Quantitative Application of TM Data in Shallow Geological Structure Reconstruction

Liu Yang, Zou Liqun, Liu Mingxin
yangliuy@petrochina.com.cn

Abstract: This paper is dedicated to studying the quantitative analysis method with remote-sensing data in shallow geological structure reconstruction by the example of TM data in western China. A new method of computing attitude of geological contacts from remote-sensing data is developed and assessed. We generate several geological profiles with remotely derived measurements to constrain the shallow geological structure reconstruction in three dimensions.

Keywords: Remote sensing, Geology, Quantitative analysis, Structure Reconstruction

1. INTRODUCTION

The shallow geological reconstruction is important not only for geologists to better understand the relationship between shallow structure and deep structure, but also for developing the quality of data collection and procession with traditional exploration means. The current shallow geological structure reconstruction are always made by field data, and restrained seriously by field situation.

Surface topography is strongly related to the surface and subsurface geological structures. For the response to the surface and subsurface geological information within certain depth, satellite imagery have been used successfully to aid the mapping of various structural geological features. To date, most of this work has been qualitative in nature. But some applications need the accurate extraction of structural parameters, such as geological attitude. This lack of quantitative measurements limits the applications of satellite imagery in structural geology in depth. With the rapid development of remote-sensing technique, quantitative information excavation to remote-sensing data is becoming more and more important. Our aim is to show that quantitative structural measurements from remote-sensing data can provide a new feasible way to the shallow geological structure reconstruction.

2. Remote-sensing reconstruction of shallow geological structure

Remote-sensing reconstruction method reveals the shallow geological structure to a certain extent by the combination of satellite imagery and terrain data. This can overcome the problems existing in the current shallow geological structure reconstruction method.

Fig.1 shows the method framework. This method can be divided into three stages: qualitative extraction, quantitative extraction, and structure reconstruction. In view of the requirement of high accuracy in the quantitative analysis, terrain data is introduced to get the color shaded relief image by fusing shaded relief image with different enhanced geological features to restrain and correct the traditional surface geological interpretation. Because the color reflects the topography features only, the fusion data give more accurate delineation to geological contacts. Qualitative result is

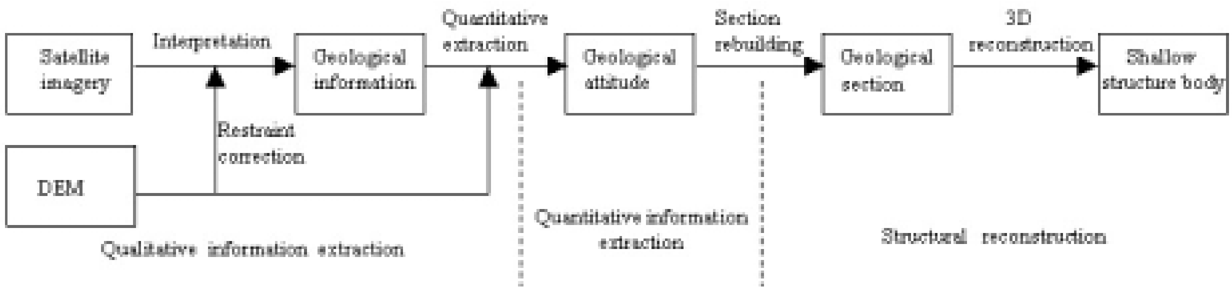

Fig.1 Shallow geological structure reconstruction framework.

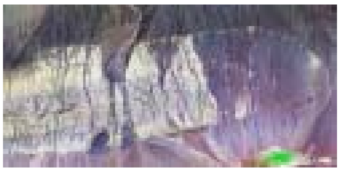

Fig.2 Kuqa test situated on flat terrain.

Fig.3 Tugulu test zone situated on middle mountainous terrain.

further used in computing geological attitude, combined with DEM. Geological sections can be generated from measurements to reconstruct the shallow geological body by suitable interpolation method. This method involves a wide range of technologies. This paper focuses on studying the quantitative extraction of attitude and geological section rebuilding.

This research has been carried out in two test zones: Tugulu area and Kuqa area (Fig.2, Fig.3), which all lie in the western China. We select these two test areas for the reasons of the distinct recognition of surface geological features on the image and different terrain used for comparative analysis. Terrain in Kuqa is quite flat while steep in Tugulu. The image data is TM data with the resolution of 30m. DEM was generated from digitizing contour lines from 1:50,000scale topographic map. The matching error between imagery and DEM is 1.9x2.1pixels in Tugulu and 1.3x1.2 pixels in Kuqa.

