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An automatic method for segmentation of fission tracks in epidote crystal photomicrographs

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ABSTRACT

Manual identification of fission tracks has practical problems, such as variation due to observer–observation efficiency. An automatic processing method that could identify fission tracks in a photomicrograph could solve this problem and improve the speed of track counting. However, separation of nontrivial images is one of the most difficult tasks in image processing. Several commercial and free softwares are available, but these softwares are meant to be used in specific images. In this paper, an automatic method based on starlet wavelets is presented in order to separate fission tracks in mineral photomicrographs. Automatization is obtained by the Matthews correlation coefficient, and results are evaluated by precision, recall and accuracy. This technique is an improvement of a method aimed at segmentation of scanning electron microscopy images. This method is applied in photomicrographs of epidote phenocrystals, in which accuracy higher than 89% was obtained in fission track segmentation, even for difficult images. Algorithms corresponding to the proposed method are available for download. Using the method presented here, a user could easily determine fission tracks in photomicrographs of mineral samples.

1. Introduction

Fission tracks are dislocated zones caused by nuclear fragments released in spontaneous fission of uranium-238. Information about fission tracks can be related to geologic events, as mineral crystallization age, geologic fault zones and thermal events (Wagner and Van den Haute, 1992).

Tracks crossing a polished mineral surface can be etched and visualized under an optical microscope, and its selection is based on the following relatively simple criteria (Fleischer and Price, 1964; Price, 2005):

- fission tracks form straight line defects of a limited length (<20 μm);
- they exhibit no preferred orientation and disappear after suitable heating.

Manual identification of fission tracks has some practical problems, such as variation due to observer–observation efficiency. Also, Gleadow et al. (2009) list some problems in discrimination of fission tracks from non-track defects as polishing scratches and resolving multiple track overlaps and small tracks amongst a similarly sized background of surface defects.

An automatic identification of fission track could solve this problem and improve the speed of track counting. Image processing can be used to automatize such task; however, separation of nontrivial images is one of the most difficult tasks in image processing (Gonzalez and Woods, 2008). Several commercial and free softwares are available for this purpose. Nonetheless, these softwares are meant to be used in specific images (Usaj et al., 2011).

1.1. Proposed methodology

In this paper we propose an automatic method based on starlet wavelets, in order to segment fission tracks in images of natural minerals obtained by optical microscopy. Commonly used objective lenses (dry or oil immersion type) have total magnification up to 1500 times. In combination with a reflected-transmitted light system, it is possible to analyze fission tracks (Wagner and Van den Haute, 1992; Gleadow et al., 1986).

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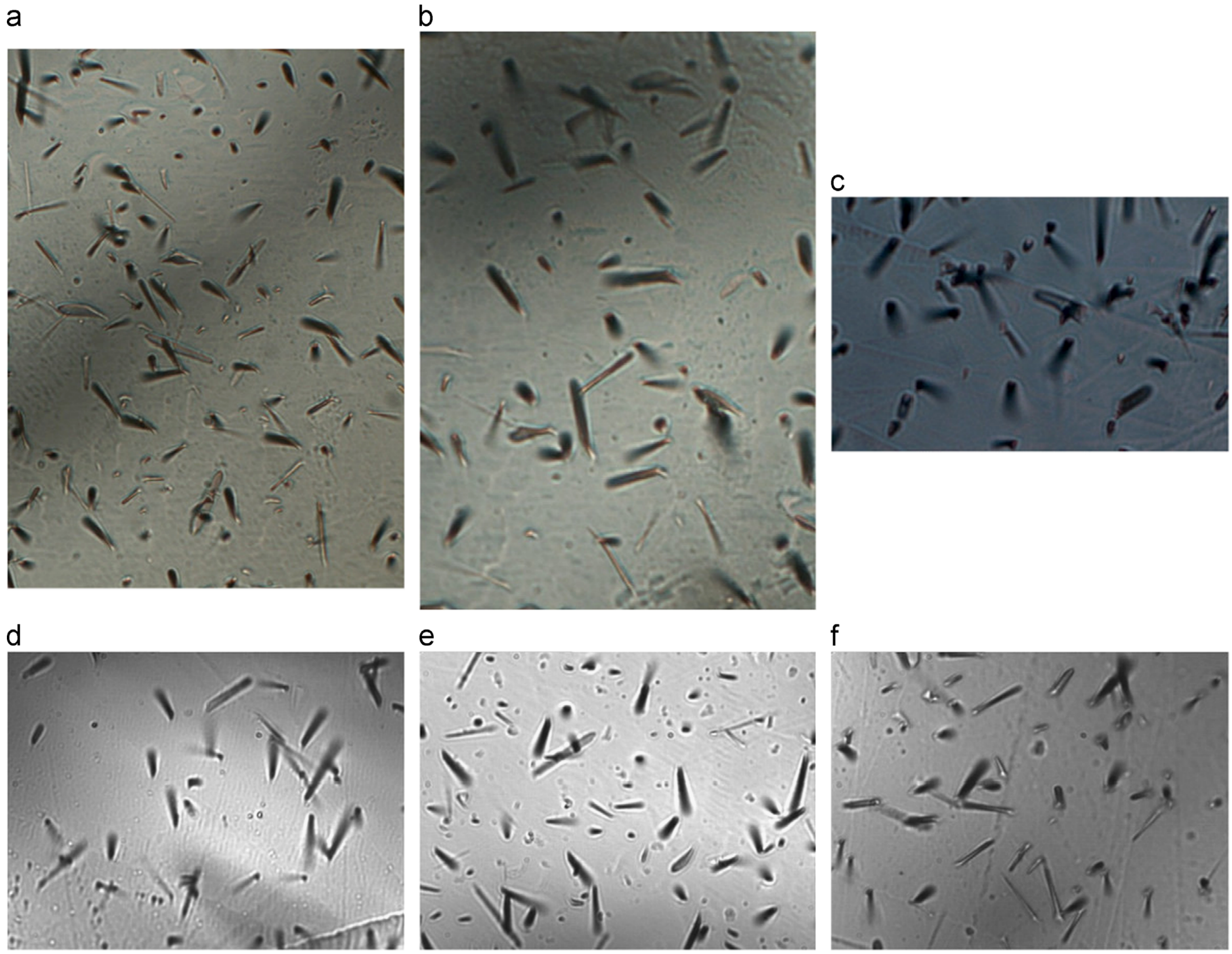

