Textural patterns at porphyroblast margins

SIR – In a recent paper, Ferguson & Harte (1975) summarize the views on textural criteria for pre-, syn-, post-tectonic porphyroblasts. They observe correctly that interpretation of porphyroblast age relationship with deformation based solely on the behaviour of external matrix fabric like foliation (*Se*) at porphyroblast margins may be hazardous. While concluding that localized 'truncation of *Se* at porphyroblast margins, with or without deflection, is not by itself a *sufficient* criterion' for syn- or post-*Se* growth, they suggest that pre-tectonic porphyroblasts could truncate *Se* margins, a point on which I would like to comment, based on studies of the porphyroblastic (-clastic) rocks from a part of the Himalayas and the Norwegian Caledonides.

In cases where the porphyroblasts contain an internal fabric (*Si*), defined by inclusions, and *Si* passes out into *Se*, there is no ambiguity that the porphyroblasts are either syn- or post-tectonic (depending on *Si* pattern). There *Se* is truncated at the porphyroblast margin. The problem encountered evidently is with inclusion-free porphyroblasts. Generally such porphyroblasts possess grain boundary features like embayments suggestive of matrix replacement. In such cases the porphyroblasts are considered to be syn- or post-tectonic, because they truncate *Se*. On the basis of these and other textural criteria the second and the main metamorphic event in the Proterozoic Daling rocks of the Eastern Himalayas is considered to be syn- to late-tectonic in relation to the second deformation (Sinha Roy, 1973). Thrusting of these rocks is related to this deformation, but has post-dated the metamorphism. Therefore, the porphyroblasts (garnet, staurolite and kyanite) behaved as pre-tectonic porphyroclasts in relation to the thrusting deformation, much in the same manner as the deformed clastic grains in associated metagraywacke did. In rocks of the thrust zone, the porphyroblasts are rotated and flattened on the foliation plane. Strain analysis on deformed garnets indicate that post-metamorphism flattening caused nearly 25% shortening across the foliation plane. *Si* and *Se* are generally discordant due to rotation of the porphyroblasts, and *Se* follows the porphyroblast outline without being truncated. Deformed clastic grains and large porphyroblasts are associated with pressure fringes. Although the long axes of the minerals (quartz and micas) developed in pressure fringes may be roughly orthogonal to the controlling porphyroblast face in ideal situation, V shape of these zones is a characteristic feature. The extent to which the pressure fringe truncates the porphyroblast margin obviously depends on the shape of V. With broad and long Vs, the truncation is restricted to a very narrow strip at the central part of the zone. The truncated fabric is however quite local, dependent primarily on porphyroblast size, its orientation and competence relative to matrix (Karunakaran & Sinha Roy, 1967). If pressure fringe fabric is considered as having the same significance as *Se* (a postulate which may be erroneous), then also *Se* truncation by pre-thrusting porphyroblasts in this situation is indeed extremely rare. Even after post-thrusting recrystallization, it is possible to distinguish between pressure fringe fabric and matrix fabric (true *Se*) by mineralogy and grain characteristics.

There can perhaps be no better case to test the point under discussion than the mylonites where the porphyroblasts (-clasts) are undoubtedly pre-tectonic in reference to the deformation which produced the mylonitic microstructures. A study on the mylonites derived from trondhjemite in a part of Major Bergen Arc in the Norwegian Caledonides, indicates that truncation of the external fabric (mylonitic foliation) by the porphycroclasts is also rare. The mylonitic fabric, superposed on an earlier foliation, recognizable in the adjacent metamorphic rocks, is defined by zones of strong cataclasis in the initial stages. The phyllosilicates, either reorientated or recrystallized, are generally aligned parallel to these zones. A later phase of flattening deformation accompanied by recrystallization and neocrystallization, accentuated the foliation and produced the mylonitic banding. The porphyoclasts (mainly feldspar, and at places quartz–feldspar aggregate) have variable shape and size. Apparently due to flattening they are almost lensoid with the long and intermediate axes generally parallel to the mylonitic foliation (*Se*). The foliation wraps around them, and *Se* truncation at their margin does not normally occur. Where the long axes of the porphyroclasts are at an angle (30–40°) with the general trend of *Se*, the matrix fabric near them is sharply bent to 'accommodate' the porphyroclasts. In such cases intrafolial microcrenulations develop in the matrix fabric around the porphyroclasts. Pressure fringes defined by recrystallized quartz are common at the margins of feldspar porphyroclasts. In fact the degree of development of mylonitic banding is directly proportional to the size of resistent porphyroclasts, which controls the width and length of the pressure fringes. In very narrow strips within this zone *Se* may appear to be truncated by the porphyroclast margins, but then this indeed is the pressure fringe fabric, similar to that described above. Although some of these rocks are blastomylonites where much of deformed quartz in the matrix has recrystallized into subgrains, the pressure fringe fabric is quite distinct from the matrix fabric. In most cases due to rotation of the porphyroclasts the pressure fringes around them are bent and

