Research on Standard Legend Production of the Geological Map Interpreted with Remote Sensing Images

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Abstract. It is necessary to standardize the legends of the geological map interpreted with remote sensing images in various application fields duly to achieve standardization and automation of the legends. This paper analyzes main contents and expression forms of legends based on the principle of legend compilation and expansion, and discusses generation method, compilation and expression of various legends. 455 legends of the geological map interpreted with remote sensing images were designed and produced by using Font Creator and ArcGIS software. These legends can be applied to remote sensing survey of regional geology and mineral geology, remote sensing monitoring of fundamental geology environment, remote sensing monitoring of geological disasters, remote sensing monitoring of mineral resources development and others, which can basically meet needs of actual work, and can provide technical support for standardized research of the geological map interpreted with remote sensing images.

Introduction
Legend refers to a description for contents and indicators represented by various symbols and colors at a corner or a side of the map, which can help readers understand the map. For the geological map, the legend is an important part of transmitting geological information, which explains symbols on the map and describes connotation of symbols. The geological map is one of important achievements of geological work, whose functions depend largely on overall functions of legend symbols.

The remote sensing geological survey technology has been widely applied to many fields such as remote sensing survey of fundamental geology, remote sensing survey of fundamental geology environment, remote sensing survey of geological disasters, remote sensing survey of mineral resources, remote sensing monitoring of mine development status, remote sensing dynamic monitoring of mine environment, etc. For a long time, symbols and legends of the geological map interpreted with remote sensing images are relatively complicated, without unified standard and specification; existing symbols and legends are not comprehensive, with overlaps and omissions, which are required to meet the need of building remote sensing geological survey technology standard system through unified standard, unified line type, unified filling pattern, etc. With wide application of remote sensing technology, remote sensing geology is increasingly expanding its application fields, and has made many new achievements constantly; therefore, it is urgent to supplement and improve symbols and legends of remote sensing geological field. A standard for remote sensing symbols and
Legends in the remote sensing geological field shall be developed to promote sound and vigorous development of remote sensing technology.

According to the author's tasks concerning China Geological Survey Project “Developing Symbols and Legends of Remote Sensing Geological Map” assumed by the author, this paper introduced production principle and work method of the legends of the geological map interpreted with remote sensing images, for the purpose that remote sensing geologists can give some valuable advice and suggestions to make the standard draft more complete and practical in the pilot process before the official release of Symbols and Legends of Geological Map Interpreted with Remote Sensing Images.

1. Principles for Compilation and Expansion of Legends

1.1. Principle of Compilation

1) Principle of inheritance. Legends of the geological map interpreted with remote sensing images are developed in accordance with China's national standards: “GB/T 958-1999 Geological Symbols Used for Regional Geological Maps, Scale 1:50000” (hereinafter referred to as “GB/T 958-1999”), “GB/T 6390-1986 Color Standard for Use in the Geological Map, Scale 1:500000-1:1000000” (hereinafter referred to as “GB/T 6390-1986”) and “DZ/T 0179-1997 The Color Standard of Geological Map and the Principle of Color, Scale 1:50000” (hereinafter referred to as “DZ/T 0179-1997”), etc., stipulating the legends involving the geological map interpreted with remote sensing images. Symbols and legends in existing national standards, industrial standards and bureau standards for relevant industries shall be adopted as far as possible, without need of redefinition [1, 2, 3].

2) Principle of universality. In the same geological map interpreted with remote sensing images, a legend can only represent meaning of a kind of content meaning. If the same nature of or the same legend appears in various fields of remote sensing technology application for many times, they shall be unified as much as possible.

3) Principle of systematicity. With the goal of standardizing symbols and legends of geological survey result map based on remote sensing interpretation, the compilation of special symbols and legends shall be carried out by category. Special symbols shall be systematically standardized according to the differences in expression content; in the map type, a complete legend system shall be formed by type, cause, etc., and a legend can only represent a kind of content meaning.

4) Principle of practicability. Various symbols are designed to ensure precise meaning and convenient mapping; the background color shall be derived from neutral tones as much as possible to avoid the users' visual fatigue and facilitate computer mapping.

1.2. Principle of Expansion

Geological symbols stipulated in GB/T 958-1999 shall be used continuously. Only specific symbols in this field not stipulated in GB/T 958-1999 shall be stipulated and produced. Newly-added legends shall be given colors according to GB/T 6390-1986 and DZ/T 0179-1997.

