Study on Geological Structural Interpretation Based on Worldview-2 Remote Sensing Image and Its Implementation

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Abstract
This paper presents the preliminary study on geological structural interpretation on the basis of Worldview-2 image. As compared with the more frequently used ETM+ and ASTER image, Worldview-2 sensor can provide much higher spatial resolution and spectral resolution in relative narrow spectral range. It is applicable to interpret strata attitudes based on bedding triangle planes, and recognize fold and faults structures. The interpretation results shows that Worldview-2 image is of advantages over the traditionally used ETM+ and ASTER data. Worldview-2 remote sensing image is, therefore, demonstrated to be of further applicability in future studies of geological structural interpretation.

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1. Introduction

In recent years, remote sensing is applied in geological prospecting more extensively; the interpretation of medium spatial resolution multispectral data in geological work has become an important basic work in advance. Geological applications of remote sensing image include interpretation of regional tectonic framework, and lithology distribution. In previous studies, such as small and medium-scale geological mapping and related, ETM+ and ASTER data are used to do preliminary geological interpretation.

However, as the gradual refinement of geological work, moderate-resolution remote sensing image has gradually failed to meet the requirements of 1:50,000, 1:10,000 scale and even the 1:5,000 scale geological interpretation, which favors multi-spectral image data with high spatial resolution remote sensing image, e.g., QuickBird and WorldView-2 image, to be introduced into the traditional geological interpretation.

WorldView-2 imaging data has eight bands cover from visible to near infrared spectrum. The fused multi-spectral images’ spatial resolution can reach 0.5 meters and are applicable into large scale remote

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sensing interpretation work. Particularly, based on its superior spectral resolution and spatial resolution, the images can be used to interpret the information of geological structures, including the attitude of strata, fold, and fault structures. This paper aims at present preliminary study on applying Worldview-2 data in geological structural interpretation.

2. WorldView-2 data

The WorldView-2, which was launched in October 6th, 2009 by the Digital Globe, is running in the 770km-high sun-synchronous orbit, providing 0.46 meter panchromatic and 1.8 meter resolution multi-spectral images. WorldView-2 not only has the standard 4 spectral bands (red, green, blue, near infrared), but also includes four additional spectrum (coastal, yellow, red edge and near-infrared 2). WorldView-2 is the first commercial high-resolution satellite to provide 8 spectral sensors in the visible to near-infrared range. Each sensor is narrowly focused on a particular range of the electromagnetic spectrum that is sensitive to a particular feature on the ground, or a property of the atmosphere. Together they are designed to improve the segmentation and classification of land and aquatic features beyond any other space-based remote sensing platform. Fusion images of the 8 multi-spectral band images have space resolution of 0.5 meters. Figure 1 shows the range of WorldView-2 bands and with WorldView-1, QuickBird comparison chart.

Considering the advanced location technology of WorldView-2 satellite, the accuracy of the sensor is much better than the other commercial satellites before. WorldView-2 satellite has Geolocation accuracy specification of 6.5m CE90, with predicted performance in the range of 4.6 to 10.7 meters (15 to 35 feet) CE90, excluding terrain and off-nadir effects. With registration to GCPs in image: 2.0 meters (6.6 feet) CE90. Table 1 shows the parameters of WorldView-2 satellite.

| Launch date       | October 2009                  |
|-------------------|-------------------------------|
| Orbit             | Altitude: 770 kilometers      |
|                   | Type: Sun synchronous, 10:30 am descending node |
|                   | Period: 100 minutes           |
| Sensor Bands      | Panchromatic + 8 Multispectral: 4 standard colors: red, blue, green, near-IR 4 new colors: red edge, coastal, yellow and near-IR2 |
| Sensor Resolution | Panchromatic: 0.46 meters GSD at nadir, 0.52 meters GSD at 20° off-nadir |
|                   | Multispectral: 1.84 meters GSD at nadir, 2.08 meters GSD at 20° off-nadir |
| Swath Width       | 16.4 kilometers at nadir      |
| Max Viewing Angle | Nominally +/-45° off-nadir = 1355 km wide swath |
### Accessible Ground Swath

| Accessible Ground Swath | Higher angles selectively available |
|-------------------------|------------------------------------|

### Max Contiguous Area

| Collected in a Single Pass | 96 x 110 km mono |
|---------------------------|------------------|
|                           | 48 x 110 km stereo |

### Revisit Frequency

| 1.1 days at 1 meter GSD or less | 3.7 days at 20° off-nadir or less (0.52 meter GSD) |

