

# LANDSAT TM IMAGE ANALYSIS FOR THE THRUST SYSTEM OF HELANSHAN MOUNTAINS, THE NORTHWEST OF CHINA

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## ABSTRACT:

On the basis of the geologic achievements of their predecessors, the authors have measured the reflective spectral values of the major geobodies in the Helanshan Mountains, made a field investigation, and then set up the interpretation keys of thrust system on TM image. Through the interpretation of TM image, image processing a field investigation and the comprehensive analyses of the geologic data, the authors consider that the structural pattern of this area belongs to a duplex. This new achievement is of great geologic significance and economic value for the exploration of coal fields.

KEY WORDS: Geological Remote Sensing, Spectral Measurement, TM Image Interpretation, Computer Processing, Thrust System, Coal Resources.

## 1. INTRODUCTION

Helanshan Mountains, which consist of Helan Mt. Gangder Mt. and Zhueai Mt. lies in the north part of the belt where the China Eastern Tectonic Province and Western Tectonic Province meet. The strata are mainly the limestone, the Cambrian System and Ordovician System, and the coal series, the Carboniferous — Permian System, and the terrestrial facies clastic rock, the Mesozoic Era. Among these, the Taiyuan Group, the Carboniferous System and Shanxi Group, the Permian System and the Ruqigou group, the Jurassic System, contain the minable coal seams. The structural features of this region are very complicated. Although the most geologists consider that the structures of the area are thrusts (Tang Xiyuan et al, 1988), the structural pattern has being disputed. This affects the study for coal and oil exploration. Hence, the authors make a study on the thrust structures in this region.

## 2. THE FEATURES OF THE THRUST ON THE TM IMAGES

### 2.1 Reflective Spectral Measurements

The authors measure the reflective spectral values in some typical structural profiles and the main strata. The instrument used is 100BX(M+T). The bands of it are in keeping with that of TM1, TM2, TM3 and TM4.

2.1.1 The Reflective Spectral Measure of the Thrust Body Huangwan Thrust; it is a typical thrust in the northern part of the Shitanjing Mining Bureau. The limestone,

the Cambrian System, directly covers on the coal series, the Carboniferous — Permian System and the broken zone exists in the front of the thrust. The result of the measurement is shown in Table 2.1.

Table 2.1 The Result of the Reflective Spectral Measurement of Huangwan Thrust

band spectrum ( $\mu\text{m}$ )	TM1 0.45—0.52	TM2 0.52—0.60	TM3 0.62—0.69	TM4 0.76—0.90
detachment, limestone	35.23	43.94	59.87	66.93
front	32.68	40.27	48.07	52.07
underlying body, coal series	23.92	27.91	32.56	34.96

This table shows that the each value of the limestone is bigger than that of the other bodies, and the differences between them are bigger than that of the others. From the principle of color composite, the detachment will appear deep red on the false color composite image (band 2—blue, band 3—green, band 4—red). The values of underlying coal series and their differences are less than that of other bodies, hence this geobody will appear dark grey. The values of the front zone is in the middle of the two bodies, and this zone will be a linear belt on the color image.

2.1.2 The Reflective Spectral Measure of the Other Geobodies For the interpretation of the lineament, we also measure the reflective spectral values of the other geobodies. The result is shown in Table 2.2.

From these values and the principle of the false color composite, we can determine the hue features of geobodies on the TM image respectively.

**Table 2.2** The Value of reflective spectral measure of the other geobodies

band spectrum ( $\mu\text{m}$ )	TM1	TM2	TM3	TM4
0.45—0.52	0.45—0.52	0.52—0.60	0.62—0.69	0.76—0.90
metamorphic rock	40.29	46.40	52.96	56.13
PrePaleozoic Era				
coal series,	19.71	19.51	19.17	22.51
Jurassic System				
the zone of Zhengyiguan Fault	31.71	37.37	39.58	42.39

## 2.2 Interpretation Keys Of Geobodies on the TM Images

### 2.2.1 Interpretation keys of Strata on the TM Image

From the reflective spectral values, principle of color composite, the analysis of image features and the field investigation, we obtain the interpretation keys of the strata. The metamorphic rock, the Pre—Palaeozoic Era; yellow brown, perfectly round in shape and dendritic drainage system; The limestone, the Lower Palaeozoic Era; deep red—dark red, and block or slice in shape, and nonlayers on the image and the strong dendritic drainage system; The coal series, Carboniferous—Permian System, light grey, dark grey or grey—yellow, and slice in shape, and the water drainage alone lineaments or faults; The clastic rock, Mid—Lower Triassic System; dark blue green, the obvious linear features and the "丰" shape in drainage system; The coal series and clastic rock, the Upper Triassic System and Jurassic System; dark grey—grey black with yellow red, the loop folds in shape and a little drainage system.

