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Using Remote Sensing Data to Improve Geological Interpretation Mapping in Heqing Area, Northwestern Yunnan Province, China

S. Al-Mokredi Mansour and Hu Guangdao
Faculty of Earth Resources, China University of Geosciences, Wuhan, 430074, China

Abstract: Using Landsat-7 ETM+ digital spectral data investigations have been carried out in northwestern part of Yunnan province (Heqing area) to generate the geological mapping interpretation. Landsat Enhanced Thematic Mapper (ETM) of (945×1232) pixels subscene acquired on 21 March 2000 covering the northwestern part of Yunnan province has been digitally processed using ER Mapper software. The aim of this paper is to improve geological interpretation map for the study area. To meet the purposes of this research, different image processing methods have been evaluated in context of geological mapping; involving color composite image, Principal Component Analysis (PCA) and IHS decorrelation processing, appear to provide the maximum geological information. Color composites techniques were used the best suited approach is given by color combination of bands 531 in (RGB) provided the best results based on the original data. In principle, comparable results can be generated by a combination of the Principal Components (PCs) 1, 4 and 7 (blue, green and red respectively) in this succession. Decorrelated and filtered color composite of ETM+ bands 1, 4 and 7 have proved to be more successful for delineation the regional geological features. IHS-transformed images, with substantially saturated color, appear generally superior in discriminating the various rock units when three least correlated bands are used. The study testifies that using Landsat-7 ETM+ data PC and IHS decorrelation-stretching methods yield the best results for geological mapping in arid regions, by preserving morphologic and spectral information and when combined, they can be very helpful for improvements in already mapped areas.

Key words: Landsat ETM+Image, color composite, PCA, IHS decorrelation, Heqing-Yunnan (China)

INTRODUCTION

The essence of using remote sensing techniques to study earth materials is to represent earth surface landscape by various kinds of image and to extract the information of earth surface environment and resources. The imaging process of remote sensing is to record the radiant and reflectance energy of earth materials by different kind of images. Remote sensing is valuable for mineral exploration in at least four ways: Mapping regional lineaments and structural trends along which mining district may occur, mapping local features pattern that may control individual ore deposits, mapping hydrothermally altered rocks associated with ore deposits and providing geological data (Sabins, 1997).

The study area is located in Heqing area northwestern part of Yunnan province, lies between latitudes (26° 00° to 26° 40°) N and longitudes (100° 00° to 101° 00°) E. The area is about 580 km^2 (Fig. 1). The climate belongs to tropical to subtropical with mean annual temperature of 17-18°C and annual average rainfall 600-2300 mm. A number of 40 ground control points, which their UTM coordinates were determined and selected to geo-reference the image according to the topographic map. The resulting Root Mean Square (RMS) error for the geo-referencing was nearly 0.6 pixels.

The ETM+ acquires data for six visible, near-infrared and shortwave infrared spectral bands at a spatial resolution on 30 m. The significant improvement to Landsat-7 ETM+ is the 15 m resolution panchromatic band (0.52-0.90 μm) and the 60 m resolution thermal band. In order to get the benefit of 15 m resolution of pan data, different image fusion methods were applied to a test area to select the best method for image fusion in the area (Bahnia and Samadzadeh, 2004).

In this study Landsat-7 ETM+ data acquired on 21 March 2000 was used to improve the visual interpretation, discrimination of different lithological units and for the detection of the structural features using different image processing techniques, such as selected band color composites, principal component analysis and Intensity Hue Saturation (IHS) decorrelation stretching.

Corresponding Author: S. Al-Mokredi Mansour, Faculty of Earth Resources, China University of Geosciences, Wuhan, 430074, China