### Geolocation Accuracy

| Specification of 6.5m CE90, with predicted performance in the range of 4.6 to 10.7 meters (15 to 35 feet) CE90, excluding terrain and off-nadir effects |
| With registration to GCPs in image: 2.0 meters (6.6 feet) |

## 3 Survey and research methods study area

### 3.1 Geological background of the study area

The paper chooses Bangong-Nujiang metallogenic belt in central Tibet as the study area, to apply WorldView-2 Imaging data in structure interpretation. The geographic extent of the study area is: latitude 32° 10' - 32° 40' North, longitude 83° 30' - 84° 30' East. Geologically, the study area is divided into three basic tectonic units from north to south: Qiangtang block, Bangong - Nujiang suture zone, and the northern margin of the Gangdise block. Tectonic evolution of the study area had experienced full Wilson cycle: from initial rifting to passive margin and oceanic crust extension to final subduction and collision. There are different geological structures and lithologic assemblages in different tectonic units, which subsequently experienced severe deformation in the Cenozoic because of the northward impinging of the Indian plate. Figure 2 shows that the WNW-trending linear structures are better developed, followed by ENE-trending structures. We had collected 1:250,000 scale geological map and of 1:100,000 topographic map, and DEM data of 5m spatial resolution.

![Figure 2. Structural map (from 1:250,000 geological map)](image)

![Figure 3. Shaded 3D topography based on 5 m spatial resolution DEM](image)

### 3.2 WorldView-2 imaging preprocessing

WorldView-2 image preprocessing includes fusion, geometric correction, orthorectification. Since the WorldView-2 has its own orthorectification parameters. We take orthorectification, then geometric correction and then fusion as the order of preprocessing. Using the orthorectification module of ENVI, with WorldView-2’s orthorectification parameters and DEM, we do orthorectification of both Multispectral and Panchromatic images without GCP. By comparing different fusion method, i.e. Pan sharpening, PC integration and Gram-Schmidt fusion methods, and considering the quality and data computation fusion of high spatial resolution WorldView-2, the Gram-Schmidt method was chosen to fuse the multi-spectral data and the panchromatic data. Topographic map at 1:100,000 scale and DEM of
5m resolution are used as reference map to select ground control points for calibration and to carry out geometric correction. The flow diagram of data preprocessing is shown in figure 4.

![Flow diagram](image)

**Figure 4.** The flow diagram for data preprocessing

### 3.3 Strata attitude interpretation

The interpretation of strata attitude is fulfilled by identification of bedding triangle planes to determine strata strike and dip (Figure 5 and Figure 6). Bedding triangle planes on the image are represented by three unevenly located points on the same bedding plane because strata are usually eroded to intervening highs and lows due to local development of fractures or other weakness. Triangle can represent the occurrence of strata attitude and it is the best sign to determine rock occurrence in remote sensing images. (Zhu, 1994) The triangle shape is related to lithology, topography, and erosion status, so on RS image most triangle plane can be in either form of the followings: iron, semi-circular, half-moon, trapezoidal, etc. A number of triangles often imbricate along the strata dips, and continue to be connected to be jagged or wavy along the strata strike. In relatively flat terrain, the exposed geological boundary trending along straight line possibly represents the strike and the dip is the perpendicular direction. Comparing ETM and ASTER images, with the WorldView-2 data, we can interpret more particular and plentiful bedding triangle planes which cannot be shown on either of ETM or ASTER image (Figure 5).

![Comparison of images](image)

**Figure 5.** Comparison of ETM+, ASTER, WorldView-2 image at the same area

![Zoom-in images](image)

**Figure 6.** Zoom-in images in box (a) and box (b) of Figure 5. (a) Interpreted of bedding triangle planes on Worldview-2 RGB753; (b) Attitude of bedding (straight line indicates Strata strike, arrow indicates dip)

### 3.4 Fold interpretation
Folds normally present as banded features or oval and elongated bedding planes, with clear symmetry (Figure 7 and Figure 8). Some bedding triangle planes or monoclinal mountains show symmetry along an interface when there is a fold. When lithologic contrasts of strata composing of a fold are obvious, micro-topography, vegetation, banded textures exhibit symmetric repetition in combination. The hinge zone of a fold always shows curved bedding plane, while the occurrence of bedding triangle planes is deflected, showing a U-shaped or curved or other geometric forms on the image.

