Quartz-bleb-rich zones in perthite phenocrysts in ekerite

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Perthite phenocrysts in an ekerite (soda granite) from the contact zone in the vicinity of Eikeren, Norway, contain concentrations of quartz blebs in roughly tabular zones that are parallel to apparently pre-existing faces of the phenocrysts' cores. It is concluded on the basis of petrography and compositional relationships that the phenocrysts grew in magma and that their quartz-bleb-rich zones represent simultaneous crystallization of the quartz and its enclosing feldspar.

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Ekerite, a soda granite of the Permian Oslo magma province, has been described by several petrologists and geochemists (e.g., Brøgger 1933, Barth 1945, Dietrich, Heier & Taylor 1965). Very briefly, the ekerite consists of quartz, perthite, and minor amounts – typically less than five percent – of mafic minerals such as aegirine, riebeckite, and/or astrophyllite. According to the nomenclature of Tuttle & Bowen (1958), it is a hypersolvus granite. In addition, both its mode and its norm indicate a composition near the trough of 'petrogeny's residua system' (Bowen 1937). And, unlike many rocks, the 'fit' involves more than 92 percent of the total composition because, for example, even calcium is absent or is nearly lacking – 0.00–0.43 weight percent CaO – in most analyses (see Dietrich & Heier 1967).

In this note, we describe and discuss the probable genesis of some especially interesting Phenorysts found in a border zone and within a dikelet that cuts the Silurian age country rock. The specimens came from exposures located near the northwestern end of Eikeren, some 20 km west-southwest of Drammen, Norway.

Description

This porphyritic ekerite consists of a fine-grained (< 1.0 mm) groundmass with sporadic perthite phenocrysts that range up to nearly 1.5 cm in longest dimension. The composition of the porphyritic rocks falls within the same field as the more common equigranular rocks (Fig. 1). So far as distribution of their perthitic components is concerned, all except one of the observed phenocrysts appear relatively homogeneous throughout. The exceptional one differs in that its central zone (# 1, below and on Fig. 2) consists predominantly of microperthite, rather than perthite, whereas its intermediate and external zones (# 2 and # 3, below) are like those of all the other phenocrysts in our thin sections. In any case, all of the phenocrysts can be described (Fig. 2) on the basis of three rather distinct parts: 1) a central portion that is essentially inclusion-free; 2) an intermediate zone that

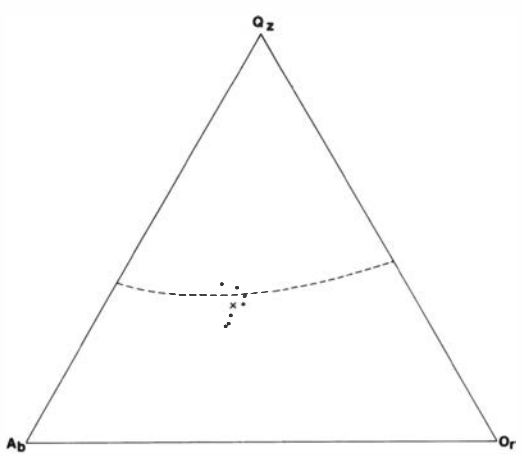


Fig. 1. Plots of ekerite compositions on an orthoclase-albite-quartz ternary diagram. The X represents the average composition of the seven rock samples plotted. Dashed line is the granite cotectic of Tuttle & Bowen (1958) at a water pressure of about 2Kb.

