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ELECTRON CHANNELING AND ITS POTENTIAL FOR PETROFABRIC STUDIES: DISCUSSION

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Saimoto *et al.* (1980) present a particularly lucid explanation of how electron-channeling patterns (ECPs) are generated with a scanning-electron microscope (SEM) and suggest several possible applications of the technique to geology, notably for the analysis of petrofabrics. Although they demonstrate that ECPs can be obtained from geological specimens, the patterns shown are diffuse, of poor quality and show little detail. We have been using ECPs for some years to study a variety of materials and have recently obtained patterns from geological specimens that are of considerably superior quality to those shown by Saimoto *et al.* We wish, therefore, to draw the attention of readers of this journal to our experimental techniques.

The ability to use ECPs for orientation studies generally requires patterns of good quality, especially when the total amount of pattern visible is small. This may occur, for example, when only small areas of specimen are available (Fig. 1a). The requirement of good ECPs is particularly necessary for geological specimens with crystal structures of low symmetry that will consequently not tend to exhibit a major crystallographic pole in the pattern. The fine detail of the high index lines in the ECP must then be used to determine the orientation, either analytically or, more frequently, by comparison with an "ECP map" of the crystal system (*e.g.*, Joy 1974).

In agreement with Saimoto *et al.* (1980), we find that ECP quality is critically dependent on the specimen-surface preparation technique. However, it is not the initial sawing that is the main problem; the final polishing is of equal if not even greater importance. Our observations are based on ECPs obtained from a natural single crystal of quartz (which did not require any sawing) using a variety of preparatory techniques, including mechanical polishing, vibratory polishing and ion-beam thinning as well as natural crystal faces. Normal, mechanically polished finished 1-μm diamond paste gave results similar to those shown by Saimoto *et al.* (1980). Further polishing for several hours using a recirculated colloidal silica solution (SYTON®, obtainable from Monsanto Chemical Corporation, 10–18 Victoria Street, London SW1H 0NQ, England) greatly improved the quality of the pattern. Figures 1a-1c show examples of ECPs obtained using this technique, which will be discussed in detail by Hall, Lloyd, Cockayne & Jones (in prep.).

We also note that Saimoto *et al.* used the specimen current to obtain their images and employ a short (1 mm) working distance. It may be that this configuration was necessary because of the type of SEM used. However, we find that the use of an annular back-scattered electron detector (Stephen *et al.* 1975) inserted between the specimen and the final lens-plate of the SEM (a Cambridge Stereoscan S4) greatly improves image detail. This does require the use of slightly longer working distances (5–10 mm) but increases the proportion of the total signal owing to electron-channeling contrast while reducing any artifacts, such as specimen contamination from the beam and charging.

In conclusion, although we agree with Saimoto *et al.* (1980) concerning the value of electron-channeling patterns for petrofabric analysis, we recommend the use of other specimen-preparation techniques (*e.g.*, Hall *et al.*, in prep.). It is also worth mentioning that there are two other related effects that become easily available when a back-scattered electron detector is used. These are atomic number contrast (due to differences in composition) and channeling or orientation contrast (due to differences in orientation; see Fig. 1d), both of which have recently been discussed (Lloyd & Hall 1980).