Figure 7. Comparison of ETM+, ASTER, WorldView-2 images of the same area for fold recognition

Figure 8. WorldView-2 RGB (7,5,3) interpretation of fold yellow lines stand for rock triangles

3.5 Interpretation of faults and linear structure

Faults can be recognized on WorldView-2 remote sensing image if one or multiple of following landforms or topographic features occur: (1) Layers of different types and ages of rock units sit side-by-side (offset) (Figure. 9); (2) Abrupt topographic discontinuities of landforms; (3) Depressions along the fault trace (broken rock is more easily eroded) (Figure 10 and Figure 11); (4) Scars or cliffs; (5) Sudden shifts of drainage courses (Figure 12); and (6) Abrupt changes in vegetation patterns.
4. Result and discussion

As compared to ETM+ and ASTER data, Worldview-2 data, equipped with the much better 0.5m spatial resolution, is feasible to be applied in middle-large scale geological mapping and structural interpretation. Bedding triangle plane is good indicator of strata attitude, especially of dipping direction and strike. Folds are usually recognizable based on strata attitudes and textural symmetry. As for interpretation of faults, combining Worldview-2 image with DEM data of 5m resolution into 3D surface model can provide better interpretability for faulted linear features in various forms, such as linearly arranged fracture zone, or sags aligned in line. Based on regional structural regime, the sense of fault
movement is also interpretable.

However, Worldview-2 image is better to be applied in small-scale structural interpretation, and its applicability to megascopic structural interpretation has been impaired because of its high data-volume and costs. Therefore, ETM+ and ASTER images are still useful for preliminary interpretation of megascopic structural framework and targeting potential area of detailed study by employing Worldview-2 image.

5. Conclusion

This paper demonstrates the effectiveness of applying Worldview-2 in geological structural interpretation. It is especially useful for interpreting strata attitude based on bedding triangle plane, recognizing structures such as folds and faults, and large scale geological mapping in great detail. Typical interpretation keys for geological structures are summed up in this paper. Nonetheless, their applicability to different study areas should be evaluated according to specific geological background.

References

[1] Taylor, M., A. Yin, F. J. Ryerson, P. Kapp, and L. Ding (2003), Conjugate strike-slip faulting along the Bangong-Nujiang suture zone accommodates coeval east–west extension and north–south shortening in the interior of the Tibetan Plateau, Tectonics, 22(4), 1044.

[2] Rokos, D., Argialas, D. and Mavrantza, R. et al., 2000. Structural Analysis for Gold Mineralization Using Remote Sensing and Geochemical Techniques in a GIS Environment: Island of Lesvos, Hellas. Natural Resources Research, 9, 277-293.

[3] Bilotti, F., Shaw, J.H., and Brennan, P.A., 2000. Quantitative Structural Analysis with Stereoscopic Remote Sensing Imagery. AAPG Bulletin, 84, 727-740.

[4] Rokos, D., Argialas, D. and Mavrantza, R. et al., 2000. Structural Analysis for Gold Mineralization Using Remote Sensing and Geochemical Techniques in a GIS Environment: Island of Lesvos, Hellas. Natural Resources Research, 9, 277-293.

[5] Drury, S.A., 1986. Remote sensing of geological structure in temperate agricultural terrains, Geological Magazine, 123, 113-121.

[6] Chen Jianping, Interpretation of Paleovolcanic Mechanism in Futuyu Ore Field, China; the 29th international geological congress, the 30th IGC, 1992.8.

[7] Chen Jianping, Liu Jianming, Lu Xiaoping, Development the Image Processed of Color Index and its Geological Interpretation, the 30th IGC, 1996.8.

[8] Chen Jianping etc, Remote Sensing Analysis of Yarlung Zanbo Suture Zone Xizang (Tibet)-on Orogenic Movement of Subduction & Collision, Optical Remote Sensing for Industry and Environmental Monitoring, SPIE, U. S. A., 41, 493-500.

[9] Zhu Liangpu, Geologic remote sensing, 1994.

[10] Chen Jianping, Evaluation of the quality of fault structure interpreted, Remote Sensing Information. 3, 14-16.

[11] Dong Qing-ji, Xiao Ke-yan, Chen Jian-ping, The quantitative analysis of regional metallogenic fault in the northern segment of the Sanjiang metallogenic belt, southwestern China, Geological Bulletin of China, 1479-1485.

[12] Chen Jianping, Mapping-Calculating Method of Attitude with Geological Triangular Facets, Journal of Chengdu University of Technology (Science of Technology Edition), 18, 121-125

[13] Chen Jianping, Miao Fang, The Calculating Method for Layer Attitude with Airphoto Pair, Remote Sensing For Land & Resources, 4, 40-45.