2. Main Content and Expression Form of Legends

2.1. Main Content of Legends

Legend is a collection of symbols representing geographic objects on a map, which can help users understand and use the map more conveniently [4]. The legend content generally includes geographic elements and professional elements. Legends of the geological map interpreted with remote sensing images are mainly used expression of professional elements in remote sensing geological interpretation product system. According to the above-mentioned principles for compilation and expansion of legends, the legends involved this research mainly include remote sensing survey legend of fundamental geology and mineral geology, remote sensing monitoring legend of fundamental geology environment, remote sensing monitoring legend of geological disasters, legend of remote sensing monitoring, legend of mineral resources development, legend of remote sensing image, etc.
2.2. Expression form of Legends
Legends are classified into point, polyline and polygon according to expression form [4, 5, 6, 7, 8, 9].

1) The point-like symbol is defined by primitive size (H×W/mm×mm) and primitive color (RGB). The point-like symbol in the legends of the geological map interpreted with remote sensing images mainly represents geological information with a map area of less than 4 mm², such as well-head, adit collar, spring, crater, etc. during mine development. Each point-like symbol specifies a specific primitive size, which shall not vary from the work scale.

2) The polyline-like symbol is defined by line type, color and line width. The polyline-like symbols in the legends of the geological map interpreted with remote sensing images mainly represent fault, fold axis, geologic body boundary and others. Each polyline-like symbol specifies a specific line type, color and line width. For example, new faults extracted by remote sensing interpretation can be classified as deep fault, regional fault, general fault, inferred fault and others, and are specified line type and line width.

3) The polygon-like symbol is defined by background color (RGB), filling primitive and primitive cycle. The background colors of the polygon-like symbols in the legends of the geological map interpreted with remote sensing images are mainly used in classification. Different degrees of divisions in the same classification are represented by color gradient. The primitives filled by polygon-like symbols represent nature of ground objects. For example, in the symbols of ecological geological environment, brown point-like primitive filling represents sandy desertification, while the color gradients of background colors represent degrees of sandy desertification: mild, moderate or severe. The colors are combined with the values of the three primary colors of R (Red), G (Green) and B (Blue).

3. Classes of Legends
According to application field, this paper divides various legends into remote sensing survey legend of fundamental geology and mineral geology, remote sensing monitoring legend of fundamental geology environment, remote sensing monitoring legend of geological disasters, legend of remote sensing monitoring legend of mineral resources development and legend of remote sensing image [10] (Table 1). A large class can be subdivided, for example, remote sensing survey legend of fundamental geology and mineral geology includes quaternary deposit legend, geological structure legend, multispectral remote sensing alteration anomaly legend, hyperspectral mineral mapping legend and ore prediction legend. The remote sensing monitoring legend of fundamental geology environment includes polyline-like and polygon-like symbols, such as glacier, coastline, tidal flat, wetland, desertification, stony desertification, etc. (current situation and change). The remote sensing monitoring legend of geological disasters includes points, polylines and polygons of geological disasters, such as collapse, landslide, mudslide, unstable slope, ground collapse, ground fracture, etc. and legend of ground subsidence (or surface deformation). The remote sensing monitoring legend of mineral resources development includes legend of mineral resources planning, legend of mineral resources development status, legend of mineral geological environment issues (including legend of mineral development land, legend of mine land change, legend of mineral geological environment evaluation, legend of mineral environment pollution, etc.) (Table 1). Each class is subdivided into multiple sub-classes, for example, remote sensing monitoring legend of mineral resources planning includes 15 sub-classes, such as key mining area boundary, incentive mining area boundary, restricted mining area boundary, prohibited mining area boundary, national planning mining area boundary, ecological environment restored governance area boundary, nature protection area boundary, water protection area boundary, geological relics reserve boundary, mineral resources protection area boundary, mining activity land boundary, mining right boundary (in accordance with planning), mining right boundary (in no accordance with planning), prospecting right boundary (in accordance with planning), and prospecting right boundary (in no accordance with planning). Each sub-class specifies and produces a specific legend symbol.
| Name of large class | Name of class | Name of sub-class | Example of legend |
|---------------------|---------------|-------------------|-------------------|
| Remote sensing survey legend of fundamental geology and mineral geology | Quaternary deposit legend | 40 sub-classes including alluvial deposit (al), proluvial deposit (pl), alluvial and proluvial deposit (pal), etc. | Eolian deposit Qeol |
| Geological structure legend | | 5 sub-classes including inferred structure, remote sensing interpretation fault, circular structure, etc. | Remote sensing interpretation fault |
| | | 27 sub-classes including oxhydryl anomaly, iron stained anomaly, etc. | High threshold level iron stained alteration |
| | | 68 sub-classes including hematite, limonite, chlorite, etc. | Hematite |
| Ore prediction legend | | 3 sub-classes including A-level prediction area, B-level prediction area and C-level prediction area | A-level prediction area |
| | | 29 sub-classes including glacier, wetland, desertification, etc. | Current situation of silt coast |
| | | 104 sub-classes including glacier, wetland, desertification, etc. | Desertification of primary saline-alkali soil |
| Remote sensing monitoring legend of fundamental geology environment | | 59 sub-classes including collapse, landslide, mudslide, etc. | Giant collapse |
| | | 14 sub-classes including incidence degree area boundary, danger degree area boundary, and prevention planning area boundary | Boundary line of seismic intensity area |
| | | 20 sub-classes including collapse, landslide, mudslide, etc. | Medium incidence area of geological disasters |
| Ground subsidence (surface deformation) legend | | 25 sub-classes | Value domain of surface deformation area unit 40~50 |
| Remote sensing monitoring legend of mineral resources development | | 15 sub-classes including key mining area boundary, incentive mining area boundary, restricted mining area boundary, etc. | Key mining area boundary |
| | | 6 sub-classes including utilized, unutilized and stopped mines | Utilized (newly-increased) |
| | | 7 sub-classes including original mineral land, newly-increased mineral land, reduced mineral land, etc. | Mineral land - agricultural land |
| | | 8 sub-classes including stope, mine construction, transit site, etc. | Stope (in use) |
| | | 3 sub-classes including serious area, relatively-serious area and general area | Serious area |
| | | 18 sub-classes including tailing mud, tailing sand, land reclamation point of mining area, etc. | Tailing sand (in use) |
| | | 4 sub-classes including earlier stage and later stage of water pollution, earlier stage and later stage of soil pollution | Soil pollution (earlier stage) |

