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Study on Remote Sensing Geological Prospecting in Telmusai Mining Area, Xinjiang

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Abstract

With the increasing global demand for strategic mineral resources, it is of great practical significance to investigate mineral resources such as fluorite and lepidolite in Termusayi mining area of Qiemang County, Xinjiang. The purpose of this study is to use remote sensing technology to accurately identify and locate the mineralization information of fluorite and lepomica in the mine area, so as to provide a scientific basis for follow-up geological prospecting. During the study, Landsat 8 remote sensing images were selected to successfully extract the abnormal information of iron stain and hydroxyl alteration, which can effectively indicate the potential mineralization area. At the same time, ASTER remote sensing image was used to select the appropriate band according to the band characteristics, and the principal component analysis method was used to clearly obtain the distribution diagram of fluorite and lepomica, which intuitively demonstrated the spatial distribution characteristics of these two mineral resources in the mining area. The research results not only reveal the regularity of mineralization of fluorite and lepomica in Termusai mining area, but also delineate the key target area for further geological prospecting in this area, which improves the efficiency of prospecting and reduces the cost of prospecting. The research method and results have a certain reference value for other regions to carry out similar remote sensing geological prospecting research, and help to promote the wide application of remote sensing technology in the field of geological prospecting.

Keywords

Termusayi Mining Area, Remote Sensing Geological Prospecting, Principal Component Analysis

1. Introduction

Qiemao County, Xinjiang is located in the southeast margin of Tarim Basin. It is an area rich in mineral resources, especially the distribution of strategic mineral resources such as fluorite and lepomica. Fluorite is an important raw material in the fields of chemical industry, metallurgy and new materials. Its main component is calcium fluoride (CaF_2). Under the background of the increasing demand for high-end fluorine-containing materials, the exploration and development of fluorite is of great significance [1]. As an important lithium source mineral, the demand for lithium continues to increase in the case of the surging demand for new energy vehicles and energy storage batteries, so the exploration of lepidolite has important strategic significance for the development of the national energy industry [2].

The application of remote sensing technology in mineral resource exploration has been widely recognized, especially its effectiveness in complex geological environments. Through multi-band analysis of remote sensing images, geological information related to mineralization can be extracted and the time and cost of traditional exploration methods can be reduced. Landsat 8 and ASTER remote sensing images have high spatial resolution and rich spectral bands, which can effectively identify minerals and alteration information in mining areas. Mineral resource exploration using these remote sensing data has become one of the important means in modern geological exploration [3].

Remote sensing technology has demonstrated strong adaptability and application value in the complex geological environment of the Telmusayi mining area in Qiemo County, Xinjiang. The mining area is located on the southeastern margin of the Tarim Basin, with complex geological structures, posing great challenges to the exploration of strategic mineral resources such as fluorite and lepidolite. Through multi-band analysis, using high-resolution and multi-spectral remote sensing images such as Landsat 8 and ASTER, remote sensing technology can effectively identify minerals and alteration information, overcoming the problems of low efficiency and high cost of traditional exploration methods. As an important raw material for high-end fluorine-containing materials, fluorite, and as a key lithium-source mineral in the new energy field, lepidolite, their exploration and development are of great significance to the national energy and materials industries. This study will apply remote sensing technology, with its efficient and accurate data analysis capabilities, to provide a scientific basis and technical guarantee for the exploration and development of strategic mineral resources such as fluorite and lepidolite.

In promoting the development of the remote sensing field in geology, new technologies and methods such as multi-source remote sensing data fusion technology, principal component analysis (PCA), spectral feature analysis and band selection, alteration anomaly information extraction, application of high-resolution remote sensing images, integration of geological background and remote sensing data, construction and verification of mineral exploration models, and combination of infrared remote sensing and geomagnetic technology are of great value. These technologies can effectively improve the accuracy and efficiency of mineral exploration. By extracting mineralization-related characteristic information, identifying the spectral characteristics of minerals, analyzing in combination with the geological background, and constructing and verifying exploration models, they provide a scientific basis and technical support for mineral resource exploration in complex geological environments, and promote the wide application of remote sensing technology in geological exploration. Based on the analysis of remote sensing images of Telmusai mining area, the potential distribution areas of fluorite and lepomica mineralization have been extracted in this study, which provides a scientific basis for subsequent geological exploration.