3. Quantitative extraction of attitude

The attitude of any planar structure can be measured by defining surface. Knowing the (x, y, z) location of three points on the same contact allows us to define it from the equation for plane in space:

$$aX+bY+cZ=0 \qquad (1)$$

where (a, b, c)is a vector normal to the plane. Once the plane has been calculated, the dip and strike values are determined. Although three-point method plays an important role in geological attitude measurement, it also brings problems in remote-sensing qualitative extraction of structural parameters simultaneously. Attitude extraction accuracy depends on point's selection excessively, and takes no account of the influence of geological structure. Multi-point directional fitting method can overcome this to a certain extent.

Responding to the distribution of test points in space, planar geological structure always has a space direction with the maximum space change rate interfered by test points. To reduce this influence, we compute the projection of test points on this direction, and compare the deviation between practical projection value and expected projection value. Least squares regression is used to fit the attitude surface:

$$S=\sum_{i=0}^{n}[G_i-G(x_i, y_i, z_i)]^2 \qquad (2)$$

where G_i is practical projection value, $G(x_i, y_i, z_i)$ is expected projection value. Attitude surface is defined when S is minimum. This can reduce the excessive dependence of attitude measurement on point selection. Moreover, it makes the fitting plane more stable in space responding to the directional feature of structure to develop the stability and reliability of attitude measurement.

To assess the validity of the computed attitudes, we have compared 190 measurements obtained in two test areas with the nearest field measurements from 1:50,000 scale geological map and practical measurements.

Table 1. Comparative statistical analysis between the computed attitudes and the nearest field measurements.

	Tugulu		Kuqa	
	Strike		Strike	
Method	Multi-point directional fitting	Three-point	Multi-point directional fitting	Three-point
Maximum error	26	46	50	48
Minimum error	4	5	9	11
Mean error	12.5	25.8	23	24.3
Error distribution % (<10degree)	65	33	8	1
Mean relative error %	25.8	49.3	69.5	71.2
	dip		dip	
Error distribution % (<10 degree)	90		28	

Statistical results are showed in Table1. In Tugulu test zone, computed strike is relatively precise, and different methods have a little effect on strike but a lot on dip, the mean error of computed dip with multi-point directional fitting method is lower than that with three-point method for 13.3 degrees. In Kuqa test zone, both the computed dip and the computed strike vary in wide ranges no matter what method is. Statistical analyses show two points:

- multi-point directional fitting method can improve the accuracy of computed attitude in area of middle mountainous terrain.
- excessive flat terrain is unfavorable to the calculate attitude.

4. Geological section rebuilding

There is no difference in essence between remote-sensing reconstruction and the current reconstruction on shallow structure. For the limitation of quantitative extraction accuracy on remote-sensing data, we employ the profile rebuilding method to predict the shallow structure so that it can be verified conveniently. In this research, several geological sections are generated from the computed attitude and geological interpretation results (Fig.4, Fig.5, Fig.6). Test zone is situated at the anticline. While the practical geological structure styles are rich and varied, and the structural surface expression is controlled by structure styles. Therefore, the validity of remote-sensing reconstruction is restrained by computed attitude and structural styles.

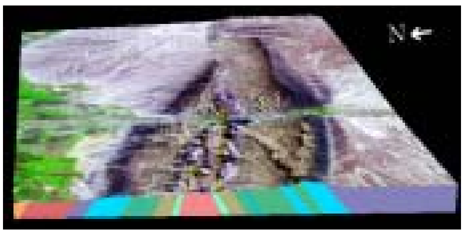

Fig.4 Three-dimensional data view incorporating satellite imagery, DEM, and geological section generated from attitude measurements.

Fig.5 Location of section.

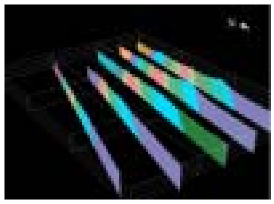

Fig.6 Several rebuilding section

5.Conclusion

Remote-sensing reconstruction method has great significance on the shallow geological structure with poor field situation. Although the full potential of this methodology has yet to be tested, it is envisioned that 3D models can be constructed from remotely sensed data sources to gain an understanding of regional geological relationships. This also provides a low-cost method that could be utilized in the early stages of petroleum exploration.

To date, most of the research carried out for this study has concentrated on quantitative extraction of attitude and geological section rebuilding. To gain the better result of reconstruction, the high resolution of image and terrain data is necessary. Future studies will focus on a more rigorous analysis of quantitative model of influence factors and reconstruction method.

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