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ScienceDirect

Advances in Space Research xxx (2018) xxx–xxx

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

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Lithological discrimination using ASTER and Sentinel-2A in the Shibanjing ophiolite complex of Beishan orogenic in Inner Mongolia, China

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Received 4 October 2017; received in revised form 20 June 2018; accepted 22 June 2018

Abstract

The Shibanjing ophiolite complex, located in the Mingshui-Shibanjing-Xiaohuangshan ophiolite belt of Beishan collage, is one of the most important components in the Beishan orogenic belt, Inner Mongolia, China. It comprises tectonic slices of ophiolite rocks including mylonitic gabbros, meta-ultramafic rocks, metabasalts, and clastic rock in a matrix of turbidites, and the mélange contains blocks of schists, gneiss, and marble. In this study, multispectral data Sentinel-2A and ASTER were employed to discriminate lithological units in the unvegetated arid region. Several image enhancement algorithms, including Band Ratio (BR), Principal Components Analysis (PCA), Minimum Noise Fraction (MNF), and Support Vector Machine (SVM), were applied to the data for lithological mapping. A specialized band ratio, (Sentinel-2A band 3+ASTER band 9)/(Sentinel-2A band 12+ASTER band 8), combining ASTER and Sentinel-2A data was designed to distinguish serpentine minerals in the ophiolite complex. Color composites of principal components (PCs) of ASTER and Sentinel-2A data were utilized to differentiate rock units within the ophiolite complex. It was found that the color composites of PCs of Sentinel-2A have higher color contrast and saturation than ASTER, enabling to better visually interpret the ophiolite rock units and provide a more detailed geological map of the study area. The SVM classification results of the original and MNF versions of the ASTER data indicate that the image processing methods such as MNF could highlight specific rock units and improve classification accuracy. In addition, with the comparison between MNF images for lithological classification of Sentinel-2A and ASTER data, it was demonstrated that Sentinel-2A data outperformed ASTER in lithological mapping in the Shibanjing ophiolite complex.

Keywords: Remote sensing; Sentinel-2A; ASTER; Lithological Mapping; Ophiolite complex

1. Introduction

The Central Asian Orogenic Belt (CAOB), also termed as the Altaid Tectonic Collage or Altaids, is one of the largest and most complicated accretionary orogenic belts in the world. It contains vast areas of Kazakhstan, Russia, Mongolia, China, and their surroundings, is about 5.3 million square kilometers, as shown in Fig. 1a (Xiao et al., 2008). The CAOB is a collage of the amalgamation of magmatic arc, seamounts, and microcontinents, with the concomitant formation of accretionary complexes and dismembered ophiolite mélanges (Song et al., 2013; Xiao et al., 2008, 2009). Three major continental cratons

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https://doi.org/10.1016/j.asr.2018.06.036
0273-1177/

Please cite this article in press as: Ge, W., et al. Lithological discrimination using ASTER and Sentinel-2A in the Shibanjing ophiolite complex of Beishan orogenic in Inner Mongolia, China. Adv. Space Res. (2018), https://doi.org/10.1016/j.asr.2018.06.036