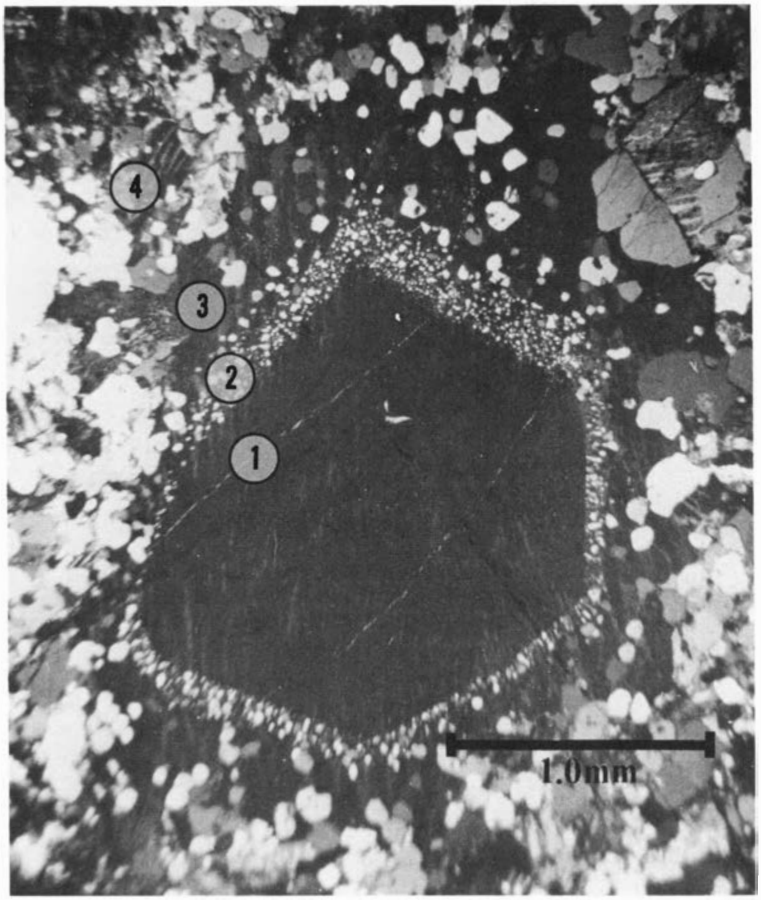


Fig. 2. Photomicrograph of typical perthite phenocryst with well-developed quartz-bleb-rich zone (area numbered 2). (See text for descriptions of numbered zones.)

is marked by a concentration of small, typically spheroidal but some irregularly shaped (Fig. 3), quartz blebs, averaging 0.04 mm in diameter; and 3) an external zone that contains scattered grains of quartz of about the same size as the grains in the groundmass – *i.e.*, ranging between 0.08 and 0.16 mm across, definitely larger than the typical blebs. The Or:Ab ratio in the perthites ranges from about 40:60 to 55:45 (the Celsian content was not checked). The actual constituents of the perthites are albite and a K-feldspar that would probably be called orthoclase on the basis of its optical properties but high microcline according to the nomenclature subscribed to by Smith (1974b:434). As can be seen in Fig. 2, the perthitic aspects exhibit a rather typical exsolution relationship with the general appearance of film perthite (Alling 1932). Some of the phenocrysts are twinned according to the Baveno and other laws, as figured by Oftedahl (1953:81). No differences have been detected between the groundmass directly adjacent to and that well away from the phenocrysts. In essence, it is a microcrystalline mass of quartz and perthite with an overall aplitic (panallotriomorphic) texture.

The quartz-bleb-rich zones are tabular and parallel to common faces of perthite phenocrysts (e.g., (110), (010), (001) and (201)). Several of the so-defined, apparently pre-existing faces are not, however, even roughly parallel to the boundaries between the overall phenocrysts and their surrounding groundmass. Rather, the overall phenocrysts have highly irregular boundaries with the groundmass – i.e. they are allotriomorphic (anhedral). Junctions between the faces as outlined by the quartz-bleb-rich zones are more or less angular. Perthite lamellae are continuous across the zones (Fig. 3); even those lamellae that appear in two dimensions to be interrupted by the blebs may be seen in the third dimension to be continuous. In fact, this relationship even obtains for a few of the lamellae in the previously described 'exceptiona' phenocryst with the predominantly microperthitic central zone. Traverses across the quartz zones transect up to ten, but typically only two or three, quartz blebs.