Fig. 1. Photomicrographs of epidote phenocrystals. Fission tracks are shown on the sample surface as dark segments. Nominal magnification factor: 1000 × (dry). (a) 668 × 909 pixels, (b) 445 × 649 pixels, (c) 501 × 321 pixels, (d) 766 × 575 pixels, (e) 766 × 575 pixels, (f) 766 × 575 pixels.

The proposed approach consists of applying starlet wavelets in a sample image to obtain its detail decomposition levels. This technique is an improvement of a recent study aimed at segmentation of scanning electron microscopy images (de Siqueira et al., 2014). An application of this method is the separation of fission tracks in images of natural minerals, such as volcanic glasses, apatite, zircon, muscovite, epidote, among others.

In this paper, the proposed methodology is applied to segment fission tracks in photomicrographs of epidote crystals. Results presented in this study will be used as a basis to develop an open source software capable of extracting fission tracks from images of natural mineral samples in order to establish the age of the material using the fission track dating method (Wagner and Van den Haute, 1992). A prototype of this software, containing the algorithms used in this study, is available for download on this journal website (see Appendix A).

The remainder of this paper follows. Section 2 introduces the material used in this study and starlet wavelets, as well as an overview of evaluation and automatization methods. Next, Section 3 presents the results from this method application in test photomicrographs. Moreover, the method performance is discussed. In the following, Section 4 presents the final considerations about this study. Finally, Appendix A explains where to obtain the cited algorithms and how to use them.

2. Material and methods

2.1. Epidote crystals

Epidote is a mineral with monoclinic crystal structure and general formula $Ca_2(Al,Fe)_3Si_3O_{12}(OH)$ (Ito, 1950). According to Poli and Schmidt (2004), it is possible to have epidote formation at temperatures of 500–700 °C (pressure range of 0.2 to 0.6 GPa), and also at 720–760 °C (pressure range of 1.6 to 3 GPa). Their formation is given by different means. One of them is deuteric action, during the late phase of magmatic crystallization stage, by regional metamorphism and hydrothermal activity, i.e. percolation of solutions which chemically react with the rock through fractures, often in temperatures between 300 and 500 °C (Bar et al., 1974).

In order to evaluate the proposed methods, we used a data set consisting of 45 images. These images were obtained from epidote phenocrystals using a Carl ZEISS optical microscope with Axiocam Imager.M1m system, nominal magnification factor of 1000 × (dry) and transmitted light.

2.2. Starlet transform

Starlet wavelet transform is an isotropic redundant wavelet based on the algorithm *"à trous"* (with holes) (Holschneider et al.,