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Lithological Discrimination Based on the Inversion of Roughness in Hami Area, Xinjiang

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Abstract. This paper is to retrieve surface roughness parameters by inverting the radar backscattered signal from natural surfaces in Hami area, Xinjiang Province, using Radarsat-2 images. Roughness information is useful to distinguish different lithological rocks. In this paper, the main work is the inversion of the combination roughness Zs (combine the effects of RMS height and correlation). The Zs was retrieved from the cross-polarization differential image (VH polarization image subtract HH polarization image), using the inversion formula of the combination roughness Zs. The Zs map was a gray-level image, and it couldn’t be better to present lithology categories, therefore the texture classification method was applied for Zs image, and the results also clearly showed the distribution of basic rock, granite and ultrabasic rock. Based on the Zs image, we verified the results of classification that were obtained from the cross-polarization differential image. Combination with fieldwork, the results of classification of basic rock, marble, granite and sedimentary rock were compliant with Geological map. According to Geological map, the results of distribution of granite, basic rock and ultrabasic rock that were obtained from the texture analysis of the Zs image were good.

1. Introduction
Imaging radar is paid more attention in many fields. It have many advantages, such as its all weather, all time earth observation, the advantages that optical images method can not to compare with, such as strong permeability of snow and fog. Especially with the great progress of geological application, Remote Sensing Technique makes great development. Abundant geological structure, lithology and deeper hidden geological information, especially in the geological detection of volcanic, meteorite strike and tectonic, can be provided by Synthetic Aperture Radar (SAR). SAR has unique advantage in mineral detection under the control of tectonic zone. So lithological classification research can achieve great results by SAR data. The differences of rock composition and surface roughness lead to the differences of Ridar wave backscatter strength. The gray texture results and landform of rocks can be

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distinguished in radar image. Results showed that SAR image is full useful to make lithology identification[5].

2. Data Presentation and Processing
Radarsat-2 is a high-resolution commercial radar satellite equipped with C-band sensor by the Canadian Space Agency and MDA, launched on December 14, 2007 in Baikonur, Kazakhstan. In this paper, RADARSAT-2 data was selected which was taken on December 28, 2011, 15:37pm, and its incidence angle ranges from 33.15 ° to 34.47 °. In the phase of pre-process of data, the NEST software was used to filter, calibrate and re-project the RADARSAT-2 data[4]. The processed images are as follows.

![Figure 1. processing of Radarsat-2](from left to right: original data - calibration - filter - reproject)

3. Introduction of the study area
The study area is located at the southeast of Hami City, Xinjiang. There are many hills in this area, about800-1000m high. The overall topography is relatively flat. The scope of the geographical coordinates: 94° 30 ′ E-94° 45 ′ E, 42° 10 ′ N-42° 20 ′ N.

4. Basic theory of radar remote sensing inversion
The radar system parameters and surface parameters are the two important parameters of affecting radar backscatter coefficient[1]. Surface parameters are important factors of affecting radar scattering echo, but the complex permittivity and surface roughness parameters play a decisive role.

The complex permittivity is used to describe the electrical properties of surfaces. The real part is expressed as the dielectric constant, and the imaginary part is the loss factor. The dielectric constant is the measurement of the surface material and electrical properties, and it is an important parameter which has effect on the absorption of electromagnetic energy of the material, and emissivity of electromagnetic wave energy. If the object’ permittivity is large, the radar echo would be strong. In the image, object would be expressed as the light tone, otherwise the deep tone[2].

In the interaction process of the ground substance and radar incident wave, the surface roughness parameters is other determining factors. Roughness usually refers to a random surface roughness of the surface of the periodic structure. The surface height or RMS height \( \sigma \) and surface correlation length \( L \) are used to express the surface roughness.

5. Lithological discrimination based the AIEM model
5.1. Introduction of the inversion model
In this study, the multi-polarization data is used to get the impact of surface roughness on the backscattering coefficient. The scope of correlation length \( (L) \) ranged from 30cm to 60cm, and the
The scope of root mean square height ranged from 0.5 cm to 2.5 cm. The roughness inversion model based on the combination of cross polarization difference was used in this paper, which was established by Ren Xin who was a student of Institute of Remote Sensing Applications, the Chinese Academy of Sciences [3].

\[
\begin{align*}
\Delta \sigma_{vv}^0 &= A_v(\theta) \ln(Z_s) + B_v(\theta) \\
\Delta \sigma_{hh}^0 &= A_v(\theta) \sqrt{Z_s} + B_h(\theta) \\
\Delta \sigma_{hh}^0 &= \sigma_{hh}^0 - \sigma_{hh}^0 \text{ (in dB)} \\
\Delta \sigma_{vv}^0 &= \sigma_{vv}^0 - \sigma_{vv}^0 \text{ (in dB)}
\end{align*}
\]