The optical orientations of the quartz blebs were measured to determine if there is any consistent crystallographic relationship between the quartz and the host perthite. The quartz grains were grouped according to the direction of their containing zone within the phenocryst. Thence, each group of quartz orientations was compared to each other group and also to the optical orientation of each of the two perthitic feldspar phases. The results of the analyses indicate that there is neither a consistent orientation of quartz grains within the phenocrysts nor any preferred crystallographic relationship between the quartz and either of the feldspar components of the perthitic host. In fact, the scatter of the optic axes plots suggests an essentially random orientation of the quartz within the perthite phenocrysts (Fig. 4). This is different from the characteristic relationship found in the granophyric intergrowths, myrmekites, and graphic granites reported by Barker (1970:3346). In addition, it is perhaps worthy of note that the general spheroidal shapes of most of the blebs precludes any shape orientation either among the blebs within a given zone or between the blebs and the apparently pre-existing crystal boundaries of the host perthite (cf. Lauder 1961).

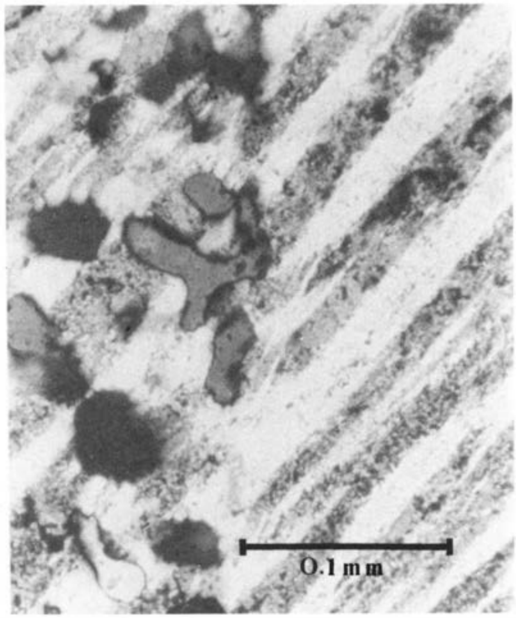


Fig. 3. Photomicrograph of quartz blebs showing some irregular, as well as the more typical spheroidal, shaped blebs. Note also the apparent continuity of perthite lamellae across the blebs.

