

Alteration zone mapping for detecting potential mineralized areas in Kaladawan of north altn tagh using ASTER data

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Abstract. The Kaladawan area has been found developing intense hydrothermal altered rocks associated with mineralized area such as Kaladaban Pb-Zn deposit, A-bei Ag-Pb deposit during earlier geological investigations. Yet the sparse vegetation cover and excellent bedrock exposure make it a suitable place for the use of remote sensing methods for lithological mapping. ASTER data has been used in this study to identify alteration zones, and then to detect potential mineralized areas. Band ratio and PCA procedures were applied based on the analysis of spectral properties of typical alteration minerals. Band4/2 and mineralogic indices proposed by Ninomiya were designed to map the distribution of Fe-oxides and alteration zones. Selected bands combinations were transformed in a PCA procedure to map the Al-OH, Mg-OH, CO₃²⁻ and Fe-oxides altered minerals. The analysis focused on the spatial distribution of hydrothermal altered minerals. Band ratio result images including both Fe-oxides and mineralogic indices show high-level similarity with the PCA transform procedure. They both show intense hydrothermal alteration zone in Kaladaban, west Kaladawan and A-bei area. Hence, these areas are considered to have potential for further mineralogic exploration. The results were validated by field work in the Kaladaban and west Kaladawan area, indicating that this method can be a useful tool for detecting potential mineralization area in Kaladawan and similar areas elsewhere.

1. Introduction

The Kaladawan area, in the southeast part of Xinjiang Uygur Autonomous Region, China (Figure 1), is mainly characterized by complexly folded and faulted late Cambrian Volcanic-sedimentary rocks. The rugged terrain and extremely arid conditions making geological investigation in this area a challenge, however, it resulted in a sparse vegetation cover and excellent bedrock exposure. This area has no reported remote sensing studies, earlier geological investigations show that intense alteration including Fe-oxides, jarositic argillic, and phyllic rocks are very common in the known mineralized area surface (CHEN, 2009; LIU, 2010). These conditions make this area a suitable place for remote sensing investigation like lithologic mapping, especially hydrothermally altered rocks.

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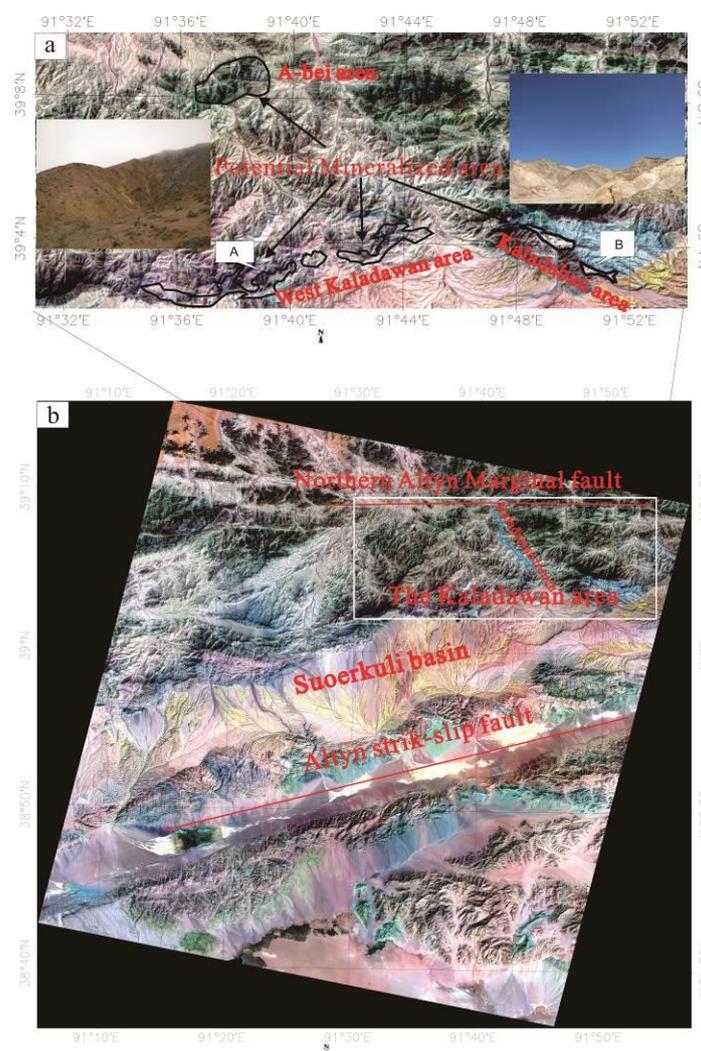


Figure1. Location of Kaladawan area of north Alyn tagh in the applied ASTER scene (R: band7, G: band3, B: band1); a-potential mineralized area illustrated by polygons; b-white rectangle show the extent of Kaladawan area, red line is the main faults in this area

