Application of remote sensing information related to mineralization alteration and new discovery in geological prospecting work

F J Yao¹, B H Fu²

¹ MLR Key Laboratory of Metallogeny and Mineral Assessment, Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing, 100037, China
² Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing, 100094, China

E-mail: fjyao@sina.com

Abstract. As an intuitive manner, Remote Sensing (RS) can be used in resource prospecting and it shows some effects in practice, but high resolution and accuracy still remain problematic because RS methods need to be improved. Based on a RS prospecting model, prospecting resolution and accuracy can be greatly elevated. Different resources need to build various RS prospecting models. Some targets were proposed using RS exploration model. According to field examination, new discoveries have been successfully obtained in hydrothermal metal mineral prospecting, sedimentary metal mineral prospecting. Therefore the RS becomes more effective method in prospecting.

1. Introduction

RS(Remote Sensing) has received a very significant effect in geological prospecting [1-3]. Initially, some limonite alteration rocks were extracted using Landsat multispectral data in 1977 [4]. The spectral characteristics were collected about hydroxyl minerals in Visible Near-Infrared (VNIR) to Short Wave Infrared (SWIR) [5]. Remote sensing alteration anomalies were extracted using RS, specifically, Principal Components Analysis (PCA) was used to estimate the response of alteration minerals and was applied in many zones [6-7]. In 2007, China started-up a big project called ‘Mineral Resources Potential Assessment Project’, in which alteration RS anomalies extraction methods using Landsat TM/ETM were extended throughout the whole Chinese mainland regarded RS techniques as an important methods [8]. Landsat TM/ETM data could not be used to distinguish minerals or mineral assemblages according to less wave bands, but the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) remote sensor provided a high spectral resolution remote sensing data, containing 14-bands: nine bands are in VNIR-SWIR regions and the other five bands are in Thermal Infrared (TIR) region. ASTER can be used for extracting alteration minerals and studying alteration zonation [9-10]. And thermal infrared RS (e.g. ASTER TIR) could be used to study the geothermal resources [11-12]. However, the Alteration RS anomalies just indicate alterations related to hydrothermal metal minerals, but can not be used in sedimentary ore deposits prospecting. In our research, based on extraction useful RS information, the RS prospecting models were built for studied hydrothermal metal minerals, sedimentary metal ores. Finally, some targets were listed and validated in many Chinese fields, with new discoveries.
2. Data and methodology

2.1. Study Area and Data
In our work, some areas in China were chosen for prospecting the hydrothermal metallic minerals, sedimentary metallic deposits. Figure 1 showed the positions of different types of resources for the RS models and prospecting. We used different types of RS data to research specific problems included ASTER data, PALSAR data, and LANDSAT data. These data were bought from PASCO CHINA. Types of data functions and purposes are shown in Table 1. In practice work, each data must be used combined with other data, but one kind of data was main used and other data served as supplements.

![Figure 1](image-url)

Figure 1. Locations of different types of resources for our research. The hydrothermal metallic minerals is located in Figure 2, the location of the sedimentary metallic deposits is marked on Figure 3.

| RS data   | Resolution | Functions                   | Purposes            |
|-----------|------------|-----------------------------|---------------------|
| ASTER     | 15m, 30m, 90m | Group-contained anomalies    |Alteration mapping  |
| PALSAR    | 7m-44m     | Structure information       | Structural mapping  |
| LANDSAT   | 15m, 30m, 90m | Lithology information       | Lithological mapping |

2.2. Methodology
Image processing methods were chosen based on specific resources. For hydrothermal metal minerals, alteration zone RS information were main extracted. Electronic anomalies extraction and lithological recognition were used in sedimentary metal deposits. Tectonic information was extracted using radar data in overlay and coverage areas.

Firstly, ASTER data were used to study hydrothermal minerals. The extraction of the alteration zones and group anomalies through NIR-SWIR and TIR of ASTER data. We mainly used ratio and PCA methods of different bands. Secondly, weak lithology information of the sedimentary minerals could be revealed used ETM or ASTER images and electronic anomalies were extracted to indicate sedimentary minerals. Finally, Structural information interpreted by RADAR data (PALSAR). the RS model of resource explorated were built by overlying different information.