**2.2.2 The Interpretation keys of Thrust** The authors make an analysis on the Huangwan Thrust and Xiaosongshan Thrust which is a typical fault and is similar to the former, and obtain the interpretation keys.

**2.2.2.1 Shape** The front edge of the thrust appears in arc form and hill shape. This phenomenon can be found from the TM image obviously (see photo 1)

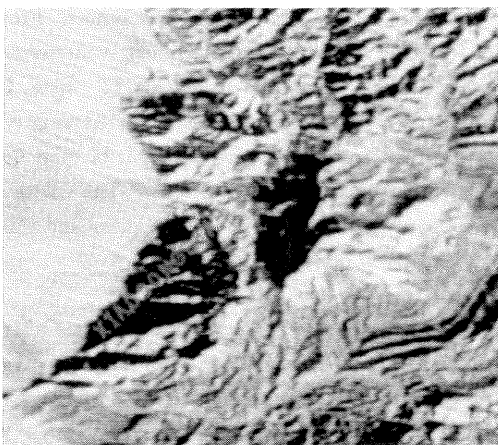


Photo. 1 TM false color image by computer enhance processing in Xiaosongshan

**2.2.2.2 Hue** Because of the large movement in horizontal

direction, the difference is big between the allochthon and autochthon on TM image. In this area, the allochthon of limestone appears in deep red, and the underlying clastic rock appears in light grey. The detachment body like a float over the coal series.

**2.2.2.3 Drainage System and Lineation Texture** The dendritic drainage exists in the allochthon. And in the coal series and clastic rock, the terrain slopes gently and the drainage system is mostly parallel in pattern.

**2.2.2.4 The distribution of Lineaments** Because the allochthon and autochthon come from different geobodies, the difference of linear pattern exists between them. The lineaments in the coal series are cut by that in the detachment.

On the other side, the authors also set up the interpretation keys of the other linear structures from the tone, and the form of lineament texture on the TM image.

## 3. STRUCTURAL INTERPRETATION ON TM IMAGE AND STRUCTURAL FEATURES

### 3.1 The Structural Interpretation on TM Image

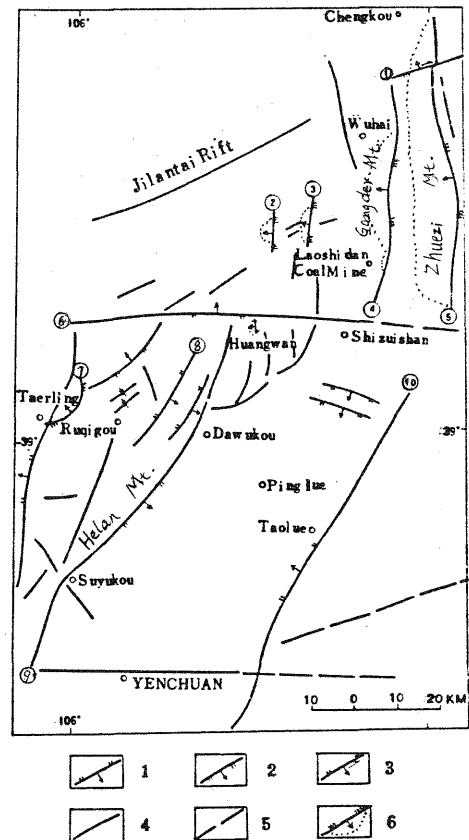


Fig. 3.1 A sketch map showing the geologic structures in the area 1—normal fault; 2—reverse fault; 3—strike slip fault; 4—lineament structure; 5—presumption and blind fault; 6—thrust fault and nappe; ① Qianlishan Fault; ② Bayinobao Thrust; ③ Wuhushan

Thrust; ④ Gangdershan Thrust; ⑤ Zhuezishan Thrust; ⑥ Zhengyiguan Thrust; ⑦ Xiaosongshan Thrust; ⑧ Nangou — Ruqigou Thrust; ⑨ Helanshan Thrust; ⑩ Huanghe Fault

According to the interpretation keys, we have finished the interpretation of the geomorphology, drainage system and lineaments on TM false color images at scale 1 : 500000 (some small area at 1 : 200000) respectively. Then, the authors determine the linear structures and the thrust structures. In the interpretation, some image data are processed with System 600. Through the contrast and the ratioing enhancement, the faults structures become more obvious and the others also become distinct on TM image. According to the interpretation and geologic data, the authors get the sketch map of structures of this area (see Fig. 3. 1). In the interpretation, we find that the features of Ganger Mt. Zhuezi Mt. and Xiaosongshan are very similar on TM image and they like a series caps over the coal series. From their features and distribution on TM image, these nappes are probably one detachment. This result is different from the predecessors' view. Then this work proposes a new point to be confirmed and this is an important enlightenment for the further research.