2. Regional Geological Overview

Telmusai ore deposit is located in Qiemao County, Xinjiang, in the middle of Altun orogenic belt, belonging to the metallogenic region on the northern margin of Qinghai-Xizang Plateau. Located at the junction of the Tarim Block and the Qaidam Block, the mine area is complex in geological structure and mainly consists of medium-deep metamorphic rocks, including gneiss, granulite and marble. The terrain of the mining area is relatively undulating, vegetation is scarce, and it belongs to arid and semi-arid climate zone, which provides good geological conditions for remote sensing geological prospecting [4].

Stratigraphy, the Termusai mining area is mainly dominated by Proterozoic Alginite group and Bashkurgan Group, the latter of which is mainly composed of mica quartz schist and granulite [5]. The tectonic features in the mining area are mainly east-trending faults in the north, the existence of which provides a channel for the migration of ore-forming fluids and significantly affects the distribution of ore bodies. In particular, the enrichment of fluorite and lepidolite deposits is closely related to the regional tectonic setting near the contact zone between the Altun group and the Bashkurgan Group [6]. The geological map of the study area is shown in **Figure 1**.

The Telmusayi deposit is located in the middle of the Altun orogenic belt in Qiemo County, Xinjiang, at the junction of the Tarim Block and the Qaidam Block. The geological structure is complex, mainly composed of medium-to high-grade metamorphic rocks such as gneiss, granulite, and marble. These geological features significantly influence the mineralization process. The east-trending fault structure in the northern part of the mining area provides a channel for the migration of ore-forming fluids, promoting the precipitation of minerals in suitable locations. In particular, the enrichment of fluorite and lepidolite deposits is closely related to the tectonic background of the contact zone between the Altun Group and the Bashikuergan Group. The mica-quartz schist and granulite in the Proterozoic Altun Group and Bashikuergan Group strata provide the material basis for mineralization. The high-temperature and high-pressure metamorphism promotes the activation and migration of ore-forming elements, which further accumulate in tectonic weak zones or lithological contact zones. In addition, the mining area has large topographic relief, sparse vegetation, and an arid-semi-arid climate, providing favorable conditions for remote sensing exploration. This facilitates the identification of mineralization-related information such as alteration zones and structural lines. These geological features jointly control the distribution of ore bodies and lay the foundation for the formation of the deposit and the application of remote sensing technology.