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an advanced multispectral satellite imaging system, which was launched on board of the TERRA spacecraft in December, 1999 by NASA and METI (Japan's Ministry of Economic Trade and Industry). It measures reflected radiation in VNIR (0.52 and 0.86 μm), SWIR (1.6 to 2.43 μm), and emitted radiation in TIR wavelength region (8.125 to 11.65 μm) with 3, 6, 5 bands and 15m, 30m, 90m resolution, respectively. The swath-width is 60 km, but ASTER's pointing capability extends the total cross-track viewing capability to 232 km (Fujisada, 1995). Since 2000, ASTER has been successfully used for hydrothermal alteration mineral mapping in well-exposed areas. Methodologies have been proposed by different authors in order to distinguish altered and unaltered rocks in different investigated areas, including band math operations like Band ratio and Relative Absorption Band Depth (Rowan, Mars, & Simpson, 2005); as well as complex statistical approaches like spectral matching (Mars & Rowan, 2006). Principle Component Analysis (PCA) (Zhang et al., 2009; LV et al., 2009).

The purpose of this study is to evaluate ASTER data for mapping altered minerals in Kaladawan area in order to detecting the potential mineralized areas. The spectral properties of main types of

alteration minerals including Fe-oxides, Al-OH, Mg-OH and CO_3^{2-} were analyzed as a basis for analysis. Image processing techniques including band ratio and PCA were tested and compared to map alteration minerals in this area. The analysis focuses on the spatial distribution of the main types of hydrothermally altered rocks as a means of determining the general extent of potential mineralization area.

2. Geological setting

The Kaladawan area of northern Altyn Tagh, tectonically belongs to the Tarim plate, was sandwiched between NE-trending Altyn strike-slip fault and EW-trending northern Altyn marginal fault (CUI, 1999). The outcrops are mainly composed of the Zhuoabulake and Simierbulake formation (Figure 2), which are mainly late Cambrian volcanic and volcanic-sedimentary rocks, including tuffs, slates, rhyolite, dacite, and tuffaceous sands. Intrusive rocks are mainly composed of early paleozoic era granites, granodiorite, etc (HAN, 2012). Holocene alluvial and eolian deposits, mainly gravel cover some of the study area.

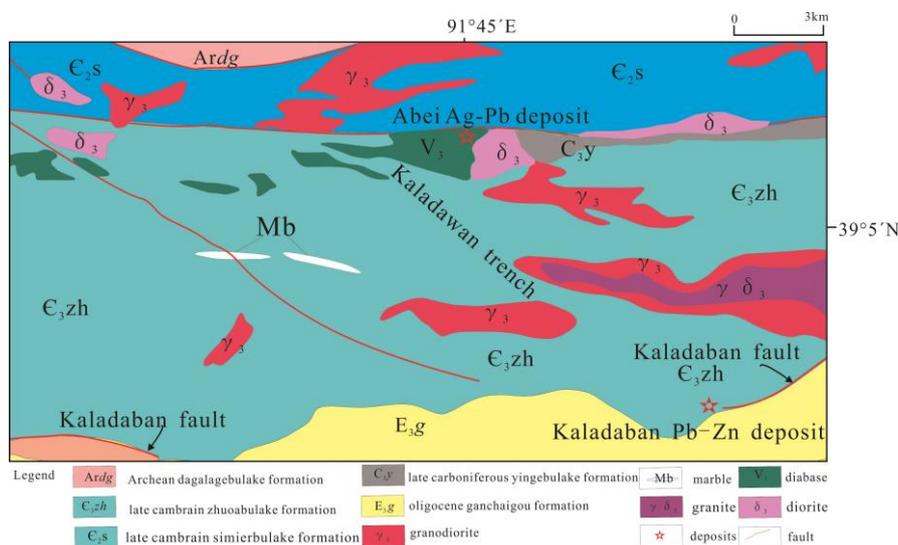


Figure 2. Geological map of Kaladawan area (modified after Bureau of Geology and Mineral Resources of Xinjiang, 1980, scale: 1:200000)

Due to the natural conditions and other reasons, geological investigations level in this area is relatively low. The notable deposits in this area, such as Kaladaban Pb-Zn deposit, A-bei Ag-Pb deposit (Figure 1) have been found less than 10 years, the ore-forming mechanism is still under discussion (CHEN, 2009). Hence, there is no detailed geological map can be used as a reference. This study will use the earlier field work taken by the author in 2012 using precise GPS investigation (Figure 1a) in Kaladaban Pb-Zn deposits and west Kaladawan as a reference, in order to judge whether the mapping results fits the reality.