3. Image processing
3.1. The Hydrothermal Metallic Minerals

In order to achieve the surface alteration zonation, about 30 samples were collected. Each sample was measured three times using ASD spectrometer and then each spectrum was analyzed for the alteration minerals distribution using PimaView software.

In Duolong deposits surface, we mainly collected the samples: metamorphic feldspathic quartz sandstone, granite porphyry, lithic quartz sandstone, gabbro, breccia, granite, basaltic andesite, quartz porphyry, and so on. Among them, 16 samples of Duobuza deposit and 18 samples of Bolong deposit were selected with sampling unequal interval along lithology and alteration variations. The alteration of the samples are limonitization, propylitization, chloritization, sericitization etc. Major alteration zones of Duolong deposits include potassium silicification zone, phyllic zone, propylitic zone, illite-hydromica zone and gossan. Alteration minerals have difference: K-feldspar, muscovite, chlorite, quartz in potassium silicification zone, muscovite, halloysite, illite, quartz in phyllic zone, calcite, chlorite in propylitic zone, illite, montmorillonite in illite-hydromica zone, and limonite in gossan. The spectral characteristics of all alteration minerals included SWIR (short-wave infrared) and TIR (thermal infrared) were analyzed and resampled to ASTER spectral responses (Figure 2).

Figure 2. RS alteration zones of Duolong ores, Tibet. According to spectral analysis, RS alteration zones information were extracted: potassic zone was shown in red, quartz-sericitization zone in yellow, propylitization zone in brown, illite-hydromica zone in pink, and gossan in blue. These anomalies of alteration zones show ring distribution.

The hydrothermal metallic minerals mostly have alteration zones, such as porphyry copper deposits. Firstly, alteration minerals assemblages of each alteration zone were analyzed, as well as spectral absorption characteristics of these minerals. Finally, alteration zones RS mapping were done using RS. Figure 2 shows the results of RS alteration zones in Duolong ore concentration regions, Tibet.

3.2. The Hydrothermal Metallic Minerals

Image lithologic enhancement process was used to extract sedimentary metallic deposits information, such as sandstone-type copper deposits. Lithologic information extraction are main methods. The spectral characteristics of sandstone copper deposits and wall rocks are slightly different. Figure 3 show known Dishui Cu deposit position and ore-bearing bed. The spectra were collected from the position which number are 1, 2, and 3. The red spectrum was gathered from ore-bearing bed, which was difficultly distinguished, while black and green spectra gathered from wall rocks. We made the A-B profile. The spectra of ore-bearing bed were small subtleties contrasted ones of wall rocks. Therefore, the special method was needed for enhancing lithologic information. In order to extract different lithologic characteristics, the frequency domain of the RS data need to re-analyze. In the
result, the weak information were enhanced. Brown color indicated ore-bearing bed. Meanwhile, we extracted electronic anomalies. The lower anomalies were shown in sandstone copper layer.

4. Result

In order to build RS prospecting model, RS information must be extracted. More information contained geophysics, geochemistry, geology, and construction need to overlay RS information. And targets can be optimized.

4.1. Establishment of the RS Prospecting Model

The RS prospecting model is based on RS information. Firstly, some important RS factors were chosen related to the analysis of the metallogenic regularity. Secondly, RS information overlay geophysics, geochemistry, geology, and construction information on GIS platform. Finally, mineral prospecting indicators were established by analysis of different useful information and specific factors of resources exploration.

4.2. Application of RS Prospecting Model

Through the RS prospecting model of sandstone copper deposits, many sandstone-type copper mineral deposits were discovered in Kuqa basin, Xinjiang. We found three copper mineralization layers. And the widths of the layers are 1.5m, 1.3m, and 10m. The 10m-wide copper mineralization layer was found in second field profile measurements.

4.3. Assessment

Practical mineral exploration is effective using mineral RS prospecting model, but it is unable to find all mineral ores and mineralization occurrences using prediction of targets proposed by RS model. Therefore, it is inefficient using RS method in public. The RS was just regarded as “ornaments”.