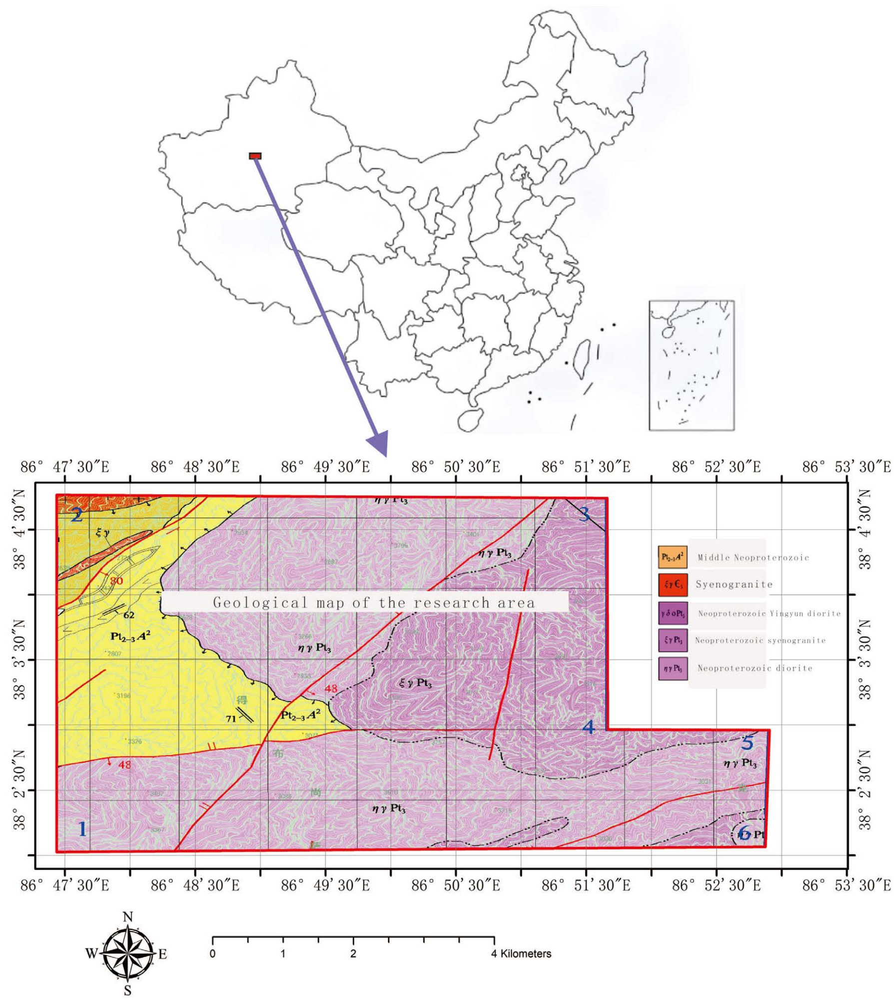

Figure 1. Geological map of the study area.

3. Research Methods and Data Analysis

3.1. Selection and Preprocessing of Remote Sensing Data

This study uses multi-source remote sensing data for geological analysis of mining areas. The selected data include ASTER, Landsat 8, Sentinel 2 and Gaofen-2 remote sensing images. These data have different spatial resolution and spectral characteristics, which can comprehensively cover the geological characteristics of the mining area. ASTER images are mainly used for mineral identification and alteration feature extraction, Landsat 8 and Sentinel 2 images provide broader regional information, and Gaofen-2 data is suitable for high-precision local surveys [7]. In the process of data processing, radiometric calibration and atmospheric correction of remote sensing images are firstly carried out to eliminate the interference of atmospheric effects and sensor noise to ensure the accuracy and reliability of data.

The GF-2 remote sensing image is shown in Figure 2.

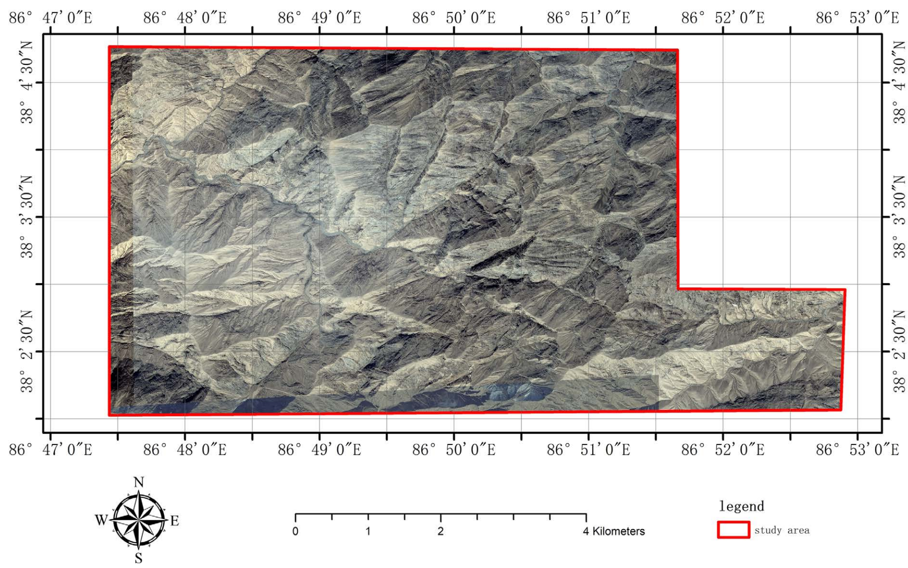

Figure 2. Gaofen-2 remote sensing image.

The Aster remote sensing satellite image is shown in Figure 3.