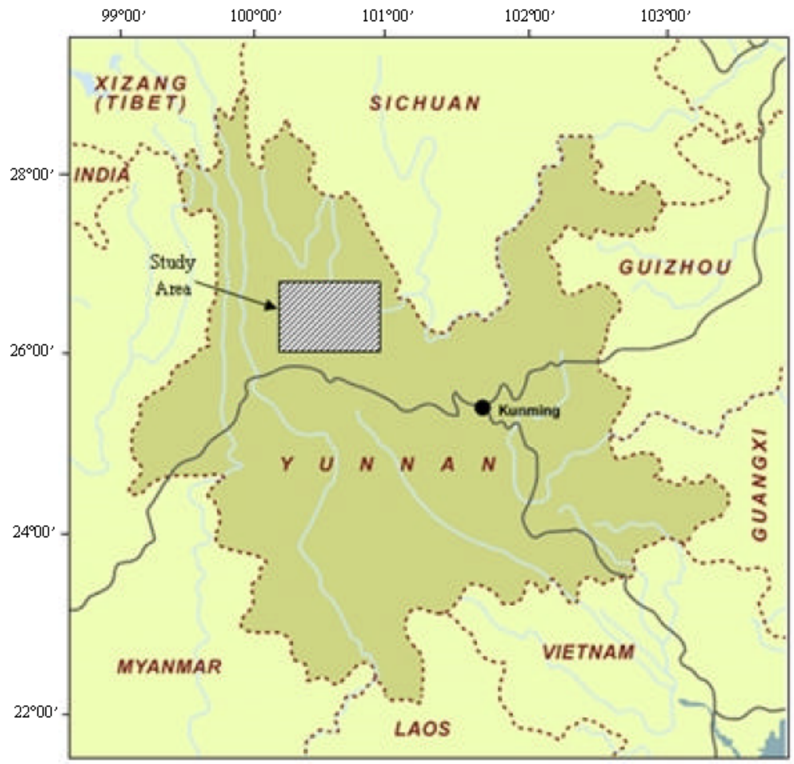

Fig. 1: Location map of study area Northwestern of Yunnan Province, China

The combination of information extracted from these three methods has been used to confirm the final produced geological interpretation map of the area with improved geological map and accuracy.

Satellite data and image processing: Landsat-7 ETM+ digital spectral image was provided by the Beijing remote sensing center, on 21 March, 2000 was used in this study. The ETM+ acquires data for six visible, near-infrared and shortwave infrared spectral bands at a spatial resolution on 30 m. The significant improvement to Landsat-7 ETM+ is the 15 m resolution panchromatic band (0.52-0.90 µm) and the 60 m resolution thermal band. The raw digital image usually needs to be corrected for geometric deformation due to variation in altitude velocity of the sensor platform, variations in scan speed, the sweep of the sensor's field of view, earth curvature and relief displacement act. The systematic errors are normally corrected at the receiving station. Random distortion needs to be corrected by the analyst through the selection of a sufficient number of Ground Control Points (GCP) with correct coordinates (Bahnia and Samadzadeh, 2004).

Through the use of a rectification algorithm image and/or vector, the column and row coordinates of the image can be fitted to the Geodetic Datum WGS84 and map projection NUTM47 coordinate system built into the vector using the linear method. The digital data were processed by using ER Mapper software version (6.4). On screen drawn vectors using different algorithms have been used for image interpretation and then ArcView GIS 3.3 software was used to display and combine the results.

Geology of study area: The strata include two parts of Yangzi platform which represented ancient Proterozoic era alterative rock system, including Ailao mountain groups, Dahong mountain groups and Kunyang mountains groups. The structure of this platform is constructed by the infra-parts of Triassic (Zhang, 2004). It is mostly of carbonate rocks and basic lavas (basalts). Upper Triassic-Cenozoic constructs the platform area structure. The strata of the Heqing area have been described concisely as follows from the Proterozoic era to the Cenozoic era.

Proterozoic rocks: Theses sediments are represented by Xiaojin formation, which mostly consists of middle to thick layer dolomitic limestone, mudstone and its thickness is over 650 m.

Paleozoic rocks

Ordovician sediments (O): Ordovician sediments reveals sporadically at the eastern of Yongsheng Area, which mainly consists of shallow sea sandstones-dolomites with shale and its thickness is over 205 m.

Silurian rocks (S): These rocks are lying at the small area of Jianchuan and San changjiu of Eryuan Area. It is mostly represented by middle Silurian Binchuan group shale with yellow-white and purple-gray sandstone. Its thickness is about 2000 m.

Devonian rocks (D): Devonian reveals sporadically at the eastern Heiwu and Golden Bay, Pingchuan of the Yongsheng Area. It is mostly consists of Devonian shore-shallow sea classic rocks, carbonate rocks with tuffs and basic lava. Its thickness is about 2000 m.

Carboniferous rocks (C): The Carboniferous distributes sporadically at Heiwu, Yongsheng area Golden Bay and Jianchuan. The reveal area is about 1.09 km^2. It is mostly represented by middle carboniferous carbonate rocks and sandstone.

