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THE ORIGIN OF SOME ANTIPERTHITES— A MODEL BASED ON NUCLEATION

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ABSTRACT

A potash-rich granitic gneiss and a potash-deficient plagioclase gneiss from New Jersey charnockitic rocks are inferred to have recrystallized at the same time under similar physical conditions. Plagioclase from the potash-deficient rocks are antiperthitic. Detailed studies with the electron microprobe confirm that the plagioclase from the granitic gneiss are not antiperthitic. These plagioclase should be antiperthitic if the exsolution model for the formation of antiperthite is applicable to these rocks. A model based on nucleation is suggested for the antiperthitic plagioclase in the potash-deficient gneiss.

INTRODUCTION

The generally accepted theory for the origin of antiperthites is that a ternary feldspar unmixes to form intergrowths of potash feldspar in a plagioclase matrix (for a general review see Deer *et al.*, 1963). Vogel, Smith and Goodspeed (1968), on the basis of field relationships, whole rock chemical analyses, as well as bulk chemical analyses of separated feldspars, suggested that antiperthites from some charnockitic rocks in the New Jersey Precambrian did not originate by exsolution. A weakness in that study is that the data were bulk analyses of the total feldspar within the rocks, whereas some of the arguments may depend on characteristics of individual grains. For example, Bambauer *et al.* (1967) and Corlett and Ribbe (1967) observed that almost all the plagioclases they studied with the microprobe were antiperthitic; if this were the case in the present study, it could prove devastating to the argument. Another uncertainty arises from the separation process where small adhering grains may contaminate the sample. This paper presents the results of a microprobe study of these same feldspars, grain by grain, to clarify the situation.

The rejection of the exsolution theory for the formation of the antiperthitic plagioclase present in these rocks is based primarily on the observation that a potash-rich rock (granite gneiss) contains plagioclase that is not antiperthitic, and a potash-deficient rock (plagioclase gneiss) contains antiperthitic plagioclase. This rock assemblage is an ideal one to test the exsolution hypothesis for the origin of antiperthite. If the origin of antiperthite is due to exsolution and if these rocks formed under similar conditions, plagioclase from the granite gneiss should be antiperthitic because the amount of potash feldspar in solid solution would represent the upper limit of solubility for the temperature and pressure environment in which the plagioclase crystallized. Vogel *et al.* (1968) concluded, on the basis of optical and X-ray powder diffraction studies, that the plagioclases from the granite gneiss were not antiperthitic. The present microprobe study was, in part, designed to determine if the plagioclases from the granite gneiss were antiperthitic on a scale detectable with a microprobe (0.2 μm is the limit of resolution on the probe used in this study).

A major premise is that the granite and the plagioclase gneisses have recrystallized concomitantly under identical physical conditions. (Smith, 1969, describes the overall geologic setting and the relationship of these rocks to others in the New Jersey Precambrian.) This premise rests on the following observations: 1) Both rock types are intimately associated and in places interlayered on a scale of a few tens of feet; 2) Both rock types are foliated and/or lineated, and everywhere the foliation of the two rock types is conformable; 3) Both rock types have mineral assemblages that indicate high temperature and pressure conditions (granulite facies), *e.g.* the granite commonly has clinopyroxene present and occasionally garnets; the plagioclase gneiss always has two pyroxenes present.

MICROPROBE STUDY

The plagioclases from the granite gneiss were studied in detail to determine if these grains were antiperthitic. Numerous traverses were made over five to ten grains from each of six different samples with high magnification (5,000×). The matrix of the plagioclases were homogeneous with no potash feldspar detected, except for two instances where potash feldspar grains were present at discontinuities which appear to be irregular fractures or cleavages. Compositions of the plagioclase from the granite gneiss range from 1.0 to 3.0 weight percent orthoclase; and, as will be seen below, this range is nearly identical to that of the plagioclase from the plagioclase gneiss. The anorthite content of the plagioclases was spot checked with the microprobe and found to be almost identical with Vogel's *et al.* (1968) optical determinations, averaging 26 percent anorthite.

