Using ASD data to identify the altered minerals for exploring of gold deposit in the Beishan area, North China

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Abstract. Hyperspectral information of altered minerals plays an important role in the identifications of mineralized zones. In this study, the altered minerals of two gold deposits from Fangshankou-Laojinchang regions of Beishan metallogenic belt were measured by ASD field Spectrometer. Many gold deposits would have a close relationship with Variscan magma intrusion, which have been found in study region. The alteration minerals have been divided six types by the spectral results, i.e. sericite, limonite, dolomite, chlorite, epidote and calcite. The distribution characteristics and formations of altered minerals were discussed here. By the ASD, the spectral curve of different geological units in the Jintanzi and Fangshankou gold deposits were analysed and summarized. The results show that the sericite and limonite are mainly related with the gold mineralization and widely occurred in the gold deposits. Therefore, we proposed that the sericite and limonite are the iconic alteration mineral assemblages for gold mineralization and the models of altered minerals for gold deposits could be established in this region.

1. Introduction

Hyperspectral remote sensing technology are widely used in mineral identification, mineral mapping, lithological mapping, mineral resources exploration, and so on, for its wide spectral bands and high spatial resolution system [1, 2]. The Hyperspectral technology system was used by researchers to recognize altered minerals information, which plays an important role to position mineralized zones and trace mineralized centre of hydrothermal alteration [3-10]. In this study, ASD field Spectrometer was used to identify the altered minerals of two gold deposits from Fangshankou-Laojinchang regions of Beishan metallogenic belt, where belongs to the Gobi hilly topography and the rocks are well bareness. So it is a favourable geological conditions and good natural environment to carry out the hyperspectral measurement.

The deposits in Beishan metallogenic belt are closely associated with magmatism [11, 12]. Different types of metal ore bodies have been documented in Shuangyingshan - Huanianshuan arc Unit [13], which had developed an Au-W-Cu-Fe-Ni magmatic hydrothermal system. The central and southern Beishan region is one of the most important gold metallogenic provinces in northwest China. Five groups of gold deposits can be distinguished according to the difference of host rocks, including (a) volcanic and volcaniclastic rocks, (b) granitoid intrusions, (c) skarn type, (d) Precambrain schists, and (e) sedimentary rocks. Gold mineralization in study area is almost confined to the gold-bearing beresite veins and the intrusions were related to gold deposits [14-16]. The gold veins mainly hosted in
the lenticular alteration zones. The hydrothermal alteration minerals contain quartz, sericite, limonite, chlorite, carbonate, epidote, iron oxides, and clay minerals [15-20]. Thus the alteration zones that have high gold concentrations can use Hyperspectral technology to identify gold ore body.

The main purpose of this study is application of ASD spectral data in determining the distribution pattern of these alteration minerals, and try to locate the potential alteration belts from these minerals.

2. Geological Setting

The study area (40°52′30″N-41°12′00″N and 94°16′00″E-95°04′30″E) is located approximately 75 km at west of side the Liuyuan town, in the Beishan mountains, showing in figure 1(a).

![Geological map of Fangshankou - Laojinchang area in Beishan.](image)

Figure 1. Geological map of Fangshankou - Laojinchang area in Beishan, (a) Location map of the Jintanzi - Laojinchang gold Mine in northwestern of China, (b) Geological setting of the Jintanzi-Laojinchang region.

The Shuangyingshan - Huaniushan arc Unit, is located in the southern margin of the Beishan epicontinental active belt, and between the tarim and sino-korean plates. The unit is a polymetallic metallogenic belt of copper, gold, silver, iron, lead, and zinc [12, 19, 20]. The study area has undergone a very complex tectonic evolution history, all stratigraphic sequences from the Ordovician to the Quaternary thus have been deformed. The mineralization and alteration are widely distributed in this region, and the main types of alterations are carbonation, chloritization, epidotization, ferritization, sericitization, and silicification [13].