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become asymmetric, and often have slid over the porphyroclast margin. The fabric trace in pressure fringes is thus asymptotic to the porphyroclast margin, so that the porphyroclasts are neither truncated by the matrix mylonitic foliation (true *Se*) nor by the pressure fringe fabric.

The conclusions relevant to porphyroblast margins in relation to *Se* from these studies are:

(i) Pressure fringe fabric should not be confused with matrix fabric. Ferguson & Harte base much of their reasoning on the alignment of minerals in pressure fringes which generally constitute a small part of the matrix, and conditioned by strain inhomogeneity around porphyroclasts, their fabric may not be correlatable with the matrix fabric. Conclusions based on pressure fringe fabric would then perhaps be misleading.

(ii) Size (particularly in weak deformation), shape, orientation of porphyroblasts, competence contrast between them and matrix, and intensity of deformation, control the nature of contact of porphyroblasts margin with both pressure fringe and matrix fabrics. *Se* deflections around pre-tectonic porphyroclasts obviously depend on these factors.

(iii) In rocks with imprints of multiple deformations, a syn- or post-tectonic porphyroblast (having truncated *Se*) with reference to an early deformation may retain such textural relations even after a late deformation of weaker intensity and matrix recrystallization. Such truncations need not be misinterpreted by relating them to the later event in reference to which the porphyroblasts are pre-tectonic. With strong later deformation (as in thrust-zone and mylonitic rocks) the porphyroblasts however tend to be moulded in the matrix, and *Se* truncation would rather be an exception than rule.

Furthermore, the mechanism of formation of slaty cleavage is yet to be fully understood. Therefore, the criterion to identify pre-tectonic porphyroblasts based on arguments (Ferguson & Harte, 1975), linking slaty cleavage and truncated *Se* at porphyroblast margins, does not seem to be *sufficient*.

References

Ferguson, C. C. & Harte, B. 1975. Textural patterns at porphyroblast margins and their use in determining the time relations of deformation and crystallization. *Geol. Mag.* **112**, 467–80.

Karunakaran, C. & Sinha Roy, S. 1967. Pressure shadows in Daling phyllite. *J. geol. Soc. Ind.* **8**, 75–80.

Sinha Roy, S. 1973. Structure and metamorphism of the Daling–Darjeeling group of rocks in the North Eastern parts of Kalimpong hills, Eastern Himalayas. *Q. Jl Geol. Min. Met. Soc. Ind.* **45**, 9–21.

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SIR – Sinha Roy apparently agrees with us (Ferguson & Harte, 1975) that an interpretation of porphyroblast age relationships (with respect to deformation events) which is based solely on the behaviour of *Se* at porphyroblast margins may be hazardous. At the same time he implies that we have proposed criteria, particularly with respect to the identification of pre-tectonic porphyroblasts, which are erroneous. It must be emphasized that we did not claim that truncation textures can be used as a criterion for identifying pre-tectonic porphyroblasts – such a claim would be absurd. In fact we claimed that truncation is not 'a sufficient criterion for direct replacement, or, therefore, syn- or post-*Se* growth'; and this is apparently accepted by Sinha Roy. To assert that truncation does not necessarily imply syn- or post-*Se* growth is not to assert that it implies pretectonic growth.