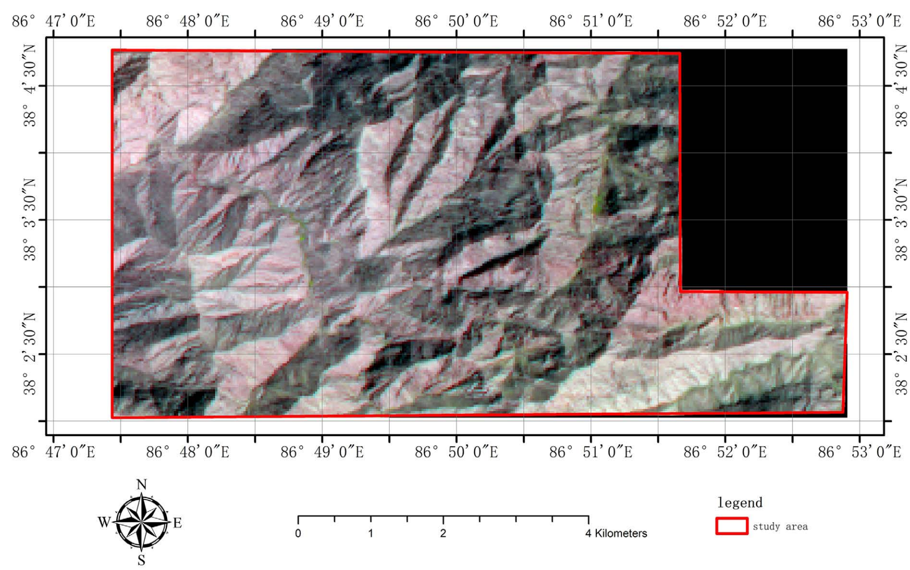

Figure 3. Aster remote sensing image.

The Landsat 8 remote sensing image is shown in Figure 4.

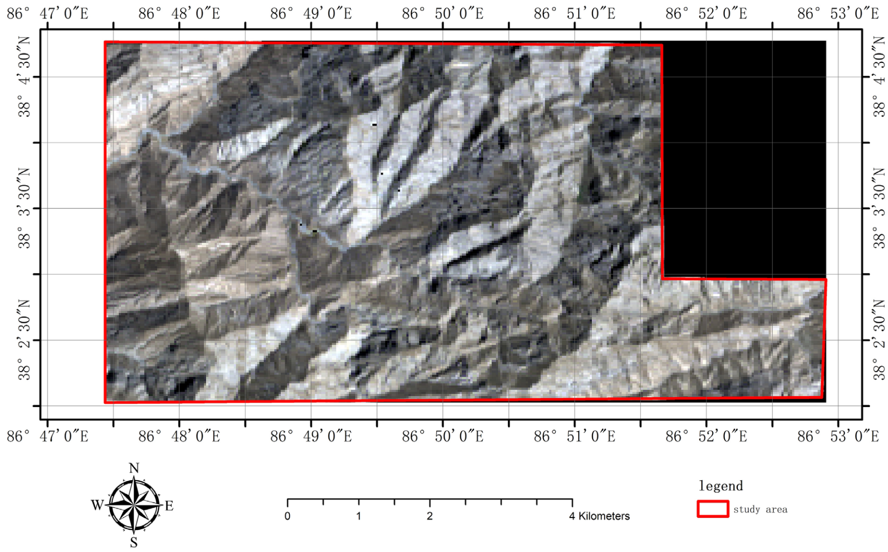

Figure 4. Landsat 8 remote sensing image.

3.2. Remote Sensing Geological Analysis Methods

The geological analysis methods of remote sensing data include band selection, principal component analysis (PCA) and alteration anomaly information extraction. Band selection is mainly based on the spectral characteristics of minerals, and the appropriate band is selected for mineral composition analysis. Principal component analysis (PCA) is used for dimensionality reduction processing to extract the characteristic information related to mineralization, so as to effectively identify the mineralized region. In this study, PCA was used to transform the original band data into the principal component and extract the alteration information related to mineralization. The process of PCA includes data standardization, covariance matrix calculation, eigenvalue and eigenvector solving, and the first few principal components are selected according to the size of the eigenvalues, which can explain most of the variance of the data. The method for extracting iron staining anomalies involves selecting Landsat8 bands 2, 4, 5, and 6, performing principal component analysis (PCA), and choosing the second principal component (PC2) as the result layer. The method for extracting hydroxyl anomalies involves selecting Landsat8 bands 2, 5, 6, and 7, performing principal component analysis (PCA), and choosing the third principal component (PC3) as the result layer.