The strata in the study area are mainly composed of Early Proterozoic metamorphic basement, Late Proterozoic- and Early Paleozoic- carbonates and clastic rocks, Late Paleozoic volcanic - clastic rocks and carbonates. The Paleoproterozoic rocks contain migmatite, gneiss, quartzite, and granulite. The Neoproterozoic meta-sedimentary rocks, which are marble, linstone, and meta-sandstone, emerged in the area [11]. The Early Paleozoic rocks and Late Paleozoic rocks are composed by dolostone and clastic rocks, and volcanic - clastic rocks, lava and carbonates, respectively (figure. 1(b)).

It is characterized by development of brittle fracture with active fault structures and magmatic activity. The intermediate acidic intrusive rock grows, which contains adamelite, biotite granite, granodiorite and other acidic intrusive body, minor gabbro in Variscan period and monzogranite in Indosinian period.

Systematic geological investigations indicated that there are different types of host rocks for the gold deposits and most of them showed a close genetic relation with the granitoid intrusions or Paleozoic felsic volcanic rocks [15, 18]. The forming processes of the gold deposits are genetically associated with Hercynian magmatic activities [14]. The tectonic movement and the granitoid
emplacement could provide a pass for the ascent and unloading of the deep-seated ore fluids. The Fangshankou and Jintanzi gold deposits are related with intrusion rocks.

Fangshankou gold deposit is located in the northwest part of the study area. Gold mineralization occurred in the late intrusive alteration granite, which is situated the contact zone between the granite porphyry and monzonitic granite (figure 2(a)). The gold mineralization hosted in quartz veins within the beresitization granite. Ore bodies contain three gold-bearing quartz veins, which were nearly parallel outputs, with the attitude of $230^\circ \angle 81^\circ$.

Jintanzi gold deposit is located in the north part of the study area, which is situated the interchange of NE and NW trending secondary faults. Gold mineralization produced in the late intrusive cataclasis alteration granite, which is in the contact zone between the Middle Variscan moyites and Early Variscan quartz diorite (figure. 2(b)). The gold mineralization hosted in quartz fragmentation zone within the altered granite. Ore bodies contain two gold-bearing broken quartz veins, which were nearly parallel outputs, with the attitude of $345^\circ \angle 76^\circ$.

Figure 2. Geological map of Fangshankou (a) and Jintanzi (b) gold deposits.

3. Data and methods
The measurement of ground spectra were carried out under cloudless conditions from 12:00 pm to 16:00 pm in study area, by using an ASD Field Spec Pro spectrometer (Analytical Spectral Devices, Boulder, Co., USA). This spectrometer was fitted with 10$^\circ$ field of view fiber optics, operated in the 350 - 2500 nm spectral regions with sampling intervals of 1 nm. Surface reflectance measurements were taken at 20 sites over each plot, and for each measurement, the ASD spectrometer was kept stationary and the average of 100 consecutively acquired spectra was recorded to reduce the noise level. We used the average of 20 sites acquired spectra as the measured spectra.

In order to analyze the alteration zoning, a series of situ spectral measurements were carried out in Fangshankou and Jintanzi gold deposits for different geological units with ASD instrument.

3.1. The Spectral measurements in Jintanzi gold deposit
ASD ground spectral measured different rocks in Jintanzi gold deposits. Spectral characteristics of different rocks in this area are as follows:
3.1.1. Quartz diorite. There are six absorption bands for altered quartz diorite in Jintanzi gold deposit, showing in Fig. 3(a). The Fe$^{3+}$ and Fe$^{2+}$ absorption was at wavelengths between 600 to 750 nm, 750 to 1000 nm, 1000 to 1200 nm, and the peak was gentle. Al-OH absorption, with shallow peak, was occurred at wavelengths between 2190 to 2220 nm. Fe-OH bands are located at wavelengths of 2250 nm. Mg-OH bands are shown at wavelengths between 2320 to 2360 nm. All these absorption peaks are associated with the alteration of surrounding rocks of the chloritization, epidotization, weak sericitezation.