Permian sediments (P): These sediments contribute widely and mostly of south-north zonal big area. And has the conformity tangency with carboniferous sediments. According to the rock characteristics, it can be divided into the Permian basalt group and the top Permian black mud group. The thickness of the whole Permian sediments is over 3000 m.

Mesozoic rocks

Triassic sediments (T): The upper Triassic rocks are represented by Songgui, Zhongwo and Shezi group, the middle Beiya group. These types of rocks mostly characterized as clastic and carbonate rocks. Triassic Beiya group gray rock has relationship with rich-alkali porphyry gold deposits and it is the main mineralization layer of the study area.

Jurassic rocks (J): Jurassic rocks layer develops completely and distributes wildly at the eastern parts of Binchuan-Chenghai, of zonal shape. It is mostly of river-lake clastic rocks with carbonate rocks. The rocks characterized are mainly sandstone, mud rocks, conglomerate and so on.

Cretaceous sediments (K): These rocks reveal at the eastern corner Zucun and Keluo. It is mainly of river-lake clastic rocks with carbonate rocks (Limestone). Its top and bottom parts with shale and mud gray rocks.

Cenozoic rocks

Tertiary (R): Tertiary reveals at Beiya and Mawan. The Paleogene rocks are mainly of river-lake red sand-mud rocks and Shanlu red thick clastic rocks. The Neogene rocks are mainly of river-lake and lake-clastic rocks with coal.

Quaternary (Q): Quaternary contributes in the western latter-day basin, such as Beiya, Songgui. It is mainly constructed by gravel, sand and clay (Zhang, 2004).

MATERIALS AND METHODS

Color composites processing: True color composite images are created by combining the ETM+ spectral bands that most closely resemble the range of vision of the human eye. A true-color composite uses the visible red (band 3), visible green (band 2) and visible blue (band 1) channels to create an image that is very close to what a person would expect to see in a photograph of the same scene. Color image prepared by projecting individual black-and-white multispectral images, each through a different color filter. A color image where parts of the non-visible EM spectrum are expressed as one or more of the red, green and blue components, so that the colors produced by the Earth's surface do not correspond to normal visual experience. Also called a False-Color Composite (FCC). The most commonly seen false-color images display the very-near infrared as red, red as green and green as blue. The more convenient way for interpreting the ETM+ data is to perform a best choice of three reflected ETM+ image bands for display a color composite (Fig. 2). The selection of band combination for generating color composite for interpretation has been carried out under the concepts:

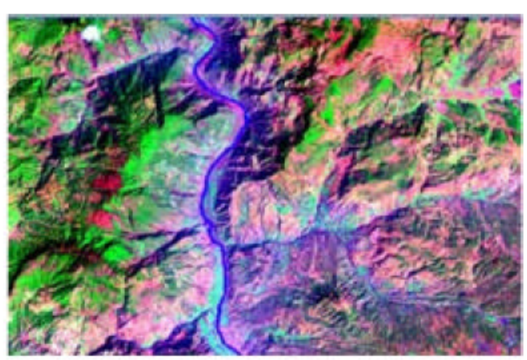

Fig. 2: Landsat ETM+ image RGB 741 color composite

- Using the correlation coefficient concept for the seven reflected bands of Landsat-7 ETM+ (Table 1), the best bands color composite have been selected are: 751, 741, 543 and 531. These bands were evaluated for their significance to display the best contrast (Kaufmann, 1988; Al-Bassam, 2003).
- The general statistics of raw ETM+ data. Band composite 751 has the highest standard deviation comparing with other fourth band composites. Table 2 shows the standard deviations of the 6 bands.
- Although studying the correlation matrix between ETM+ bands can remarkably help know of bands correlation, but we can not obtain a quantitative result to select the best bands combination for information extraction. In order to overcome this problem (Chavez *et al*., 1982) introduced Optimum Index Factor (OIF) which provide optimum band selection based on the variances and correlation of bands.

In this research OIF for all bands was calculated. Table 3 shows the result of these calculations. OIF was used based on total variance within band correlation coefficients to join the possible three bands. Three bands combination with high total variance within bands and low correlation coefficient between bands will have high OIF value. These combinations are expected to have the maximum extractable lithological information since they use bands with the least redundancy in the remotely sensed data.

