

Application of remote sensing technique to mapping of the map series of karst geology in China and Southeast Asia

BI Xue-li, XU Qi*, ZHANG Fa-wang

Institute of Karst Geology, Chinese Academy of Geological Sciences, Guilin 541004, China.

Abstract: Based on the mapping program of the map series of karst geology in China and Southeast Asia, the paper summarizes the application of remote sensing technique and the process of acquiring information from remote sensing images. Generally, remote sensing technique serves as an effective method to recognize information about karst topography, rocky desertification and karst collapse. Interpretation of remote sensing images, in combination with field verification and cartographic generalization, provides basic data for updating the program database and compiling synthetic maps. In interpreting remote sensing images, automatic extraction can make it more efficient and visual interpretation can improve its accuracy.

Keywords: Remote sensing; Karst geology; Mapping; Southeast Asia

Introduction

Karst region is characterized by fragile ecologic system and harsh living conditions with underdeveloped economies and therefore it attracts much attention from international scientific organizations, geological research institutions, and governments of countries. The southern part of China and Southeast Asian countries belong to the same karst region. To study karst geology of this region can meet the modern development need of karst research and will bring about a positive effect on karst groundwater exploitation and karst environment protection. Mapping of the map series of karst geology can systematically review, refine and summarize the existing research results. Therefore, the program will prepare important basic data for further comprehensive study of cross-border karst geology. This research program covers a wide range of areas but lacks data about regions outside the territory of China. As a valuable technological tool for supplementing related data for the mapping, remote sensing is

applied to the program thanks to the fact that it can acquire a large amount of information covering a vast region in a short time span. The paper examines the application of RS to the mapping of the map series of karst geology in the southern part of China and Southeast Asia based on the characteristics of this program.

1 Overview of the area studied

For this mapping program, the area of research covers the karst region in southern China and Southeast Asia, which is one of the three major karst regions of the world (the Mediterranean region in Europe, the eastern part of the U.S., and southern China and Southeast Asia). The area studied within Chinese territory includes karst regions of different types in the southwest, southeast, Taiwan, Hainan and the South China Sea Islands, and the Tibetan Plateau. The Southeast Asian countries involve Indonesia, Thailand, Myanmar, Singapore, Malaysia, Vietnam, Cambodia, and the Philippines. With the effect of the rainy, humid tropical monsoon climate and tropical rainforest climate, the southwestern part of China and Southeast Asia have well-developed

*XU Qi (1984-) mainly engaged in environmental geology research and informatization of geological investigation as an assistant researcher. E-mail: xuqi@karst.ac.cn.

surface and underground karst. Karst landforms of the area have a full development because of the special tectonic features of high mountains and steep slopes, high temperature and large scale precipitation which occurs irregularly in seasons. Moreover, in this densely populated area, the pressure from human activities has exceeded the bearing capacity of karst soil and thus resulted in increasingly prominent ecological problems, such as drought, floods, soil erosion, soil degradation, ecological imbalance, rocky desertification and ground collapse.

2 Application of remote sensing

In this mapping program, remote sensing is mainly applied to revision and updating of basic geological data and extraction of thematic information. The former part includes supplementing and revising geographic elements, such as rivers, waters, and residential locations, and geological elements like tectonic features and lithology. The latter part involves extracting karst geological information about karst landform, rocky desertification, and karst collapse. The detailed technical roadmap is as described in Fig. 1.