Some workers (Hubbard, 1965; Griffin, 1969) have noted that in antiperthites there is a change in composition of the plagioclase as the microcline intergrowths are approached. With this in mind, detailed traverses were made with the microprobe across twenty-five antiperthitic plagioclases from six samples of the plagioclase gneiss. In these traverses zoning was the exception and the composition of the plagioclase, in all but two of these traverses, showed no regular variation up to the margin of the microcline bleb. In the two exceptions, the anorthite content in one case increased regularly 3.5 weight percent anorthite over a 60

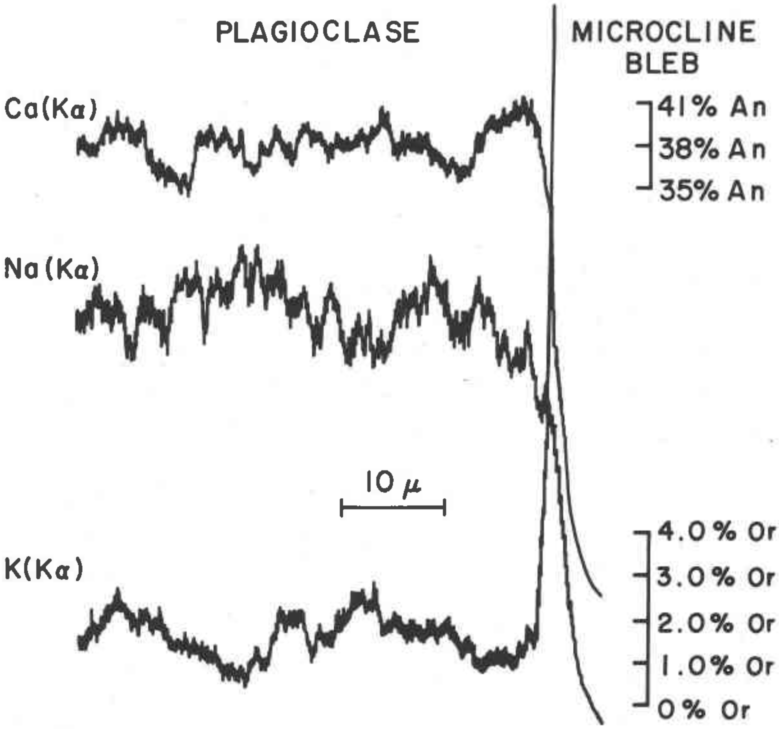

FIG. 1. Na(α), Ca(Kα) and K(Kα) traces across the matrix of an antiperthitic plagioclase grain as a microcline bleb is approached. Weight percent anorthite and weight percent orthoclase are calculated from calcium and potassium counts.

micron scan; and in the other case it increased 6.6 percent over 60 microns.

Figure 1 shows a typical trace of Ca(Kα), Na(Kα) and K(Kα) as a microcline bleb is approached. Although there is marked heterogeneity of potassium, sodium and calcium in the plagioclase matrix, it does not appear to be related to the microcline bleb.

The plagioclase matrix contains between 1.5 and 3.0 weight percent orthoclase in solid solution. The microcline blebs range in composition between 0.0 to 7.8 weight percent albite with most analyses falling between 4.0 and 5.0 percent albite. The composition of the microcline blebs within a particular thin section shows compositional variations of up to 2.5 percent albite; the larger range exists between grains in different thin sections. Microprobe analyses confirmed the optically determined anorthite compositions (Vogel *et al.*, 1968) which range from An_{33}–An_{49}.

Vogel *et al.* interpreted the X-ray diffractograms of the microcline blebs that were separated from the matrix as indicating that these blebs