Remote sensing image map Legend

No detailed regulations
4. Legend Generation Method

To make symbols that meet the requirements of specifications, there are usually the following methods [4, 5, 9, 10, 12, 14]: (1) Produce by using software, such as ArcGIS, AutoCAD and Coreldraw. However, the produced symbols can only be imported as bitmap symbols. In the vectorization process, the symbols are not handsome due to limited resolution. (2) Add new fonts and symbols in the operating system. Corresponding new fonts and legends will be added into the GIS software systems, such as Mapinfo, ArcView, ArcGIS, etc. by directly installing the produced new fonts and legends under the Windows fonts subdirectory. (3) Compile a symbol production system through GIS interface to achieve visualized operations of symbol production. This needs a considerable basic programming, that ordinary users are hard to achieve it.

This work uses the Font Creator software. Font Creator editing function can simply select and amend any TrueType fonts and character set based on OpenType font technology, convert image into outline, create new symbols or fonts, amend outline of single fonts, add or edit composite symbols, adjust character distance, edit and amend names of fonts, and convert single character or entire font. Font Creator also can be used in producing a professional symbol library, which is suitable for ArcGIS Style Manager. When using Font Creator, you need to consider correspondence and universality of symbol unit, size, positioning and others in ArcGIS, so that you can use them more flexibly [13, 14, 15, 16, 17].

Six graphic variables that make up a map symbol include shape, size, direction, luminance, density and color, among which shape, size and color variables are the most important. The shape variable is a single body that visually distinguishes a geometric figure.

The general thought of legend generation method is to generate a legend unit for each legend symbol, and then combine all legend units into final legend. The legend unit is an annotation of a map symbol, which consists of a map symbol and text describing the symbol. Primitives in this paper are produced based on Font Creator software platform. The detailed production steps are no longer repeated. Point, polyline and polygon legend symbols are completed in ArcGIS[14].

5. Compilation and Expression of Legends

Legend symbols of each sub-class are described by name, legend symbol, primitive parameters (polyline type or size, cycle, color), RGB value of base color respectively. Table 2, Table 3 and Table 4 respectively show representative legends for polygon-like, polyline-like and point-like symbols [4, 9, 12].