Sinha Roy's own textural descriptions are interesting as examples of textural patterns from which porphyroblasts can be recognised as pretectonic with, it seems, little possibility of misinterpretation. Such patterns are common in some tectonic environments – we have not suggested otherwise. We did, however, suggest that in other rocks pretectonic porphyroblasts are associated with a different set of textural patterns; indeed, we believe that the evidence for this presented in our paper (evidence that Sinha Roy does not challenge) is overwhelmingly strong. With respect to Sinha Roy's itemized conclusions:

(i) We noted (Ferguson & Harte, 1975, p. 478) that pressure fringes usually formed entities distinct from matrix *Se*, though we also noted that this is not always the case (Williams, 1972). We considered the fabric developed in pressure fringes to be important because it has obvious bearing on strain and stress relationships and fabric orientation in the immediate vicinity of pre-tectonic porphyroblasts. Pressure fringes may therefore provide useful information in attempting to understand how truncation relationships are formed.

(ii) Sinha Roy's second conclusion accords with our discussion (pp. 476–8).

(iii) The third conclusion endorses our assertion (pp. 471 and 476) that in cases of multiple deformation a truncation relationship does not necessarily imply porphyroblast growth subsequent to all deformation and crystallization. We do not doubt that porphyroblasts embedded in a matrix subjected to strong deformation 'tend to be moulded in the matrix'. Nor do we doubt, with reference to the examples quoted by Sinha Roy, that strained porphyroblasts around which *Se* is deflected must be earlier than a deformation event. Where such criteria exist misinterpretation is difficult. But where unstrained porphyroblasts truncate *Se*, then care must be taken and additional criteria sought in order to decide which if any of the deformation events the porphyroblasts postdate. To say that 'such truncations need not be misinterpreted by relating them to the later event in reference to which the porphyroblasts are pre-tectonic' is to miss our point.

Reference additional to the above

Williams, P. F. 1972. 'Pressure shadow' structures in foliated rocks from Bermagui, New South Wales. *J. geol. Soc. Aust.* **18**, 371–7.

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The role of CO_2 in alkali rock genesis

SIR, – Rock (1976) has collected a convincing volume of data from natural occurrences which seems to indicate antipathy in the association of carbonatite with igneous rocks which contain calcic plagioclase. He suggests that this antipathy may be masked to the casual observer if it is not recognized that different ages of intrusion may occur at a single centre, but he chooses to illustrate this point by considering the Damaraland Province in South West Africa (Martin, Mathias & Simpson, 1960).

Rock (p. 104) refers to 'tholeiitic Bushveld gabbros' in relation to the Damaraland Province which are presumably those of the Bushveld Igneous Complex some 1300 km to the SE and not associated with the Damaraland alkaline and carbonatitic rocks at all. The Damaraland intrusions occur within high grade metasedimentary rocks and associated granitic rocks of the Pan-African Damara Mobile Belt. Perhaps the confusion arose through the misidentification of the Spitzkop intrusion (a granite pluton) of the Damaraland province with the well known Spitzkop carbonatite complex in the Transvaal, which is indeed intrusive into gabbros of the Bushveld Complex.

In the same discussion Rock seems to imply that all the other southern Africa carbonatite occurrences are part of the Damaraland Province, including the well known Palabora complex which lies some 1400 km to the SE. This generalization can only confuse the point he is attempting to clarify.

There are several features of other southern African carbonatites which are at variance with data assembled by Rock. Modern interpretation (Verwoerd, 1967) indicates that the carbonatite at Kruidfontein is *not* a xenolith of carbonate sedimentary rock but is magmatic in origin and is therefore one instance where carbonatite and basaltic rocks do occur intimately related. The entry for this occurrence should therefore be deleted from Table 3.

Small inclusions of hortonolite monzonite (of uncertain origin) occur in the Okorusus [*sic*] intrusion in Damaraland and fayalite diorite and theralite are not associated with this carbonatite. As has been mentioned this intrusion is geographically unrelated to the Bushveld Complex and the entry in Table 3 is therefore erroneous.

The entry of Swartbooisdrift as a gabbro complex in Table 2 is also incorrect. Swartbooisdrift is the location of a group of alkaline and carbonatitic rocks which have been dated at 749 Ma (Verwoerd, 1967). These rocks are intrusive into basic rocks of the Kunene anorthosite complex which has a minimum age of

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