In addition, the combination of alteration information from multi-source remote sensing images helps to identify potential distribution areas of fluorite and lepomica deposits [8]. Through this method, we can extract abnormal information related to the mineralization of fluorite and lepomica, which provides a reliable basis for the subsequent exploration of mining areas.

3.3. Analysis of Remote Sensing Characteristics of Fluorite and Lepomica Mining Areas

3.3.1. Remote Sensing Feature Identification of Fluorite Ore

The recognition of remote sensing features of fluorite ore mainly depends on the spectral response of the mineral in the short wave infrared (SWIR) band. For the detection of fluorite ore, bands 1 (visible-near-infrared band), 5, 6 and 7 (shortwave infrared band) in ASTER image are selected in this study, because these bands are very sensitive to the spectral characteristics of fluorite. These bands are effective in identifying fluorite and its associated minerals [9]. Through principal component analysis (PCA) and band combination technology, anomaly information related to fluorite mineralization in mining area can be extracted. Especially in the short-wave infrared region, fluorite ore usually exhibits characteristic spectral absorption peaks, which provides a key basis for remote sensing identification.

3.3.2. Remote Sensing Feature Identification of Lepidolite Ore

The identification of remote sensing features of lepidolite mainly depends on its spectral response in infrared band, especially short-wave infrared band. The spectral characteristics of lemica ore are usually manifested in bands 1, 4 (visible-near-infrared band), 5 and 7, which can effectively identify hydroxyl absorption characteristics associated with lemica ore, which is closely related to its hydroxyl (OH) component [10]. In the detection of lithiolite ore, the spatial distribution of lithiolite mineralized regions can be identified by analyzing different remote sensing data (such as ASTER, Landsat 8, etc.). These characteristics are closely related to the geological background of the region, especially in the mica quartz schist and metamorphic rock zones, where lithiolite mineralization is often accompanied by characteristic alteration phenomena.

3.3.3. Correlation Analysis of Remote Sensing Features and Geological Phenomena in Mining Area

Through the analysis of remote sensing images of the mining area, it is found that there is a significant spatial correlation between the remote sensing features of fluorite and lepomica deposits and regional geological phenomena. The mineralized zones in the Termusayi mine area are usually closely related to faulted structures, which provide channels for ore-forming fluids. The distribution of anomalous areas with remote sensing characteristics is highly consistent with the known mineral sites and their structural Settings, indicating that remote sensing data can effectively indicate the location of mineralized areas [11].

4. Remote Sensing Data and Mineral Prospecting Model Construction

4.1. Remote Sensing Data Fusion and Mineral Model Construction

In this study, multi-source remote sensing data fusion technology is used, combining ASTER, Landsat 8, Sentinel 2 and Gaofen-2 images to improve the accuracy and efficiency of mineral prospecting. Through data fusion, the advantages of all kinds of remote sensing images in spatial resolution and spectral response can be fully utilized, and the identification ability of mining features can be improved [12]. After the fusion of remote sensing data, principal component analysis

(PCA) is used to extract the main characteristic information of the mining area, and then combined with the geological structure analysis, the prospecting model of fluorite and lepomica ore is constructed.

4.2. Prospecting Prediction of Fluorite and Lepomica Deposits

Based on remote sensing data and geological background analysis, a prospecting prediction model for fluorite and lepidolite is established. The model takes into account the alteration characteristics of the mining area, the distribution of the mineralized zone and the fault structure. Through the fusion analysis of multi-source remote sensing data, it can effectively predict the mineralization potential area and guide the field exploration work.