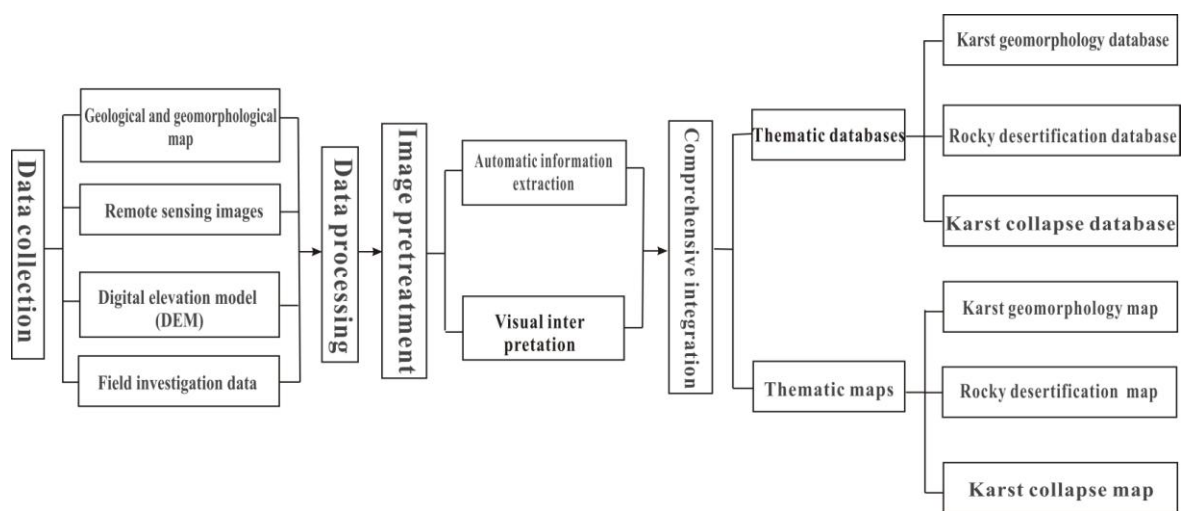


Fig. 1 Technical roadmap

According to the definition of karst rocky desertification, carbonate rocks is one of the essential conditions for rocky desertification (YUAN Dao-xian, 1988; WANG Guo-jiang, 1995). In addition, karst landforms and geological disasters like karst collapse are also unique to karst regions. Therefore, based on the existing geological maps and data, we identify the distribution area of soluble rocks in southern China and the Southeast Asia to preliminarily define the karst area. In the extracted areas, researchers collect remote sensing images and DEM data in need of remote sensing interpretation. The paper will focus on the application of RS to extraction of karst information in the following part.

2.1 Extraction of karst geomorphic information based on RS and DEM

Traditionally, geomorphic mapping is conducted through manual compiling and field investigation. Specifically, researchers would first extract geomorphic information from large-scale maps to have transitional maps and add related contents to them while in the case of regions with uncertain limits, they would conduct field reconnaissance. This mapping method is of high accuracy but a demanding task requiring a long period of time (LONG En, 2005). Therefore, RS-based geomorphic mapping has become the mainstream at home and abroad (ZHANG Jin-ping *et al.* 2005; WANG Bing *et al.* 2008; YANG Shu-wen *et al.* 2012).

According to the mapping characteristics, researchers use DEM and Landsat 8 as the main remote sensing data source, and then collect related geological and geomorphic maps as auxiliary material. With ENVI and ArcGIS as the platform, Classification System of Digital Land

Geomorphology of 1/1 000 000 in China (ZHOU Cheng-hu *et al.* 2009) and Classification Plan for Karst Geomorphology of Tropic and Subtropical Regions in Southern China (QIN Hou-ren and ZHU De-hao, 1984) are used as references for the classification of geomorphology from two levels, that is, genetic types and combination forms. And the extraction of karst geomorphology is realized through visual interpretation and computer automatic interpretation. Detailed interpretation approaches are as follows:

Step one: data collection and pre-processing. This step involves collecting remote sensing images, DEM data and geological and geomorphic maps to be interpreted of the related regions and preprocessing the data. Specifically, researchers need to make projection transformation and geometric correction of remote sensing images, and select the most suitable combination of spectral bands for generating false-color images (LANDSAT RGB (753) was used in the program) for image fusion to generate a complete single image of the related regions for interpretation. DEM data and geological and geomorphic data should be preprocessed through projection transformation, geometric correction and format conversion. At last, all of the data would be put in the same coordinate system-the WGS84 ellipsoid and UTM projection were applied to the program;

Step two: classification of basic geomorphic types. Based on ArcGIS platform and DEM-generated elevation map and relief amplitude map, basic geomorphic types can be classified with the overlay analysis function of ArcGIS. Specifically, geomorphic types can be classified, by relief amplitude, into plateau, tableland, hill, mountain with low degree of relief amplitude, mountain with medium degree of relief amplitude, mountain with high degree of relief amplitude, and mountain with extremely high degree of relief amplitude. And by elevation, geomorphic types can be classified into low altitude, medium altitude, high altitude and extremely high altitude;

Step three: remote sensing interpretation of geomorphology. Based on remote sensing images, existing maps and DEM data, interpretation keys were identified for typical karst landforms. With human-computer interactive interpretation, karst landforms can be classified into different types.

The interpretation was conducted by analyzing easier material first and then data, which is more difficult to be dealt with based on existing information, from regional to local level and from macroscale to microscale. The interpretation started with the general situation to specific one from qualitative to quantitative level. The general principle was to carry out the work step by step with continuous feedback to a deeper level. Researchers delineated the map and recorded (filling in interpretation cards) while making the interpretation;

Step four: researchers made map examination and revision, and carried out the essential synthetic mapping according to map scale to produce the karst geomorphic map and database based on remote sensing interpretation.