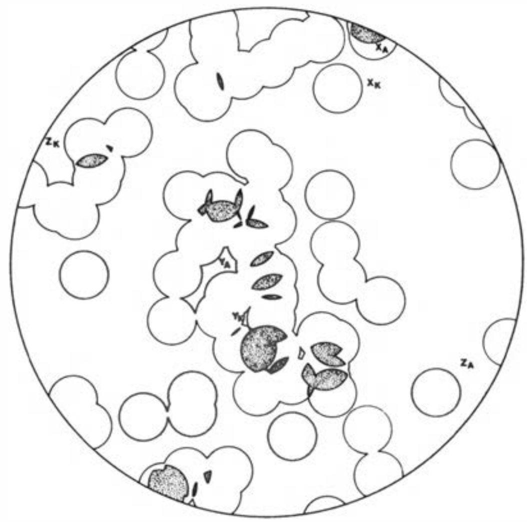
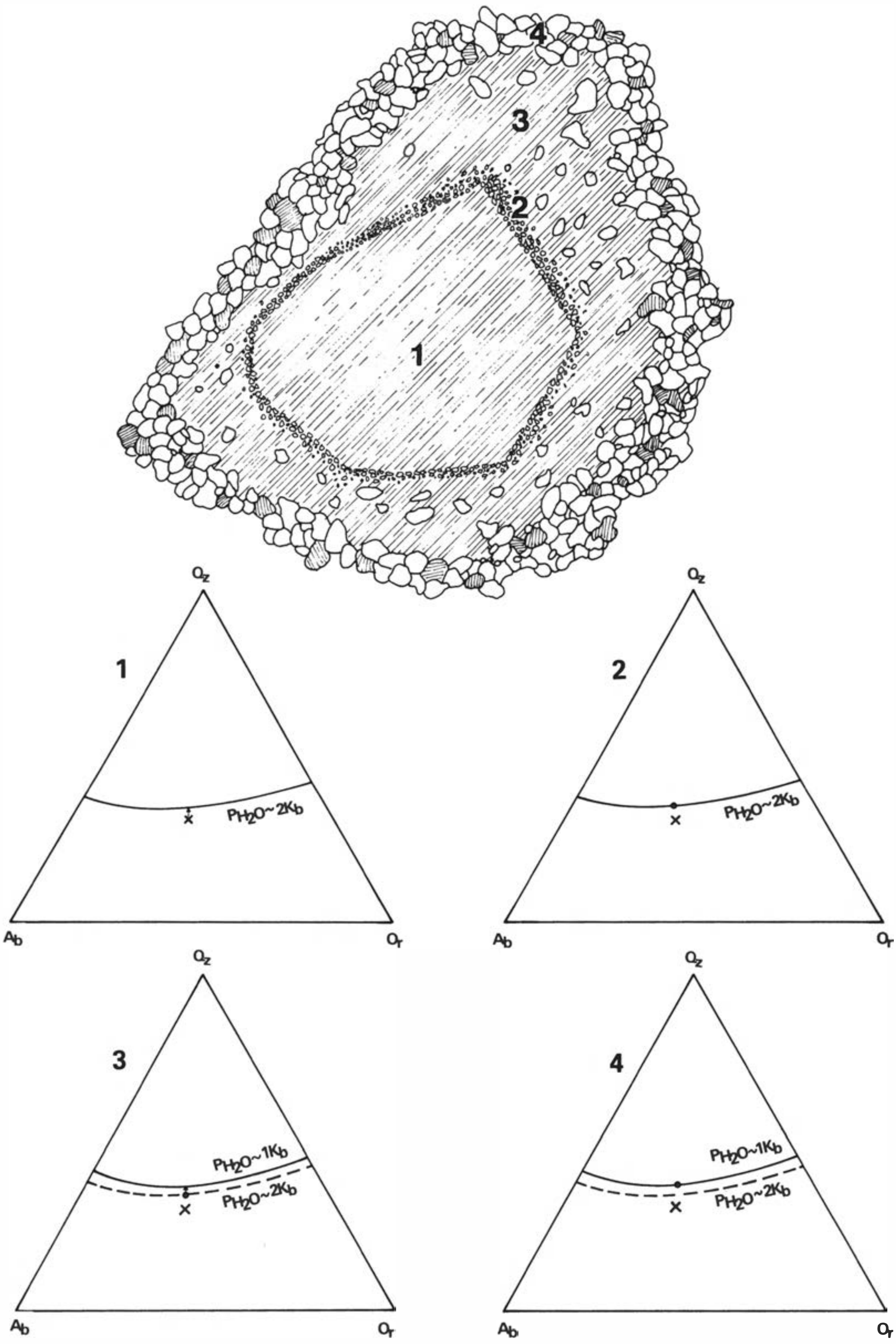


Fig. 4. Preferred orientation of *c*-axes of quartz grains in the quartz-bleb-rich zone of a single perthite phenocryst. The weak, almost random pattern is apparent in the diagram, and the randomness is even more evident when a number of perthite grains are compared. X_k, Y_k, Z_k, and X_a, Y_a, Z_a are the optical orientations of the K-feldspar and albite phases, respectively, of the perthite. The stippled pattern represents a concentration of three points per one-percent area. Sixty-seven c-axes were plotted.

Origin

The sequence numbered 1–4 on Fig. 5 appears to fit the observed features best. To elaborate on the diagrams, step by step, it is suggested that:

1. a) Initial crystallization of the alkali feldspar was in a magma where there was 'freedom' for idiomorphic crystal growth.
   b) As a consequence of the crystallization of the feldspar, the composition of the remaining magma changed; it moved, so to speak, towards the granite cotectic in the Or-Ab-Q-H_2O system (Tuttle & Bowen 1958).
2. When the composition corresponded with that of the appropriate granite cotectic, both quartz and feldspar were crystallized nearly, if not actually, simultaneously.


4
3
2
1
Qz
1
PH2O~2Kb
Ab
Or
Qz
2
PH2O~2Kb
Ab
Or
Qz
3
PH2O~1Kb
PH2O~2Kb
Ab
Or
Qz
4
PH2O~1Kb
PH2O~2Kb
Ab
Or

3. Some change – e.g., a decrease in hydrostatic pressure – then caused renewed crystallization within the feldspar compositional field.
4. Subsequently, more rapid cooling took place, perhaps attendant upon movement of the magma into relatively cool country rock, with consequent crystallization of the fine-grained groundmass.