\(Z_s\) was a combination of roughness parameters (root mean square height and correlation length) the coefficients, such as \(A_h(\theta), B_h(\theta), A_v(\theta), B_v(\theta)\), were only related to the incident angle.

\[
\begin{align*}
A_h(\theta) &= -27.016 + 27.735 \sin \theta - 13.151 \sin^2 \theta \\
A_v(\theta) &= 18.657 - 26.889 \sin \theta + 10.809 \sin^2 \theta
\end{align*}
\]

In this paper, the mean incident angle \(\theta\) was 33.34°:

\[
\begin{align*}
A_h(\theta) &= -15.7452 \\
B_h(\theta) &= 7.1438
\end{align*}
\]

\[
\Delta \sigma_{hh}^0 = -15.7452 \sqrt{Z_s} + 7.1438, \text{ the relation between } Z_s \text{ and } \Delta \sigma_{hh}^0 \text{ was followed:}
\]

\[
Z_s = \left(\frac{\Delta \sigma_{hh}^0 - 7.1438}{15.7452}\right)^2
\]

5.2. Field experiments and laboratory determination

The profile board measuring method was used to measure the roughness parameters. We took some rock samples from the field to the laboratory, and used Agilent Microwave Network Analyzer to measure the dielectric constant of the rocks.

The measurements of rock showed that the dielectric constant of the different of the rock didn’t change drastically, about 3-4. The dielectric constant of metamorphic rock was slightly larger than that of ordinary rock, and the dielectric constant of altered rocks was slightly larger than that of the surrounding rock. Dielectric constant was very difficult to become a dominant factor in hilly or mountainous areas. Therefore, in this article, we took the surface roughness as a dominant factor of lithology identification, and judged the rocks from the differences of surface roughness.

From the field measurement, the values of the root mean square height \(s\) and correlation length \(l\) were obtained. The values and the formula \(Z_s = s^2/l\) were used to calculate the value of \(Z_s\) [6]. Contrasting the theoretical and measured values, we got three conclusions: 1) roughness of mineralization rock mass was larger than that of sedimentary rock; 2) surface roughness of rock mass was small. Because the overall structure of rock mass was uniform, the stress rock mass facing and deformation of rock mass were small; 3) roughness of granite was small.

6. The application of the inversion model in Huangshan area

Two Radarsat-2 images including VH polarization and HH polarization were selected. \(Z_s\) was inverted from the formula \(Z_s = \left(\frac{\Delta \sigma_{hh}^0 - 7.1438}{15.7452}\right)^2\), the map of the distribution of \(Z_s\) was followed.
In the figure 2, the light tone showed the large Zs, and the dark tone showed the small tone, three conclusions were drawn from Zs maps complying with section 5.

7. Texture classification

7.1. Texture classification of Zs image

After obtained the results of Zs image, we got the results of images of characteristics by calculating the gray level co-occurrence matrix, such as Mean, Homogeneity, Contrast, Entropy and Correlation.

The basic rocks were classified through calculating the spatial texture of Zs (See figure 3). In the figure 3, the white area represented basic or ultrabasic rocks, which may be classified for mistake into other classes. For instance, the upper-right corner of the gullies part whose average Zs value was approximately with basic or ultrabasic rocks were often classified into basic or ultrabasic rocks. Sometimes, we could distinguish the granite by means of its oval shape.

7.2. Texture classification of the image of combined polarized

The file combined by four polarized images was classified by texture. In the texture analysis results, there were several images of characteristic quantities. Mean feature images were added to one file. In figure 4, by displaying high values of the mean feature images, the distribution of the granite and diorite were showed clearly. The boundary line of granite (red box) was clearer than that of the diorite (green boxes).

Variance characteristics from the results of texture were added into one file, and the high value parts were showed in Figure 5. Figure 5 showed the distribution area of diorite.

The heterogeneities images of each polarization from the results of texture analysis were summed. High value parts were stated in Figure 6. The figure 6 showed the distribution of the Quaternary sediments.
8. Discussion
Comparing different classification methods, there were two conclusions: 1) Based on direct classification of the combined roughness Zs, the carboniferous quaternary and rock mass were distinguished, but the different lithology of the rock mass could not be distinguished. Sedimentary rocks in the Zs image had lighter color. 2) Based on the four polarization synthetic image, texture analysis was used to get different the characteristic quantities images. The classification of granite, diorite and Quaternary could be got. Using different classification methods obtained different classification results. Using SAR image texture analysis, the distribution of granite and diorite could be obtained, and by the roughness inversion method, the results showed the distribution of mafic-ultramafic rock and granite.

It was inevitable to have misclassification error. It was necessary to improve the accuracy of the inversion model and the classification methods.
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References