3.1.2. Sericite crushed rock. As showing in figure 3(b), there are also six absorption peaks for gold mineralization rock in mylonitized fracture zone. Its original rock is quartz diorite and it has similar alterations with quartz diorite, which contains chlorite, epidote, and sericite absorption peaks. The Al-OH absorption, which was at the wavelengths between 2190 to 2220 nm, was obvious deep. It displayed strong sericitezation.

3.1.3. Beresitization. The beresitization has four absorption bands (figure 3(c)). The wavelengths between 600 to 750 nm, 750 to 1000 nm, are the Fe$^{3+}$ absorption and showing in intensive limonitezation. Al-OH and -OH has absorption at wavelengths of 2205 to 2345 nm, respectively.

3.2. The Spectral measurements in Fangshankou gold deposit
Spectral characteristics of different rocks from Fangshankou gold deposit are as follows:

3.2.1. Granitoid. They include including porphyry (BSY-109), monzogranite (BSY115) and granodiorite (BSY119). Spectral analysis showed that sharp absorption peaks of the Al-OH were appeared at 2207 nm, and -OH absorption peaks at 2345 nm, suggesting the attendance of the sericite minerals. At 600 to 750 nm and 750 to 1000 nm, it appeared weak Fe$^{3+}$ absorption (figure 3 (d)).

3.2.2. Phyllic altered granite. In addition to its Al-OH and -OH absorption peaks, 600 to 750nm and 750 to 1000 nm absorption bands of Fe$^{3+}$ (figure. 3 (e)), they also showed strong limonitization and obvious combination of limonite and high alumina sericite anomaly. Microscopic identification indicated phyllic occurred due to gas-liquid rock metasomatism. In the development process of faults, the rock appears a lot of pyritized phyllic vein, and both sides of the surrounding rocks were breaking contacts.

3.2.3. Beresitization. Spectral analysis of pyritized phyllic veins showed that there were two absorption peaks due to Fe$^{3+}$ ions located at 600 to750 nm and 750 to 1000 nm, sericite characteristic absorption peaks were occured at 2204 nm, -OH absorption peaks appeared at 2345 nm (figure 3 (f)).
Its anomaly types, geological features and spectral peaks are similar to the Mingjingou gold deposits [7] within the pyritized phyllic gold ore. Altogether, it showed relatively good mineralization potential of gold ore.

The cross sections in Fangshankou gold deposit were studied for which spectral analysis of the rocks. Its gold ore bodies occur in the altered crush zone, which were hosted in the cataclastic - alteration granite. The geological cross section shows, since the ore body to the periphery development silicification, limonite (pyrite), chlorite, epidote, minor carbonate, sequentially.

As a result, prospecting models of hyperspectral technology were established on the basis of the gold deposits in this region. The pyrite phyllic gold ore are the important gold mineralization type in this area and limonitzation and sericite are the important mineral alteration anomalies for gold mineralization prospecting. The typical alteration zoning section analysis showed that zoning characteristics of gold mineralization zone, representing centre limonite + sericite, which change to chlorite + epidote + weak sericite (Fig. 4). Therefore the selected iconic alteration mineral anomaly combined by the CASI/SASI was effective for the mineral prospecting. Its conclude that hyperspectral remote sensing can provide precise and reliable information for mineral exploration.

4. Conclusions
The ASD field Spectrometer was used to analyse and summarize the spectral curve characteristics of different geological units at Jintanzi and Fangshankou gold deposits. Prospecting models of hyperspectral information are established here. It investigated that mineralized bodies were related with pyrite phyllic and mylonitized alteration zone. Hyperspectral data demonstrated that limonite + sericite are the typical alteration minerals for identification of golden mineralization. Chlorite + epidote abnormal are possibly caused by the alteration of the host rocks.

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