In this study, based on the principal component analysis results of Landsat 8 images, we successfully extracted the abnormal information of iron staining and hydroxyl alteration. Iron stain anomalies are usually related to oxidized minerals, while hydroxyl anomalies are closely related to the alteration of aqueous minerals. These anomalies are important indicators of mineralization of fluorite and lepomica. In the actual interpretation process, combined with the spectral characteristics and geological background of the known mineral sites, we established the remote sensing interpretation markers for fluorite and lepomica ores, which provided important technical support and scientific basis for the follow-up exploration work. Studies have shown that the potential distribution area of fluorite ore is mainly concentrated near the contact zone of carbonate rock and metamorphic rock, while leucite ore is closely related to the mica quartz schist zone [13].

4.3. Verification and Evaluation of the Accuracy of the Prospecting Model

In order to verify the validity of the mineral prospecting model, the accuracy evaluation was carried out by comparing with the data of existing mineral sites. By calculating the coincidence between the mineralized area predicted by the model and the actual mineralized area, the results show that the prediction accuracy of the model is high, and it can effectively guide the further exploration of the mining area. The evaluation results of the model show that the ore prospecting prediction is highly reliable with the support of remote sensing data [14].

5. Results and Discussion

5.1. Prospecting Results of Fluorite and Lepomica Deposits in Mining Area

Through the analysis of remote sensing image of Telmusai mining area, this study successfully identified the mineralization potential of fluorite and lepomica in the mining area. The mineralization of fluorite is mainly concentrated in the

NE-trending fracture zone and its adjacent carbonate formations, which are highly consistent with the known distribution of fluorite deposits. The lipolite deposits are mainly located in the contact zone between mica quartz schist and metamorphic rocks, and these areas are consistent with the metallogenic background of rare metals in the mining area. The combination of mineralized anomalies extracted from remote sensing data and regional geological characteristics successfully provides potential mineralized areas for the mining area.

5.2. Promoting Effect of Remote Sensing Technology on Mineral Exploration

Remote sensing technology has shown important advantages in mineral exploration, especially in improving prospecting efficiency and reducing exploration costs. Through the integration of multi-source remote sensing data, combined with principal component analysis and alteration information extraction technology, this study can efficiently identify mineralized zones and potential mineralized areas. The high resolution and multi-spectral characteristics of the remote sensing image make the extraction of mineralization information more accurate, and effectively guide the follow-up exploration work, especially in the mining area with a large area.

The distribution map of iron staining alteration information is shown in Figure 5. According to Figure 5, the iron staining alteration information is linearly distributed along the fault.

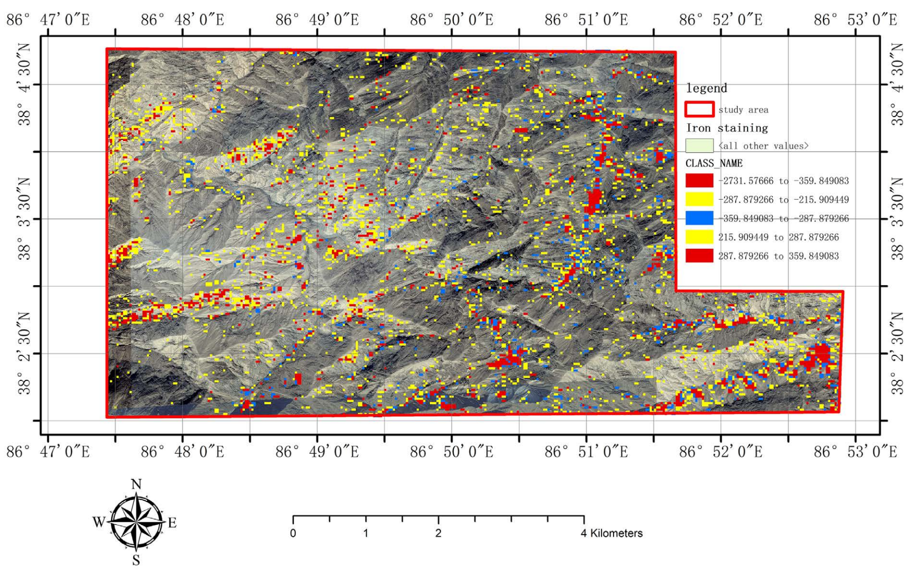

Figure 5. Iron staining alteration information.

