Research and Development of a Geological Remote Sensing Information Extraction System

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Abstract: This paper presents a geological remote sensing information extraction system, the aim of which is to provide practical models and powerful tools to extract geological information from remote sensing images for geological exploration applications. After reviewing and analyzing the existing methods for geological information extraction, we developed more than ten models to enhance and extract geological information, such as alteration information, linear features and special lithological characters. The system is developed based on Erdas Imagine using its programming language. It has been successfully used in the "Great Investigation of Land and Natural Resources of China" program.
Keywords: Geological Remote Sensing, Alteration, Linear Feature, Lithological Character, System Development.

1. Introduction

Geological information extraction and analysis is a very active application of remote sensing (RS) and Geographic Information Systems (GIS). To meet the challenges of geological exploration tasks, such as multiple data analysis and GIS supported remote sensing image interpretation, it is highly desirable to develop a geological exploration oriented software system that integrates RS and GIS technologies and tools.

We have developed an integrated geological exploration oriented remote sensing information processing and analysis system. The system consists of six sub-systems, including remote sensing image processing, geological information extraction, spectral analysis, thematic mapping, spatial analysis, and spatial data visualization. It is developed based on ArcGIS and Erdas Imagine using their programming languages and customization tools. The data processing scheme and interactive interfaces are deliberately designed and implemented according to geologists' workflow. It has been used in the "Great Investigation of Land and Natural Resources of China" program, which is one of the major projects organized and sponsored by The Ministry of Land and Resources, P. R. China. Due to the limit of the paper size, we only describe the geological information extraction system, which is the key sub-system of the entire system.

2. Geological Information Extraction Methods

In the state of the art research and applications, geological remote sensing information extraction mainly includes alteration information extraction, linear feature (linearment) extraction, and lithological character extraction. So far, great progresses have achieved in alteration information and linearment extraction, while there is still no reliable method for lithological character extraction. We summarize the current status of alteration information and linearment extraction below.

1) Alteration Information Extraction

In terms of mineral resource investigation and evaluation, mineral anomaly information is quantitive remote sensing anomaly that associates with alteration mineral of wall rocks. Anomaly strength can be depicted by some indices that characterize the spectral absorption caused by alteration minerals. To identify and extract remote sensing anomaly information that reflects mineral alteration has been an important research topic in the geological remote sensing community. Currently, there are a number of methods for extraction of alteration information from Landsat TM images, such as band ratio, principal analysis, color space transformation, and spectral angle analysis, etc. Out of these methods, the band ratio and principal analysis are the most widely used methods. Therefore, we develop alteration information extraction models with different spectral bands using these two methods.

2) Linearment Extraction

One of the major remote sensing applications in mineral exploration is to extract linearments from remote sensing images with subsequent structural analysis to study regional and local regularities of ore structural control. Linearments are very helpful to study river network and geological structure. There are different image characteristics and patterns of linearments: (1) Some linear features, such as water boundaries, shadows and roads, have clear traces on the image. (2) In some cases, linear features have no clear traces on the image. That is, the image contrast is low or the image intensity changes gradually. (3) Some linearments are partially covered by houses, land parcels and trees. For the last two cases, it is very hard to interpret the linearments. To tackle these difficult cases, the image details or high frequency components need to be suppressed at first and then linear stretching, directional filtering and homomorphic filtering can be used to enhance the linearments.

3. Development of Computational Models for Geological Information Extraction

1) Alteration Information Extraction Module

This module consists of ten spectral enhancement tools, each of which corresponds to one model. The models are listed as follows.

- Principal transformation (Band 4)
- Principal transformation (Band 6)
- Infra-red / Red
- SQRT(Infra-red / Red)
- Vegetation index
- Normalized vegetation index
- Transformed normalized vegetation index
- Iron oxygenated substance (Band 3/ Band1)
- Clayish mineral (Band 5/Band 7)
- Iron ore (Band 5/Band 4)

The interface of the developed alteration information extraction module is shown in Fig.1.

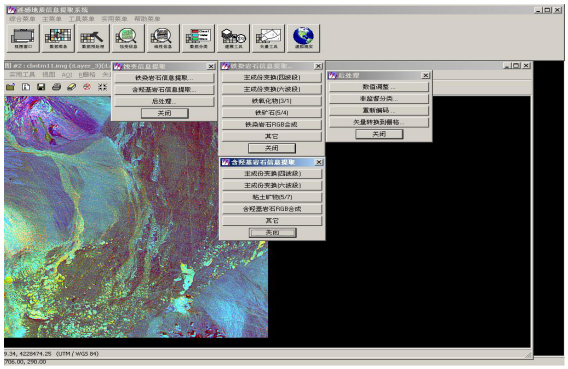

Fig.1. The interface of the alteration information extraction module

2) Linear Feature Enhancement Module

This module includes four directional filtering tools to extract linearments in east-west, south-north, north-east and north-west directions. We defined four directional filter kernels and developed four small programs using Microsoft Visual Basic to covert these kernels to Erdas Imagines's default kernel. The interface of this module is shown in Fig.2.