2.2 Extraction of rocky desertification information based on remote sensing

Rocky desertification refers to a type of landscape and process like desertification characterized by lack of earth, water and vegetation. It is caused by karst effect of humid climate and improper human activities in karst mountain area where surface earth erodes with exposure of bedrocks (SU Wei-ci, 2002). Rocky desertification is widely distributed in the southwestern area of China. Rocky desertification has become a hot topic for current researches on global changes because it is not only changing biological diversity of ecosystem but also exerting a deep impact on regional land use and global climate. Scholars and experts have tried different approaches to the study on application of RS to extraction of rocky desertification information and dynamic monitoring (CHEN Qi-wei *et al.* 2003; YU Qin, 2009; HU Shun-gang *et al.* 2010; ZHANG Pan-pan *et al.* 2010). The following process is adopted by the program:

Step one: data collection and pre-process. Researchers chose landsat8 as the main source of remote sensing data and downloaded images covering the area studied. In deciding what images of rocky desertification to be extracted, researchers took into consideration of cloud amount, data currency, seasons and other factors-for example, cloud amount may be less than 10%; images of recent years would be collected to ensure data

currency; and images of the autumn would be used because those images can reflect the most detailed possible surface information in an instantaneous state. In case of irresistible objective reasons (such as weather conditions, *etc.*), researchers may choose images before or after one to two coverage cycles (ZHOU Zhong-fa, 2001). Auxiliary material comprised DEM, land use maps and rocky desertification distribution maps of karst area in the southwest. The pre-process of data included atmospheric correction of remote sensing images, projection transformation, geometric correction, combination of spectral bands and fusion. Necessary projection transformation and geometric correction were made for DEM, land use maps and rocky desertification distribution maps of karst area in the southwest. At last, all the data were put into unified coordinate systems (WGS84 ellipsoid and UTM projection);

Step two: researchers used remote sensing images to calculate vegetation coverage and earth exposure ratio which were then corrected with vegetation coverage maps. The final results were used to calculate bare rock ratio;

Step three: based on the bare rock ratio map, the grade classification criteria widely adopted at home and abroad (see Table 1) and images' hue, texture, shape, size and other indirect interpretation marks, grade of rocky desertification was finally decided by applying comparative analysis, information synthesis and complex reasoning with the help of overlapping and managing topographic maps, geological maps, land use maps, gradient maps and other factors;

Step four: researchers conducted map examination and cartographic generalization to produce the distribution map of desertification and related database by remote sensing interpretation.

Table 1 Grade classification of rocky desertification

Grade	Severe	Moderate	Light	No
Degree of bedrock exposure (%)	>70	50-70	30-50	<30

2.3 Extraction of karst geological disaster (collapse) based on remote sensing

The program plans to mainly extract karst collapse as the geological disaster from remote sensing images. Karst collapse refers to the karst dynamic action and phenomena with collapse craters on the earth surface and deformation of soluble karst caves, rocks and soil body above fissures caused by natural or human factors (LEI Ming-tang and JIANG Xiao-zhen, 1998). China is home to one of the most extensive karst collapse development in the world and also one of countries the earliest to study karst collapse (RU Jin-wen *et al.* 1992). Scholars at home and abroad have extensively explored the application of remote sensing images in karst collapse inspection. It's hard to identify karst collapse with diameters ranging from several meters to a dozen meters through satellite images with medium resolution, like LandsatTM/ETM; satellite images with high resolution must be leveraged; however, satellite

images like SPOT 5 and Quickbird are relatively costly, therefore large-scale application is not very feasible. In view of this, the program, based on comprehensive information collection and analysis, applies homemade satellite images with high resolution (such as GF-1, China-Brazil Earth Resources Satellite 1 (CBERS-1), CBERS-3, *etc.*) in areas lacking information and in need of remote sensing interpretation and combines the use of Google earth to extract karst collapse information. Major steps are: image preprocessing, interpretation signs establishing, human-computer-interaction interpretation and karst collapse remote sensing image interpretation map generation.

3 Conclusions

Currently, in spite of considerable domestic and international achievements in environmental geological research and mapping of regions in Asia and China, there is still in lack of geological maps to reflect the general situation of the karst area in

China and Southeast Asia. This makes it difficult for China and related Southeast Asian countries to conduct comprehensive research of cross-border karst environmental geological problems. Luckily, remote sensing images, with a broad perspective, can reflect plenty of information, present geomorphic features in a vivid manner and well illustrate the general geological situation. Application of remote sensing images to geological mapping can help reduce workload with significant reference data.

Based on the mapping program of the map series of karst environmental geology in the south part of China and Southeast Asia, the paper generalizes the application of RS to the program and the remote sensing information extraction process. To sum up, as to the area in lack of geological data, remote sensing information can lead to karst environmental geological data necessary for the mapping. Information extracted from remote sensing images can be used as basic material for the program database and synoptic maps after ground verification and cartographic generalization. Remote sensing interpretation can also add some basic geographic and geological data to the existing material of some areas. These new information is helpful in improving the accuracy of mapping after being confirmed by comparing with existing maps and material. One of the approaches to interpreting remote sensing images is automatic extraction. This method is effective in improving interpretation efficiency. And the key to make interpretation more accurate is to correct visual interpretation. Because the program involves a wide range of area which varies greatly in climate and geology, for the future study researchers may try to divide subregions according to the climate, ecosystem and geological conditions of the area studied. They can select typical districts of the subregions to explore the application of support vector machine, decision tree classification to the extraction of karst geological and geomorphic information. Researchers can also explore the possibility of applying those methods to the study on more aspects.

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