International Journal of Applied Earth Observation and Geoinformation 26 (2014) 205–216

Contents lists available at ScienceDirect

International Journal of Applied Earth Observation and Geoinformation

journal homepage: www.elsevier.com/locate/jag

Lithological and mineralogical survey of the Oyu Tolgoi region, Southeastern Gobi, Mongolia using ASTER reflectance and emissivity data

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ARTICLE INFO

Article history:
Received 12 March 2013
Accepted 5 July 2013

Keywords:
ASTER
Oyu Tolgoi
SWIR
TIR
BRLO model
Matched filtering

ABSTRACT

The Oyu Tolgoi porphyry Cu–Au deposits, Southeastern Gobi, Mongolia, are estimated to be among the world's largest reserves. Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) reflectance and emissivity data were used to map distribution patterns of hydrothermal alteration and igneous rocks, and to locate areas with potential mineral deposit in the Oyu Tolgoi region. To obtain more accurate information for the detection and classification of minerals, pre-processing such as crosstalk correction and additional radiometric correction was performed. The shortwave infrared band ratio logical operator (SWIR-BRLO) models and matched filtering were used to map alteration zone and minerals in the Oyu Tolgoi region. These results were fairly consistent with mineralogical information of previous researches. In addition, we identified mineral potential areas with characteristics similar to the Oyu Tolgoi Cu–Au deposits. In particular, in the northwestern part of the OT North Pluton, an extensive area predicted to be an argillic zone was newly detected. ASTER Level 2B surface emissivity data was effectively used for lithological mapping of the Oyu Tolgoi region. The new thermal infrared band ratio logical operator (TIR-BRLO) models could detect areas showing emissivity features of quartzose and alkalic rocks. These results indicate that despite some limitations, ASTER data can provide basic information in the initial steps of ore deposit exploration, or when mapping the distribution of altered, quartzose and igneous rocks, especially in areas where direct field survey is difficult.

1. Introduction

There has been an increased interest in Central Asian countries that are rich in mineral resources due to the rise in mineral prices. Mongolia has received particular attention as a country for mineral exploration. However, most of the region is difficult to access due to harsh climatic conditions and poor infrastructure. The Oyu Tolgoi region is located within a distance of approximately 600 km south of Ulaanbaatar (Fig. 1a). This region is situated in the Central Asian Organic Belt, in which several important mineral deposits have been discovered during the last decade (Blight et al., 2008). The Oyu Tolgoi porphyry Cu–Au deposits (Fig. 1c), which are among the major deposits discovered in the Southeastern Gobi region, have been estimated to be one of the world's largest reserves, at approximately 11.43 million tons of Cu and 13.1 million ounces of Au, with an additional inferred Cu resource of 12.38 million tons, and 13.3 million ounces of Au (Ivanhoe Mines Ltd, 2010). The Southeastern Gobi region has favorable conditions for the identification of spectral features of deposits using remote sensing techniques because this region has a dry continental desert climate with annual precipitation of only around 116 mm, relatively well exposed bedrock, and scarce vegetation (Son et al., 2012).

Several studies using multi- and hyper-spectral images have been published in order to identify distribution patterns of minerals, or to detect hydrothermal alteration zones which may contain valuable ore deposits (Loughlin, 1991; Crosta et al., 1998; Rowan and Mars, 2003; Galvao et al., 2005; Di Tommaso and Rubinstein, 2007; Mars and Rowan, 2006, 2010; Bedini, 2011). van der Meer et al. (2012) presented an overview of nearly 30 years of science at the interface of geology and remote sensing. The Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER), which is one of the multi-spectral satellite imageries, is suitable for the detection of spectral properties of minerals. It has three bands in the visible/near infrared (VNIR) wavelength region between 0.52 and 0.86 μm, six bands in the short wave Infrared (SWIR) from 1.60 to 2.43 μm, and five bands in the thermal infrared (TIR) from 8.125 to 11.65 μm, with 15 m, 30 m, and 90 m spatial resolution, respectively, in three subsystems (Table 1; Yamaguchi et al., 1998; Abrams, 2000). The VNIR region provides information about the absorption of light in transition metals such as iron. The spectral

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http://dx.doi.org/10.1016/j.jag.2013.07.004

