote amphibolite — or the lower part of amphibolite facies. In rocks related to granulite facies we do, however, also find another type of perthitic feldspar than those described by Andersen. As regards shape and orientation this perthite is strongly related to the string perthites, but do, however, differ from these in showing a much more intimate growth of the potash- and plagioclase feldspar lamellae. For these perthites Michot (11) has proposed the name mesoperthite: a feldspar with such an intimate perthitic intergrowth that it is impossible the discriminate between the exsolution phase and the host. It is the feldspar which C. F. Kolderup has named "basic microperthites" and Goldscmidt has called "Jotun perthites". Michot believes these feldspars to have been formed by exsolution from an original homogenous phase.

Some work done by the author in the Ørsdalen area suggests replacement to be responsible for the formation of similar perthites found there.

The area is situated in the parish of Bjerkreim, Rogaland, S. Norway and represents a border zone between the Egersund area of

[1] For detailed description reference is given to the original paper of Andersen.

anorthositic and monzonitic rocks and the gneiss — granites of the Telemark — Setesdal region. The nearest anorthosite body is just a little more than 10 km to the west of the examined area. Here two kinds of quartz-feldspatic gneisses are recognised, both probably formed under the PT conditions of granulite facies which is also the metamorphic facies found in parts of the area today. In some places the rocks have undergone a retrograde metamorphism. (This is without any importance, however, to the present discussion, and even in the low metamorphic rocks, remnants of high metamorphic minerals are found).

The one kind of quartz-feldspatic gneisses is a common granodiorite, which vary in grainsize from pegmatitic to aplitic types. Irrespective of grainsize the gneisses are rather uniform in mineralogy and chemistry. They are believed for a large part to have been formed by metasomatism of amphibolites .which occur as bands and lenses all over the area, and show all gradations from unaltered rocks to ghostly remnants in the gneisses. In passing from an amphibolite into a homogenous granodiorite a gradual increase in quartz and potash feldspar takes place, at the same time the amount of femic minerals decreases, while the content and composition of the plagioclase remains nearly constant. Potash feldspar replaceing plagioclase is seen but is not very common; it would seem that the former for the most part has replaced the femic minerals. The feldspar show the usual perthitic structures while mesoperthites are very rare in these rocks.

The Ca, Na and K content of a potash feldspar from an augengneiss was determined chemically and the following molar percentages of the feldspar components were obtained: $Or_{68,9}$ Ab_{30} $An_{1,1}$. Plotted in relation to the probable phase diagram of Laves (9, p. 561) this corresponds to a minimum temperature of formation of nearly 500° C. The amount of exsoluted plagioclase was measured in thin-section to be about 20 mol %, and the amount of albite still remaining in solid solution with orthoclase should then be about 10 %. Using the X-ray method of Bowen and Tuttle (12), however, it was found that the spaceing of the critical (201) reflection corresponded to the pure potash member (4,23 Å) .This means that some of the albite must be present in the form of cryptoperthitic lamellae. As the potash feldspar is monoclinic, the diagram fig. 9 p. 557 in the work of Laves can be used, giving the minimum temperature of formation at 600°. As the plagioclase of this rock is of composition Ab_{70} a temperature of formation of about 600° C would agree to the one found useing the coefficient of distribution of soda in the feldspar phases as calibrated by BARTH (4).[1]

The second kind of quartz — feldspatic gneisses is a peculiar white looking rock with a low content of femic minerals. The grain-size may vary within wide limits, and when coarse-grained they have a pegmatitic appearance. Garnet is a very common femic mineral. Amphobolitic bands occur here as they did in the granodiorites. Contrary to the latter, however, the white gneisses themselves vary to a large extent in chemical composition. All gradations exist between rocks where plagioclase is the dominant feldspar to rocks where plagioclase is present almost only in perthitic lamellae. The potash rich and intermediate types are most frequently encountered.

In this rock series several examples of potash feldspar replaceing plagioclase are seen in the thin-sections, and mesoperthites are frequent.

A chemical determination of the Ca, Na and K content in a feldspar and quartz fraction from a rock where mesoperthites where the only feldspar phase (just a few small grains of plagioclase with the composition Ab_{88} could be seen) yielded the following molar ratio of the feldspar components: Or_{35}, Ab_{57}, An_{8}. According to this ratio the feldspar should be recognised as an antiperthite.

The presence of such perthites in a metasomatic rock suggests a formation by replacement and not by exsolution. The five photographs on plate 1 are believed to be convincing in this respect. (They are all taken from the same thinsection).

The photographs 1—5 illustrate the processes leading to the formation of mesoperthites. It is concluded that, in this area, the mesoperthite represents an intermediate stage in the complete replacement of plagioclase by potash feldspar. If a formation by exsolution is maintained, an explanation has to be given for the equilibrium between three feldspar phases, mesoperthite, perthite and plagioclase, occuring side by side in the same rock and even in the same thinsection.