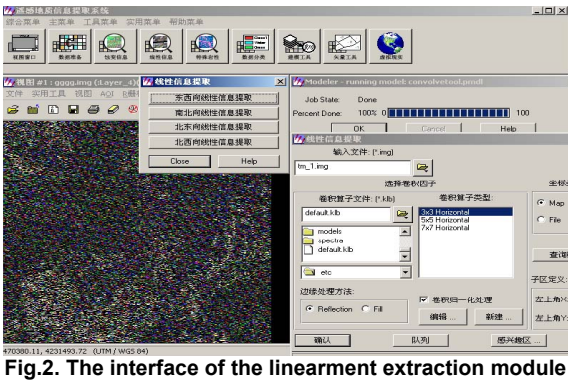

Fig.2. The interface of the linearment extraction module

3) Special Lithological Character Extraction Module

This module includes the tools for extraction of ferric contamination rock information and hydrothermal alteration rock information. A diagram that consists of multiple image processing steps is established in one EML (Erdas Macro Language) program. The band ratio model is modified to prevent divided-by-zero error. Image composition and band combination functions are added in the process. The developed interface of this module is shown in Fig.3.

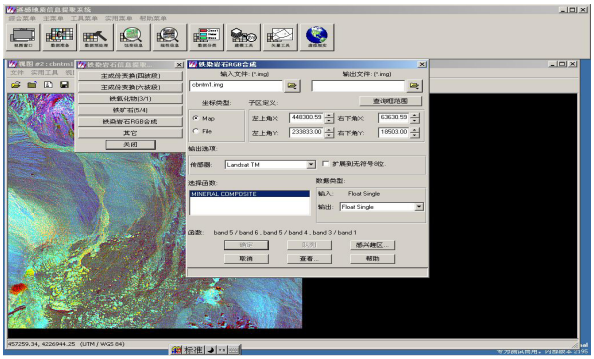

Fig.3 The interface of the special lithological character extraction module

4. Development of the Geological Information Extraction System

The geological remote sensing information extraction system is developed based on the above mentioned models, the existing Erdas Imagine functions and its program language EML. In the system implementation, it has five top-level menus and nine modules. The five menus are miscellaneous, main menu, tools, utility and help. The modules include view, data preparation, alteration information extraction, linearment extraction, special lithological character extraction, data classification, spatial modeler, vector tools and vitual GIS. The main interface of the system is shown in Figure 4.

Fig.4. The main interface of the geological remote sensing information extraction system

In practical application, a task can be accomplished by combination of these developed tools and Erdas functions. For example, a flowchart for alteration information extraction and analysis is illustrated in Fig.5.

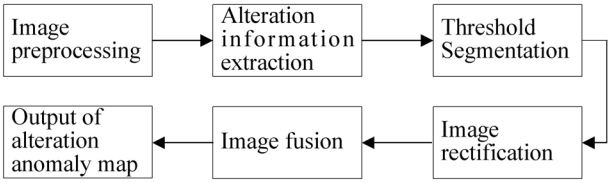

Fig.5. A flowchart for alteration information extraction and analysis

Here we give an example of the extraction of ferric contamination information and alteration information of clayization mineral. Figure 6 shows the resultant alteration anomaly map of a copper deposit in Tuwu. The alteration information is clearly revealed in the map and the extracted information is reasonable and consistent with the mineral information obtained from a field investigation.

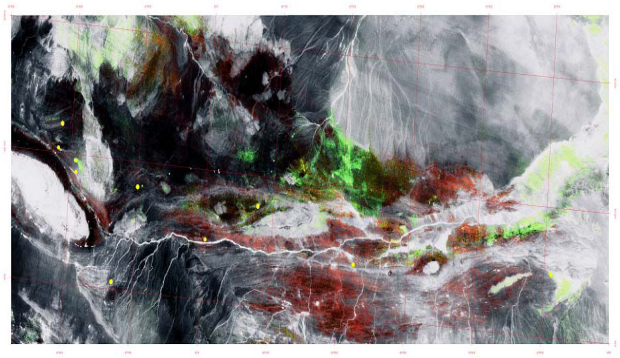

Fig.6. Alteration anomaly map of a copper deposit in Tuwu

5. Summary

We presented a geological remote sensing information extraction system in this paper. With general-purpose image processing functions and specially developed geological information extraction tools, this system has been very useful in real-world applications, such as the related projects in the "Great Investigation of Land and Natural Resources of China" program. We believe that with further improvement this system will play an important role in geological exploration research and applications.

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