For all possible three bands combinations made from six bands have been evaluated using the following equation.

$$\text{OIF} = \frac{\sum_{k=1}^{3} S_k}{\sum_{j=1}^{3} |r_j|}$$

Where, S_k is standard deviation for band k, r_j is the correlation coefficient between any two of the three bands being evaluated. Since the estimation of optimum index factor is based on the amount of total variance and correlation within and among various band combinations, the combination with the largest optimum index factor will generally have the most information with the least amount of duplication. Optimum index factor values of all possible three bands combinations which have been selected for this study area were 751, 741, 543 and 531 Table 3.

Table 1: Correlation matrix between ETM + bands

Band No.	ETM + 1	ETM + 2	ETM + 3	ETM + 4	ETM + 5	ETM + 7
ETM + 1	1.000	0.954	0.873	0.374	0.623	0.664
ETM + 2	0.954	1.000	0.946	0.509	0.746	0.777
ETM + 3	0.873	0.946	1.000	0.442	0.838	0.882
ETM + 4	0.374	0.509	0.442	1.000	0.564	0.438
ETM + 5	0.623	0.746	0.838	0.564	1.000	0.973
ETM + 7	0.664	0.777	0.882	0.438	0.973	1.000

Table 2: General statistics of dataset

Band No.	Band 1	Band 2	Band 3	Band 4	Band 5	Band 7
S. Deviation	8.555	10.477	17.925	12.709	28.244	24.714
Average	71.435	59.466	65.698	57.707	95.750	68.926

Table 3: Optimum Index Factor (OIF) for ETM+ image of the study area

BCC	ΣS_k	$\Sigma\|r_j\|$	OIF
754	63.667	1.975	32.236
753	70.883	2.693	26.321
752	63.435	2.496	25.415
751	61.513	2.260	27.218
743	53.348	1.762	30.276
742	54.901	1.724	26.624
741	43.978	1.476	29.795
732	53.116	2.605	20.390
731	51.149	2.419	21.163
721	43.746	2.395	18.265
543	58.878	1.844	31.930
542	49.430	1.819	27.147
541	47.805	1.561	30.434
532	56.646	2.530	22.389
531	54.724	2.334	23.446
521	47.276	2.323	20.351
432	39.111	1.897	20.617
431	37.189	1.689	20.018
421	29.741	1.837	16.189
321	36.957	2.773	13.327

Σs_k = Sum of standard deviation of bands combinations.
$\Sigma|r_j|$ = Sum of the absolute values of the correlation coefficient.
BCC = Band Color Combination.

Principal Component Analysis (PCA): The principal component transformation is a widely used method to calculate N new, statistically independent components of n input bands, band on the covariance matrix. It can be applied to any number of bands. Three of the resulting components may be displayed as a color composite or the components are used for decorrelation stretching before transformation. Principal Component Analysis (PCA) is a spectral enhancement, which can be used to compress the information content of a multispectral dataset (Sabins, 1997).

A variation on PC enhancement is the decorrelation stretch where an original three band image is taken into PC space, the variance of these bands increased and then transformed back into normal color space. This has the effect of saturating or increasing the color information in a normal three band color composite.

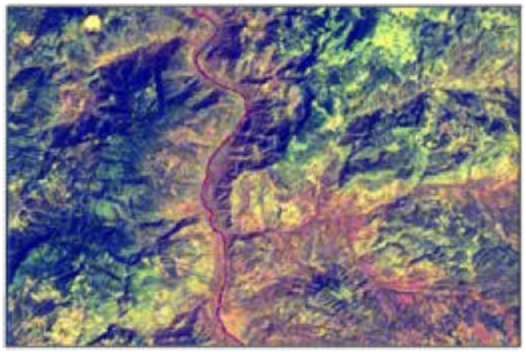

Fig. 3: Landsat ETM+ image RGB 741 represents PC1

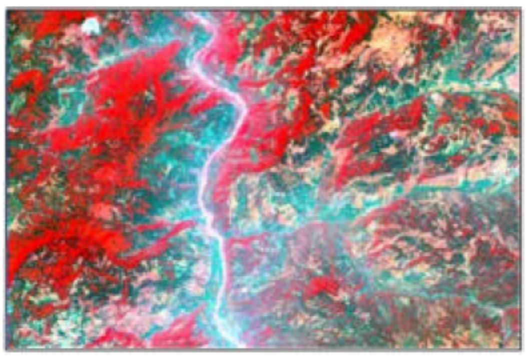

Fig. 4: Landsat ETM+ image RGB 741 represents IHS

The use of principal components in exploration has been to separate variable associations into a number of groups of variables that together account for the greater part of the observed variability in the original data (Davis, 1986). This type of analysis is useful when there are number of data layers which can be overlain one over another. With the advent of geographic information system, integrated analysis of spatially distributed data can be done easier. This type of analysis can either be done on satellite images or other geo-data sets.