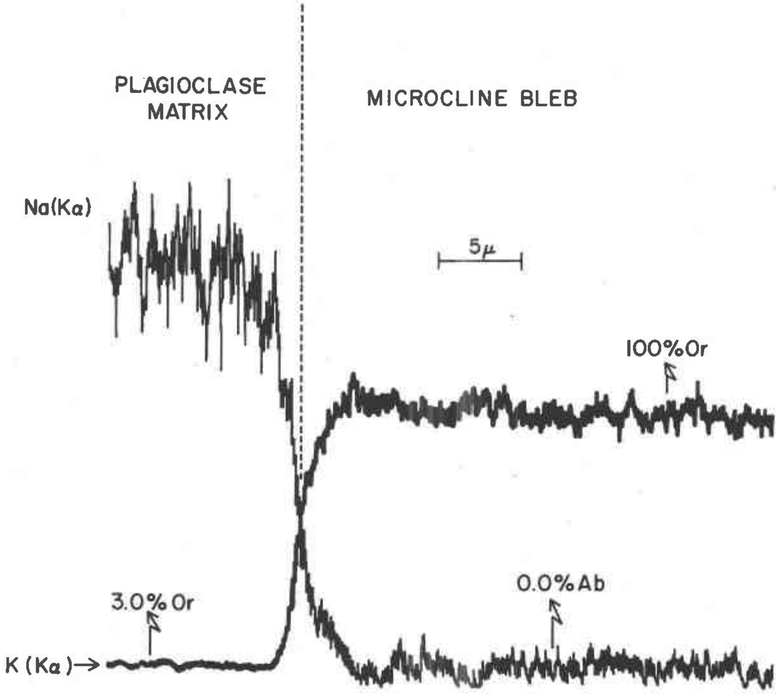

FIG. 2. Na(Kα) and K(Kα) traces across the boundary of a microcline bleb in an antiperthitic plagioclase grain in the plagioclase gneiss.

were perthitic. However, detailed traverses across these microcline blebs show that albite does not exist as a separate phase within these blebs (Figure 2). Apparently in separating the very small microcline blebs from the plagioclase matrix, for X-ray diffraction analyses, some plagioclase grains were present as an impurity. The $\bar{2}01$ peak of plagioclase was interpreted as an albite peak from perthite. In the present study, dozens of traverses taken across microcline blebs and visual display of Na(Kα) X-rays have shown that these microcline blebs are not perthitic.

In any one thin section the amount of free microcline present within plagioclase grains is highly variable, with twenty to forty percent of the plagioclase grains containing no microcline blebs. The antiperthitic plagioclase grains contain variable amounts of microcline blebs up to ten percent by area.

DISCUSSION

Features that pertain to the origin of antiperthite have been interpreted by various workers. Carstens (1967) has used the similarity of the microstructure of antiperthites with those of unmixed alloy systems as supporting an exsolution theory, whereas Griffin (1969) has used irregular textures and zoning around microcline blebs to support a replacement theory. Hubbard (1965) has used the presence of similar types of zoning to support an exsolution theory. Part of the problem is that *regardless* of the origin of the potash feldspar (*e.g.*, either external to the plagioclase or unmixing from a homogeneous plagioclase) the growth of the potash feldspar within a plagioclase grain involves *replacement* of a volume of plagioclase by potash feldspar.

Regardless of the origin of the potash feldspar, there are problems in replacement of a calcium-bearing plagioclase feldspar by potash feldspar since this involves breaking strong aluminum and silicon bonds and removal of calcium and aluminum from the replaced site (Goldsmith, 1952). However, that this replacement has occurred is demonstrated by the presence of antiperthite. Griffin (1969), based on Orville's (1963) ion exchange work and Hoffman's (1967) alkali infiltration model, has developed a model for an alkali exchange of plagioclase which may account for the replacement of plagioclase by a metasomatic process. In the present study, Griffin's model may apply but the criteria necessary to support or reject his model have not been identified.

The principal thrust of the present argument is that the plagioclase from the granite gneiss should have been antiperthitic if the exsolution model is applicable to these rocks. According to the exsolution model, the plagioclases from the granite should have been saturated in potash feldspar when it first crystallized and upon cooling should have exsolved when the solvus was reached. The plagioclases from the granite gneiss are not antiperthitic on any observable scale.

Assuming that exsolution is not a viable model, the major questions are: why does antiperthite not exist in the granite gneiss, and why is it present in the potash-deficient plagioclase gneiss? The answer may lie in nucleation energies. In the granite gneiss, during recrystallization, the growth of potash feldspar proceeded at a much faster rate on preexisting potash feldspar nuclei than on plagioclase surfaces, since the free energy of activation for development of nuclei on plagioclase interfaces would have been relatively greater than growth of potash feldspar on preexisting potash feldspar grains. On the other hand, in the potash-deficient plagioclase gneiss, no preexisting potash feldspar nuclei were present, and the free energy of activation for nucleating on the plagioclase interfaces was much lower than that for the formation of new independent nuclei of potash feldspar.

In conclusion, for any given occurrence of antiperthite there exists two antithetical genetic models, with each model implicitly carrying a different set of petrogenetic interpretations. Assuming an exsolution model, the presence of antiperthite is interpreted on the basis of classical thermodynamics. If antiperthite is assumed to be a result of kinetics, which is consistent with the results of this study, nucleation and not saturation plays the dominant role.

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