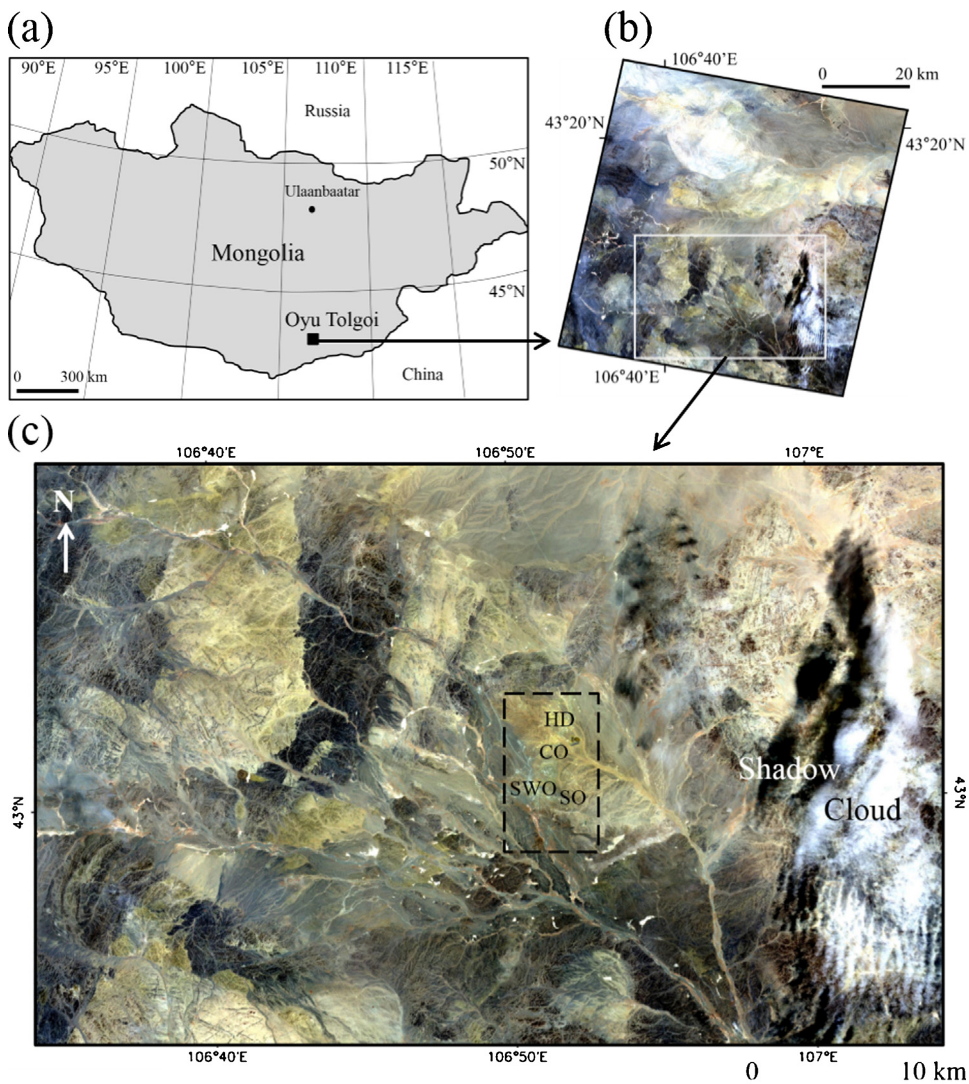

Fig. 1. Location map of study area (a) and full ASTER Level 1B scene (b). Subset color composite image of the Oyu Tolgoi region. RGB is band 3, band 2, and band 1, respectively (c). Dashed line in (c) is Oyu Tolgoi deposit area: Hugo Dummett (HD); Central Oyu (CO); Southwest Oyu (SWO); South Oyu (SO).

features of carbonate, hydrate, and hydroxide minerals appear in the SWIR region (van der Meer, 1995; Clark, 1999). Major minerals composing the earth crust such as quartz and feldspar do not appear as spectroscopic features in the SWIR region. However, most of them exhibit important spectral features in the TIR and are detectable with the ASTER TIR band set (Rowan and Mars, 2003; Hecker et al., 2010).

Table 1
Performance parameter for the ASTER ((m)*: spatial resolution).

Subsystem (m)*	Band number	Spectral range (μm)
VNIR	1	0.52–0.60
(15 m)	2	0.63–0.69
	3N	0.78–0.86
	3B	0.78–0.86
SWIR (30)	4	1.60–1.70
	5	2.145–2.185
	6	2.185–2.225
	7	2.235–2.285
	8	2.295–2.365
	9	2.360–2.430
TIR (90)	10	8.125–8.475
	11	8.475–8.825
	12	8.925–9.275
	13	10.25–10.95
	14	10.95–11.65

The purpose of this study is to map distribution patterns of hydrothermal alteration and igneous rocks in the Oyu Tolgoi region including Oyu Tolgoi and Hugo Dummett Cu–Au deposits (Fig. 1c) using ASTER data and previously published geological studies without direct access, and to identify mineral potential areas having characteristics similar to the Oyu Tolgoi Cu–Au deposits.

2. Geological setting

The regional geology of Oyu Tolgoi consists of Siluro-Carboniferous sedimentary and volcanic sequences, which are dominated by terrigenous sedimentary and intermediate to felsic volcanic rocks (Fig. 2). These sequences are intruded by Devonian syenite and granite, and by Carboniferous diorite, granite, granodiorite, and syenite bodies, ranging in size from dikes to batholiths. The Permian, REE (Zr, NB)-rich peralkalic granite complex located to the east of the study area at Khan-Bogd (or Han-) intrudes Siluro-Devonian volcanic and sedimentary rocks (Perello et al., 2001; Kovalenko et al., 2006).