The conversion of the original alkali feldspar to perthite is interpreted to have taken place later, at a lower temperature, as a result of exsolution.

It is further thought that the zoning of these phenocrysts was formed under the influence of rather local controls and, despite our use of the term cotectic, perhaps under less than thermodynamic equilibrium conditions (see Smith 1974 b: 593).

The main supporting evidence and considerations may be summarized:

The composition of the magma, as indicated by the composition of the rock, is consistent with the suggested origin (Fig. 1).

That crystallization of a magma was involved is corroborated by geological relationships, e.g., intrusive relationships between the ekerite and the surrounding country rock.

The fact that the quartz-bleb-rich zones outline images of a relatively early stage of growth of their host grains (which are otherwise homogeneous in overall aspect) is readily explained by formation of the quartz blebs during the same magmatic consolidation.

The irregular shapes of some of the quartz blebs (Fig. 3) are explicable if the quartz crystallized essentially simultaneously with its host feldspar.

It is further concluded that the quartz blebs probably nucleated within the liquid near the then existing feldspar surfaces, i.e., that they were formed in essentially the same relative positions that they now occupy. (This conclusion, of course, rules out epitaxial growth of the quartz on the feldspar. In the terminology of Maaløe (1974), the quartz blebs would be 'fluentive' as contrasted to 'sedentary'.) This conclusion is based on considerations relating to the shapes of the blebs, especially the irregular-shaped ones, and on the fact that unlike the quartz in granophyre and graphic granite, nearly all of the blebs are isolated from each other within the host feldspar phenocrysts.

Fig. 5. Illustration of a possible mechanism for the origin of the perthite phenocrysts. The X in each composition triangle is the average of seven rock samples, as in Fig. 1. Zone 1 in the sketch corresponds to ternary diagram 1 in which the initial liquid magmatic phase (X) changes composition toward the granite cotectic as alkali feldspar phenocrysts form. At the cotectic (the dot in triangle 2), quartz and feldspar crystallize simultaneously, yielding the quartz-bleb-rich zones, zone 2. A change in P_{H_2O} (triangle 3) could make alkali feldspar the stable phase once again, resulting in growth of the feldspar beyond the quartz-bleb-rich zone (zone 3). Eventual re-equilibration to the 'adjusted' cotectic results in simultaneous crystallization of quartz and feldspar as the liquid phase disappears (zone 4 and triangle 4).

The shapes and distribution of the perthitic lamellae and the fact that some of the lamellae transect the zoning, as well as considerations of the probable thermal history of the rock, lead to the conclusion that the lamellae were formed by later, very likely post-magmatic, exsolution rather than by simultaneous crystallization of the two phases or by some replacement process.

The suggestion that local controls prevailed is based on a number of considerations, one relating to a group of features not previously mentioned. Briefly, other kinds of zoned perthite phenocrysts occur within other porphyritic phases of the ekerite and within spatially related, compositionally similar nordmarkite. Two types are particularly common: those that are simple (*i.e.*, of essentially the same overall composition throughout) and those that exhibit a zoning that is different from that described in this paper (i.e., a zoning based on differences in both the sizes of the perthite phases and their proportions – see Oftedahl (1953, fig. 26b)). In addition, and of primary import, there appears to be no regular spatial relationships among the diverse kinds of phenocrysts or between any of the phenocrysts and any particular geological feature.

Our suggested origin is different from the origin suggested by Mehnert (1968) for phenocrysts that appear in illustration to resemble closely those that we have described. Mehnert (1968: 190) interpreted the outer parts of those phenocrysts, from Fichtegebirge, to have been 'crystallized in a postmagmatic stage'. On the other hand, in his two-volume classic on the 'Feldspar Minerals', Smith (1974 a; 593) has noted: 'The simplest conclusion is that most granophyric intergrowths form by simultaneous growth of feldspar and quartz from a liquid at or near cotectic or eutectic composition ...' And, as our conclusions indicate, we concur. Indeed, we consider the quartz-bleb-rich zones that we have described to be analogous to the apparently more common, so-to-speak more typical granophyric intergrowths.

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