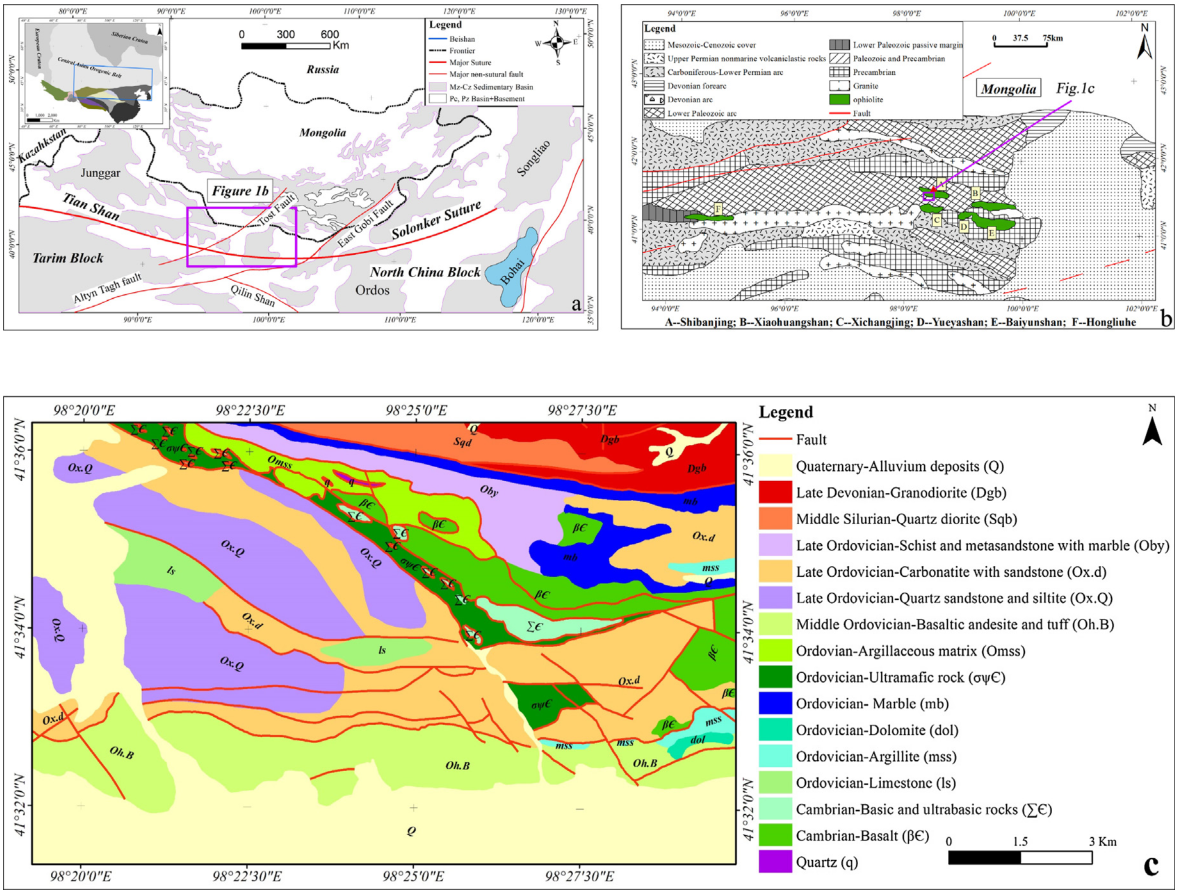

Fig. 1. (a) simplified tectonic map of the southern and eastern CAOB, modified after Jolivet (2017); Song et al. (2013); Xiao et al. (2009). Pc, Pz, Mz, and Cz represent Precambrian, Paleozoic, Mesozoic and Cenozoic, respectively; (b) simplified geological map of the western Beishan orogenic belt, modified after Davis and Marc (2001); and (c) Geological map of the Shibanjing ophiolite.

surround the CAOB, including the Siberia Craton, the Tarim Craton, and the North China Craton (Fig. 1a).

The Beishan orogenic belt, located in the Siberian-Kazakhstan-Tarim plate border region, is a complex convergent zone along the southern margin of CAOB (Fig. 1a; Xiao et al., 2009; Zheng et al., 2013). It is a crucial tectonic connection, joining the southern Tianshan suture to the west with the Solonker suture to the east (Xiao et al., 2009). The orogenic belt is composed of several arc belts that are separated by ophiolite belts (Mao et al., 2012). The ophiolite complexes attract much attention recently, representing the vanished oceans between blocks, which provide significant evidence to understand the tectonic evolution history of orogenic belts and the sutures of the ancient oceanic lithosphere (Miao et al., 2008). These ophiolite belts and related magmatic rocks in the Beishan orogenic belt play a significant role in the understanding of the tectonic evolution of Beishan orogenic belt. The Shibanjing ophiolite mélange, as one of the most important ophiolite complexes located in the Beishan orogenic belt, was selected for this study.

Due to the vast Gobi Desert, inconvenient traffic and the complex structural and metamorphic history in the Beishan orogenic belt, detailed field investigation is time-consuming and challenging. Remote sensing data, such as aerial and satellite multispectral and hyperspectral imagery, have been successfully utilized for identifying altered minerals for deposits as well as lithological mapping in arid and semi-arid regions for decades (e.g., Emam et al., 2016; Ge et al., 2016, 2018; Qari, 1989; Rothery, 1984; Rowan et al., 2003). One of the major advantages of geological mapping using remote sensing imagery is the ability to generate lithological or mineralogical maps over large areas rapidly and efficiently. Common multispectral data, such as Landsat series and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery, have been efficiently applied to map ophiolite complexes in arid and non-vegetation in recent decades (e.g., Emam et al., 2016; Grebby et al., 2010; Harding et al., 1989; Rajendran et al., 2012, 2014). Abrams et al. (1988) and Rothery (1984) demonstrated that Landsat Thematic Mapper (TM) data have the capacity to distinguish apparently different rock types and to allow consistent mapping across the Oman ophiolite complexes. ASTER imagery contains more multispectral bands and spans wider spectral ranges than TM imagery, and is more widely applied to discriminate mineral compositions and lithologic units than Landsat series data. For example,

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