Principal component analysis has been used in several ways to enhance imagery. For example, the first three principal components can be displayed as an RGB composite (Fig. 3).

IHS-decorrelation stretching transformation: The RGB displays are used extensively in digital image processing to display normal color, false color infrared. An alternative to describing color by their RGB components is the use of the Intensity-Hue-Saturation (IHS) system. Intensity relates to the total brightness of a color. Hue refers to the average wavelength of light contributing to the color. Saturation specifies the purity of color relative to gray.

This color transform method has been widely used to display the information in remote sensing (Pohl and Vangendern, 1988; Harris *et al.*, 1990). Based on the prior knowledge of the spectral properties and statistical investigation, this method has been conducted as follow: IHS decorrelation stretching method using stretched (uniform distribution stretch) selected band 741 in RGB (Fig. 4).

CONCLUSION

Conclusions of the geological study and digital image processing techniques in the study area like Heqing Area can be combined for the objectives of geological interpretation. Depending on the geological details and surface observations, the rock formations (rock units) were classified into eleven groups according to lithology (rock types) and the age of rocks. An observed and inspected algorithms which produced by using the composites techniques in addition PC and IHS decorrelation space transformation have been shown that each category or group has its distinctive properties or characteristics on each image. This was useful to obtain obviously a good relation in using satellite image data for geological interpretation mapping. These groups are:

Group (A): Consists of gray basalt, green almond comprises speckle basalt, tuffs Represented by Wuyan formation (Pβ2).

Group (B): This group consists of black shale, dark gray thin layer limestone, Represented by Heini formation (P2h).

Group (C): Consists of mauve middle fine feldspar quartz sandstone with mudstone, purple and gray green silt mudstone.

Group (D): Represented by Beiya formation (T2b1), which consists of gray mudstone with oolitic limestone, shale.

Group (E): Consists of gray limestone and pelitic limestone, which represented by Beiya formation (T2b2).

Group (F): This group consists of dolomitic limestone, tint gray pure limestone with bio-limestone, represented by Wo formation (T3z).

Group (G): Represented by Shedian formation (J2s), which consists of marlite with silltite, yellow green mudstone and thin sandstone.

Table 4: Image characteristics of different types of rocks group on the study area

	Band color composites in RGB					
Group	751	741	543	531	PCA	IHS
A	Greenish dark with blue	Red and light green	Light green brown spots	Dark red with light green	Dark blue to greenish	Reddish dark blue spots
B	Dark blue purple	Pink with light blue	Dark blue orange	Light blue with greenish	Reddish light yellow lime	Turquoise to light blue
C	Light green with yellow	Reddish with orange	Light purple light yellow	Purple dark to light red	Light yellow greenish light	Dark greenish reddish spots
D	Yellowish dark brown	Light red purple	Brownish light blue	Yellowish with blue spots	Yellowish to green blue	Rose to blue with purple
E	Dark green blue	Pink with green spots	Greenish blue purple	Reddish with yellow spots	Dark blue to yellowish	Reddish light with aqua
F	Light green yellow	Greenish red yellow	Dark green with yellow	Yellowish to light green	Green light to dark	Pink light to yellow
G	Purple with blue spots	Light pink dark red	Light Pink with green	Purple yellow greenish	Reddish with yellow green	Blue light reddish light
H	Greenish with yellow spots	Dark green to light	Greenish with orange	Dark reddish to dark brown	Dark blue yellow spots	Dark greenish to red light
I	Blue light purple	Dark blue to light	Blue with light purple	Turquoise with blue light	Orange with light red	Turquoise with purple
J	Light Blue reddish	Pink with green spots	Dark Pink to light	Light blue with yellow spots	Yellowish to orange green	Light blue to brownish
K	Dark gray with blue	Dark blue to gray	Light blue to dark red	Gray to dark brown	Red to blue brownish	Dark blue light gray