The hydroxyl alteration is shown in Figure 6. The hydroxyl alteration information is mainly distributed in the central regions.

The distribution of fluorite is shown in Figure 7. The distribution map of lepidolite is shown in Figure 8.

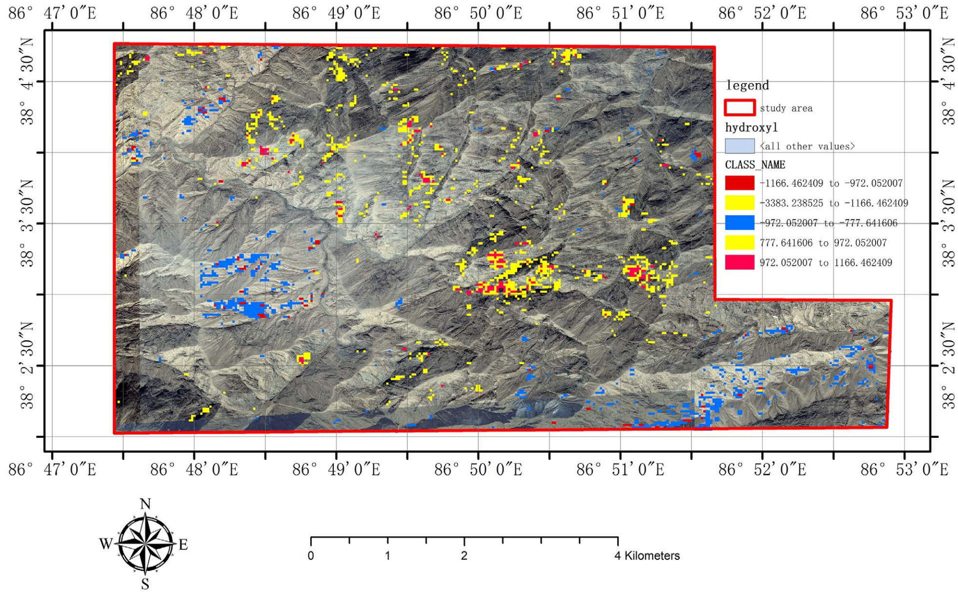

Figure 6. Hydroxyl alteration information.

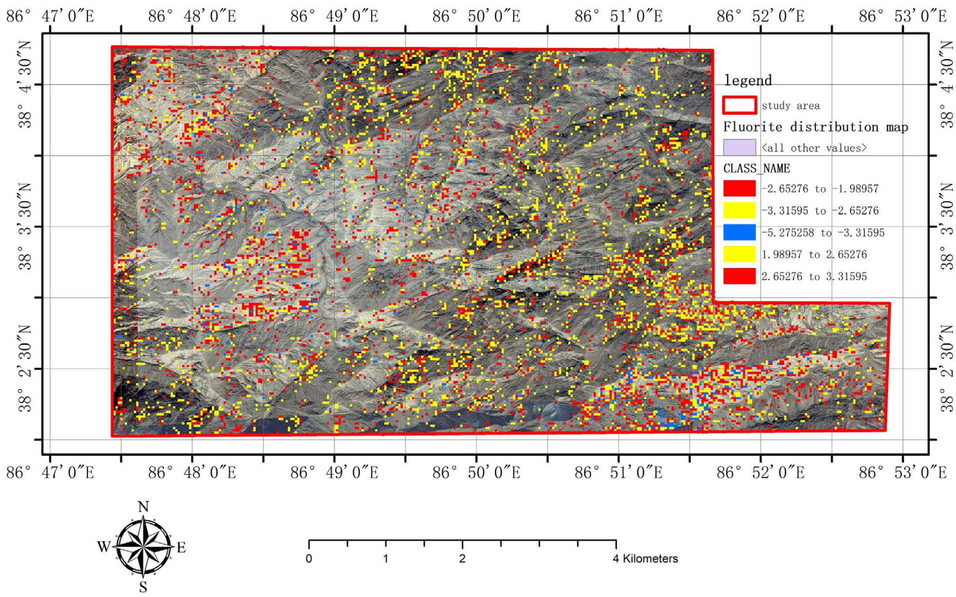

Figure 7. Distribution map of fluorite.