3. Alteration mineral mapping techniques

3.1. ASTER data & pre-processing

One ASTER cloud-free level 1B scene acquired on Aug 15, 2004 has been applied in this study. The 6-bands SWIR were resampled from 30m to 15m in order to overlaid to the 3-bands VNIR region. Cross-talk correction were performed through the software available from www.gds.aster.ersdac.or.jp in order to removing the effects of energy overspill from band 4 into bands 5 and 9. Atmospheric correction were performed using IARR (internal average relative reflection) method by ENVI 4.8.

3.2. Spectral properties

ASTER SWIR wavelength region have 6 band passes, providing sufficient resolution to define distinct spectral shapes for different minerals such as carbonate, hydrate and hydroxyl-bearing sulfate, silicate and other minerals that contain significant SWIR absorption features (Rowan & Schmidt, 2006).

According to numerous studies by different authors (Clark et al., 1993; Zhang et al., 2009;), common alteration minerals like kaolinite, alunite, jarosite, muscovite, calcite and so on, they all have different yet detectable spectral features in different ASTER bands results from molecular or electronic mechanism such as Al(Mg)-OH, CO_3^{2-} , Fe^{3+} (LV et al., 2009). Alteration minerals contain Al(Mg)-OH exhibits absorption feature located near $2.20\mu\text{m}$, $2.30\mu\text{m}$ correspond to ASTER band 6 and band 8. Minerals contain Fe^{3+} exhibits intense absorption and reflect feature located near $0.92\mu\text{m}$ and $1.47\mu\text{m}$, correspond to ASTER band 3 and band 4. Minerals contain CO_3^{2-} exhibits intense absorption near $2.35\mu\text{m}$, slight absorption feature near $2.16\mu\text{m}$, which correspond ASTER band 8 and band 5. These features provides a spectral basis for using different approaches to mapping altered places in different investigated areas.

3.3. ASTER image processing techniques

Based on the spectral properties of typical alteration mineral and the geological background, two image processing techniques were selected to identify different alteration minerals, including Band ratio and PCA.

3.3.1. Band ratio

Band ratioing can maximize the signal-to-noise ratio by suppressing the expression of topography (Sabins, 1997), which is very useful for qualitative detect hydrothermal alteration minerals. ASTER band ratio technique has been widely used in geological mapping by different authors (Gad and Kusky, 2007; Amer et al., 2010). In this study, we use (1) band 4/band 2 for identifying Fe-oxides; (2) Mineralogical indices proposed by Ninomiya (2003) for identifying alteration zone, the formulas are:

$$\text{OHI} = (\text{band7}/\text{band6}) * (\text{band4}/\text{band6})$$

$$\text{KLI} = (\text{band4}/\text{band5}) * (\text{band8}/\text{band6})$$

$$\text{CLI} = (\text{band6}/\text{band8}) * (\text{band9}/\text{band8})$$

where OHI is OH-bearing mineral index, KLI is kaolinite index, CLI is calcite index. These minerals are common in hydrothermal alteration zones, they can be used as a sign to define where hydrothermal alteration happens.

3.3.2. Principal Component Analysis (PCA)

PCA is a mathematical procedure which is widely used in alteration information extraction studies, different ASTER bands were selected to perform PCA transformation based on LV (2009), they are as follows: (1) bands 1, 3, 4, 5 for identifying CO_3^{2-} minerals; (2) bands 1, 3, 4, 6 for identifying Al-OH minerals; (3) bands 1, 3, 4, 8 for identifying Mg-OH minerals.

4. Results & analysis

4.1. Band ratio

Results obtained from band ratio is a DN value image. Higher DN values in the image is considered have the similar spectral signatures to the desired minerals which were designed to map. The result images were enhanced using a 2% linear enhancing performance. High DN value pixels in each band ratio image which have spatial coherence and lied in bedrock area were selected and marked by polygons, they are considered to be the alteration zones. Figure 3 shows the OH altered zones, the distribution of kaolinite and Fe-oxides. CLI in Figure 3c which is supposed to show the distribution of calcite minerals, however, it does not have special bright pixels, this may means that this area has a low level of CO_3^{2-} altered mechanism or lack of calcite rocks. OHI and KLI in Figure 3a and 3b shows that that intense hydrothermal alteration took place in Kaladaban and west Kaladawan (Figure 3a, 3b), and Figure 3d shows that Fe-oxides mainly distributed in Kaladaban and west Kaladawan.

