# The influence of foliation on the fragility of granitic rocks, assessed with image analysis and quantitative microscopy

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## **1. INTRODUCTION**

Rock texture is of great importance in understanding the mechanical properties of rocks. The texture is defined as the size, shape and spatial arrangement of mineral grains, and it is a product of the rock's origin and tectonic history.

However, when a rock becomes foliated, the texture changes due to flattening, elongation, grain-boundary migration and in some cases, formation of subgrains. The present study investigates how the change in texture with increasing foliation affects the resistance to fragmentation. Foliation is an important parameter because it creates mechanically weak discontinuities.

The relationship between foliation and the mechanical behaviour has been studied by several authors (e.g. Schön, 1996; Bohloli, 2001) using ultrasonic measurements and by measuring rock-strength properties. We have used the image-analysis technique of Åkesson et al. (2001) to numerically describe the texture. The degree of foliation was quantified by measuring linear traverses parallel and perpendicular to the mineral fabric. The fragility was measured using the Los Angeles test method. The studied samples were a group of granitic rocks, that displays a range of textures from foliated nonfoliated, located in southern Sweden.

# 2. ROCK-TEXTURE ANALYSIS

Two methods were used to quantifying rock texture. (1) The perimeter of mineral grains and grain aggregates of the same phase was measured from images taken with a scanning electron microscope with backscattered detector (SEM/BSE), using image analysis (Åkesson et al., 2001). The perimeter is the circumference of an object, and by using this parameter it is possible to describe the shape of a mineral phase. For mineral phases with similar areas, the perimeter will increase with increasing complexity of the grain boundaries. The grain size is also included. Because all analysed images have the same area, if the number of objects increase (decreasing grain size) the total perimeter will increase assuming similar shape of the mineral phases. The SEM cannot identify boundaries between minerals of the same phase and adjacent grains of the same mineral will be measured as one object. For this reason, the spatial dispersion of the mineral is also taken into consideration when the perimeter is measured.

(2) The degree of foliation was quantified by using optical microscopy, counting linear traverses on thin sections, oriented perpendicular to the foliation. The number of grain boundaries on a 1-mm line transect were counted. Two-hundred line transects were counted for each sample. The line transects were oriented parallel  $(P_L)_{II}$  and perpendicular  $(P_L)_{\perp}$  to the mineral fabric. The results from the linear travers measurements were the basis for the calculation of a foliation index (FIX).

#### $FIX = \Sigma(P_L) \perp / \Sigma(P_L)_{II}$

where  $\Sigma(P_L)_{II}$  and  $\Sigma(P_L)_{\perp}$  is the sum of the number of grain boundaries parallel and perpendicular to the mineral fabric from all measured line transects. A FIX near 1 corresponds to an isotropic rock and it will increase with increasing foliation.

#### **3. MECHANICAL ANALYSIS**

The samples in this study were collected from unweathered outcrops using a sledgehammer and crowbar. The rock material was crushed with a gyratory crusher (Svedala Arbro 50-26-64) and a laboratory jaw crusher (Morgårdshammar A23) to achieve the desired fraction. The fragility of the fragmented material were analysed using the Los Angeles test method (EN 1097-2, European Comitee for Standardisation, 1997).

#### 4. RESULTS AND DISCUSSION

The samples show foliation indices between 1.02 and 1.91. The petrographic studies indicate that the FIX must be more than approximately 1.15 before it is possible to detect the foliation (with the naked eye?)((isotropic samples show FIX up to 1.12). The relationship between the perimeter and the LA values is shown in figure 1a. The foliated samples plot above the curve established by Åkesson et al., (2001), whereas the isotropic samples plot along the curve, showing that the measured perimeter of the foliated rocks imply lower LA - values than obtained in the actual LA tests. For instance CHW7 would have a predicted LA value of 17 instead of the measured 23.4. This confirms that the degree of foliation must be taken into consideration when comparing the perimeter measurements with the LA tests. One exception is CHW10, which shows a foliation (FIX = 1.61) but showing the same features as isotropic rocks. This can be explained by the low content of mica in this sample. The mica content itself has a limited direct influence on the resistance to fragmentation, but if micas form plane foliation, they can interact as a large flaw and cause fracture initiation and propagation. The difference in textural character due to foliation is reflected in the perimeter measurements of foliated samples. However, the mechanical behaviour of foliated rocks is not predicted by the perimeter measurements alone. A way to include this behaviour in the perimeter measurements is to calculate the ratio between the perimeter and the FIX for the foliated samples. Figure 1b indicates that it is possible to account for the effect of foliation on a rock's resistance to fragmentation.



Fig. 1. (a) Perimeter values plotted against the LA values. The diagram show that the foliated samples plots above the curve established by Åkesson et al. (2001). (b) Relationship between the perimeter and the LA values when the influence of the foliation is taken into account, samples from Åkesson et al. (2001) are also included. The correlation coefficient is - 0.94.

## **5. CONCLUSIONS**

The texture of foliated rocks has been quantified using image analysis and optical microscopy. The measurements of the grain size from optical microscopy make it possible to quantify the degree of foliation, expressed as a foliation index (FIX). The results indicate that the mica content becomes an important parameter when forming the plane of foliation, resulting in a negative effect on the resistance to fragmentation (high LA values). The study confirmed the results from Åkesson et al. (2001) that the perimeter is a parameter that can predict mechanical properties. The relationship between the texture and the mechanical properties of foliated samples is also possible to describe in a quantitative way if both the perimeter and the FIX are taken into account. We suggest that this alternative method could be a tool to predict rocks suitability as an aggregate as it gives a better understanding of the material properties compared to mechanical testing.

## **6. REFERENCES**

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