5.3. Limitations and Future Prospects of the Study

Although this study has achieved remarkable results, due to the complex geological background of the mining area, there are still some limitations in the extraction of mineralization information. Future research should combine more geological survey data and remote sensing images to further improve the accuracy of the results. At the same time, with the continuous development of remote sensing technology, the use of higher resolution images and new analysis methods will further improve the accuracy of mining exploration and provide a more accurate basis for the exploration of mineral resources.

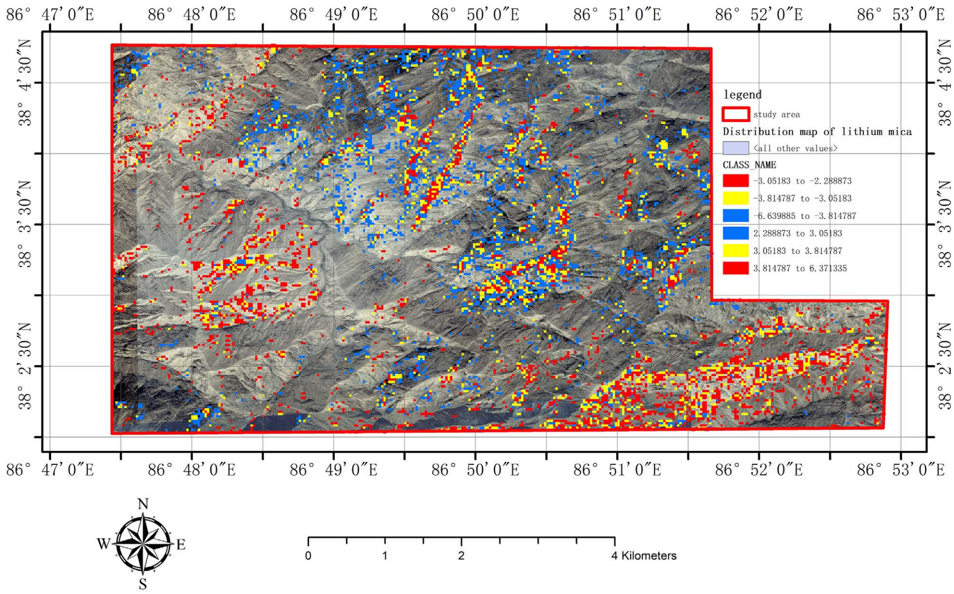

Figure 8. Distribution map of lepidolite.

6. Conclusions

6.1. Main Research Conclusion

Based on multi-source remote sensing data, this study conducted remote sensing geological prospecting research on fluorite and lepomica deposits in Termusai mining area, Jiemang County, Xinjiang, and reached the following main conclusions: First, through comprehensive analysis of ASTER, Landsat 8, Sentinel-2 and other remote sensing images, the mineralization potential of fluorite and lepomica deposits in the mining area was successfully identified. Fluorite mineralization is mainly concentrated in the northeastward fault zone and carbonate formations, while the lithiolite mineralization area is distributed in the contact zone between mica quartz schist and metamorphic rocks. Secondly, remote sensing technology combined with principal component analysis and alteration information extraction can effectively identify the abnormal mineralization area of the mining area and provide important prospective area information for the subsequent mineral exploration work. Finally, this study verifies the efficiency and reliability of remote sensing technology in mineral resources exploration, especially under complex geological conditions, remote sensing data can provide important support for the location of mineralized areas.

6.2. Innovation and Application Value of the Research

The innovation of this research is reflected in the following aspects: First, the use of multi-source remote sensing data (including ASTER, Landsat 8, Sentinel-2, etc.) combined with advanced principal component analysis and alteration information extraction technology provides a new idea and method for prospecting fluorite and lepomica deposits in mining areas. Secondly, the research combines the remote sensing data with the geological background of the mining area, which effectively improves the accuracy of mineralized area identification. The application value of the research is that the effective application of remote sensing technology provides efficient and low-cost technical support for the preliminary exploration of large-scale mining areas, which can greatly improve the efficiency and success rate of mineral resource exploration, and provide strong support for resource development.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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