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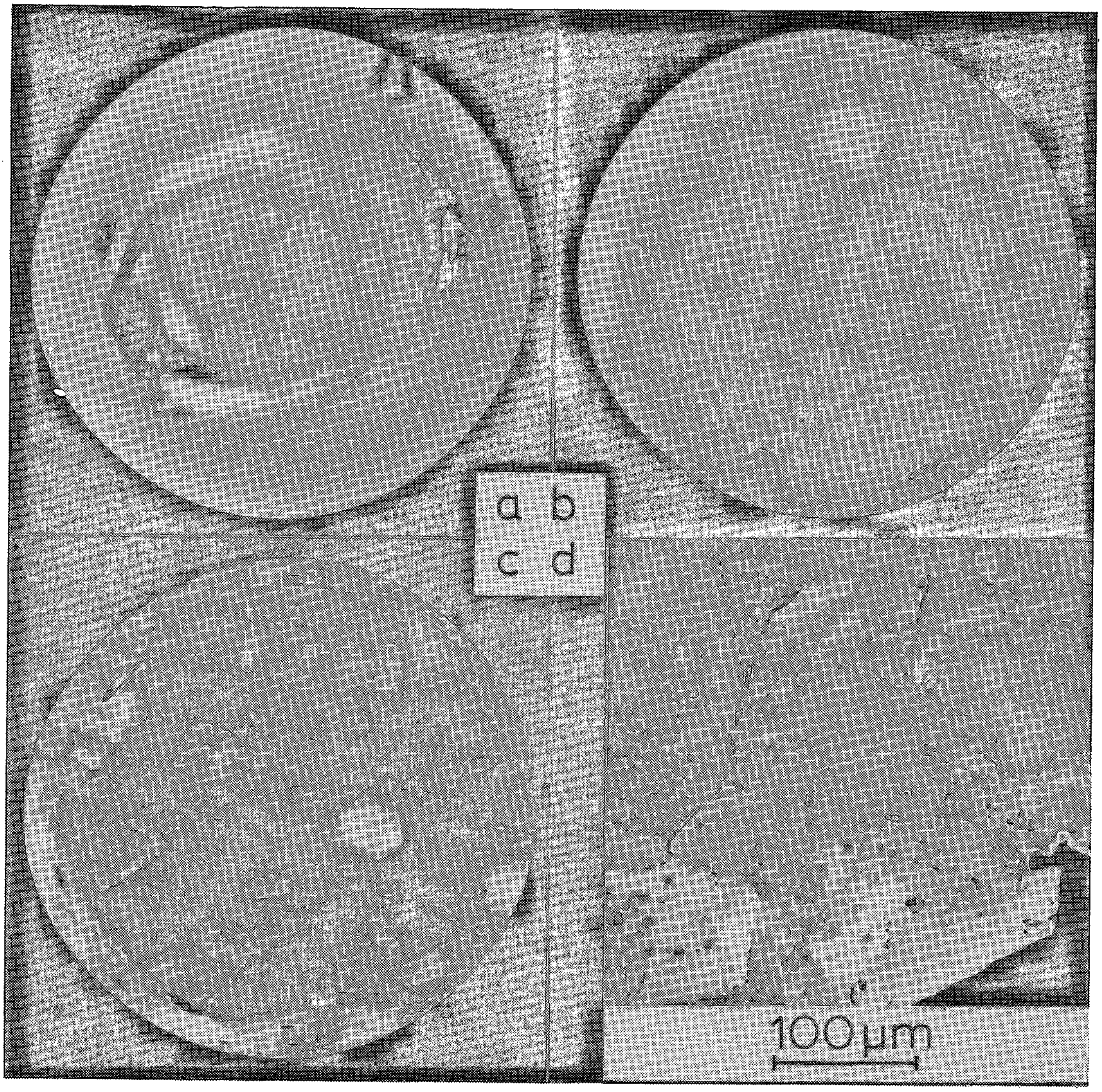

FIG. 1. (a) "Flash" ECP from quartz single crystal. The pattern originates from a crack in a surface layer of carbon; the region surrounding the pattern is interference from the amorphous carbon layer. Pattern generated at 30 kV (as in b, c and d). (b) Full ECP from quartz single crystal coated with 5 nm of carbon to prevent charging. The pattern contains a (1$\bar{1}$00) crystallographic pole. (c) ECP from a grain of pyrite (specimen courtesy of Prof. J.G. Ramsay); no coating was required. The pole shown is (114). (d) Channeling-contrast image of the pyrite specimen used in (c) showing the different grains and subgrains. The ECP originates from the central grain.

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ELECTRON CHANNELING AND ITS POTENTIAL FOR PETROFABRIC STUDIES: REPLY

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We are indeed grateful to Hall & Lloyd for informing us about their work in ECP generation in minerals. We compliment them on their high-contrast patterns. Most of our patterns were taken prior to our recent modifications of the scan generator, which has improved the contrast. Another contributing factor arose from our efforts to determine orientations by enhancing the resolution of the second- and higher-order bands, which are sharper than the first order. This procedure tended to result in patterns with lower contrast, which are not nearly so pleasing to the eye. This effect becomes quite apparent in the reproductions. We agree with Hall & Lloyd that any method that reduces mechanical damage on the surface will produce a sharper ECP. In our endeavors, we attempted to generate ECP on standard thin sections as used for petrofabric examination. If such were possible, the utility of this tool would be obvious.

We also experimented with the annular back-scattered electron detector (ORTEC surface-barrier detectors), and agree with Hall & Lloyd that its usage improves image detail. However, the fragility of this device made maintenance painstaking, especially for use in axial-distribution analysis of samples where grains of 50 μm diameter are plentiful, requiring the shortest working distance possible. In conclusion, we are delighted to learn that ECP generation for petrofabric examination is being pursued elsewhere; hopefully this technique will now become more widely accepted, in the light of our report and that of Hall & Lloyd.

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