### 3. 2 The Structural Features in the Study Area

From the Fig. 3. 1 and the other geologic data, the authors divided the region into two parts: North Structural Part and South Structural Part

3. 2. 1 North Structural Part This part covers from Chengkou in the north to Zhengyiguan fault in the south. Its eastern border lies on the east of Zhuezi Mt. and the west border on the west of Huanghe River. The structural lines stretch at N—S direction. The structures are shown in Fig. 3. 2.

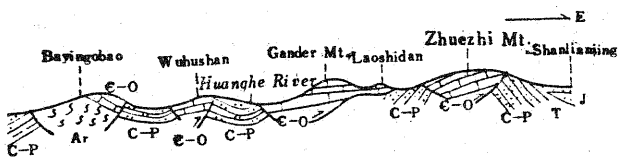


Fig. 3. 2 The structural profile in the North Structural Part (Modified from Tang Xiyuan et al, 1988)

**Gangdershan Thrust:** It stretches along the eastern edge of the Gander Mt. at N—S direction for about 60 Km, and tends toward west. The main body of roof wall is Gangerder-shan Uplift Belt, which is obvious dark red on TM color image. The core is composed of the metamorphic rock, the Archeozoic Erathem, and the limbs are of the limestone. Wuda Syncline is on the west of the belt, and is composed of clastic rock, and coal series. A fault cut off the syncline and that belt.

**Zhuezishan Thrust:** This fault is very obvious on TM im-

age. it stretches along the eastern edge of Zhuezi Mt. at N—S direction for about 100 Km and tends toward west. The roof wall is the well — known Zhueaishan Anticline. It is composed of metamorphic rock and the limestone. On the west of the anticline, there is a Kabuqi Syncline, which is composed of the strata, the Carboniferous—Permian System. It is an asymmetrical fold with a high—angle west limb. A small thrust exists between this syncline and that anticline with east dipping.

**Bayinobao Thrust and Wuhushan Thrust:** They are small at scale and are the same as the above mentioned features of that two thrusts.

3. 2. 2 Southern Structural Part This part covers from Zhengyiguan fault in the north to Yenchuan in south, and from the west of Helan Mt. in the west to the east of Taolue County in the east, and is a zone in form at NE by north. The main faults are Xiaosongshan Thrust and Huanghe Palaeo—thrust (see Fig. 3. 3).

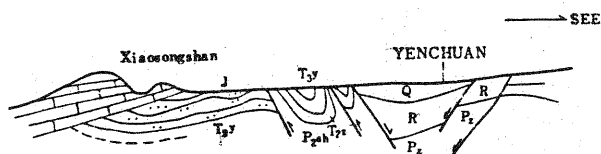


Fig. 3. 3 The structural profile in the South Structural Part (modified from Tang Xiyuan et al, 1988)

**Xiaosongshan Thrust:** It is obvious on the TM image. The fault stretches along the eastern edge of Xiaosongshan Mt. in an arc form and tends to west. The roof wall is Xiaosongshan Mt. , which is composed of the limestone, the Ordovician System, and the floor wall is of the terrestrial facies coal series, and the clastic rock, the Mesozoic Erathem. In many ground sites, the detachment of the limestone is directly on the coal series.

The structures are relative complex in Helan Mt. They belong to a synclinorium. This fold stretches at NW direction. The dipping angle of the west limb is bigger than that of the east limb. There is a series of subfolds in the synclinorium. The axes of the folds turn from the NE direction in the south to NE by north in the north, and arise and change into some small thrusts tended to west. This is an imbricate structural area.

**Huanghe Palaeo—thrust:** It is a presumed thrust and is in the present Huanghe Normal fault which lies along the eastern edge of Yenchuan Rift and was formed in Cenozoic Era. On the regional geologic data, the Yenchuan Rift was an asymmetric palaeo—anticline in Mesozoic Era. The east limb of the fold was cut by the thrust which moved toward east.