Table 2. An Example for Remote Sensing Survey Legend (polygon-like) of Geological Disasters

| Name                                               | Symbols | Primitive parameters | RGB value of base color |
|----------------------------------------------------|---------|----------------------|-------------------------|
| High incidence area of geological disasters        | 3×3     | 8×8                  | (0,0,0) (255,80,130)    |
| Medium incidence area of geological disasters      | 3×3     | 8×8                  | (0,0,0) (255,180,130)   |
| Low incidence area of geological disasters         | 3×3     | 8×8                  | (0,0,0) (250,240,200)   |
| Uneasy incidence area of geological disasters      | 3×3     | 8×8                  | (0,0,0) (220,255,50)    |
| Type | Name | Description | Symbols | Line type | Line width/mm | Line color (RGB value) |
|------|------|-------------|---------|-----------|---------------|-----------------------|
| Glacier | Locations of modern glacier and glacier tongue | Mainly applied to glacier monitoring research | Solid line | 0.25 | (0,0,0) |
| Glacier | Recession of glacier and glacier tongue | | Solid line | 0.25 | (255,0,0) |
| Glacier | Advance of glacier and glacier tongue | | Solid line | 0.25 | (0,255,0) |

Table 3. An Example for Remote Sensing Legend (Polyline-like) of Fundamental Geology Environment

| Name | Symbols | Primitive size (H×W/mm×mm) | Primitive color (RGB value) | Description |
|------|---------|-----------------------------|-----------------------------|-------------|
| Barren rock pile (in use) | △ 7×7 | (100,0,0) | Solid line |
| Tailing sand (in use) | △ 7×7 | (100,0,0) | Solid line |
| Tailing sand (abandoned) | △ 7×7 | (100,0,0) | Dash line (solid 5, dash 5) |
| Tailing mud (in use) | ◇ 7×7 | (100,0,0) | Solid line |
| Tailing mud (abandoned) | ◇ 7×7 | (100,0,0) | Dash line (solid 5, dash 5) |
| Land reclamation point of mining area | △ 7×7 | (0,0,0) (0,180,0) | |
| Governance point of collapse | △ 7×7 | (255,0,0) (130,130,130) | |

Table 4. An Example for Legend of Geological Environment Issues (Solid Waste)

According to current needs of editing remote sensing geological map, after the legends specified in GB/T 958-1999, GB/T 6390-1986, etc. are deducted, this paper has designed and produced 455 legends of the geological map interpreted with remote sensing images (77 point-like legends, 80 polyline-like legends and 298 polygon-like legends), involving 4 large classes, 19 classes and 455 sub-classes. After extensively soliciting opinions from a hundred of experts from 32 remote sensing technology research and application organizations, according to compilation and expansion principle of the above legends, the legends involved in this study are being tested in specific work and have received good response.

6. Conclusion
With rapid development and wide application of remote sensing technology and GIS mapping technology, remote sensing technology has been applied to various fields of national economic construction, and its application field and application range have made a great change. In order to meet new requirements for remote sensing geological survey work in the new era, unifying the legends of the geological map interpreted with remote sensing images is of great significance, which can lay a solid foundation for normalization and standardization of relevant results.
According to professional needs of remote sensing geological survey, by comparing, analyzing and screening the legends in previous result maps, and seeking for experts' opinions, this paper has designed and produced 455 legends of the geological map interpreted with remote sensing images, involving 5 large classes (remote sensing survey legend of regional geology and mineral geology, remote sensing monitoring legend of fundamental geology environment, remote sensing monitoring legend of geological disasters, remote sensing monitoring legend of mineral resources development, and remote sensing image legend), 18 sub-classes and 455 sub-classes, including 77 point-like legends, 80 polyline-like legends and 298 polygon-like legends, which can basically meet the needs of current remote sensing geological survey work. It is recommended to use this legend in demonstrative application, amend and improve according to application result, publish and apply it as a recommended standard as soon as possible.

2) Producing the legends of the geological map interpreted with remote sensing images is a long-term and complicated work. According to changes in application field and application range of remote sensing geological survey technology, through a certain period of running-in and communication, revision and addition of the legends of the geological map interpreted with remote sensing images shall be carried out to ensure that relevant standards can meet the needs of actual work.

7. Acknowledgements
This paper is based on the achievements of China Geological Survey Project “Developing Symbols and Legends of Remote Sensing Geological Map”. In the process of project implementation, guidance and help have been obtained from Bai Ye, Du Zitu, Liu Xinji, Tang Wenzhou, Liu Gang, Qi Zerong, Zhang Zhende, Zhao Fuyue, Fan Jinghui, Yan Baikun, Tong Liqiang, Chen Wei, Chen Hua, Wang Yan, Zhang Ling, Gan Fuping, Jin Dingjian, Li Xiaojin, Zhang Youying, Wang Jianchao, Zhu Guichang, Liu Dechang, Liu Zhanzheng, Yang Ziming, Yang Zilan and other experts. Moreover, I also express my thanks to master students Lou Yaqing and Pan Yi for their contribution.

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