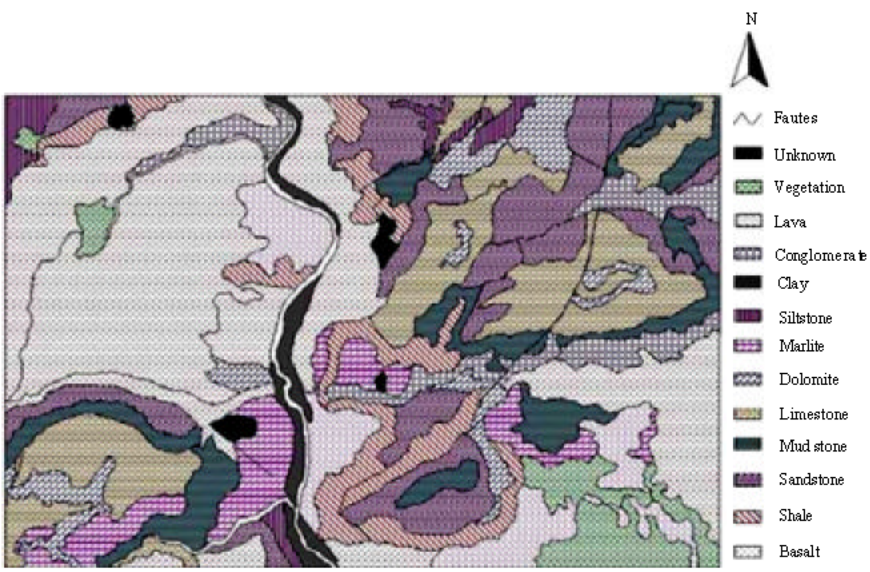

Fig. 5: Geological interpretation map of the study area

Group (H): This group represented by Early tertiary Eocene formation (E), which consists of brown, gray purple comprises siltstone.

Group (I): Consists of gray black, gray brown clay and silt inter bedded.

Group (J): Consists of brown, brown-red sandy gravel, conglomerate.

Group (K): This group is consists gray comprises basaltic tuffs, lava flows (Table 4).

The characteristics of different image which use false color composite approach have been shown a positive relationships with the lithological units in the study area. Thus, combining the results from different color composites will be useful in extracting good information for the purpose of geological interpretation mapping (Fig. 5). The resulted image has shown some degree of discrimination between the structural units and lithology. Besides the simultaneously enhanceable structural and spectral elements and the processing approach, the major advantages of the IHS-decorrelation concept are that the pixel oriented algorithm generates transferable results whereby no reduction of any image contents takes place. In addition, the resulting standardizable product is a valuable and understandable tool for mapping and carefully directing fieldwork.

REFERENCES

Bahnia, P. and Z. Samadzadeh, 2004. Application of Principal Component Techniques on ETM+ Data for Detecting Actinolite Metasomatite Zones Related to Uranium Mineralization in Saghand Area, Central Iran. J. China Univ. Geosci., pp: 67-72.

Bassam F. Al-Bassam, 2003. Improved Geological Interpretation Using Landsat TM Data in Lancang-Jinghong Area, Yunnan Province, China. J. China Univ. Geosci., pp: 52-58.

Chavez, P.S., G.L. Berlin and L.B. Sowers, 1982. Statistical Method for selecting Landsat MSS Ratio. J. Applied Photographic Eng., 8: 23-30.

Davis, J.C., 1986. Statistics and Data analysis in Geology. (2nd Edn.), Singapore: John Wiley and Sons, pp: 646.

Harris, J.R., R. Murray and T. Hiros, 1990. HIS Transformation for Integration of Radar Imagery with Other Remotely sensed Data. Photogrammetric Engineering and Remote Sensing, 56: 1631-1641.

Kaufmann, H., 1988. Mineral Exploration along the Aqaba-Levant Structure by use of TM Data. Concepts, Processing and Results. Int. J. Remote Sensing, 9: 1630-1658.

Pohl, C. and J.L. Vengendern, 1988. Multisensor Image Fusion in Remote Sensing Concepts, Methods and Application. Int. J. Remote Sensing, 19: 823-854.

Sabins, F.F., 1997. Remote Sensing: Principles and Interpretation. (3rd Edn.), New York: Freeman.

Zhang, H.W., 2004. The integrated information Exploring model Prediction and evaluation Indicators of Beiya Alkali Porphyry Gold deposits in Heqing Yunnan. China University of Geosciences.