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Detection of pre-defined boundaries between hydrothermal alteration zones using rotation-variant template matching ☆

Frank J.A. van Ruitenbeek[a,*], Harald M.A. van der Werff[a], Kim A.A. Hein[b], Freek D. van der Meer[a,c]

[a]*Department of Earth Systems Analysis, International Institute of Geo-information Science and Earth Observation (ITC), P.O. Box 6, 7500 AA, Enschede, The Netherlands*

[b]*School of Geosciences, University of the Witwatersrand, Johannesburg, P. Bag 3, 2050, WITS, South Africa*

[c]*Faculty of Geosciences, University Utrecht, PO Box 80.021, 3508, TA Utrecht, The Netherlands*

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Abstract

A new method for the detection of pre-defined boundaries in single-band image data that uses a rotation-variant template matching (RTM) algorithm is presented. This algorithm matches a miniature image of a pre-defined boundary to image data at various orientations. The image pixels that match boundary criteria are reported in output imagery together with the rotation angle of the template. The method is applied to identify boundaries between hydrothermal alteration zones in processed airborne hyperspectral imagery, based on the presence of white mica minerals. Results show that boundaries identified with RTM are relatively free of noise and more coherent than those identified with, for instance, image slicing techniques. Identified boundaries can be used for image segmentation. The output of the RTM algorithm also provides information on the type of boundary, whether it is crisp or gradual. This information can be used to better characterize mineral variation in the alteration halo associated with fossil hydrothermal systems.

Keywords: Boundary detection; White mica; Imaging spectroscopy; Template matching

1. Introduction

Airborne imaging spectroscopy allows identification of surface mineralogy at high spatial resolution for certain groups of minerals (Kruse, 1988; Van der Meer and de Jong, 2001). In areas of abundant rock outcrop, limited presence of weathered materials, and sparse vegetation cover, surface mineral associations reflect conditions that prevailed when minerals were formed by, for instance, hydrothermal alteration, metamorphism, and sedimentary deposition. The high spatial resolution in which mineralogical information is obtained and the continuous coverage enables identification and mapping of mineral zoning across the exposed rock. Furthermore, zones of mineral variation or mineralogical boundaries, possibly reflecting changing conditions during formation or later processes

☆ Code available from server at http://www.iamg.org/CGEditor/index.htm.

*Corresponding author. Tel.: +31 53 4874280.

E-mail address: vanruitenbeek@itc.nl (F.J.A. van Ruitenbeek).

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affecting the rock, can be mapped and aid the study of paleo-conditions.

A mineralogical boundary in rock can be defined as an area of certain width in between two areas of homogenous mineralogy. The boundary zone then reflects the change in mineralogy from the first to the second homogenous area. In this way, the boundary can be characterized in terms of the two mineral assemblages on either side of the boundary zone, as well as the width and the strike of the boundary.

Identification of pre-defined boundaries in image data is not straightforward when using common pixel-based techniques. It would first require classification of the image data into two mineralogical classes, each reflecting the mineralogy on one side of the boundary. Subsequently, the classified data must be interrogated manually in order to extract exactly those boundary zones that meet the criteria, which is inefficient and also subjective.

In this paper, we present an alternative method which directly detects pre-defined boundary zones using a rotation-variant template matching (RTM) technique. This technique was originally developed by Van der Werff et al. (2007) who detected pre-defined boundaries between spatially coherent zones by fitting a miniature-image of the boundary zone (the template) to hyperspectral imagery at various rotation angles. The output is a series of likelihood images indicating the presence of a boundary. We have modified this implementation to make it suitable for detection of boundary zones in single-band floating-point images. Instead of generating a series of likelihood images, the implementation described in this paper generates a series of points that exactly match pre-defined boundary criteria.

This new implementation of the RTM technique has been used to identify mineral zones in the footwall of the Kangaroo Caves volcanic massive sulfide deposit in the Soanseville greenstone belt in the Pilbara block, Western Australia (Fig. 1). Zones of chlorite and white mica minerals in this fossil Archean hydrothermal system have been interpreted as part of the alteration halo that formed during massive sulfide deposition (Brauhart et al., 1998, 2000; Van Kranendonk et al., 2006; Van Ruitenbeek et al., 2005). Direct detection of various boundary zones between alteration facies may be used in reconstructing fossil hydrothermal conditions and in segmentation of airborne imagery into spectrally defined alteration zones.

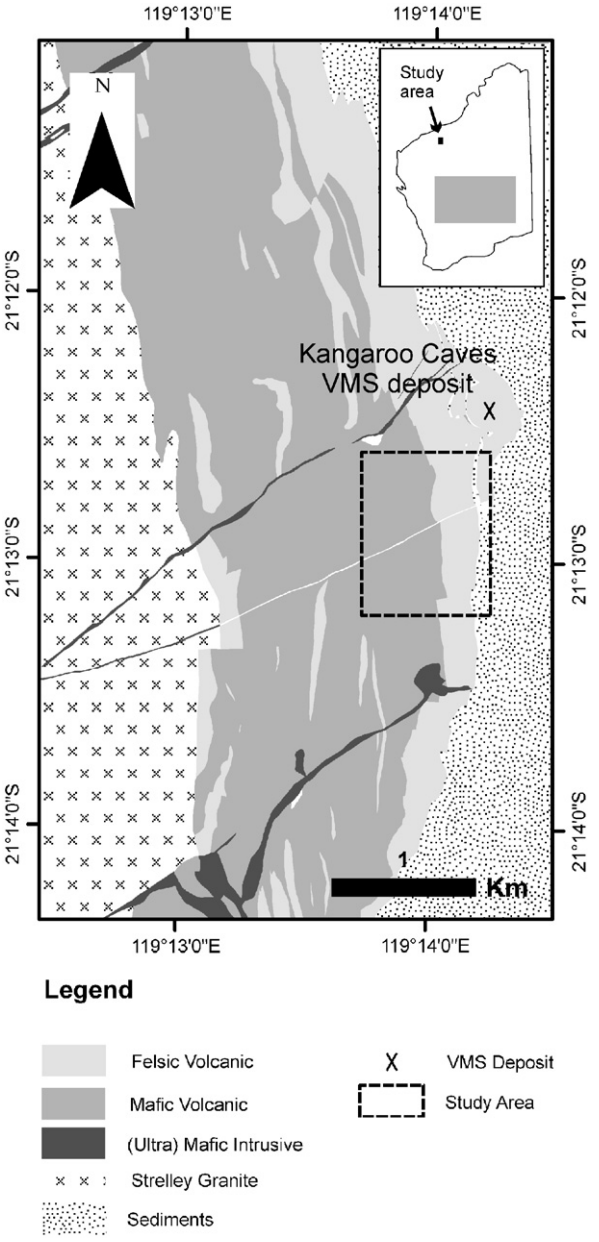

Fig. 1. Outline and geology of study area. Geology after Brauhart et al. (1998) and Van Kranendonk (2000).

2. Methods

2.1. The RTM algorithm

Template matching is a pattern recognition technique that is widely used for detection of objects in gray-level images (Tsai and Chiang, 2002). In the past, it has been applied for machine vision such as optical character recognition, face detection, object