**Zhengyiguan fault:** It is very obvious on TM image and is

a right turning transcurrent thrust. It likes a transform fault to adjust the difference of the thrust velocities of the two sides.

#### 4. THE PATTERN OF THE THRUSTS AND ITS PROCESS ON COAL RESOURCE

##### 4.1 The Structural Pattern Of Thrust System

This problem has been discussed for about 50 (Li Jie, 1954). By the enlightenment of interpretation, the authors make a field investigation on some special sites and a comprehensive analysis of the geologic data. From these results and the classical model (S. E. , Boyer, et al, 1982) , the authors consider that the structural pattern belongs to a duplex, i.e, the present limestone bodies were one integral body in the past, below which it is a unified roof thrust, under which it is an imbricate fault zone, the main body of Helan Mt. , and below which there will be a floor thrust, under which there do be the autochthon. The main evidences are shown as the following.

1). On the TM image, some roof wall of limestone of the main thrusts are in blocks with dark red. They like a series of floats over the light hue coal series and the clastic rock. The features of the nappes in the roof wall are relatively unity.

2). As above mentioned, the limestones of roof wall are cut by the low-angle fault with the underlying clastic rock, and directly cover on the underlying coal series. Fig. 4. 1 is one of examples.

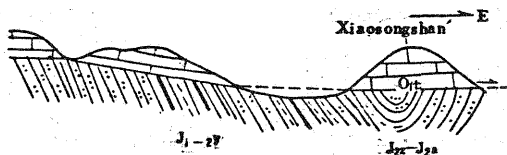


Fig. 4. 1 A sketch map showing the feature of Xiaosongshan Thrust. O<sub>16</sub>— Tianjingshan Group; J<sub>1-27</sub>— Yan'an group; J<sub>21-22</sub>— Zhilue group— An'ding Group.

3). The relation between the limestone and the clastic rock which is on the west of the former, is not normal superposition, but is in fault which tends to east direction at low-angle. The best evidence is shown in Fig. 4. 2

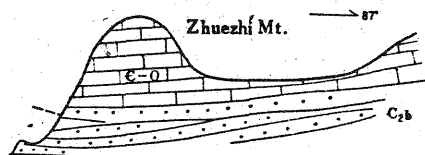


Fig. 4. 2 A sketch map showing the structural features in Heilonggui; the southern of zhuezishan Mt. C<sub>2b</sub>— Benxi Group.

4). The detachment is of a single older limestone stratum, under which it is the younger clastic rock. The surfaces under the limestones can be contacted to form one low-angle fault surface.

In the light of the duplex, there is a floor thrust below the imbricate zone. We haven't found the direct evidence on it. The main body of Helanshan Mt. is a contracted deformation because of folds and thrusts, then there must be a detachment surface below this body; In the area, the clastic rock and the coal series exist at an elevation of 1500—1800m. On the east of Zhuezi Mt. , the same stratum is under the desert (an elevation of 1400—1500m) for about 1600—2000m. Then, a structural surface must exist between the rock in Helanshan Mountains and the bedrock on the east of it. The two evidence indirectly confirm the detachment surface is below Helanshan Mt. .

As above mentioned, the deges of nappes are at N—S direction, and some of them appear arc forms convex toward SE direction, such as Xiaosongshan nappe. The small folds in the front of the nappes are asymmetric with high angle or reversed west limbs. These evidences show that the detachment moves toward east direction or SE by east direction.

On the space image, the authors delineate the area of thrust structures isn't less than 8000 Km<sup>2</sup> from the distributon of limestones by image processing on a computer. The farthest distance between two limestones is 50 Km. If one detachmrt of limestone is changed into this distribution, it must move over the underlying strata for 50 Km, and more. This shows that the thrust transport distance isn't less than 50 Km.

##### 4.2 The Duplex Pattern for the Exploration of Coal Field

This duplex is of great geologic significance and economic value for the exploration of coal field. From the duplex pattern the new coal resource will be found below the limestone in Helan Mt. , Zhuezi Mt. , Gangder Mt. , etc. Furthermore, under the main body of Helanshan Mountains, we will find the autochthon system and will obtain a large amount of coal resources. On the other side, this new result is important for the distribution of coal ranks. The thrust can produce not only a limited dynamic metamorphism of coal, but also the movement of coal metamorphic zones for the transport of the walls. In the area, the distribution of coal ranks is abnormal; the mesozoic Era coal seam is of higher mark, but the upper Palaeozoic Era coal seam lower mark. Hence, to study the features of the thrust structures has an important role for the coal metamorphism.

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