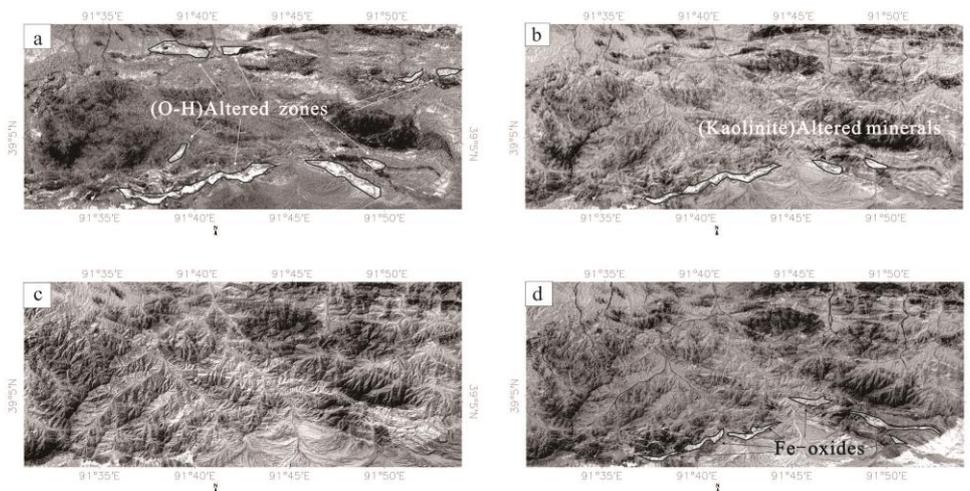


Figure3. ASTER band ratio images show altered zones in bright pixels(a-OHI;b-KLI;c-CLI;d-Fe-oxides)

4.2. PCA

The standard PCA procedure outputs are statistic factors like image eigenvectors, correlation coefficient of each PC image. The statistic factors were analyzed to decide which PC image can be used to map the target mineral based on the eigenvectors of different bands. In this study, the statistical factors were not listed. Figure 4a, b, c, d show the selected PC images that represent the target altered minerals, which are Fe-oxides, Al-OH, Mg-OH and CO_3^{2-} altered minerals respectively. Al-OH and Mg-OH altered minerals which have a close relationship with hydrothermal alteration show similar distribution in Figure 4b and 4c. In Figure 4a, Fe-oxides show slight different results with the band ratio image (Figure 3d), this may cause by the mathematical principle of the two different techniques, although they have the same results in Kaladaban and west Kaladawan area. The similar condition happens in CO_3^{2-} in Figure 4d.

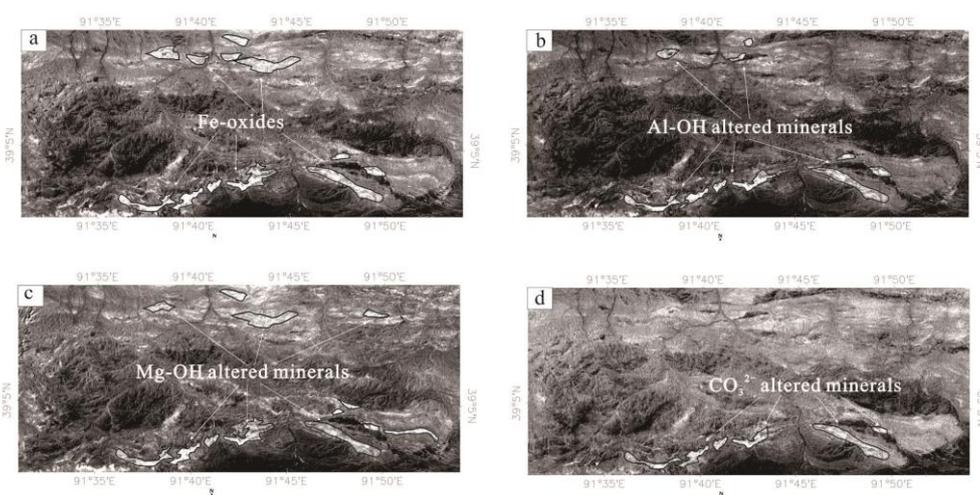


Figure4. PC images transformed from PCA procedure show altered minerals as bright pixels marked by polygons(a:Fe-oxides,PC3;b:Al-OH altered minerals,PC4;c:Mg-OH altered minerals,PC4;d:CO₃²⁻ altered minerals,PC4)

5. Discussion

The spectral properties of typical hydrothermally altered rocks provide a basis for mapping the alteration minerals using ASTER VNIR+SWIR data. Band ratio and PCA were selected for detailed alteration minerals mapping. The two methods have high-level of similarity in the mapping results, especially in Kaladaban, west Kaladawan and A-bei illustrated in Figure 1a using polygons. Both ratio result images and PCA transformation show these areas have intense alteration zone. As a result, these 3 sites were mapped as the high-potential mineralized area and worth for further investigation.

The alteration zones identified by the image processing techniques were verified through in situ inspection (digital photos in Figure 1a, sites A&B) in Kaladaban area, August, 2012. The results were proven to be effective in this known Pb-Zn deposit, indicating that these methods can be a useful tool for detecting mineralized areas in Kaladawan and similar areas elsewhere.

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