Figure 3. The known Dishui sandstone-type copper RS information in Baicheng, Xinjiang. The red spectrum collected from ore-bearing bed was difficultly distinguished with black and green spectra gathered from wall rocks. The spectra of ore-bearing bed were small subtleties compared ones of wall rocks form profile A-B.
However, this job can improve the probability of RS prospecting. 1) RS is indeed a high-technical and practical method, which can be used to discovered new mineralization occurrences. 2) RS has many advantages, such as economy, environment protection, high-efficiency, and it is the most reasonable first to use RS for resource prospecting.

5. Conclusions
The RS prospecting model indicates mineral exploration in field and there are many new discoveries in the actual prospecting. Therefore, RS is indeed effective for resources exploration.

1) Different resources need to choose different RS information extraction. Group-anomalies extraction indicated alteration zone for metal hydrothermal mineral prospecting and electronic-anomalies was used for metal sedimentary mineral exploration.
2) It to apply By using the RS prospecting model to guide the mineral exploration, the prospecting probability can be improved. In field verification, many new mineral deposits and mineralization occurrences were discovered.
3) Important RS factors of mineral prospecting must be rare. For example the stratum contained sandstone-type copper deposits shown different color in RS lithologic enhanced image. For more accurate exploration, other information needs to overlay the RS information and analyze prospecting indicators.

Acknowledgments
This work was supported in part by the National Natural Science Foundation of China (No. 41102205) and Special Funds Projects for Basic Scientific Research Business Expenses of Mineral Resources Research Institutes in Chinese Academy of Geological Sciences (Nos. K1501). We thank greatly Prof. Y.J. Zhang, Prof. J.M. Yang, X.X. Geng, J. Sun for participating research. We are grateful to relevant Bureau of Geology and Mineral Exploration and its affiliated Geological parties and related leaders and staff members for their great logistical and moral support.

References
[1] Kratt C, Calvin W M, Coolbaugh M F 2010 Mineral mapping in the Pyramid Lake basin: Hydrothermal alteration, chemical precipitates and geothermal energy potential Remote Sens. Environ. 114 2297-304
[2] Rajendran S, Thirunavukkarasu A, Balamurugan G, Shankar K 2011 Discrimination of Iron Ore Deposits of Granulite Terrain of Southern Peninsular India using ASTER data J. Asian Earth Sci. 41 99-106
[3] Gabr S, Ghulam A, Kusky T 2010 Detecting Areas of High-potential Gold Mineralization Using ASTER Data Ore Geol. Rev. 38 59-69
[4] Abrams M J, Ashley R P, Brown L C, Goetz A F H and Kahle A B 1977 Mapping of hydrothermal alteration in the cuprite mining district, Nevada, using aircraft scanning images for the spectral region 0.46 to 2.36 mm Geology 5 713-18
[5] Hunt G R 1979 Near-infrared (1.3-2.4µm) spectra of alteration minerals-potential for use in remote sensing Geophysics 44 1974-86
[6] Tangestani M H and Moore F 2011 Comparison of three principal component analysis techniques to porphyry copper alteration mapping: a case study, Meiduk area, Kerman, Iran Can. J. Remote Sens. 27 176-81
[7] Crowley J K, Hubbard B E, and Mars J C 2003 Hydrothermal alteration on the cascade stratovolcanoes: a remote sensing survey Geological Society of America Abstracts with Programs 35 552
[8] Zhang Y J, Yang J M, Yao F J, Geng X X, Yu X Z 2014 Practical Technology of Multi-Spectral Remote Sensing Prospecting information (Beijing: Geological Publishing House) pp 1-10 (In Chinese with English Abstract)
[9] Amer R, Mezayen A E, and Hasanern M 2016 ASTER spectral analysis for alteration minerals associated with gold mineralization Ore Geol. Rev. 75 239-51
[10] Ding C, Li X Q, Liu X N and Zhao L T 2015 Quartzose-mafic spectral feature space model: A methodology for extracting felsic rocks with ASTER thermal infrared radiance data Ore Geol. Rev. 66 283-92
[11] Calvin W M, Littlefield E F and Kratt C 2015 Remote sensing of geothermal-related minerals for resource exploration in Nevada Geothermics 53 517-26

[12] Meer F V D, Hecker C, Ruitenbeek F V, Werff H V D, Wijkerslooth C D, Wechsler C 2014 Geologic remote sensing for geothermal exploration: A review Int. J. Appl. Earth Obs. 33 255-69