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[1] Barth has informed me that his diagram should be modified so that the actual temperature corresponding to the observed coefficient of distribution is 650° C.

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PLATE I

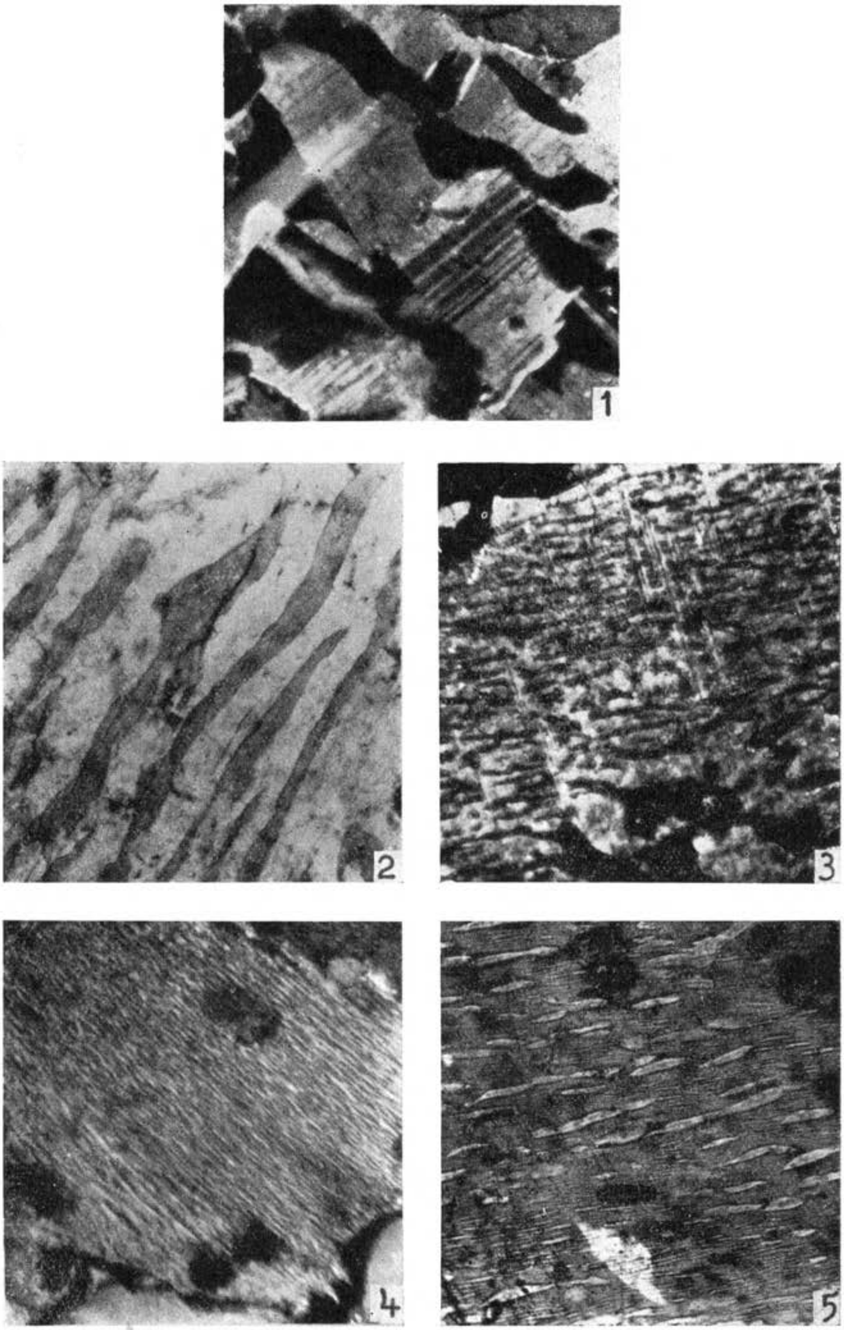
Fig. 1. Veins of potash feldspar (black) replace plagioclase. Note the orientation of the veins with respect to the plagioclase + n. 100 x.

Fig. 2. Veins of potash feldspar (grey) replace plagioclase (white). The orientation of the veins are the same as in no. 1, but this fact cannot be seen on the photograph because the orientation of the thin-section on the microscope is turned to bring notice upon the perthitic nature of the veins. + n. 100 x.

Fig. 3. This shows an increased mixture of potash feldspar (black) and plagioclase (white) lamellae. Note that the orientation of the albite twins with respect to the elongation of the potash lamellae are the same as in no. 1. + n. 100 x.

Fig. 4. Here a typical mesoperthite is pictured. + n. 100 x.

Fig. 5. This represent a more ordinary type of an alkali feldspar perthite. The type of albite lamellae are the same as those seen in the potash feldspar veins of no. 2. + n. 100 x.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